MODELING NUTRIENT AND DISSOLVED-OXYGEN TRANSPORT IN THE TRUCKEE RIVER AND TRUCKEE CANAL DOWNSTREAM FROM RENO, NEVADA

By Jon O. Nowlin

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IN THE TRUCKEE RIVER AND TRUCKEE CANAL

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ABSTRACT

The Truckee River is a unique water resource in the Great Basin, flowing about 116 miles from the pristine mountain waters of Lake Tahoe in the Sierra Nevada of California to the brackish waters of Pyramid Lake, lying some 2,400 feet lower in the desert of Nevada. At the foot of the Sierra about midlength along the river is the semi-arid Truckee Meadows, a valley in which river water is diverted for agriculture and municipal supplies in the rapidly urbanizing Reno-Sparks area, and from which discharges advanced secondary-treated effluent to the river. At Derby Dam, about 21 miles below Reno and 35 miles above Pyramid Lake, water from the Truckee River is diverted into the Truckee Canal for use in the Newlands Irrigation Project in the Carson Desert at the lower end of the adjacent Carson River basin. Small agricultural diversions also exist along much of the Truckee River below Reno, reducing river flows during low-flow periods; diverted waters return to the river, contributing nonpoint loadings along much of the studied reach.

Principal water-quality issues for the river below the Reno-Sparks area include (1) instream concentrations of dissolved oxygen and nutrients with respect to management of threatened and endangered fish (Lahontan cutthroat trout and Cui-ui lakesuckers) in the Pyramid Lake Indian Reservation and (2) nutrient loads to Lahontan Reservoir (at the end of the 34-mile Truckee Canal) and Pyramid Lake.

The U.S. Geological Survey conducted intensive studies in 1979 and 1980 to provide information on factors affecting water quality in the Truckee River and to support development of a water-quality transport model of (1) the river from Reno to Pyramid Lake and (2) the Truckee Canal. Field studies included dye-tracer injections to determine traveltime for much of the river and canal, gas-tracer studies to test equations for prediction of instream reaeration coefficients, and four intensive synoptic sampling programs to provide data to calibrate and validate the water-quality transport model. Calibration, validation, and some initial applications of the model were completed under a cooperative program with the Cities of Reno and Sparks.

Field studies showed that oxygen concentrations in the river and canal generally met State standards, except for nighttime minima during low flows in areas with large daily cycles in oxygen concentration from photosynthesis and respiration of aquatic plants. During low flows in August of 1979 and 1980, sags in mean daily dissolved-oxygen concentrations of up to 2 milligrams per liter from initial near-saturation values were observed in a 19-mile reach of the river below the Reno-Sparks discharge, principally due to oxidation of ammonia from the sewage effluent. Below Derby Dam, mean daily dissolved-oxygen concentrations generally were close to, or exceeded saturation. Large daily cycles in oxygen concentration were observed in both the river and canal. Daytime maxima were measured as high as 13 milligrams per liter (190 percent of saturation) in the river and 14 milligrams per liter (210 percent) in the canal. Nighttime minima in the river were measured as low as 3.4 milligrams per liter (45 percent) in reaches of high algal productivity (compared to the State water-quality standard of 5.0 milligrams per liter). During the 1979-80 field programs, State standards also were exceeded for concentrations of un-ionized ammonia, nitrite, total-nitrogen, and ortho- and total phosphorus.

A steady-state one-dimensional water-quality transport model for the lower 56 miles of the river and the entire canal was calibrated and validated against independent field data for both June and August flow conditions. Traveltimes in the model are predicted as a function of streamflow based on the intensive dye-injection studies. The model predicts mean daily concentrations of: dissolved solids; carbonaceous biochemical oxygen demand; organic-, ammonia-, nitrite-, and nitrate-nitrogen; ortho- and total phosphorus; and dissolved oxygen. Estimates of minimum daily dissolved-oxygen concentrations are also calculated using empirical factors for photosynthesis and respiration. Reaeration rates in the model are calculated from instream velocities and channel slopes for each of 43 river and 9 canal segments on the basis of the results of the gas-tracer studies. Estimates of nonpoint loadings from both surface agricultural returns and ground-water inflows are provided for each modeled segment.

Although some coefficients varied from segment to segment in the modeled reaches of the river, one consistent set of model coefficients was found to apply to both the June and August data sets. Calibrated ranges in model coefficients (units of measure: per day, base e, at 20 degrees Celsius) for the river are: carbonaceous biochemical oxygen demand decay, 0.14 to 1.7; carbonaceous biochemical oxygen demand oxidation, 0.14 to 0.20; organic-nitrogen decay, 0.10 to 1.7; organic-nitrogen hydrolysis, 0.10 to 0.80; ammonia-nitrogen decay and oxidation, 0.40 to 2.4; nitrite-nitrogen decay and oxidation, 1.0 to 10; nitrate-nitrogen decay, 0.30 to 2.0; and reaeration, 0.12 to 120.

The calibrated model was applied to alternative processes for sewage treatment ranging from continued advanced secondary treatment to tertiary treatment with denitrification of the effluent. Simulations at projected effluent discharges for the year 2000 were performed for average June, August, and low (10-year recurrence of 7-day low flows) river flows. For the low-flow conditions, simulations projected that water-quality standards for dissolved solids, nitrite, nitrate, phosphorus, and minimum daily dissolved oxygen would not be met in one or more reaches of the river for all modeled alternatives at the proposed municipal sewage-discharge rate for the year 2000 (40 million gallons per day). However, projected violations of standards were not entirely attributable to the sewage discharge; sensitivity analyses of model simulations for the observed August 1979 low flows indicate that even with no loadings from sewage effluent, upstream tributaries and downstream nonpoint sources alone would result in probable failure to meet standards at low flows for nitrite, phosphorus, and minimum daily dissolved oxygen.

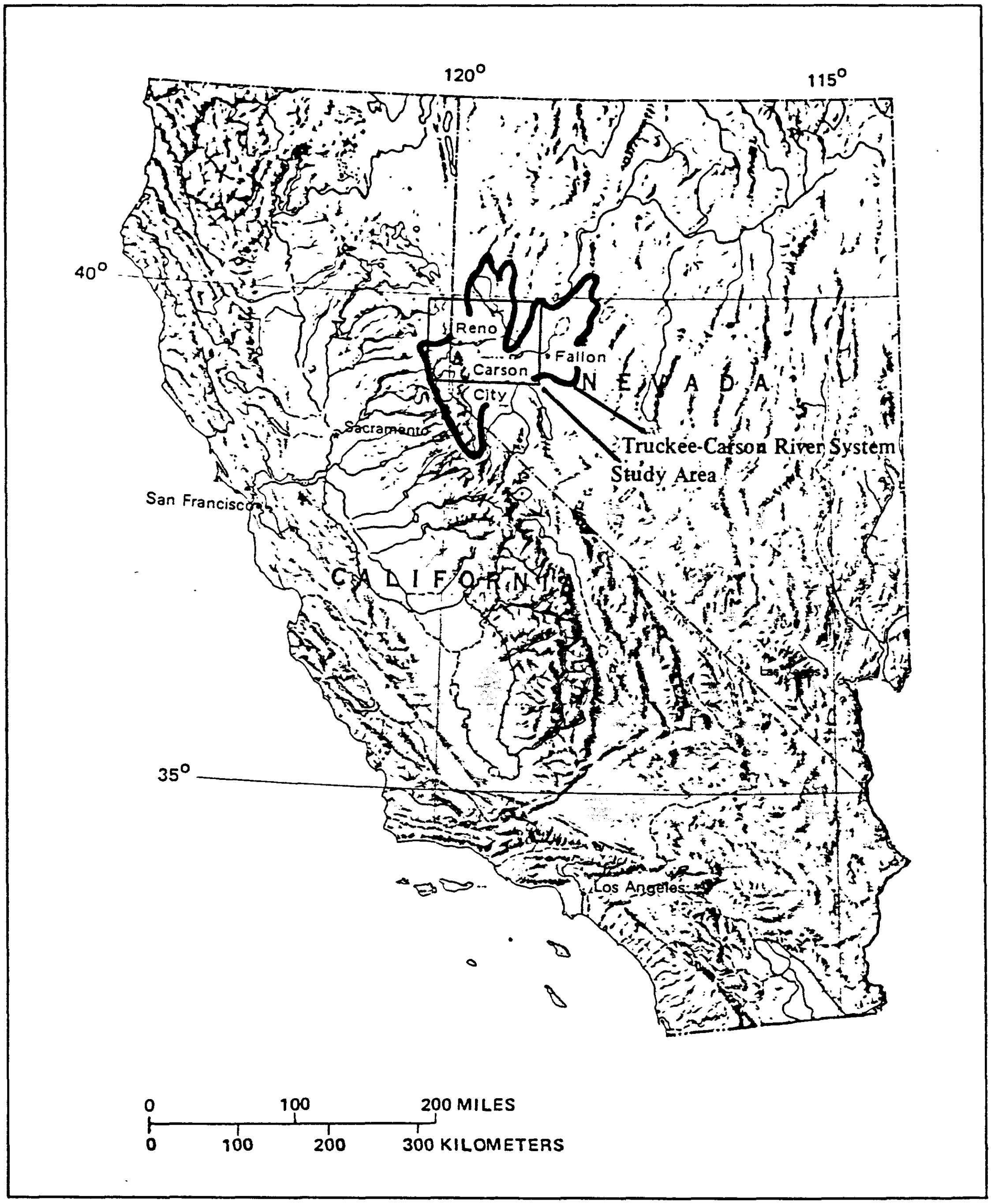
Calibration and application of the model provided an evaluation of the relative importance of processes and sources of loading that affect water quality in the river and canal. Between Reno and Derby Dam, river quality is greatly influenced by discharges from Steamboat Creek and North Truckee Drain, the two principal tributaries draining urban and agricultural lands in the Truckee Meadows, and from the Reno-Sparks sewage plant. At typical summer low flows, river assimilation in this reach results in a substantial reduction in concentrations of nutrients and oxygen-demanding substances attributable to the upstream sources and the sewage effluent. Below Derby Dam, in contrast, the effects of nonpoint agricultural returns and ground-water inflows predominate over those of upstream sources.

INTRODUCTION

In October 1978, the U.S. Geological Survey began an assessment of river quality in the Truckee and Carson River basins, California and Nevada (figure 1), as one in a series of national River Quality Assessments (RQA). The objectives of the Truckee-Carson RQA were to (1) identify the most significant resource-management problems concerning water quality in the two basins, (2) develop and apply methods to rationally assess these problems, and (3) communicate the results to the responsible managers and the public in an effective manner. The study consisted of six integrated parts, which are shown schematically in their relation to each other in figure 2.

Figures 1 & 2 near here

The details of the planning and design element of the study are discussed in a report by Nowlin and others (1980). The processes used in the fact-finding and communication workshops are covered in a report by Andrews and others (1981). Brown and others (1986) present a summary of basic hydrologic characteristics of the two basins. The planning process resulted in the selection of the Truckee River for intensive phases of investigation. Data collected during extensive field studies on water quality, traveltime, reaeration, and channel geometry of the Truckee River are compiled in a report by La Camera and others (1985). Hoffman (1982, 1986) described methodologies developed for studying water quality in spawning habitats of cold-water fish. The results of studies relating spawning success of Lahontan cutthroat trout to the quality of river and intragravel waters are reported by Hoffman and Scoppettone (1984). This current report presents the results of mathematical modeling of dissolved oxygen and nutrient concentrations in the Truckee River and Truckee Canal.



Base from U.S. Geological Survey, National Atlas
Of the United States, 1:7,500,000, 1970

FIGURE 1.--The Truckee-Carson River system spans diverse terrains in northeastern California and northwestern Nevada.

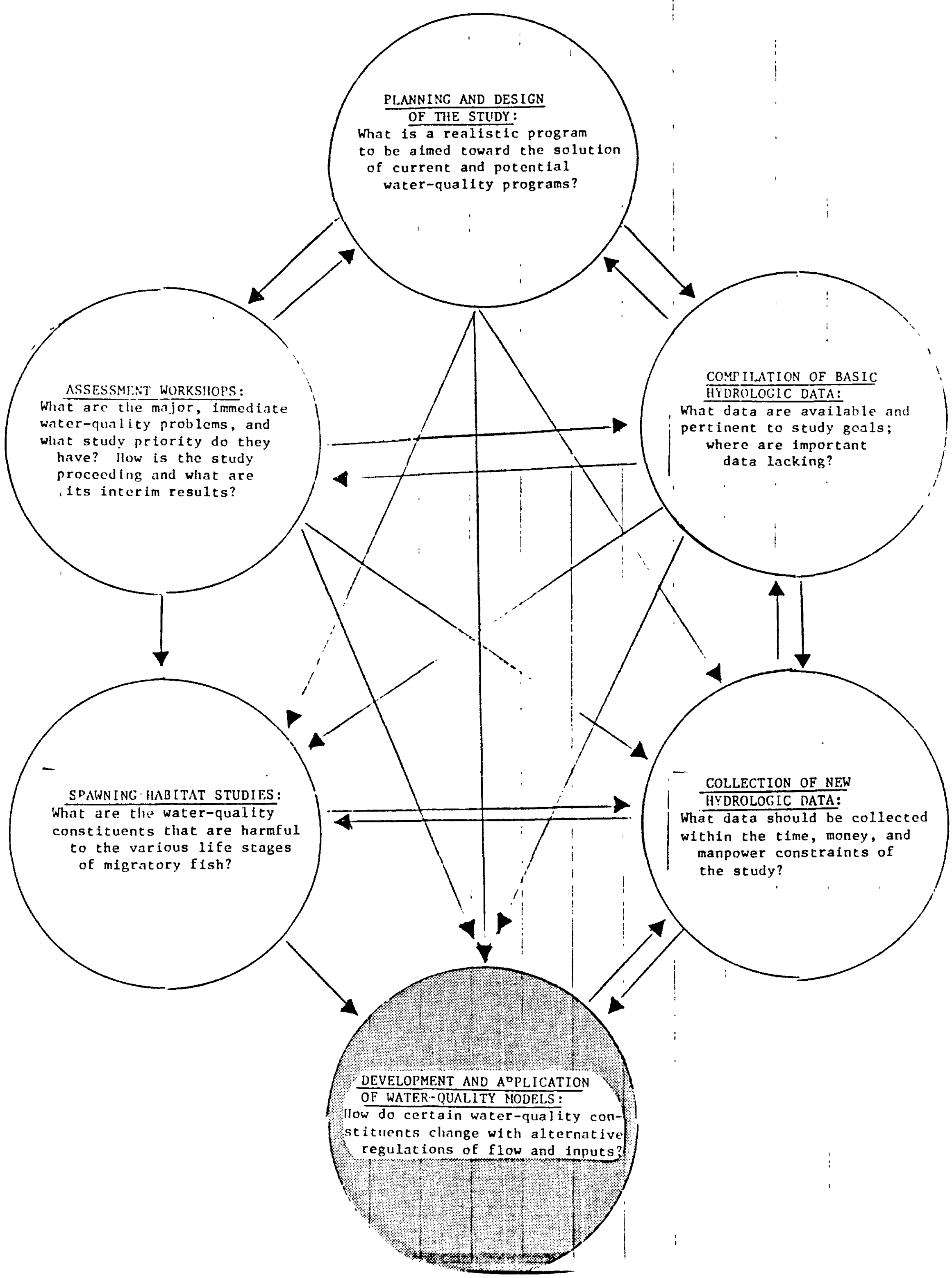


FIGURE 2.--Water-quality modeling was one of six integrated elements of the Truckee-Carson River-Quality Assessment.

The RQA workshops identified a number of water-quality related problems in the Truckee River basin below Reno, Nev. Planners and managers in the Reno-Sparks urban area were examining alternatives for expansion of the Sewage-Treatment Plant jointly operated by the two cities, hereafter referred to as Reno-Sparks STP. State officials were in the process of revising water-quality standards for the river and canal. The lower portion of the Truckee River and its terminal receptor, Pyramid Lake, are within the Pyramid Lake Indian Reservation. The Pyramid Lake Paiute Indian Tribe and the U.S. Fish and Wildlife Service (USFWS) have been intensively involved in re-establishment of the Lahontan cutthroat trout, a threatened cold-water fish species, and the Cui-ui lakesucker, an endangered warm-water fish genus, in the Truckee River. Fishery managers were interested in determining cause-and-effect relationships between river concentrations of dissolved oxygen and nutrients and potential point and nonpoint sources of pollutants. An additional concern with respect to water quality has been definition of the sources and magnitude of loads of nutrients contributed by the Truckee River to Pyramid Lake. Similar concerns have been expressed by State officials with respect to the contribution of nutrients from the Truckee Canal to Lahontan Reservoir. In the RQA planning process, development of a quantitative water-quality transport model to address some of these problems for the Truckee River and Canal was determined to be possible. Data collection and development of the model were begun under the Federally funded RQA program. Completion of the model and applications to planning for construction and to operational alternatives for the Reno-Sparks STP have been done through a cooperative program with the Cities of Reno and Sparks.

Purpose and Scope

This report presents results of water-quality modeling of the Truckee River and Truckee Canal. Specific objectives of the modeling study were:

1. Adaptation of a one-dimensional model to predict concentrations of dissolved oxygen, nitrogen species, and phosphorus in the Truckee River and Truckee Canal under steady-state assumptions of streamflow and input loadings.
2. Calibration and validation of the model using detailed data collected by the USGS RQA during spring snowmelt streamflows and summer low-flow conditions observed in June and August of 1979 and 1980.
3. Application of the model to simulate river quality in response to various river flows and management alternatives for the expansion of the Reno-Sparks STP.

The geographic scope of the model was limited to the 56-mile reach of the Truckee River from the downstream boundary of Reno to Marble Bluff Dam at the head of the delta into Pyramid Lake, and to the 31-mile length of the Truckee Canal from the point of diversion at Derby Dam to the terminal drop structure at Lahontan Reservoir (figure 3). The model was designed for steady-state applications; that is, river and tributary point and nonpoint discharges are assumed to be constant in time for the period modeled.

The model is one-dimensional in construction, assuming uniform mixing at all points along the longitudinal profile. Water-quality constituents modeled include dissolved solids (DS); ultimate carbonaceous biochemical oxygen demand ($CBOD_u$); dissolved-oxygen (DO) concentrations, deficits, and percent saturation; organic-, ammonia-, nitrite-, nitrate-, and total-nitrogen; ortho- and total phosphorus; and inorganic nitrogen/phosphorus ratios (N/P). Dissolved solids are modeled as a conservative constituent, all other water-quality constituents are modeled assuming first-order reactions, decays, or transformations.

Figure 3 near here

Acknowledgments

The author is grateful to numerous individuals and agencies contributing data, time, and manpower to this study. Major contributors to field studies are acknowledged by La Camera and others (1985). All members of the original RQA team, Lawrence H. Smith, William Brown, III, Ray J. Hoffman, and Richard J. La Camera, gave unstintingly of their time and energy to the efforts culminating in this report. Suzanne Lima, Jan M. Surface, Jonathan J. Rhodes, and David E. Blackstun made substantial contributions to the data reduction and computer applications of the study. Other agencies providing data and consultation included the Cities of Reno and Sparks, the Nevada Division of Environmental Protection, the U.S. Fish and Wildlife Service, the Pyramid Lake Paiute Indian Tribe, the Truckee-Carson Irrigation District (TCID), the Washoe Council of Governments, the Sierra Pacific Power Company, and the U.S. Bureau of Reclamation. Special tribute goes to the memory of Claude Dukes (Federal Watermaster, 1958-84), who shared his many years of experience with the

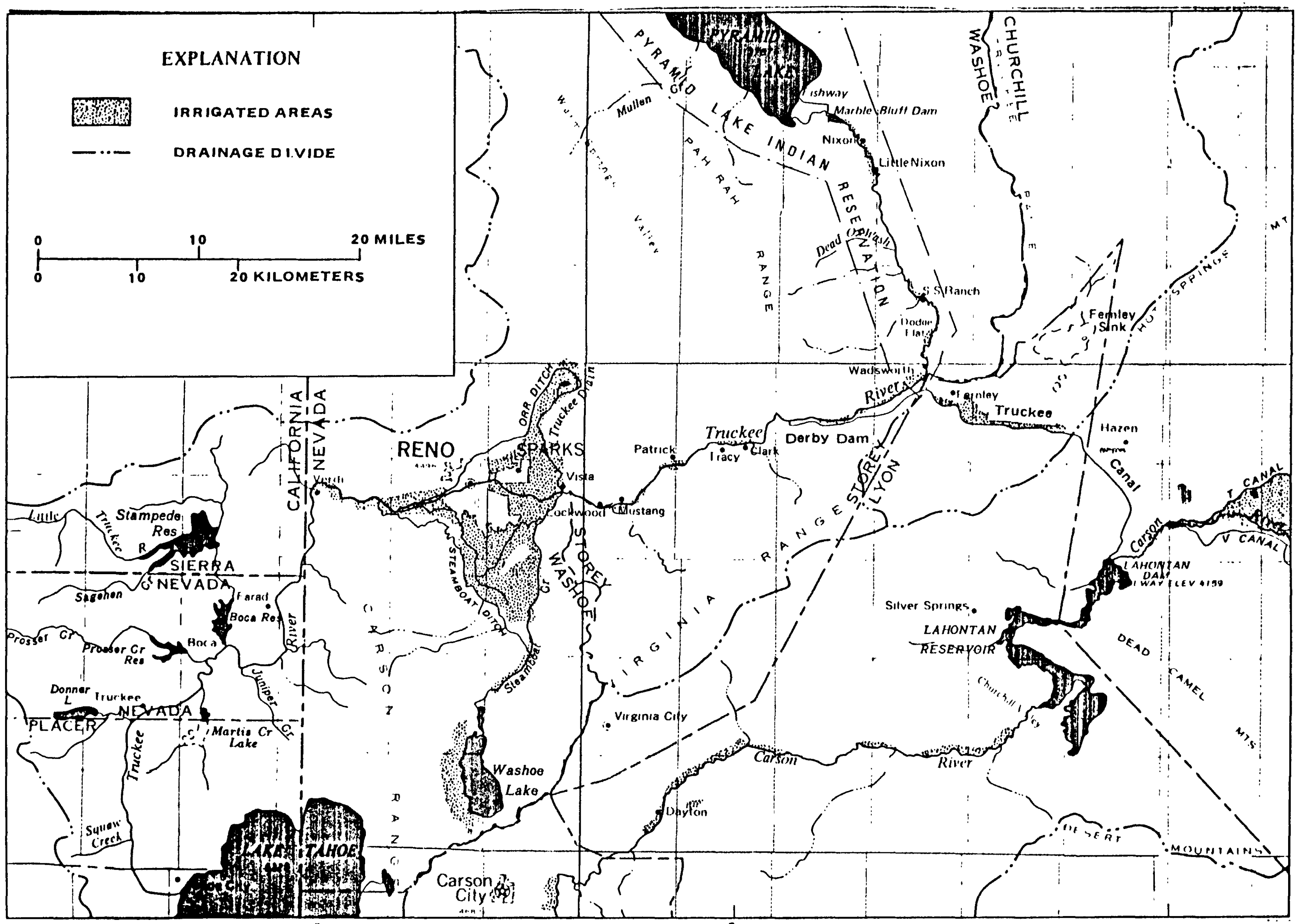


FIGURE 3.--The Truckee River flows from Lake Tahoe to Pyramid Lake in a closed basin. Water diverted to the Truckee Canal at Derby Dam is used for irrigation and is stored in Lahontan Reservoir.

operational hydrology of the Truckee River. We are also grateful to the many landowners along the Truckee River and Canal for permitting access (often during very unreasonable hours) for field studies.

DESCRIPTION OF THE STUDY AREA

The physical and hydrologic characteristics of the Truckee River basin have been described in detail in a preceding report by Brown and others (1986). Additional background hydrologic information, including estimates of water budgets for segments of the river basin in Nevada are given in a report by Van Denburgh and others (1973). For an in-depth understanding of this complex hydrologic system, the reader is referred to those publications and other individual references as cited below.

Physical Setting

The Truckee River watershed is a topographically enclosed basin with its headwater in the Sierra Nevada range of California and its terminus at Pyramid Lake in the Basin and Range province of Nevada (figures 1 and 3). Altitudes in the headwater of the basin exceed 10,000 feet above sea level in the mountains surrounding Lake Tahoe. At the terminus, Pyramid Lake lies at an altitude of 3,795 feet (1977) surrounded by stark desert mountains with altitudes from 7,000 to 8,000 feet. The total drainage area of the basin is 3,120 mi^2, of which 1,940 mi^2 contribute to the 116-mile length of the main-stem river between the Lake Tahoe and Pyramid Lake drainage basins.

The headwater of the Truckee River is Lake Tahoe, surrounded by the mountains of the Sierra Nevada on the California-Nevada State line. The lake is world renowned for the beauty of its setting and the purity and clarity of its deep, cool waters (Crippen and Pavelka, 1970). About two-thirds of the lake is in California and one-third in Nevada. The economy of the Tahoe basin is dominated by tourism, centering on summer recreation on the lake and the surrounding mountains, winter alpine and nordic skiing, and year-round gaming at casinos in the Nevada portion of the basin. Homes and businesses are concentrated in a ring about 2 miles wide surrounding the lake; the remainder of the basin is essentially undeveloped mountains. The Tahoe basin is completely sewered, with treated sewage from the northeast, east, and southeast shores exported to the Carson Valley in Nevada, and sewage from the northwest, west, and southwest shores transported into the Truckee River basin for treatment and disposal at a facility near the mouth of Martis Creek near Truckee, Calif.

From the the outlet of Lake Tahoe at Tahoe City, Calif., the Truckee River flows north about 15 miles to the town of Truckee, then northeasterly for about 26 miles across the California-Nevada state line to Verdi. Throughout most of this upper reach, the basin is a forested mountain watershed, with the last 16 miles traversing the Truckee Canyon, a deeply incised breach through the Sierra Nevada. Land development in this upper reach of the Truckee River is relatively light, with the economy based on recreation and, to a lesser extent, logging in the surrounding mountains. Principal tributaries are Squaw, Donner, Martis, and Prosser Creeks, and the Little Truckee River.

Downstream from Verdi, the Truckee River flows to the east about 10 miles to Vista, through the Truckee Meadows, an alluvial valley containing the Reno-Sparks urban area. Development in the Truckee Meadows was historically based on agriculture (principally alfalfa and pasture for cattle). Irrigated lands are bounded on the west by supply ditches diverted to the north and south of the river, and on the east by return drains into North Truckee Drain north of the river and Steamboat Creek to the south. The current economy of the Reno-Sparks area is dominated by gaming and tourism; growth of those industries has resulted in rapid urbanization of the Truckee Meadows, with a concomitant shift in land and water use (Dahl, 1978, 1980; Gruen Gruen and Associates, 1979). During the period 1970 to 1980, the combined population of Reno and Sparks townships grew 160 percent to 190,800.

Below the Truckee Meadows, the river flows about 29 miles in an easterly direction to Wadsworth. The first 17 miles below Vista traverses a shallow canyon to Derby Dam, the point of diversion to the Truckee Canal. Population is sparse, centered in the vicinity of Lockwood and Patrick. Agriculture is limited to the narrow flood plains of the river and is supported by surface diversions from the river. Tributaries to the river are ephemeral; flows occur only in response to major precipitation events, usually summer thunderstorms. From Derby Dam to Wadsworth, the river is bordered by small ranches irrigating with diversions from the river and canal.

At Wadsworth, the river turns to the north and flows about 23 miles through the Pyramid Lake Indian Reservation to Marble Bluff Dam. This point on the river, known historically as the "Big Bend of the Truckee River," was the first resting stop after the arduous crossing of the Forty-Mile Desert for emigrants on the Overland Trail (Curran, 1982), and marks the southernmost boundary of the Pyramid Lake Indian Reservation, founded by an Executive Order in March 1874 (Knack and Stewart, 1984). Population in the lower river basin is sparse, limited to Wadsworth, the Indian communities of Little Nixon and Nixon, and a few private ranches within the reservation. Tributaries are limited to washes that are dry except during and immediately following major precipitation events. Marble Bluff Dam was constructed in 1976 for fishery management to stabilize erosion at the mouth of the river and to provide fish passage around the delta of the river via a fishway. The length of the delta below the dam varies with lake stage (about 4 miles in 1979); thus, the crest of the dam is used in this report as river mile (RM) 0.00 for referencing upstream river locations on the Truckee River (Brown and others, 1986, p. 80). The delta is characterized at low flows by a braided channel incised in older deltaic sediments, and at high flows by a rapidly shifting and severely eroding channel that contributes major loads of sediment to Pyramid Lake (Born 1970, 1972; Born and Ritter, 1970; Glancy and others, 1972).

Pyramid Lake is the terminus of the Truckee River system, and is a remnant of Pleistocene Lake Lahontan that once covered much of the Great Basin (Wheeler, 1967). The lake is the largest water body wholly within Nevada. The lake is about 25 miles long, averages about 7 miles wide, and is over 350 feet deep. At the 1980 water-surface altitude of 3,794 feet, the lake had a surface area of about 109,000 acres and a volume of 21 million acre-feet (Harris, 1970). It has no outlet; inflows are balanced by evaporation.

Upstream water use and diversions of about 35 percent of the annual flow of the Truckee River through the Truckee Canal have greatly contributed to the observed decline in lake elevation of about 80 feet between 1844 (when discovered by John Fremont) and its recent mininum in 1967. Because Pyramid Lake has no outlet, its salinity is a function of the total volume of the lake and the loading of salts by the Truckee River and ephemeral tributaries within the Pyramid Lake basin. As the volume of the lake was reduced by evaporation exceeding inflow, the salinity has increased at a rate greater than prior to diversions from the Truckee River (Smith, 1980). ~~Current~~ As of 1980, dissolved solids concentrations in the lake are about 5,300 milligrams per liter (mg/L), limiting the species diversity of lake biota.

Pyramid Lake is the habitat of the Lahontan cutthroat trout (*Salmo clarki henshawi*), the largest subspecies of its kind. The world's sportfishing record for the species (41 pounds) was caught in the lake in 1941. The lake and lower river are also the sole habitat of the cui-ui lakesucker (*Chasmistes cujs*), an endangered genus of fish and a historical food resource to the Pyramid Lake Paiute Indian Tribe. Fishery management at the lake is concerned that the future of both fish will be in jeopardy if lake levels continue to decline with concomitant increases in salinity.

Pyramid Lake is entirely within the Pyramid Lake Indian Reservation of the Paiute Tribe, which manages the recreational and fishery resources of the lake and lower (below Wadsworth) river. Water management conflicts focusing on the lake include conflicts over rights to inflowing waters, endangered species issues, and conflicting Indian, State, and Federal claims for management and administrative authority (Townley, 1977; Knack and Stewart, 1984).

The Truckee Canal diverts water from the Truckee River at Derby Dam to supply irrigation water to the Newlands Project, the first Federal reclamation program in the United States (Townley, 1977). Construction of the dam and canal was begun in 1903, and the project was operational in 1915 with the completion of Lahontan Dam. Water is used to irrrigate about 3,500 acres of farmland in the Fernley area (Van Denburgh and Arteaga, 1985) and is stored along with water from the Carson River in Lahontan Reservoir for subsequent irrigation of about 60,000 acres in the Newlands Project in the vicinity of Fallon. Minor irrigation releases are made from the canal between Derby Dam and Fernley to irrigate ranches along the Truckee River.

Design capacity of the Truckee Canal was about 1,500 ft^3/s, but siltation and minor cave-ins in three tunnels in the upper reach of the canal limited the maximum effective capacity during this study to about 900 ft^3/s.

Lahontan Reservoir stores diverted water from the Truckee Canal and largely unregulated flows from the Carson River for agricultural use in the Newlands Project. At maximum pool, the reservoir has a surface area of about 10,900 acres and a usable storage of about 300,000 acre-feet. In addition to the designed argicultural uses, the reservoir has become a popular recreational area for northern Nevada, with a State park offering camping, boating, fishing, and other water-related activities.

The gradient of the Truckee River and Canal is shown by the channel profile in figure 4. The river gradient is steep in the passage through the Sierra Nevada above the Truckee Meadows, averaging 34 ft/mi above Farad and 35 ft/mi from Farad to Reno. The gradient through the Truckee Meadows is controlled by a bedrock sill at Vista, resulting in a relatively flat (1.6 ft/mi) reach through the last 8 miles of the Truckee Meadows. Below Vista the slope averages 9.6 ft/mi in the 10-mile reach to Derby Dam, and 9.7 ft/mi in the 35 miles from Derby Dam to Marble Bluff Dam. The gradient for the 34-mile length of the Truckee Canal averages 1.1 ft/mi. The canal terminates in an inclined concrete drop structure into Lahontan Reservoir. Because the total length of the canal is a function of reservoir stage, the control gate at the head of the drop structure is designated in this report as canal mile (CM) 0.00 to reference upstream canal locations (Brown and others, 1986, p. 80). The numerous diversions from and agricultural returns to the river are shown schematically on the channel profile. The diversion structures have important localized effects on channel slope for modeling and affect both the quantity and, by the associated returns, quality of the river as is discussed in following sections of this report.

Figure 4 near here

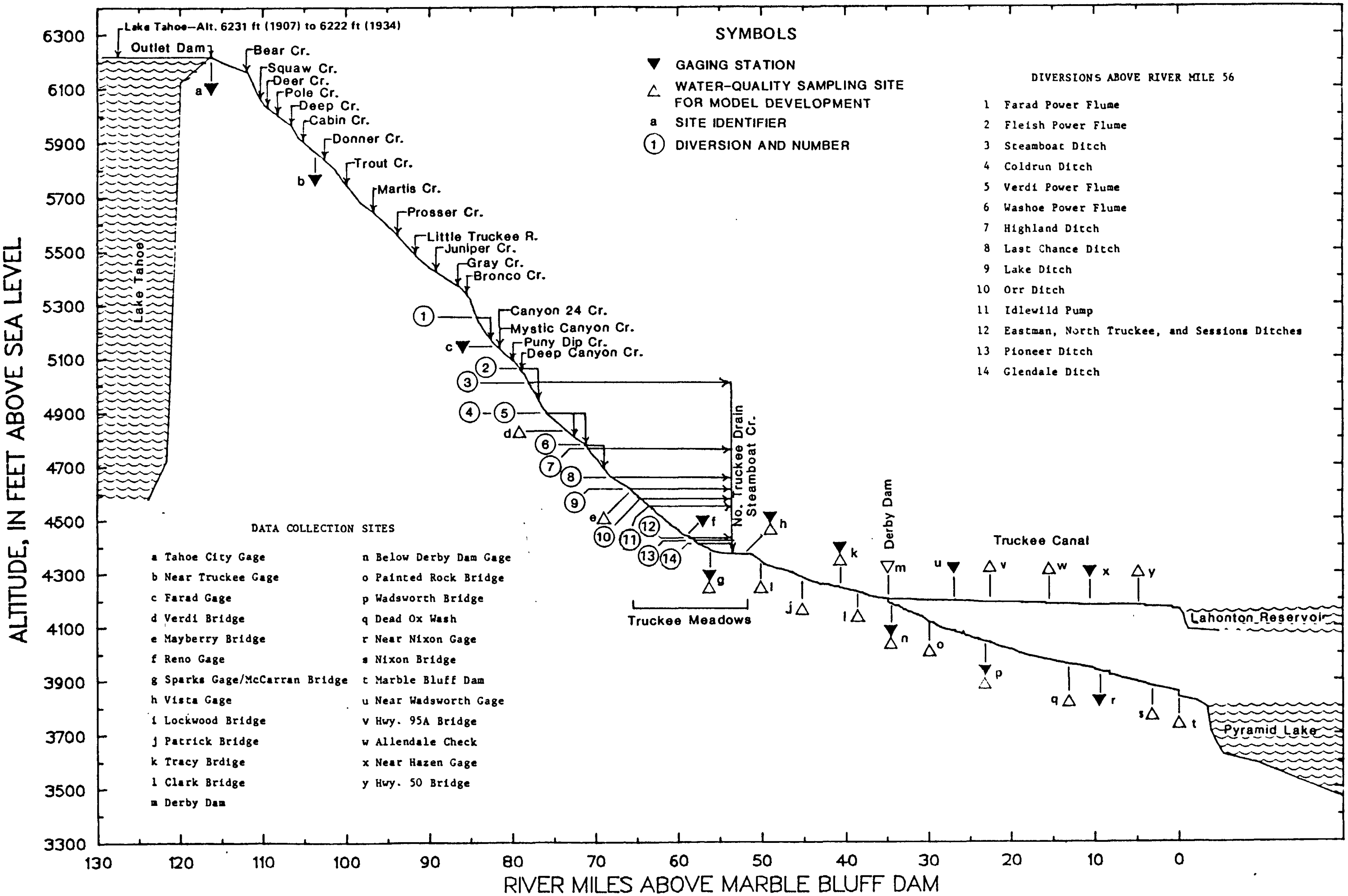


FIGURE 4.--The Truckee River and Canal have distinctly different channel profiles.

Climate

Climate in the basin is controlled by the orographic barrier of the Sierra Nevada. As the prevailing westerly winds laden with moist Pacific air ascend the Sierra slopes west of the basin to altitudes where temperatures are lower, condensation causes abundant snow and rain during the winter and spring. Most of the precipitation in the mountains is in the form of snow, with more than 90 percent of the annual precipitation at altitudes above 8,000 feet consisting of snow. The average annual snowfall in the Sierra Nevada amounts to more than 20 feet, with as much as 65 feet falling in some years (Houghton and others, 1975). During some winters, warm storms move through the Sierra, raising the altitude of the snow line and dropping significant amounts of warm rain on the winter snowpack. These storms, usually occurring in January or February, can cause significant short-term snowmelt and may cause significant flooding in downstream reaches of the Truckee River, particularly in the urban Truckee Meadows area.

Relatively little moisture passes to the east side of the Sierra and into the Basin and Range Province. As the winds descend the east slope, they are warmed and consequently are able to evaporate moisture from the ground. The Truckee Meadows is classified as semi-arid and precipitation decreases across the valley with distance from the Sierra. Along the Sierra crest at the west boundary of the basin, annual precipitation may exceed 30 inches; however, at the Reno airport, on the east side of the valley, average annual precipitation is about 7 inches. Downstream from (east of) Vista, the basin is arid, with annual precipitation averaging less than 6 in/yr. The precipitation in the Basin and Range is unevenly distributed through the year. About 70 percent of the annual precipitation at Reno is rain, with most rainfall occurring in the spring and late autumn, and an average of less than 1 inch falling from July to October.

Hydrology

The following narrative offers a simplified outline of the complex natural, structural, and institutional controls on streamflow in the Truckee River basin. A more complete overview of the physical system is presented by Brown and others (1986), and by Jones and Stokes Associates (1980). Short summaries of the legal and institutional conflicts affecting water management are given by Dahl (1978, 1980); a more detailed discussion may be found in Jones and Stokes and Stanford Environmental Law Society (1980).

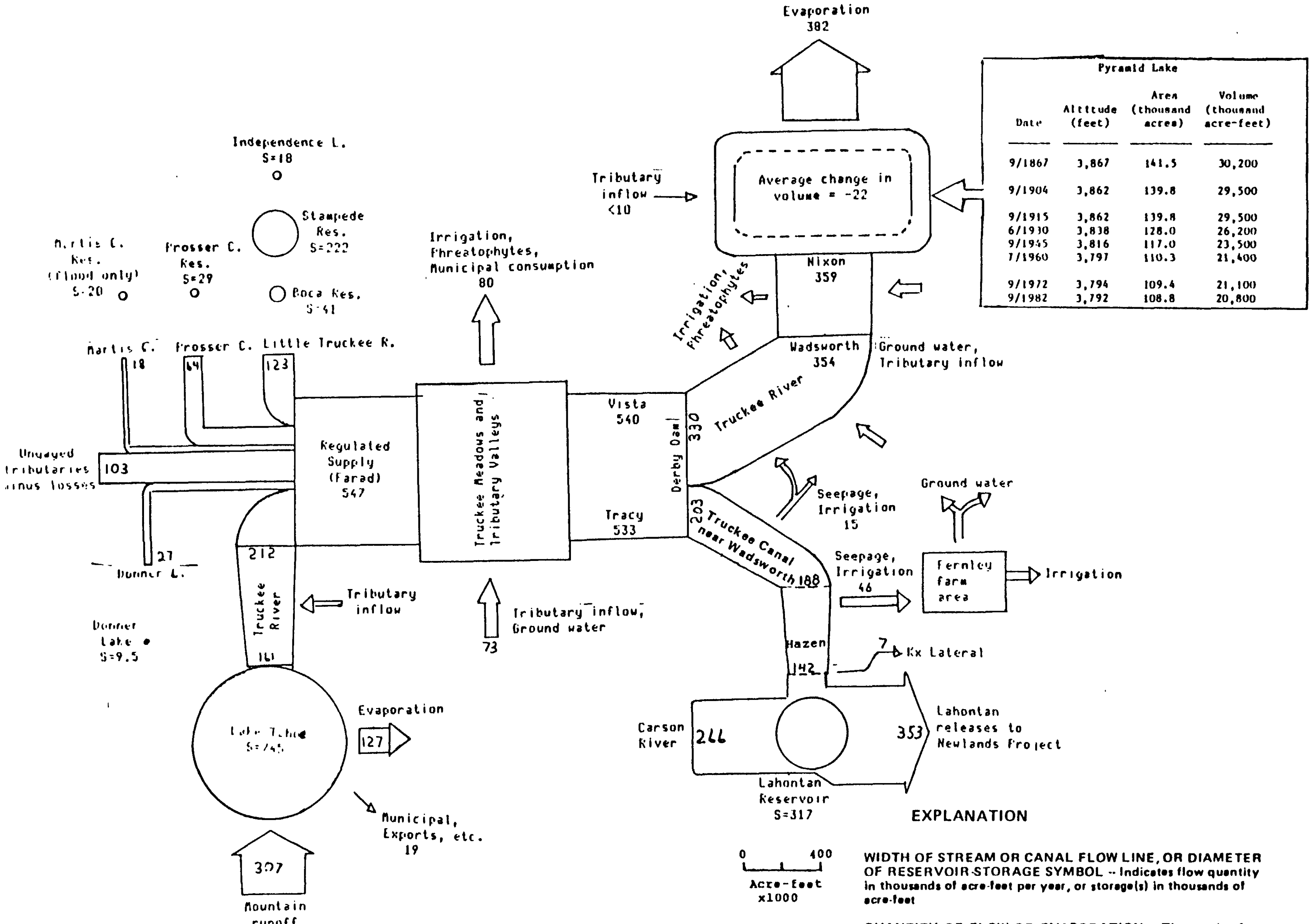
Streamflow

Most streamflow in the Truckee River basin is derived from snowmelt in the headwater in the Sierra Nevada. Under natural (pre-diversion and regulation) conditions, Lake Tahoe served as a control for downstream flow in the Truckee River. During spring runoff, snowmelt water would be stored and released as determined by preceding lake levels and the capacity of the lake outlet. During drought years, the lake level could drop below the outlet of the lake, resulting in no flow in the downstream Truckee River after the end of spring runoff from other tributaries. Currently, regulation of the river above (upstream of) Farad is achieved by controlling releases from eight reservoirs (including Lake Tahoe) on tributaries above the Nevada-California state line. Withdrawals and diversions of water for agricultural and municipal uses are concentrated in the valleys downstream of the Sierra; consequently, streamflow decreases with distance from the mountain front.

The basic flow system for the Truckee River is shown in figure 5, which is a simplified flow schematic based on mean annual streamflows for the 10-year period including water years (October to September) 1973-82 (table 1). Releases of water from Lake Tahoe for this period averaged 161,000 acre-feet. Combined inflows from Donner, Martis, and Prosser Creeks, the Little Truckee River, and other ungaged tributaries resulted in a mean annual discharge for the Truckee River at Farad, Calif., of 547,000 acre-feet, representing the total available water supply from the main-stem river to Nevada. At the Vista gage below (downstream from) agricultural and municipal diversions in the Truckee Meadows, the mean annual discharge for the period was 540,000 acre-feet, slightly less than at Farad, even though the drainage area is 53 percent greater at Vista than at Farad. About 7,000 acre-ft/yr were lost above Derby Dam, between Vista and Tracy, from irrigation diversions and evapotranspiration of riparian vegetation.

Figure 5 near here

Table 1 near here



Pyramid Lake			
Date	Altitude (feet)	Area (thousand acres)	Volume (thousand acre-feet)
9/1867	3,867	141.5	30,200
9/1904	3,862	139.8	29,500
9/1915	3,862	139.8	29,500
6/1930	3,838	128.0	26,200
9/1945	3,816	117.0	23,500
7/1960	3,797	110.3	21,400
9/1972	3,794	109.4	21,100
9/1982	3,792	108.8	20,800

EXPLANATION

0 — 400 Acre-Feet x1000 — WIDTH OF STREAM OR CANAL FLOW LINE, OR DIAMETER OF RESERVOIR-STORAGE SYMBOL -- Indicates flow quantity in thousands of acre-feet per year, or storage(s) in thousands of acre-feet

353 — QUANTITY OF FLOW OR EVAPORATION -- Thousands of acre-feet per year

S=20 — QUANTITY OF STORAGE -- Thousands of acre-feet

Note: Sources of data, Nevada State Study Team (1973) and VanDenburgh and others (1973)

FIGURE 5.--The Truckee River ceases to gain water after flowing into the Truckee Meadows; downstream diversions have resulted in declining levels of Pyramid Lake.

TABLE 1.--Comparative streamflow records for water years 1973-82

Gaging station	River mile	Drainage area (mi^2)	Mean annual flow (acre-feet x 1,000)	Mean annual flow (ft^3/s)	Basin yield [(ft^3/s) /mi^2]
Truckee River above Truckee Meadows:					
10337500 at Tahoe City	116.20	507	161	222	0.44
10338000 near Truckee	103.62	553	[a]212	[a]292	.53
10346000 at Farad	81.89	932	547	755	.81
In the Truckee Meadows:					
10348000 at Reno	59.07	1,067	461	637	.60
10348200 near Sparks[b]	56.15	1,070	--	--	--
Truckee Meadows to Derby Dam:					
10350000 at Vista	52.23	1,431	540	746	.52
10350400 below Tracy	40.62	1,590	533	736	.46
Below Derby Dam:					
10351600 below Derby Dam	34.49	1,676	330	456	.27
10351650 at Wadsworth	23.11	1,728	354	489	.28
10351700 near Nixon	9.42	1,827	359	496	.27
Truckee Canal:					
at Derby Dam	31.42	--	[c]203	[c]280	--
10351300 near Wadsworth	22.85	--	188	259	--
10351400 near Hazen inflow	6.15	--	142	196	--
to Lahontan Reservoir	.00	--	[d]135	[d]186	--

[a] Estimated (Blodgett and others, 1984).

[b] Only 5 years of data, starting April 1977.

[c] Estimated as Tracy minus below Derby.

[d] Estimated as Hazen minus 7 ft^3/s for unmeasured diversion.

Below Derby Dam, the river flows averaged 330,000 acre-ft/yr, reflecting diversions of about 38 percent of the available flow into the Truckee Canal. About 11 miles downstream, at Wadsworth, average flows increased to 354,000 acre-ft/yr due to seepage losses from the Truckee Canal and ground-water returns from the Fernley area. Average flows near the terminus of the river as gaged near Nixon is 359,000 acre-ft/yr. Pyramid Lake levels declined about 2 feet ~~lower~~ over the 10-year period (1973-82), resulting in a loss of about 220,000 acre-feet of water, or about 22,000 acre-ft/yr. This loss was due to the imbalance between river inflow and lake evaporation (about 382,000 acre-ft/yr), and continued a historical trend in declining lake level since the beginning of diversions into the Truckee Canal in 1915.

Diversions from the river into the Truckee Canal averaged about 203,000 acre-ft/yr for the 10-year period (1973-82). Flows at the U.S. Geological Survey gage on the canal near Wadsworth were 188,000 acre-ft/yr, reflecting irrigation diversions and seepage losses in the intervening reach from the point of diversion at Derby Dam. Between the Wadsworth and Hazen canal gages, diversions to the Ferley Farm area and seepage losses from unlined reaches of the canal reduced flows to 188,000 acre-ft/yr. Net inflows to Lahontan Reservoir for the period were about 135,000 acre-ft/yr.

Regulation

Regulation of streamflow in the Truckee River began in 1870 with construction of a timber dam across the natural outlet of Lake Tahoe. The last regulatory structure added to the system was Martis Creek Dam, finished in 1972. The history, capacity, and operation of the eight reservoirs on the system are shown in table 2. The operation of the system is complex and is detailed by Brown and others (1986).

Table 2 near here

The river has been managed by a court-appointed Federal Watermaster since 1926 as an "interim" procedure awaiting settlement of several suits over water rights. Water releases are controlled to meet appropriated water rights for municipal and irrigation uses, for flood-control purposes, and for fishery management on the Pyramid Lake Indian Reservation. The principal legal mandates for streamflows are the Floriston Rates, established by a Federal District Court in 1915 to specify minimum flows across the California-Nevada State line as measured at the Floriston gage (moved to Farad in 1935). The Floriston Rates are keyed to the water-surface altitude at Lake Tahoe and the irrigation season (table 3, figure 6). In addition to the minimum flows specified by the Floriston Rates, minimum flows are specified for fishery purposes at the outlets of Lake Tahoe (50 ft^3/s winter, 70 ft^3/s summer), Prosser Creek Reservoir, and Stampede Reservoir.

Figure 6 near here

Table 3 near here

TABLE 2.--Operational criteria for storage reservoirs in the Truckee River basin
[after Brown and others, ~~in press~~ 1986]

Reservoir name	Minimum outflow (ft^3/s)	Maximum outflow (ft^3/s)[1]	Flood storage reserve for indicated time period (acre-feet)[2]	Priority of storage[3]	Priority of release[4]	Usable volume (acre-ft)[5]	Date of beginning of operation
Lake Tahoe	[6]50-70	2,500	--	[7]3	[8]2	744,600	[9]1913
Lahontan	0	3,000	[10]80,000-Nov 1-Mar 1	[11]3	--	[12]295,150	1914
Independence Lake	3	300	--	[13]2 [15]6	(14)	17,500	[9]1937
Boca	0	900	8,000-Nov 1-Apr 30	[7]5	[8]1	40,900	1938
Donner Lake	0	700	7,300-Nov 15-Apr 15	1	(14)	9,500	[16]1943
Prosser Creek	5	1,950	20,000-Nov 1-Apr 10	[16]4,8	[6]3	28,640	1963
Stampede	[17]30 or inflow	2,740	22,000-Nov 1-Apr 20	[7]7	(18)	221,500	1969
Martis Creek Lake	Inflow	620	19,600-year around	flood only	--	19,600	1972

[1] Indicates outflow that can be regulated up to conditions of flow over spillway.

[2] Flood storage reserves are maintained in decreasing amounts until as late as July, depending on runoff predictions. Flood storage is used whenever flow at Truckee River at Reno gage (10348000) exceeds 6,000 ft^3/s.

[3] Priorities under flood conditions are ignored.

[4] To maintain Floriston rates, water is drawn from the reservoir in this order to the extent possible.

[5] Best available data based on records or reservoir operators and the Office of the Federal Watermaster, Reno, Nev. (written communication, 1979).

[6] If equivalent rates of flow can be stored in Prosser Creek Reservoir, releases from Lake Tahoe will be 70 ft^3/s from April 1 to November 1 and 50 ft^3/s for the rest of the year. Release priority for Prosser Creek Reservoir pertains only to water stored in this manner.

[7] When Floriston rates are exceeded as much water as possible is stored.

[8] When the elevation of Lake Tahoe drops below 6,225.5 feet, the release priorities of Lake Tahoe and Boca Reservoir are exchanged.

[9] Storage occurred earlier; date indicates entrance into the integrated operation.

[10] Temporary restrictions until modifications to the dam are completed.

[11] Storage rate is limited by the rate of flow diverted throught the Truckee Canal.

[12] May be increased to 317,280 acre-feet with the use of flashboards on spillways.

[13] Storage up to 3,000 acre-feet.

[14] Privately owned water is not used to maintain indicated rates. Sierra Pacific Power Company and Truckee-Carson Irrigation District acquired storage rights for Donner Lake water in 1943 from Donner Lake Company. Sierra Pacific Power Company acquired storage rights for Independence Lake water in 1937.

[15] Storage up to 14,500 acre-feet.

[16] Truckee-Carson Irrigation District acquired storage righta for Lahontan Reservoir in 1926 from the U.S. Bureau of Reclamation. Storage of this priority is related to the flow rates that can be released from Lake Tahoe, and may not exceed 70 ft^3/s for the rest of the year.

[17] If content is greater than 5,000 acre-feet, then 30 ft^3/s is the minimum; otherwise, the outflow may equal the inflow.

[18] Rate of release is determined by the Secretary of the Interior.

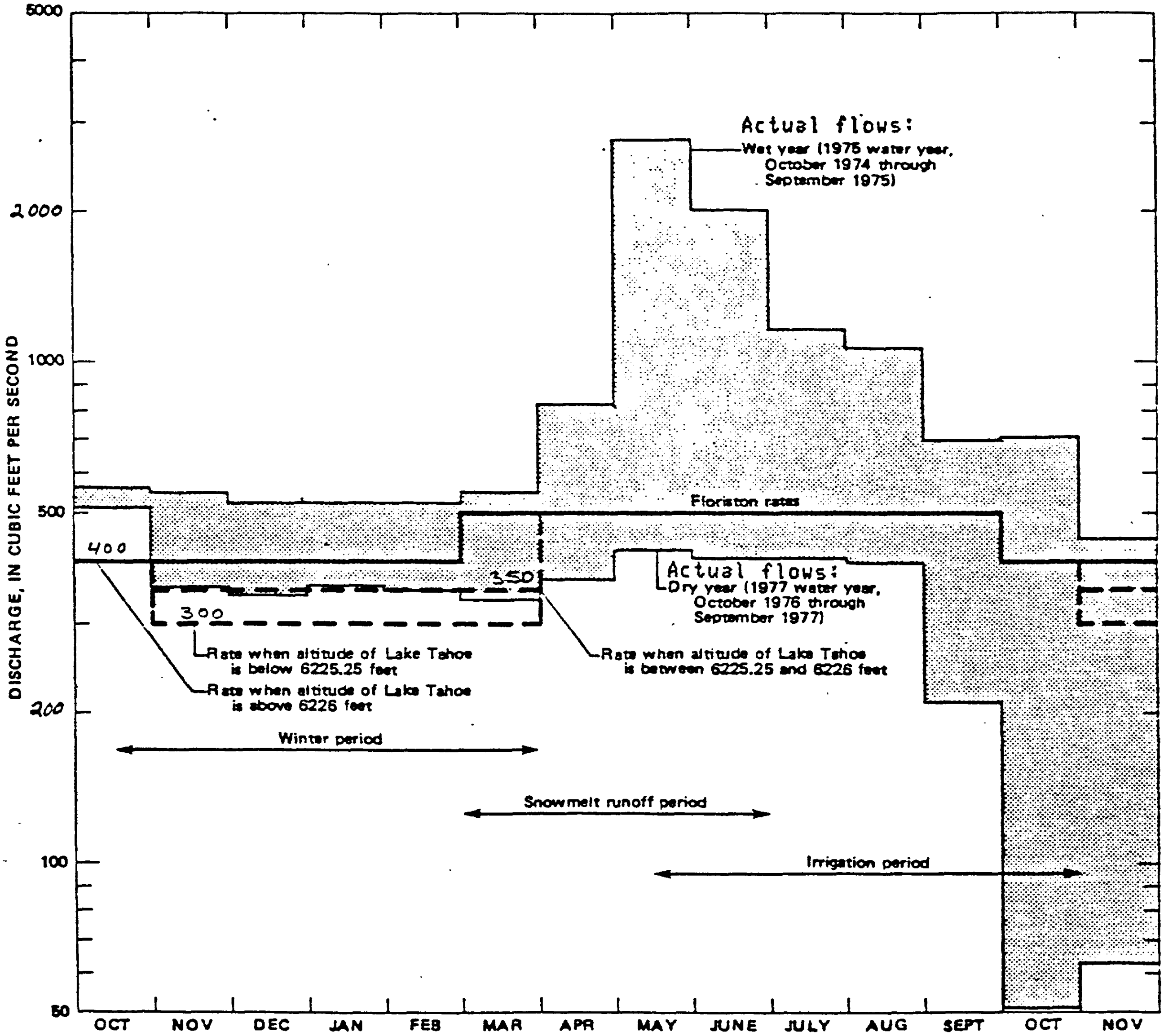


FIGURE 6.--The Floriston rates set seasonal requirements for minimum streamflows in the Truckee River at the California-Nevada State line.

TABLE 3.--Floriston rates controlling minimum Truckee River flows from California into Nevada

[from Brown and others, ~~in press~~ 1986]

Water-surface altitude at Lake Tahoe Dam (feet above sea level)		Floriston rates: Flow at Farad Gage (10346000) (ft^3/s)			
		Oct	Nov-Feb	Mar	Apr-Sept
Below	6,225.25	400	300	300	500
Between	6,225.25 and 6,226	400	350	350	500
Above	6,226	400	400	500	500

Flood-control criteria also affect reservoir operation. Flood storage begins in three reservoirs (table 2) when streamflow at the Reno gage exceeds 5,000 ft^3/s and continues, if sufficient storage is available, as long as flow at Reno exceeds 5,000 ft^3/s. Flood-control criteria also can have seasonal impacts on low flows as flood-storage reservoirs must be drawn down to provide specified flood-storage capacity in October of each year. Water rights on the Truckee River are assigned on the prior-appropriation basis common to Western water law ("first in time, first in right"). Conflicting claims for water rights have been a matter of litigation on the Truckee River for decades. The river is fully appropriated; thus in dry years, junior rights for water may not be fully met.

Diversions

Water is diverted at a number of places along the Truckee River for municipal, industrial, and agricultural uses. A detailed documentation of the diversion systems can be found in Brown and others (1986). A summary of dams and diversion structures is given in tables 4 (Truckee River) and 5 (Truckee Canal). Water rights for diversions in the basin were allocated by the Orr Ditch Decree of 1944, after 31 years of litigation. With expanding urban and suburban growth in the basin, particularly in the Truckee Meadows, development of former agricultural lands has resulted in abandonment of many diversions and conversions of water rights from agricultural to municipal use. Water rights and irrigated acreages decreed in 1944 are shown in table 6 in comparison with estimates of diversions and agricultural uses in 1978 and 1979.

Tables 4, 5, and 6 near here

TABLE 4.--Summary of dams and diversions structures on the Truckee River

Location: River miles above Marble Bluff Dam; landline locations give township, range, section and quarters based on Mt. Diablo baseline and meridian. Locations in brackets give original decreed location where different from current location.

Structures: Type--D = dam, P = electric pump, S = siphon, G = gate, N = none remaining, R = dam ruins; Construction--C = fixed-crest concrete, E = earth-fill with radial gate and concrete sluiceway, G = concrete with gates, R = rock-rubble with adjacent fixed diversion gate.

Head: approximate drop in water surface, variable with streamflow.

Diversions: Status (1979-80)--A = active, I = inactive, N = abandoned; To--diversion to right (R) or left (L) bank of river, looking downstream. Purpose--F = fish ladder, I = irrigation, H = hydroelectric power, M = municipal supply, N = industrial, T = thermoelectric power cooling.

Returns: River-mile locations given for point returns or reaches receiving principal nonpoint surface returns. Unless otherwise stated in Remarks, returns are to mainstem Truckee River.

Structures					Diversions						Returns	Remarks
	Location											
Number	River mile	Landline	Type	Construction	Head (ft)	Number	Status	To	Name	Purpose	River miles	Returns to versus returns at
1	116.27	N15 E17 07BA	D	G	—	-	-	-	Lake Tahoe Outlet	-	--	controls Lake Tahoe releases
2	84.30	N18 E18 30B	D	C	—	1	A	R	Farad Power Flume	H	82.5	returns to Farad Powerhouse
3	79.08	N19 E18 30CA	D	C	—	2	A	R	Fleish Power Flume	H	76.75	returns to Fleish Powerhouse
4	78.00	N19 E18 31CA	D	C	—	3	A	R	Steamboat Canal	I	53.53	returns to Steamboat Creek
--	76.3a	N19 E18 19DD	-	-	—	-	-	R	Coldron Ditch	I	--	former site
5	75.88	N19 E18 19DD	D	C	—	4	A	R	Verdi Power Flume	H	72.50	returns at Verdi Powerhouse
						5	A	R	Katz Ditch	I	--	--
						6	A	R	Coldron Ditch	I	71.16	last return
6	71.24	N19 E18 16AB	D	C	—	7	A	R	Washoe Power Flume	H	68.90	returns at Washoe Powerhouse
										I	--	--
7	70.95	N19 E18 16AA [N19 E18 09DC]	S	-	—	8	A	L	Highland Ditch	M	53.53	returns to Reno-Sparks STP
										I	--	--
--	70.7a	N19 E18 16AC	-	-	—	9	N	L	Hogan Ditch	I	--	abandoned
--	68.74	N19E18 14CD	-	-	—	10	N	L	Masten Ditch	I	--	abandoned
8	68.00	N19 E18 14AD	D	C	—	11	A	L	Last Chance Ditch	I	53.53	returns to Steamboat Creek
--	67.15	N19 E18 13DB	-	-	—	12	I?	L	Sparks-Cappurro Ditch	I	--	abandoned
9	65.88	N19 E19 19BA	D	-	—	13	A	R	Lake Ditch	I	53.53	returns to Steamboat Creek
						14	N	L	Irwin-Mayberry Ditch	I	--	abandoned
10	64.88 [64.81]	N19 E19 17CA	D	-	—	15	A	R	South Side Canal	I	63.51	last return

TABLE 4.--Summary of dams and diversions structures on the Truckee River--Continued

Structures					Diversions						Returns	Remarks
	Location			Con-								
Number	River mile	Landline	Type	struction	Head (ft)	Number	Status	To	Name	Purpose	River miles	Returns to versus returns at
11	64.70	N19 E19 17CA	D	C	—	16	A	L	Orr Ditch	I	53.66	returns to North Truckee Drain
--	64.42	N19 E19 17DA	-	-	—	17	N	R	Indian Flat Ditch	I	--	abandoned
12	63.11	N19 E19 16AA	D	C	—	18	N	R	Reno Power & Light Ditch	H	--	dam at Ivan Sack Park
--	62.75	N19 E19 16AA	D	-	--	19	N	L	Countryman Ditch	I	--	abandoned
						20	N	L	Chism Ditch	I	--	abandoned
--	61.23	N19 E19 10D	-		—	21	N	R	Hayden (Court) Ditch	I	--	abandoned
13	61.70	N19 E19 10DD	P		—	22	A	R	Idlewild Water Plant	M	53.53	returns to Steamboat C. via Reno-Sparks STP
--	60.05	N19 E19 10DB	-		—	23	N	L	English Mill Ditch	I	—	abandoned
14	60.94	N19 E19 11DB	D		—	24	N	L	Riverside Mill Flume	H	—	Dam at Arlington Park former site
							N	L	Sullivan & Kelley Ditch	N	—	
15	60.77	N19 E19 11DB	G		--	25	A	R	Cochran Ditch	I	53.53	returns to Steamboat Creek
16	58.77	N19 E20 07AB	P		—	26	A	L	Sullivan & Kelley Ditch	I	53.66	returns to North Truckee Drain
--	59.9a	N19 E19 12BC	-	-	—	27	N	R	Scott Ranch Ditch	I	—	abandoned
--	59.7a	N19 E19 12AD	D	-	—	28	N	R	Abbee Ditch	I	—	abandoned
						29	N	R	Perry Ditch	I	—	abandoned
17	58.61	N19 E20 07AC	D	R	4.7	30	A	L	North Truckee Ditch	I	53.66	returns to North Truckee Drain
						31	A	L	Sessions Ditch	I	53.66	returns to North Truckee Drain
						32	A	L	Glendale Water	M	53.66	returns to Steamboat C. via Reno-Sparks STP
						33	A	R	Eastman Ditch	I	53.53	returns to Steamboat Creek
18	58.05	N19 E20 07DD	D	R	5.8	34	A	R	Pioneer Ditch	I	53.53	returns to Steamboat Creek
19	57.66	N19 E20 08CD	D	R	4.9	35	A	L	Glendale Ditch	I	53.66	returns to North Truckee Drain
						36	N	L	Stephens Ditch	I	—	abandoned
--	51.7a	N19 E20 13AD	P	-	—	37	N	L	Fairchild Pump	I	--	abandoned
20	51.25	N19 E21 18DA	D	R	1.5	38	A	L	Largomarsio-Noce Ditch	I	51.25-50.45	—
21	51.10	N19 E21 18DB	D	R	4.9	39	A	R	Largomarsio-Murphy Ditch	I	50.06-46.68	—
22	49.90	N19 E21 17DA	D	R	1.2	40	A	R	Groton Ditch	I	49.90-48.98	—
--	49.70	N19 E21 16CB	R	R	--	41	I	L	Sheep Ranch Ditch	I	—	abandoned
23	46.70	N19 E21 11BA	D	R	3.5	42	A	L	McCarran Ditches (Northside & Southside)	I	45.95-43.04	—
--	44.9a	N19 E21 01BC	R	R	—	43	N	R	McCarran Southside Ditch	I	—	riffle at site
—	43.42	N20 E22 06AB	R	R	—	44	N	R	Old Ditch	I	—	riffle at site
24	42.02	N20 E22 32AB	D	R	3.5	45	A	L	Hill Ditch	I	40.97-38.61	—
25	40.76	N20 E22 33BA	D	C	3.5	46	A	R	Tracy Power	T	40.78	makeup water for cooling ponds, no returns

TABLE 4.--Summary of dams and diversions structures on the Truckee River--Continued

Structures: Number	Location: River mile	Location: Landline	Type	Con-struc-tion	Diversions: Head (ft)	Diversions: Num-ber	Diversions: Sta-tus	Diversions: To	Diversions: Name	Diversions: Pur-pose	Returns: River miles	Remarks: Returns to versus returns at
--	38.44	N20 E22 26CD	R	R	--	47	I	R	Eagle Pitcher pump	N	--	riffle at site
26	34.88	N20 E23 19C	D	G	13.0	48	A	R	Truckee Canal	I 1	32.70-25.0	Derby Dam
--	34.88	N20 E23 19CA	-	-	--	49	I?	R	Cadlini Ditch	I	--	diverted from Truckee Canal
--	34.36	N20 E23 20BD	R	R	--	50	N	R	Preston Ditch	I	--	riffle at site
27	31.28	N20 E23 22BD	D	C	2.0	51	A	L	Washburn Ditch	I	30.87-29.99	--
--	29.90	N20 E23 23AB	R	R	--	-	N	L	abandoned ditch (Preston?)	I	--	riffle at site
28	29.35	N20 E23 14DD	D	-	3.5	52	A	L	Gregory Ditch	I	28.41-23.72	connects with Herman Ditch
--	29.18	N20 E23 13CB	N	-	--	53	N	L	Wadsworth Light & Power Ditch	M I	-- --	site abandoned
29	26.75	N20 E24 17BB	D	R	3.5	54	A	L	Herman Ditch	I	26.50-23.72	Gregory and Herman Ditches combine
30	25.95	N20 E24 09CB	D	R	3.9	55	A	L	Pierson Ditch	I	25.35-24.51	--
31	23.90	N20 E24 03BC	D	R	3.5	56	A	R	Proctor Ditch	I	23.6 -19.16	--
--	25.1a	N20 E24 09ab	N	R	--	-	N	R	Olinghouse #1 Ditch	I	--	Decreed site
32	23.05	N21 E23 34CC	P	-	--	57	A?	R	Olinghouse #1 Ditch	I	23.0 -22.14	--
33	23.02	N21 E23 34CC	D	R	2.0	-	-	-	--	-	--	dam for Olinghouse pump
34	22.55	N21 E24 33DB	D	R	3.0	58	A	L	Fellnagle Ditch	I	21.67-19.85	--
--	20.70	N21 E24 22DC	N	R	--	-	N	R	Olinghouse #2 Ditch	I	--	decreed site
35	19.84	N21 E24 22DB	R	R	2.0	59	A	L	Gardella Ditch	I	19.84-17.00	Dam washed out Jan. 1980.
36	18.82	N21 E24 15DC	P	-	--	60	A?	L	Olinghouse #2 (Hamilton) Ditch	I	18.82-18.50	--
37	17.82	N21 E24 16AA	P	-	--	59	A	L	Gardella Ditch	I	17.82-17.00	supplemental pumping
--	18.40	N21 E24 15BC	N	R	--	-	N	R	Olinghouse #3 Ditch	I	--	Decreed site
38	17.50	N21 E24 16AA	P	-	--	61	A?	R	Olinghouse #3 (Hills) Ditch	I	17.50-15.91	--
39	8.21	N22 E24 18	D	C	11.6	62	A	L	Indian Ditch	I	6.30- .20	Numana Dam
40	0.00	N23 E23 15CC	D	E	20.0	63	A	R	Marble Bluff Fishway	F	--	Marble Bluff Dam and Fishway to Pyramid Lake

TABLE 5.--Summary of diversions from the Truckee Canal

Canal miles: Miles above terminal weir at Lahontan Reservoir.

Status (in 1979-80): A, active; I, inactive; N, abandoned or destroyed.

Purpose: I, irrigation; S, stockwater; M, municipal supply; H, hydropower.

[Diversion records obtained from Truckee Carson Irrigation District. Stockwater diversions are unmeasured, operate year round, and are estimated at 200 acre-feet/year.]

Canal mile	Name	Status	Purpose	1979 Diversions: Total acre-feet/ year	1979 Diversions: Average flow (April-November) (ft^3/s)	Remarks
30.92	Slattery #1 (TC-T2) Turnout, vested rights	A	I	220	0.4	--
30.09	Slattery #2 (TC-T3) Turnout, vested rights	A	I	200	.4	--
29.41	Thornton (TC-T4) Turnout	A	I	160	.3	--
28.57	Rocky (TC-T7) Turnout	A	I	99	.2	--
27.59	Frosdick (TC-T8) Turnout, vested rights	A	I	76	.2	--
27.47	Diversion gate	I	--	--	--	--
26.73	Derby Spillway	A	--	--	--	Used to bypass water to river
25.89	Diversion gate	I	--	--	--	--
25.35	Pyramid Check Dam	N	I	--	--	Original location for Pyramid Lake canal
24.63	Diversion gate and pipeline	I	--	--	--	--
23.76	Gilpin Spillway	A	--	--	--	Used to bypass water to river
20.93	KA (TC-1) Turnout	A	I	900	1.9	--
20.51	KA Pipeline	A	S	200	.3	--
20.10	Wilson (TC-T13) Turnout	A	I	740	1.5	--
19.73	Studer (TC-T14) Turnout	A	I	166	.4	--
19.08	KIB (TC-2) Turnout	A	I	876	1.8	--
18.58	KB Stockwater Turnout	A	S	200	.3	--
18.55	KIB (TC-3) Turnout	A	I	269	.6	--
18.26	KB (TC-4) Turnout	A	I	1,720	3.6	Maintains water-surface altitude for upstream diversions
18.03	KBA (TC-5) Turnout	A	I	4,810	10.0	--
18.02	Fernley Check Dam	A	--	--	--	--
17.85	KBA Stockwater Turnout	A	S	200	.3	--
17.40	KBB (TCT17) Stockwater Turnout	A	S	340	.7	--
16.61	TC-T18 pipeline diversion	N	I	--	--	Abandoned
16.19	Diversion gate	I	I	--	--	--

TABLE 5.--Summary of diversions from the Truckee Canal--Continued

Canal mile	Name	Status	Purpose	1979 Diversions: Total acre-feet/ year	1979 Diversions: Average flow (April-November) (ft^3/s)	Remarks
16.12	K2C (TCT19) Turnout	A	I	419	0.9	--
15.62	KC Turnout Picetti (TC-T20) Turnout	A	I	915	1.9	--
		A	S	200	.3	
15.22	Curry Pipeline (TC-T21) Turnout	A	I	246	.5	--
15.08	KC (TC-6) Turnout	A	I	2,057	4.3	--
	KIC (TC-7) Turnout	A	I	851	1.78	--
15.07	Anderson Check Dam	A	--	--	--	Maintains water-surface altitude for upstream diversions
14.53	Stockwater	A	S	200	.3	--
13.68	KC Turnout	N	I	--	--	--
13.54	KD (TC-8) Turnout	A	I	2,940	6.2	--
12.71	Anderson-Davis (TC-9) Turnout	A	I	368	.8	--
12.15	Davis (TC-T25) Turnout	A	I	652	1.4	--
11.63	KE Stockwater	A	S	200	.3	--
11.25	KE (TC-10) Turnout	A	I	1,015	2.1	--
11.08	TC-T28, private Turnout	A	I	306	.6	--
11.07	Allendale Check Dam	A	--	--	--	Maintains water-surface altitude for upstream diversions
8.08	Steneri (TC-T11) Turnout	A	I	674	1.4	--
6.70	SP (Hazen) Pipeline	N	M,I	--	--	Abandoned
6.55	KF (TC-12, Mason) Turnout	A	I	2,453	5.1	--
6.39	Mason Check Dam	A	--	--	--	Maintains water-surface altitude for upstream diversions
3.27	KX (TC-13) Turnout	A	I	5,490	11.5	--
3.25	Bango Check Dam	A	--	--	--	Maintains water-surface altitude for upstream diversions
.88	TC-13 Turnout	N	I	--	--	Abandoned
.21	Penstock to power house	I	H	--	--	--
.04	Bypass gate	I	--	--	--	--

TABLE 6.--Summary of irrigation water rights and diversions for the Truckee River

Status (1979-80): A, active; I, inactive; N, abandoned.

Purpose: H, hydroelectric power; I, irrigation; M, municipal; N, industrial; T, thermoelectric power cooling.

Decreed Diversions: Water rights as stated by the Orr Ditch Decree of 1944 for the point of application or diversion as shown. Most rights determined by a maximum annual use at point of application after any conveyance loss given in the Decree. Data for point of diversion flagged by (e), calculated from decreed rights at point of application and estimated conveyance losses in the Decree and are rounded to nearest 10 acre-feet.

Estimated for 1978: From Federal Watermaster's office as reported in Walters Engineering, 1979; may include municipal as well as irrigation uses.

Diversions in 1979: Federal Watermaster records for calendar year 1979. Data generally based on once-weekly measurements during the irrigation season and should be considered estimates. Measurements generally made near heads of ditches and thus reflect gross supply including conveyance losses.

Irrigated acreages: 1978 estimates from Federal Watermaster's office as reported by Walters Engineering, 1979.

Number	Name	Status	Purpose	Diversion quantities (acre-feet/year except as noted): By Orr Ditch Decree: Maximum diversion (ft^3/s)	By Orr Ditch Decree: At point of application	By Orr Ditch Decree: Estimated conveyance loss (percent)	By Orr Ditch Decree: At diversion	Estimated for 1978	Diverted in 1979	Irrigated acreages: Decreed	Irrigated acreages: Estimated in 1978	Remarks
1	Farad Power Flume	A	H	400	—	—	—	—	—	—	—	—
2	Fleish Power Flume	A	H	327	—	—	—	—	—	—	—	—
3	Steamboat Canal	A	I	90.87	16,468	30	23,530 (e)	15,870	35,924	4125.3	3,903	—
4	Verdi Power Flume	A	H	399	—	—	—	—	—	—	—	—
5	Katz Ditch	A	I	5.50	477	—	480 (e)	334	2,000	106.0	74	Supplied from Verdi Power Flume
6	Coldron Ditch	A	I	18.67	1,390	25	1,850 (e)	1,390	5,810	308.5	263	—
7	Washoe Power Flume	A	H	396	—	—	—	—	—	—	—	—
			I	1.56	307	—	310 (e)	307		76.6	77	
8	Highland Ditch	A	M	40	—	—	28,980	34,620	—	—	—	—
			I	36.43	6,889	15	8,100		—	1,832.5	540	
9	Hogan Ditch	N	I	9.68	712	8	770	0	0	178.0	0	—
10	Masten Ditch	N	I	1.29	98	3	100 (e)	0	0	24.3	0	—
11	Last Chance Ditch	A	I	47.35	8,644	20	10,800 (e)	6,791	9,721	2,039.9	1,736	—
12	Sparks-Cappurro Ditch	I	I	2.11	228	5	240	224	0	56.9	0	—
13	Lake Ditch	A	I	44.08	7,948	20	9,940	6,792	12,769	1,945.5	1,663	—
14	Irwin-Mayberry Ditch	N	I	2.16	186	7	200	0	0	46.4	0	—
15	South Side Canal	A	I	39.33	5,555	20	6,940	265	977	1,326.6	66	—
16	Orr Ditch	A	I	87.09	15,601	28	21,670	10,870	27,073	3,999.1	2,921	—
17	Indian Flat Ditch	N	I	23.85	1,942	15	2,280	0	0	420.2	0	—
18	Reno Power & Light Ditch	N	H	296	—	—	—	—	0	—	—	—

TABLE 6.--Summary of irrigation water rights and diversions for the Truckee River--Continued

Num-ber	Name	Status	Purpose	Diversion quantities (acre-feet/year except as noted): By Orr Ditch Decree: Maximum diversion (ft^3/s)	At point of application	Estimated conveyance loss (percent)	At div-ersion	Estimated for 1978	Diverted in 1979	Irrigated acreages: Decreed	Estimated in 1978	Remarks
19	Countryman Ditch	N	I	3.39	232	5	240	0	0	51.1	0	—
20	Chism Ditch	N	I	2.68	145	5	150	0	0	32.2	0	—
21	Hayden (Court) Ditch	N	I	--	(140)	(5)	(150)	0	0	—	0	Irrigation to be subtracted from total municipal right
			M	.53	—		384	--	--	—	--	
22	Idlewild Water Plant	A	M	—	--	-	--	14,669		--	—	--
23	English Mill Ditch	N	I	16.76	1,922	8	2,090	0	0	561.0	0	—
24	Riverside Mill Flume	N	H	70	—	-	—	0	0	—	—	—
25	Cochran Ditch	A	I	47.89	8,151	7	8,760	1,767	4,105	2,015.7	468	—
26	Sullivan & Kelley Ditch	A	I	27.76	2,830	10	3,140	174		706.7	44	—
27	Scott Ranch Ditch	N	I	28.76	2,352	18	2,870	0	0	527.4	0	—
28	Abbee Ditch	N	I	12.00	1,842	12	2,990	0	0	420.5	0	—
29	Perry Ditch	N	I	2.80	216	10	240	0	0	48.0	0	—
30	North Truckee Ditch	A	I	42.81	7,490	10	8,320	1,698	4,973	1,719.3	425	—
31	Sessions Ditch	N	I	16.39	1,654	8	1,800	301	1,806	372.4	67	—
32	Glendale Water	A	M	--	--	-	--	2,242		—	—	—
33	Eastman Ditch	A	I	11.96	1,759	10	1,950	301	1,806	428.5	9	—
34	Pioneer Ditch	A	I	55.08	7,678	15	9,030	5,462	14,492	2,020.5	1,521	—
35	Glendale Ditch	A	I	22.38	3,490	15	4,110	1,184		914.7	307	—
36	Stephens Ditch	A	I	40.45	2,029	10	2,250	0	0	535.8	0	—
37	Fairchild Pump	N	I	.5	16	--	20	0	0	45.0	0	—
38	Largomarsion-Noce	A	I	1.72	142	8	150	49	804	31.4	11	—
39	Largomarsion-Murphy	A	I	13.90	874	30	1,250	874	6,505	194.2	194	—
40	Groton Ditch	A	I	1.49	151	14	180	151	1,116	33.5	34	—
41	Sheep Ranch Ditch	N	I	3.53	360	15	420	210	0	79.9	47	--

TABLE 6.—Summary of irrigation water rights and diversions for the Truckee River--Continued

Number	Name	Status	Purpose	Diversion quantities (acre-feet/year except as noted): By Orr Ditch Decree: Maximum diversion (ft^3/s)	By Orr Ditch Decree: At point of application	By Orr Ditch Decree: Estimated conveyance loss (percent)	By Orr Ditch Decree: At diversion	Estimated for 1978	Diverted in 1979	Irrigated acreages: Decreed	Irrigated acreages: Estimated in 1978	Remarks
42	McCarran North Side Ditch	A	I	8.60	823	20	1,030	601	4,579	182.9	134	South side combined with North side
43	McCarran South Side Ditch	N	I	1.39	138	17	170	--	--	30.6		
44	Old Ditch	N	I	4.54	460	15	540	0	0	102.0	0	--
45	Hill Ditch	A	I	11.87	1,067	25	1,420	1,067	1,600	236.9	237	--
46	Tracy Power	A	T	--	--	--	--	5,375	2,900 (b)	--	--	--
47	Eagle Pitcher pump	I	N	--	--	--	--	--	0	--	--	--
48	Truckee Canal	A	I	1,500.	--	--	--	--	--	232,800	--	--
49	Cadlini Ditch	I	I	3.25	346	--	350	346	--	86.5	87	--
50	Preston Ditch	N	I	1.90	168	17	200	168	0	42.0	42	--
51	Washburn Ditch	A	I	1.52	131	17	160	131	787	32.7	33	--
52	Gregory Ditch	A	I	6.80	666	25	890	666	1,180 (c)	147.8	148	--
53	Wadsworth Light & Power Ditch	N	M	3.13	1,811	20	2,270	--	0	--	--	--
			I	2.00	192	15	230	0	0	45.0	0	--
			H	31.3	--	20	--	--	0	--	--	--
54	Herman Ditch	N	I	15.55	1,493	15	1,760	1,493	4,428	351.1	351	--
55	Pierson Ditch	A	I	3.69	352	15	410	261	1,320	82.8	61	--
56	Proctor Ditch	A	I	11.42	1,094	20	1,370	912	2,467	243.0	204	--
57	Olinghouse #1 Ditch	I	I	4.80	487	15	570	0	--	107.9	0	--
58	Fellnagle Ditch	A	I	10.20	457	12	520	381	2,724	239.1	95	--
59	Gardella Ditch	A	I	2.84	226	20	300	226	805	56.3	56	--
60	Olinghouse #2 (Hamilton) Ditch	I	I	1.54	130	20	160	0	____	32.4	0	--
61	Olinghouse #3 (Hills) Ditch	I	I	3.65	322	17	390	322	____	80.3	80	--
62	Indian Ditch	A	I	58.7	23,775	20	30,080	4,000	6,738	5,875.0	1,000	--
63	Marble Bluff Fishway	A	F	--	--	--	--	--	--	--	--	--

With the exception of the Truckee Canal at Derby Dam, the largest diversions are in and above the Truckee Meadows, with water going to agriculture within the area and to the area's principal municipal supply operated by the Sierra Pacific Power Company. Return flows from irrigation accumulate in North Truckee Drain and Steamboat Creek. Municipally-used waters return to the river via Steamboat Creek, which receives effluent from the Reno-Sparks STP a short distance above the confluence with the river, or by way of recharge to the ground waters (from irrigation of lawn and landscape plantings) that ultimately discharge to the river above Vista.

In the reach considered by the water-quality model below Vista, 13 irrigation ditches and one diversion for a thermoelectric power plant were active during the 1979 to 1980 period of field studies (table 7). The effective irrigation season in most years is from mid-April to mid-October. Most diversion structures are rock-rubble low-head dams that are annually refurbished prior to the irrigation season. Irrigation is accomplished on most ranches by wildflooding of fields from unlined distribution ditches. During the irrigation season, weekly estimates of the diversions are made at points near the ditch headgates by the Federal Watermaster's office. In addition, the Federal Watermaster maintains recording gages on Steamboat Creek and North Truckee Drain near their confluences with the Truckee River.

Table 7 near here

TABLE 7.--Mean monthly discharges for diversions from the Truckee River below Reno for the period October 1969 through September 1979

[Records from the Federal Watermaster except for Tracy power diversion. Agricultural diversions measured once- or twice-weekly during the irrigation season. Tracy power diversion: Estimation from Sierra Pacific Power Company of continous diversion to provide make-up for cooling ponds.]

USGS site number	Name		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.
Diversions from Vista to Derby Dam:														
10350048	Largomarsino-Noce Ditch	mean (ft^3/s)	2	--	--	--	--	--	2	2	2	2	2	2
		range (ft^3/s)	0-5	--	--	--	--	--	0-3	0-4	0-4	0-5	0-5	0-5
		number of measurements	22	0	0	0	0	0	11	53	75	80	92	55
10350150	Largomarsino-Murphy Ditch	mean (ft^3/s)	10	--	--	--	--	--	15	15	14	16	18	14
		range (ft^3/s)	1-19	--	--	--	--	--	11-29	2-24	4-22	7-23	8-32	7-20
		number of measurements	29	0	0	0	0	0	39	63	76	82	95	58
10350130	Groton Ditch	mean (ft^3/s)	3	--	--	--	--	--	4	3	4	4	4	4
		range (ft^3/s)	1-4	--	--	--	--	--	1-6	1-6	1-7	2-8	2-7	1-6
		number of measurements	31	0	0	0	0	0	34	57	69	73	80	52
10350140	Sheep Ranch Ditch[1]	mean (ft^3/s)	2	--	--	--	--	--	10	9	8	7	8	8
		range (ft^3/s)	1-7	--	--	--	--	--	6-16	5-18	2-16	0-14	1-17	1-11
		number of measurements	8	0	0	0	0	0	5	37	60	68	76	43
10350320	McCarran Ditch	mean (ft^3/s)	8	--	--	--	--	--	14	16	13	13	12	11
		range (ft^3/s)	1-17	--	--	--	--	--	5-20	2-26	0-20	0-19	3-19	1-14
		number of measurements	29	0	0	0	0	0	18	55	60	67	82	53
10350475	Hill Ditch	mean (ft^3/s)	5	--	--	--	--	--	6	7	5	6	6	7
		range (ft^3/s)	3-8	--	--	--	--	--	2-15	0-15	2-12	0-12	0-20	0-12
		number of measurements	9	0	0	0	0	0	12	36	66	69	72	51
Tracy Power Diversion		(ft^3/s)	4	4	4	4	4	4	4	4	4	4	4	4

TABLE 7.--Mean monthly discharges for diversions from the Truckee River below Reno for the period October 1969 through September 1979--Continued

USGS site number	Name		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.
Diversions below Derby Dam:														
10361615	Washburn Diversion	mean (ft^3/s)	3	--	--	--	--	--	3	3	4	2	3	3
		range (ft^3/s)	1-5	--	--	--	--	--	1-6	1-5	0-7	0-5	0-6	1-4
		number of measurements	28	0	0	0	0	0	6	46	63	66	67	27
10351638	Gregory-Monte Ditch	mean (ft^3/s)	8	--	--	--	--	--	11	14	7	9	9	7
		range (ft^3/s)	0-15	--	--	--	--	--	1-17	0-26	0-26	0-33	0-24	0-21
		number of measurements	31	0	0	0	0	0	16	56	67	79	80	49
10351635	Herman Ditch	mean (ft^3/s)	8	--	--	--	--	--	13	10	12	13	13	8
		range (ft^3/s)	1-12	--	--	--	--	--	8-18	0-19	1-22	0-21	0-23	1-17
		number of measurements	33	0	0	0	0	0	27	80	88	95	111	65
10351630	Pierson Ditch	mean (ft^3/s)	1	--	--	--	--	--	5	5	4	6	5	3
		range (ft^3/s)	0-6	--	--	--	--	--	2-8	0-12	0-14	0-15	1-10	0-10
		number of measurements	23	0	0	0	0	0	4	47	45	65	69	35
10351668	Proctor Ditch	mean (ft^3/s)	2	--	--	--	--	--	4	5	3	6	8	8
		range (ft^3/s)	1-4	--	--	--	--	--	3-5	0-17	0-21	0-10	0-14	2-19
		number of measurements	2	0	0	0	0	0	2	40	48	63	72	41
10351660	Fellnagle Ditch	mean (ft^3/s)	7	--	2	2	2	2	7	15	7	9	11	5
		range (ft^3/s)	1-15	--	2-2	0-2	0-2	0-2	5-12	2-37	0-26	1-31	0-31	1-18
		number of measurements	29	0	4	2	2	2	9	51	52	82	78	51
10351682	S Bar S Ditch	mean (ft^3/s)	2	--	--	--	--	--	2	2	2	1	2	2
		range (ft^3/s)	--	--	--	--	--	--	--	1-2	1-3	1-3	1-3	1-2
		number of measurements	1	0	0	0	0	0	1	12	15	44	39	24
10351755	Indian Ditch	mean (ft^3/s)	5	--	--	--	--	--	16	12	15	14	17	11
		range (ft^3/s)	2-23	--	--	--	--	--	2-30	0-35	3-26	6-34	0-28	0-20
		number of measurements	33	0	0	0	0	0	9	91	114	114	110	76

[1] Abandoned in fall of 1978.

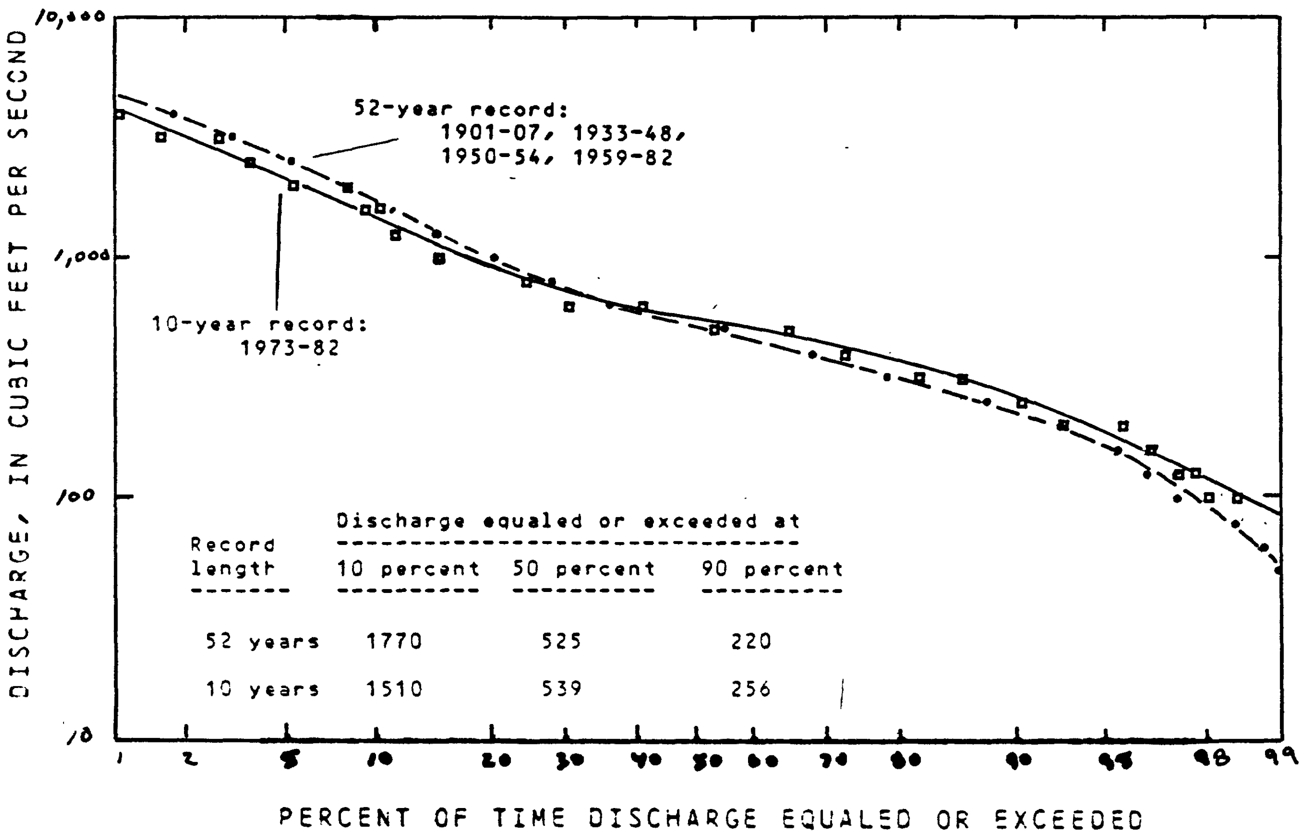
Streamflow Characteristics

The flow of the Truckee River has been gaged at one or more sites since September 1899, when the first gage was installed near Farad. Historical flow data not only reflect the effects of climatic changes on water supply, but also the effects of man's regulation of the river, a factor that has been significantly changing over the past 100 years. Thus, use of statistical streamflow characteristics on the river must be tempered with consideration of the period of record chosen, and the likelihood that future management practices and resultant flow regimes may not be the same as the past, or the present.

Flow duration

The variability of streamflow can be summarized by a flow-duration curve and associated statistics (Riggs, 1968a; Searcy, 1959). Such a curve combines a streamflow record into a unit and indicates the percentage of time historical discharges were equaled or exceeded. Two flow-duration curves for the Truckee River at Vista are shown in figure 7. One was developed for the entire 52-year period of record at the gage, the other for the 10-year period 1973-82, for which concurrent records are available at most river and canal gages below Vista. The curves show, for example, that for 50 percent of the time the mean daily discharge equaled or exceeded 525 ft^3/s in the 52-year period and 539 ft^3/s in the 10-year period.

Figure 7 near here



Record length	Discharge equaled or exceeded at 10 percent	50 percent	90 percent
52 years	1770	525	220
10 years	1510	539	256

FIGURE 7.--Flow-duration curves give an indication of the comparability of short- and long-term statistics of streamflow for the Truckee River at Vista.

The mean annual discharges of the same two periods are 755 and 747 ft^3/s, respectively. The similarity of the mean and median (50 percent) discharges for the two periods might imply that the streamflow regimes for the two periods are similar; the flow-duration curves indicate, however, that differences increase during both high- and low-flow extremes. At high flows, the curve for the long-term record indicates a greater discharge for a given probability level than the curve based on records of the last 10 years. Conversely, at low flows, the curve for the long-term record indicates a lower flow than the short-term curve for the same level of probability. Some of these differences may be due to climatic factors; the principal factor, however, probably has been the increased capacity for regulating extreme flows due to new reservoirs being added to the system.

Comparative flow-duration statistics for long-term records and for the 1973-82 concurrent base period are presented for other gages on the river and canal below Reno in table 8. Flow-duration curves for selected gages for the 1973-82 period are shown in figure 8. The 1973-82 concurrent record was chosen as a base for all further streamflow statistics in this report due to the relatively consistent regulation practices in this period and the desirability of using the same period for comparisons among gages.

Table 8 near here

Figure 8 near here

The shape of a flow-duration curve is one index to the hydrologic characteristics of a basin. A steep curve denotes highly variable flows--high peak discharges, poor sustained flows, and low drought flows. Conversely, a flat curve denotes relatively stable flows from season to season. In figure 8, the relatively uniform slope of the curve for the Vista gage reflects the

TABLE 8.--Summary of flow-duration statistics for selected gaging stations on the Truckee River and Truckee Canal

USGS site number	Name	Drainage area (mi^2)	Period of record	Years of record	Mean annual discharge (ft^3/s)	Discharge (ft^3/s) equaled or exceeded for indicated percent of time					
						10	25	50	75	90	95
10346000	Truckee River at Farad, Ca.	932	1973-82	10	755	1,470	804	529	406	314	258
			1910-82	73	747	1,580	753	502	392	238	137
10348000	Truckee River at Reno, Nev.		1973-82	10	637	1,350	678	420	285	191	149
			1913-19, 1931-34, 1947-82	47	629	1,510	642	376	210	133	79
10348200	Truckee River near Sparks, Nev.	1,070	1978-82	5	604	1,500	629	306	194	128	97
10350000	Truckee River at Vista, Nev.	1,431	1973-82	10	746	1,510	795	539	375	256	194
			1901-07, 1933-48, 1950-54, 1959-82	52	805	1,770	851	525	331	320	156
10350400	Truckee River below Tracy, Nev.	1,590	1973-82	10	736	1,470	784	534	371	253	185
10351600	Truckee River below Derby Dam near Wadsworth, Nev.	1,676	1973-82	10	456	1,220	558	213	41	20	11
			1961-82	22	337	985	338	28	13	3.2	1.9
10351650	Truckee River at Wadsworth, Nev.	1,728	1973-82	10	489	1,290	599	211	45	26	18
			1966-82	17	550	1,600	630	202	42	26	20
10351700	Truckee River at Nixon, Nev.	1,827	1973-82	10	496	1,300	593	232	58	36	30
			1958-82	25	456	1,280	526	80	37	26	22
Truckee Canal Gages											
10351300	Truckee Canal near Wadsworth, Nev.		1973-82	10	259	507	363	238	123	18	.10
			1967-82	16	300	550	392	250	118	17	.08
10351400	Truckee Canal near Hazen, Nev.		1973-82	10	196	481	333	128	47	9	.01
			1967-82	16	223	519	351	139	47	9	.01

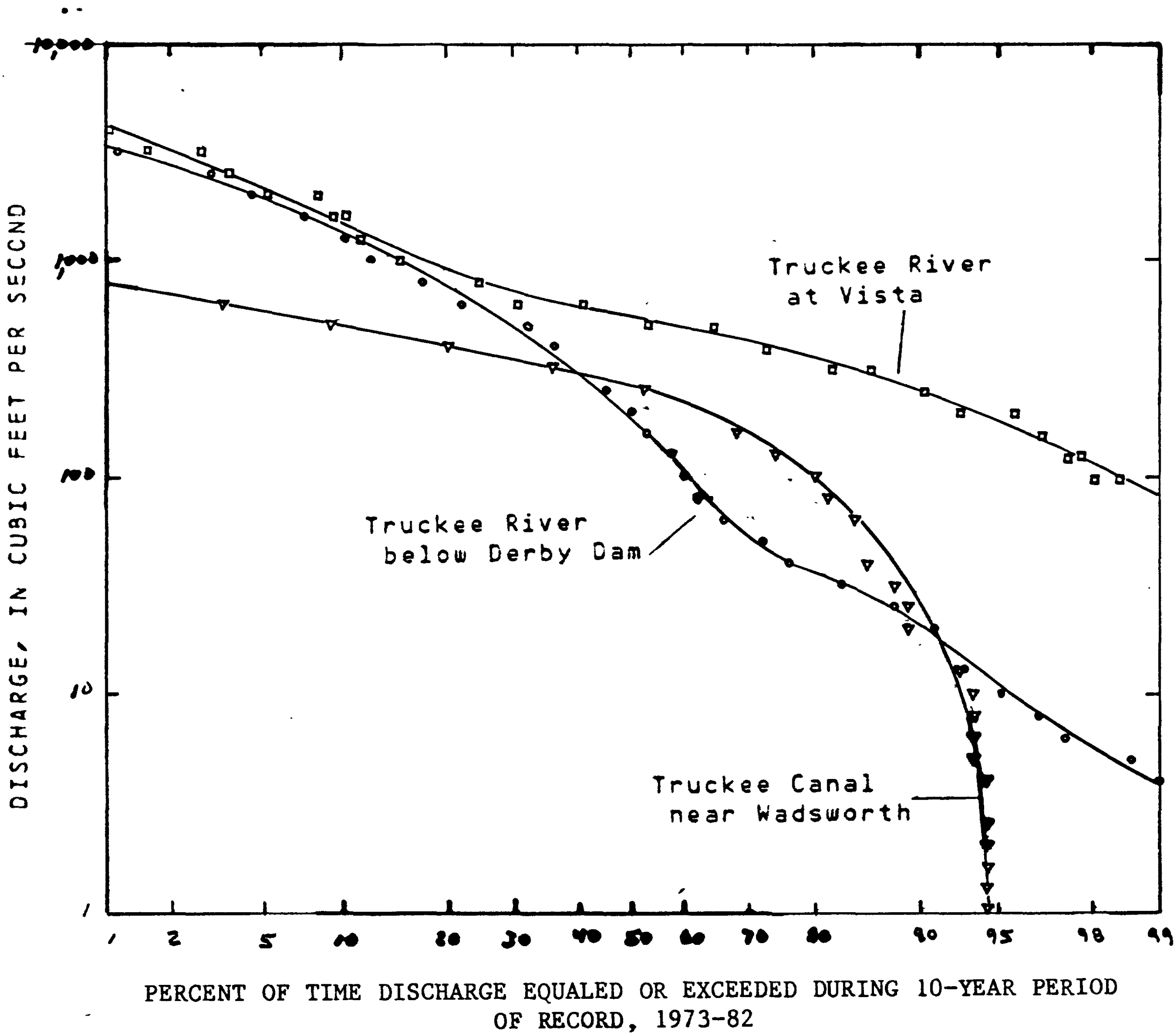


FIGURE 8.--Flow-duration statistics vary for the Truckee River above and below diversions into the Truckee Canal at Derby Dam.

effects of regulation on the Truckee River flows. The curve for the gage below Derby Dam differs from the Vista curve by the amount of diversion to the Truckee Canal. Canal diversions, as measured at the canal gage near Wadsworth, are relatively uniformly distributed from 200 to 800-900 ft^3/s, the normal range of diversions for irrigation.

Low-flow frequency

Flow-duration curves combine an entire period of streamflow into one group for determining probabilities without regard to whether or not low- or high-flow events are uniformly recurring or are isolated extremes. Flow-frequency curves overcome this problem by indicating the magnitude and frequency of sustained flow events, and thus are often used for analysis of flood and drought flows (Riggs, 1968b). Low-flow frequency curves show the magnitude and expected frequency of recurrence for droughts of given periods of duration. For example, figure 9 shows a family of curves developed for the Vista gage giving the expected recurrence interval for 1, 7, 14, and 30 consecutive days of low flow. A comparison of these values for an expected recurrence interval of 10 years illustrates another effect of regulation on the river. The magnitudes of expected low-flows for 1-day, 7-day, and 14-day periods are very similar, indicating that drought flows in the river are relatively stable for as long as a month. The average 7-day low-flow with a 10-year recurrence interval (abbreviated $7Q_{10}$) is a commonly used index of low flows, especially in water-quality planning. The $7Q_{10}$ values in table 9 are used to specify drought flows for water-quality simulations in later sections of this report.

Figure 9 near here

Table 9 near here

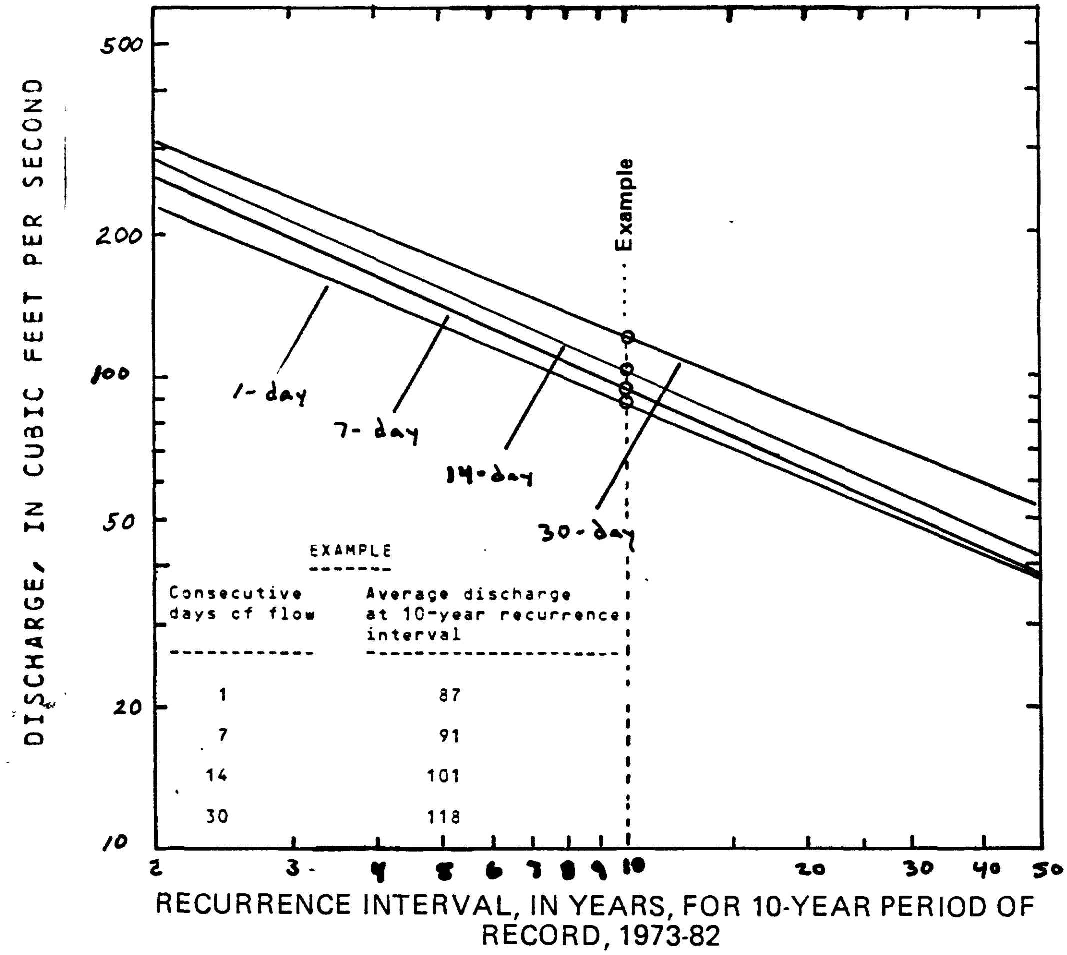


FIGURE 9.--Low-flow frequency curves for the Truckee River near Vista illustrate that regulation provides relatively stable low flows for periods up to 30 days long.

TABLE 9.--Summary of low-flow frequency statistics for selected gaging stations on the Truckee River and Truckee Canal

[Log Pearson Type III distribution, zero flow days omitted from analysis.]

USGS site number	Name	Period of record	Years of record	Consecutive days of low flow	Probable discharge (ft^3/s) for indicated average recurrence interval, in years				
					2	5	10	20	50
10346000	Truckee River at Farad, Calif.	1973-82	10	1	245	115	68	42	22
				7	259	128	79	51	28
				14	276	139	87	55	31
				30	342	188	117	73	39
		1910-82	73	1	249	124	78	51	30
				7	268	136	87	57	34
				14	280	145	94	62	37
				30	306	166	110	74	45
10348000	Truckee River at Reno, Nev.	1973-82	10	1	147	66	39	23	12
				7	175	78	45	27	14
				14	196	92	56	34	19
				30	229	117	74	48	27
		1913-19	47	1	106	44	24	13	6
		1931-34		7	125	56	32	19	10
		1947-82		14	138	66	39	24	13
				30	158	80	49	31	17
10348200	Truckee River near Sparks, Nev.	1978-82	5	1	91	31	13	5.8	1.9
				7	104	37	17	7.5	2.6
				14	114	43	21	10	3.8
				30	128	56	30	16	7.0
		1978-82	5	1	91	31	13	5.8	1.9
				7	104	37	17	7.5	2.6
				14	114	43	21	10	3.8
				30	128	56	30	16	7.0

TABLE 9.--Summary of low-flow frequency statistics for selected gaging stations on the Truckee River and Truckee Canal--Continued

USGS site number	Name	Period of record	Years of record	Consecutive days of low flow	Probable discharge (ft³/s) for indicated average recurrence interval, in years				
					2	5	10	20	50
10350000	Truckee River at Vista, Nev.	1973-82	10	1	242	129	86	59	36
				7	267	139	91	61	37
				14	286	152	101	69	43
				30	313	173	118	82	52
		1901-07	52	1	217	105	61	35	17
		1933-48		7	239	116	68	40	20
		1950-54		14	254	128	78	47	25
		1959-82		30	269	140	88	57	32
10350400	Truckee River below Tracy, Nev.	1973-82	10	1	237	112	68	42	23
				7	257	125	78	50	29
				14	275	138	88	58	34
				30	303	159	103	69	41
		1973-82	10	1	237	112	68	42	23
				7	257	125	78	50	29
				14	275	138	88	58	34
				30	303	159	103	69	41
10351600	Truckee River Below Derby Dam near Wadsworth, Nev.	1973-82	10	1	8.7	2.8	1.7	1.1	.75
				7	12	3.9	2.3	1.5	.95
				14	18	5.9	3.4	2.2	1.4
				30	27	9.5	5.6	3.6	2.2
		1961-82	22	1	4.0	1.4	.79	.50	.29
				7	4.8	1.6	.89	.55	.31
				14	5.5	1.7	.95	.57	.32
				30	6.9	2.1	1.1	.67	.37

TABLE 9.--Summary of low-flow frequency statistics for selected gaging stations on the Truckee River and Truckee Canal--Continued

USGS site number	Name	Period of record	Years of record	Consecutive days of low flow	Probable discharge (ft^3/s) for indicated average recurrence interval, in years				
					2	5	10	20	50
10351650	Truckee River at Wadsworth, Nev.	1973-82	10	1	18	5.7	3.1	1.9	1.1
				7	26	10	6.2	4.2	2.7
				14	34	13	7.4	4.7	2.8
				30	40	19	13	9.9	7.4
		1966-82	17	1	17	7.0	4.4	3.0	2.0
				7	23	11	8.1	6.3	4.8
				14	28	13	9.4	7.1	5.3
				30	31	19	15	13	12
10351700	Truckee River near Nixon	1973-82	10	1	38	21	16	13	11
				7	44	25	19	15	12
				14	50	27	20	16	13
				30	54	28	21	17	13
		1967-82	16	1	26	15	12	10	8.8
				7	28	17	14	12	10
				14	31	19	15	13	12
				30	33	20	17	15	13
Truckee Canal Gages									
10351300	Truckee Canal near Wadsworth, Nev.	1973-82	10	1	4.7	1.0	.44	.21	.09
				7	14	2.2	.63	.19	.04
				14	23	3.4	.81	.20	.03
				30	42	4.8	.82	.13	.01
		1967-82	16	1	4.9	1.4	.68	.37	.18
				7	16	3.3	1.2	.43	.12
				14	25	5.3	1.6	.50	.10
				30	42	7.6	1.7	.38	.05
10351400	Truckee Canal near Hazen, Nev.	1973-82	10	1	.88	.17	.06	.02	.01
				7	4.1	1.6	1.0	.71	.50
				14	11	1.3	.24	.04	.00
				30	20	8.9	5.8	4.1	2.7
		1976-82	16	1	2.0	.45	.17	.07	.02
				7	3.9	1.0	.50	.26	.12
				14	12	2.1	.52	.13	.02
				30	18	7.6	4.7	3.1	1.9

ASSESSMENT METHODS AND PROCEDURES

During the RQA planning process, it was concluded that a predictive water-quality model of the Truckee River would be useful for assessment of probable impacts of current and future water-resource management on the quality of the river and canal below Reno. Such a model would predict, in response to alternative plans for waste-water treatment in the Truckee Meadows for various river flow regimes, changes in concentrations of selected constituents in the river and canal, and changes in loading to Pyramid Lake and Lahontan Reservoir. In addition, the model could be used to assess the relative importance to river quality of loadings of constituents from nonpoint sources in the Truckee Meadows (as represented by loadings from Steamboat Creek and North Truckee Drain), and of loadings from downstream surface and ground-water nonpoint returns. Another benefit of modeling is the increased understanding of cause-and-effect relationships affecting water quality, gained by studying the river system in the structured, quantified manner required by a mathematical model.

Two principal flow regimes were chosen for modeling: (1) the latter part of the summer when high-temperature and low-flow conditions typically prevailed and thus river quality could be expected to be under maximum stress, and (2) spring snowmelt runoff conditions when the effects of water-quality on fishery resources is a principal concern. In reviewing typical streamflow records for these periods, it was concluded that streamflows were likely to be relatively constant for these periods, allowing a steady-state model to be used for the analysis.

Variables chosen for modeling included dissolved solids (DS), ultimate carbonaceous biochemical oxygen demand ($CBOD_u$), dissolved oxygen (DO), the principal nitrogen species [organic-nitrogen (ON), ammonia (total, NH_4-N, and un-ionized, NH_3-N), nitrite (NO_2-N), and nitrate (NO_3-N)], and ortho- (PO_4-P) and total phosphorus (TP). DS were included in the model as a conservative indicator of performance in mass-balancing inputs from the major sources of point and nonpoint loadings to the river. DO and the nitrogen species were selected because of concerns about toxicity to fish and the influence of nitrogen nutrients on algal growth, both in the river and in the receiving waters of Pyramid Lake and Lahontan reservoir. Phosphorus species also were chosen because of concerns regarding stimulation of algal growth. $CBOD_u$ was modeled as a potentially major oxygen demand.

A steady-state, one-dimensional, segmented stream-quality model (Bauer and others, 1979) previously used in a number of USGS studies was selected for this assessment. Consideration of data requirements for the model resulted in a number of field studies to provide sufficient data for successful calibration and validation of a useful model. The model requires estimates, for each river and canal segment, of stream velocities (or traveltimes), and channel hydraulic characteristics such as slope, depth, and width. Stream reaeration capacity was expected to be an important component of the oxygen balance, thus relations between reaeration and channel hydraulics needed definition. Model calibration required a detailed set of water-quality data for both the low- and high-flow conditions. Independent data sets were required for model validation. These data requirements resulted in the design and execution of the field studies for the RQA.

Water-Quality Model

The computer model used in the assessment is described by Bauer and others (1979). The model is steady-state, assuming that the various flows, constituent concentrations, and other factors used do not vary significantly with time (relative to total traveltime through the modeled reach) for a given simulation. Previous studies have demonstrated the utility of the model under these assumptions (Bauer and others, 1978; Miller and Jennings, 1978; Crawford and others, 1979, 1980; Goddard, 1980; Cain and others, 1980; Terry and others, 1983, 1984). The model has been shown to produce comparable results in steady-state simulations to the more widely used QUAL II model (Roesner and others, 1977a, 1977b; National Council of the Paper Industry for Air and Stream Improvement, 1980) in a comparative study of data from three river basins (McCutcheon, 1983a, 1983b).

The model uses a modified Streeter-Phelps equation for dissolved oxygen that incorporates terms for carbonaceous, nitrogenous, respiration, and benthic demands for oxygen and for photosynthetic and atmospheric inputs. Nitrogen transformations from organic-nitrogen to nitrate are described as first-order reactions using equations developed by Thomann and others (1971). Orthophosphorus may be modeled as a function of algal uptake and benthic sources or sinks. The model also may simulate up to three conservative substances by simple mass balance and two nonconservative substances assuming first-order reactions. The model allows segmentations of the stream into as many as 50 segments, with individual specification of channel hydraulics, reaction rate coefficients, and point and nonpoint loadings for each segment. In addition, each segment may receive a tributary inflow which is defined by the results of a fully configured submodel with all the above specifications.

As in any modeling study, a distinction needs to be made between a general computer program that mathematically describes the processes being simulated and the specific application with individual options and data fine-tuned to a particular hydrologic system. The later product of this study will hereafter be referred to as the Truckee River Water-Quality (TRWQ) model.

Several modifications were made to the original computer program as described by Bauer and others (1979) in the course of adapting the program to the Truckee River system. These include enhancement of input and output formats, expansion to include two independent nonpoint sources, options for calculation of channel hydraulic properties and reaeration coefficents, and addition of un-ionized ammonia and nitrogen/phosphorus ratios to the output variables.

Processes considered in the model are shown conceptually in figure 10. Inputs from the upstream river, tributary, point, and nonpoint source loadings are mass-balanced at the start of each segment for each modeled constituent. Conservative substances, by definition, are unchanged by reactions within the water column. Most nonconservatives are modeled assuming first-order decay, that is, the rate of loss or transformation of the substance with time is proportional to the original concentration of the substance. Two rate coefficients[1] are used to model most nonconservatives: (1) an instream decay or removal coefficient defining the overall rate of loss of the substance to the water column (coefficients ending in "R"), and (2) a reaction coefficient defining the effects on other variables in the modeled reactions. For example, $CBOD_u$ is lost from the water column at a rate that is a function of the decay coefficient K_{CR}. A portion of the total loss is due to biochemical

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[1] In this report all rate coefficients, unless otherwise specified, are for base e and corrected to a standard reference temperature of 20 °C.

oxidation (rate coefficient K_C); the remainder is considered to be lost to the bottom sediment. Nitrogen is lost from the water column (coefficient K_{NR}). A portion may be biochemically oxidized by bacteria (K_N); the remainder is considered to be used as a nutrient by aquatic plants or lost to the bottom sediments. Orthophosphorus may be used as a nutrient by algae (K_{PO4A}), or lost to the benthos (K_{PO4B}). Optional modeling of additional nonconservatives assumes loss to some unspecifed sink (K_{NCR1} and K_{NCR2}).

Figure 10 near here

Oxygen modeling begins with a mass balance of all inputs, expressed as a DO deficit (the difference between the in-stream concentration and theoretical saturation at ambient temperature and pressure). The atmosphere may be either a source or a sink for oxygen, as defined by the ambient DO deficit and the reaeration rate coefficent, K_2. Oxygen demands include the oxidation of $CBOD_u$ (rate coefficient K_C) and nitrogenous biochemical oxygen demand (NBOD, rate coefficient K_N). Daytime photosynthesis (P) of aquatic plants is another source of oxygen; conversely, respiration (R) by plants constitutes an oxygen demand, particularly at night when photosynthesis is inactive. Oxidation of benthic deposits (B) is also a potential oxygen demand.

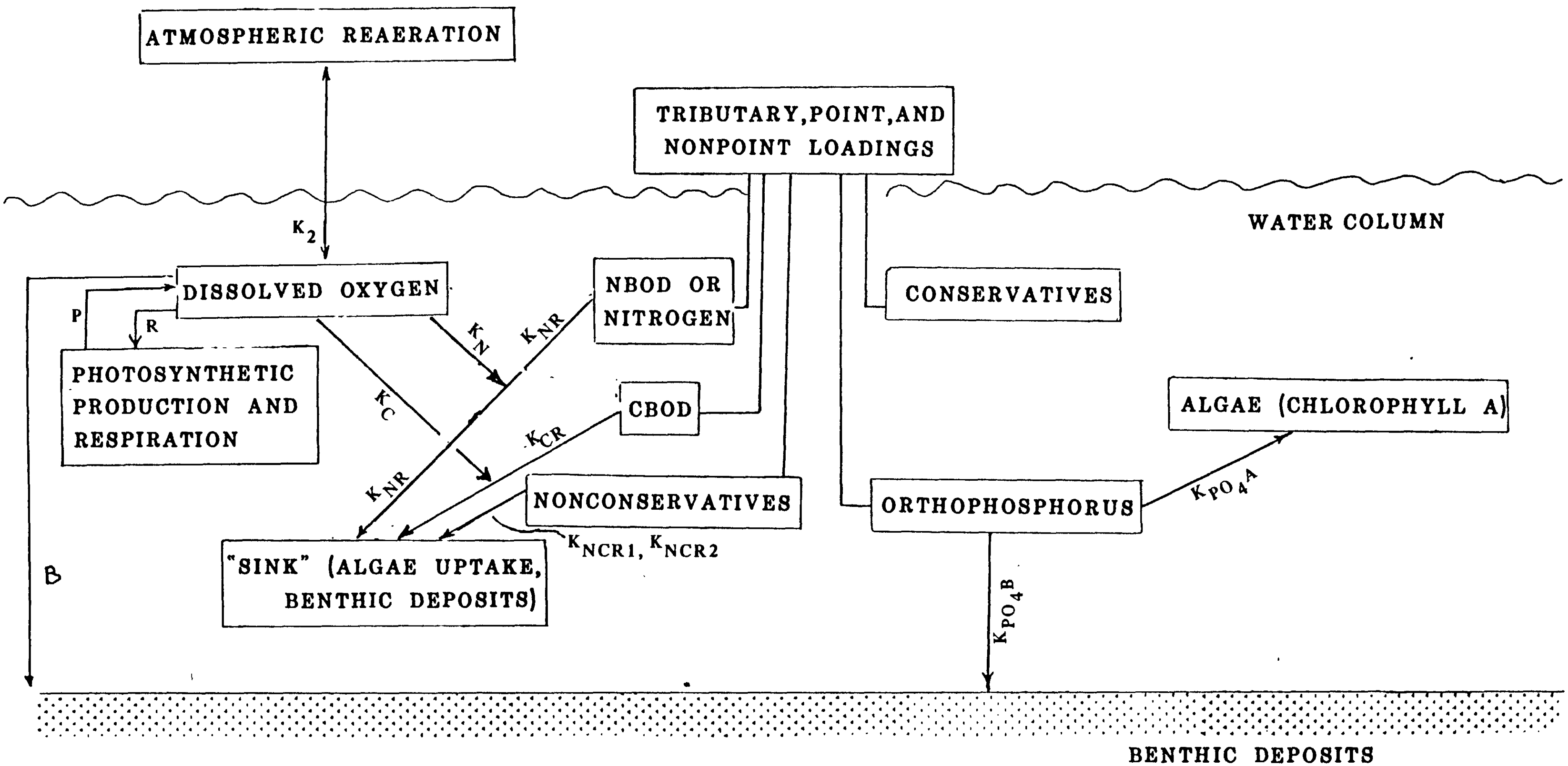


Figure 10.--The water-quality model addresses complex interactions between the stream environment and resulting quality.

Nitrogen transformations may be considered in the model as lump-sum decays (rate coefficent K_{NR}) and oxidation (K_N) or, as in this study, may be represented in detail as shown in figure 11. The process of converting all forms of nitrogen to the nitrate, the oxidized end product of nitrogen, is known as nitrification. Kinetics for each step in the nitrification process are described by a rate coefficent for total decay (ending in "R") and a forward-reaction coefficent for conversion to the next species in the cycle (ending in "F"). The nitrogen cycle starts with organic-nitrogen, derived from external sources and decaying organic matter within the water column. Organic-nitrogen is decayed or lost from the water at an overall rate described by the coefficient K_{ONR}; a portion of the nitrogen lost is due to hydrolysis to ammonia at a rate described by the coefficient K_{ONF}. Ammonia-nitrogen is removed from the water at a rate described by the coeffcient K_{NH4R}; a part of the loss is due to oxidation to nitrite (K_{NH4F}). Nitrite total loss is described by the coefficient (K_{NO2R}); a part is due to oxidation to nitrate (K_{NO2F}). Finally, the resultant nitrate is removed from the water at a total rate described by the coefficent K_{NO3R}.

Figure 11 near here

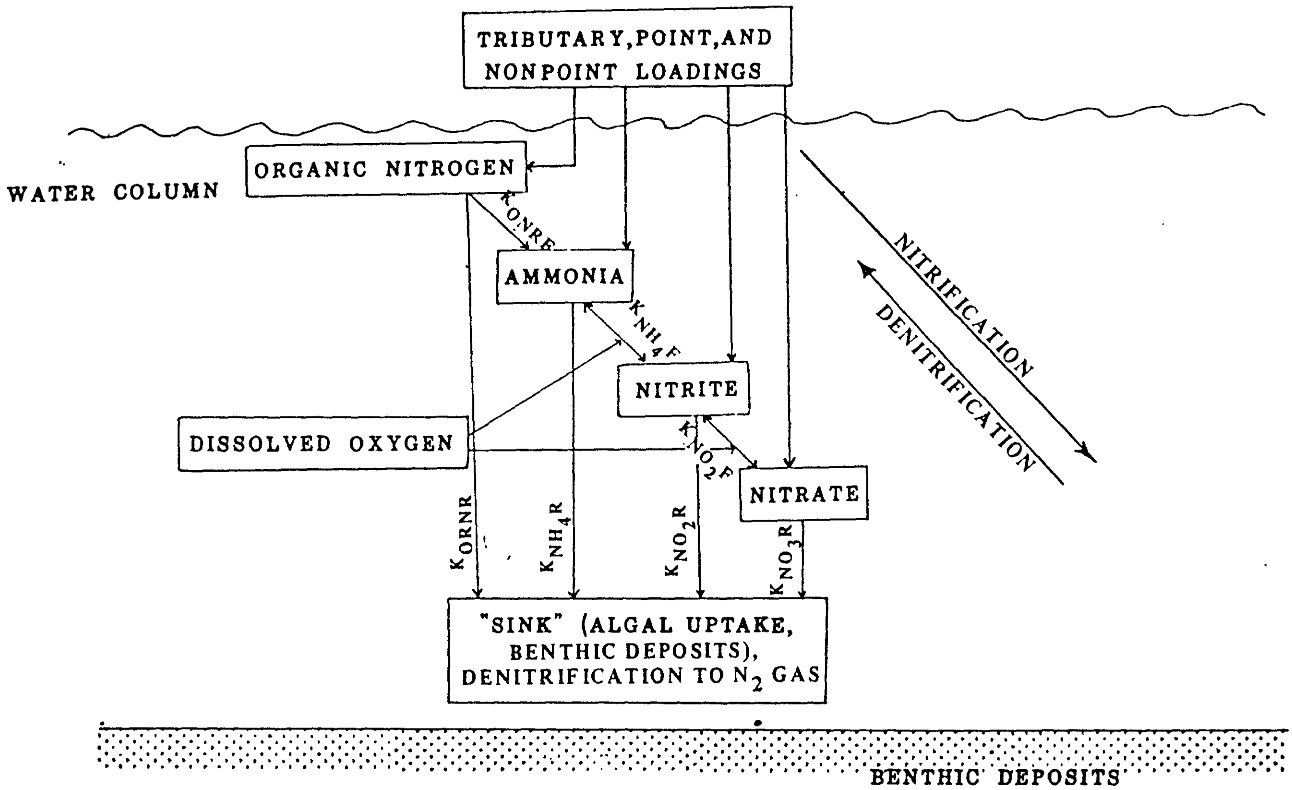


FIGURE 11.--Nitrogen transformations (and resultant oxygen demands) are modeled in a sequential manner.

River Segmentation for Modeling

Computer representation

The computer program used for the TRWQ model requires three levels of detail in representing a physical river system (figure 12). First, the main-stem of the river is divided into up to 50 segments on the basis of considerations of uniform reaches with respect to channel geometry, tributary inflows, diversions, and point and nonpoint sources of constituent loadings affecting the modeled constituents. For each river segment, four sources of loading can be modeled:

(1) A major tributary entering at the head of each segment. Major tributaries are modeled in submodels, each of which may be represented by 50 segments with all options.

(2) Minor tributaries and point sources entering at the head of each segment.

(3) Surface nonpoint returns. Loadings are considered to be uniform over the length of the segment.

(4) Ground-water nonpoint returns. Loadings are considered to be uniform over the length of the segment.

Figure 12 near here

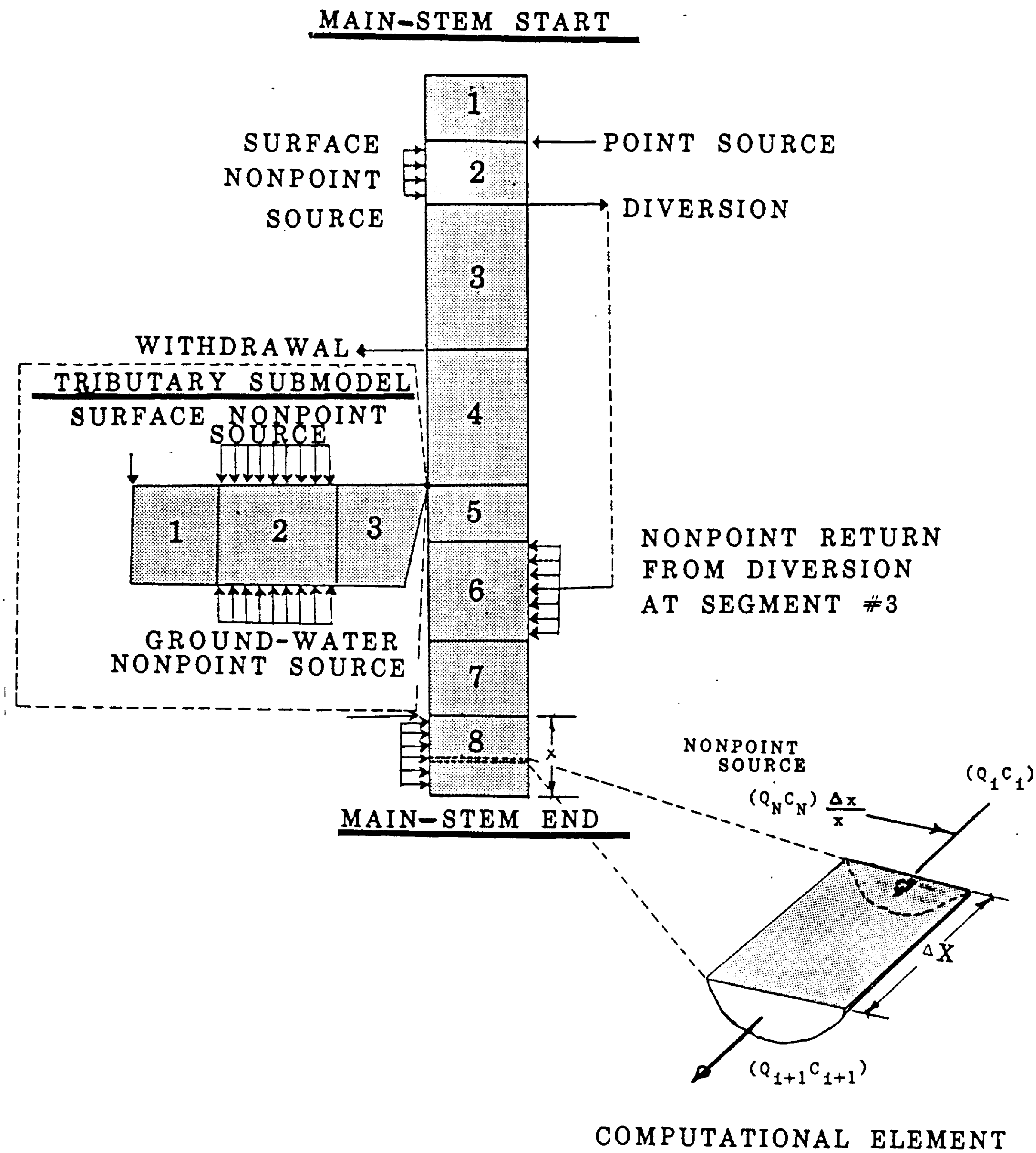


FIGURE 12.--The computer program used for the TRWQ model provides for realistic representation of a stream, its tributaries and return flows.

Stream segments are further subdivided into computational elements based on a specified element length. The computer program mass-balances and decays concentrations of modeled constituents over the length of each computational element. The differential equations used for nonpoint sources are not explicitly solved; instead the nonpoint loadings are assumed to be constant for the length of the receiving model segment and are simply prorated by the ratio of the lengths of the calculation increment to the total segment length. The resultant incremental loadings are mass-balanced with the other inputs at the head of each calculation increment. If no nonpoint sources are modeled, the computational length is selected by the user based on the desired spatial resolution of model outputs. If nonpoint sources are modeled, the length should be based on the desired spatial resolution and needed accuracy of estimation or nonpoint loadings. With the Truckee River data, a calculation interval of 0.01 mile produced acceptable results with modeled nonpoint sources, and was used consistently for all simulations.

Segmentation for the Truckee River

Representation of the Truckee River by the model considered points of change in channel geometry, locations of tributary inflows, locations of diversions and returns, and delineation of areas of surface irrigation returns and ground-water inflows. A map of the modeled reaches of the river is shown in figure 13. Figure 14 is a detailed channel profile and schematic of diversions and returns for the modeled reaches of the Truckee River and Canal. For modeling purposes, the river was broken into 43 segments (table 10), 19 in the 21-mile reach from the McCarran bridge in Reno (RM 56.15) to Derby Dam (RM 34.88; figure 15), and 24 in the 35-mile reach from Derby Dam to Marble Bluff Dam (RM 0.00; figure 16). Major division of the river into subreaches was based on locations of tributaries with significant observed or potential inflows, diversion dams, and reaches receiving return flows. Further subdivision was based on changes in channel geometry, primarily with respect to slope. Inputs from North Truckee Drain (RM 53.66) and Steamboat Creek (RM 53.53) are determined in separate submodels configured as indicated in figure 15. North Truckee Drain was modeled in one 0.26-mile segment from the sampling site at Kleppe Lane to the mouth. Steamboat Creek was broken into two reaches; from the sampling site at Kimlick Lane to the outfall of the Reno-Sparks STP (0.62 mile), and from the STP outfall to the mouth (0.13 mile). Marble Bluff dam was chosen as the end of the model for the river. Distance from the dam through the delta to Pyramid Lake depends upon lake stage, and was approximately 3.5 miles in 1979.

Figures 13, 14, 15, and 16 near here

Table 10 near here

Segmentation for the Truckee Canal

The 31.4-mile canal was divided into nine segments for modeling on the basis of the location of diversion check dams that control water-surface elevations (table 10, figure 17). Since the actual length of the canal varies slightly with the stage of Lahontan Reservoir, the end of the model for the canal is the terminal-control weir (CM 0.00), 0.06 to 0.08 mile above the reservoir.

Figure 17 near here

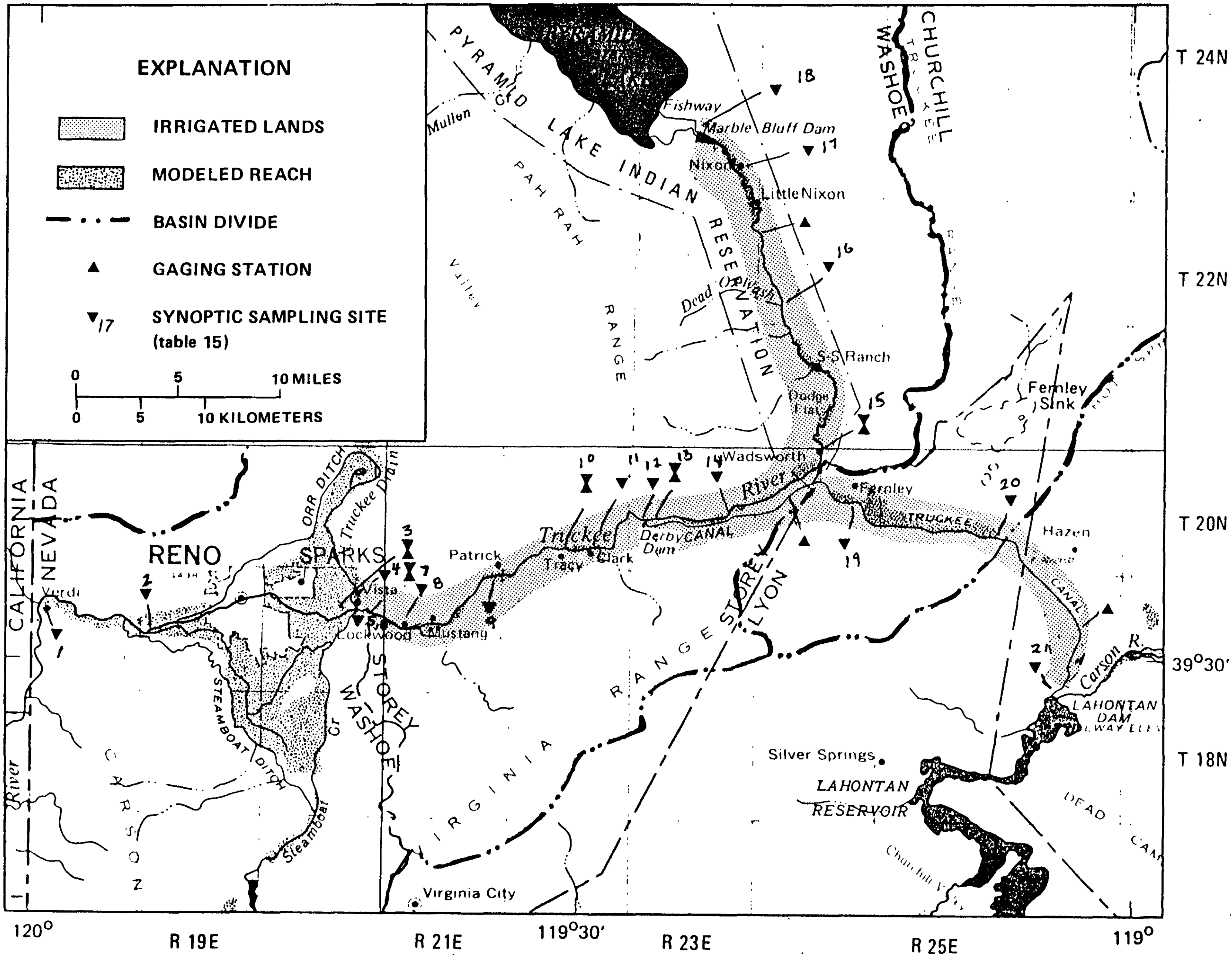


FIGURE 13.--The TRWQ model is set up to simulate water quality in the Truckee River from Reno and Sparks to Marble Bluff Dam and throughout most of the Truckee Canal; sampling sites were chosen to provide coverage of modeled reaches.

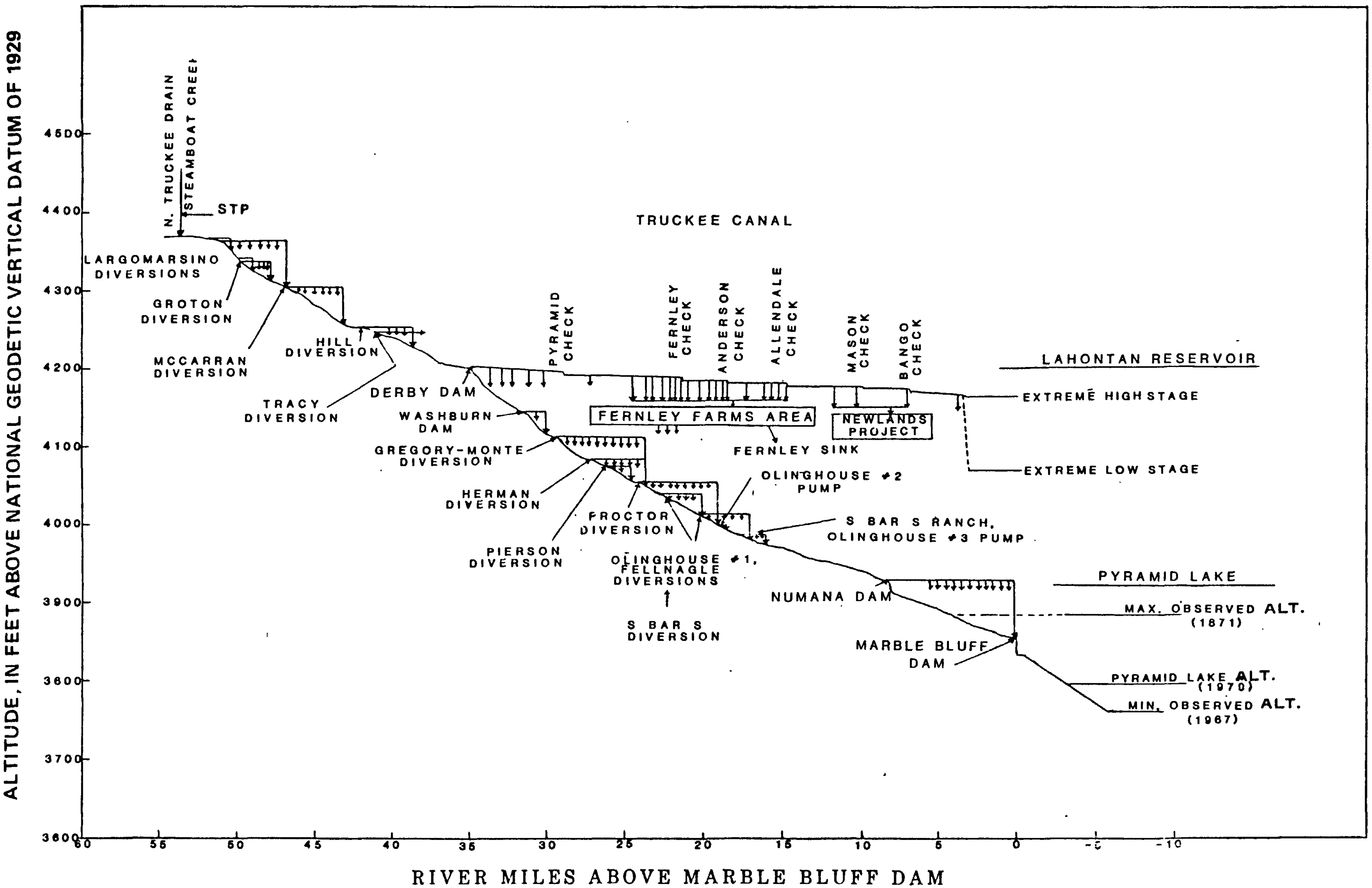


FIGURE 14.--A detailed profile illustrates the complexity of diversions and returns along the modeled reaches of the Truckee River and Canal.

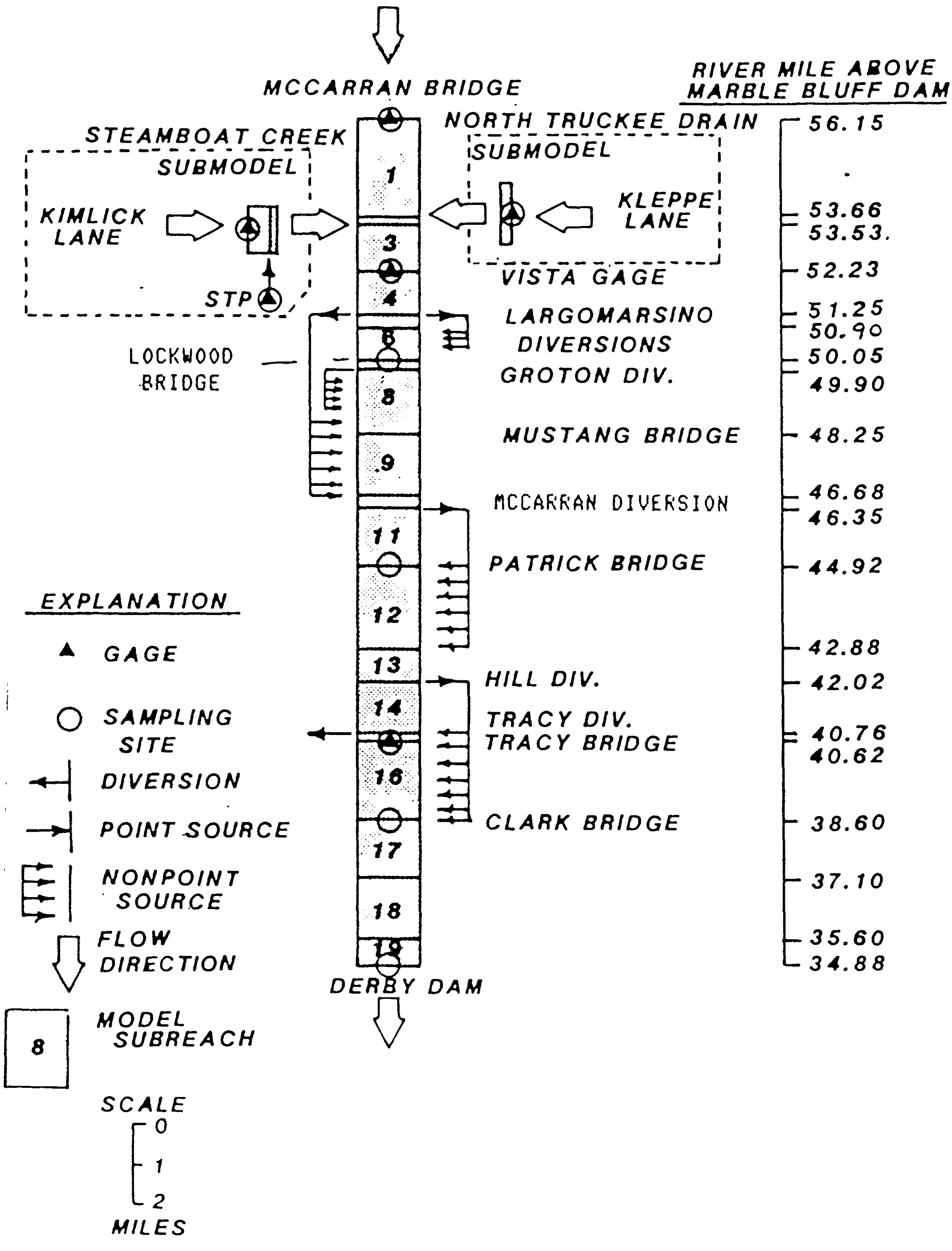


FIGURE 15.--The Truckee River from McCarran Bridge to Derby Dam is divided into 19 segments for representation by the TRWQ model, based on locations of tributaries, principal diversions, and nonpoint returns, and significant changes in channel geometry.

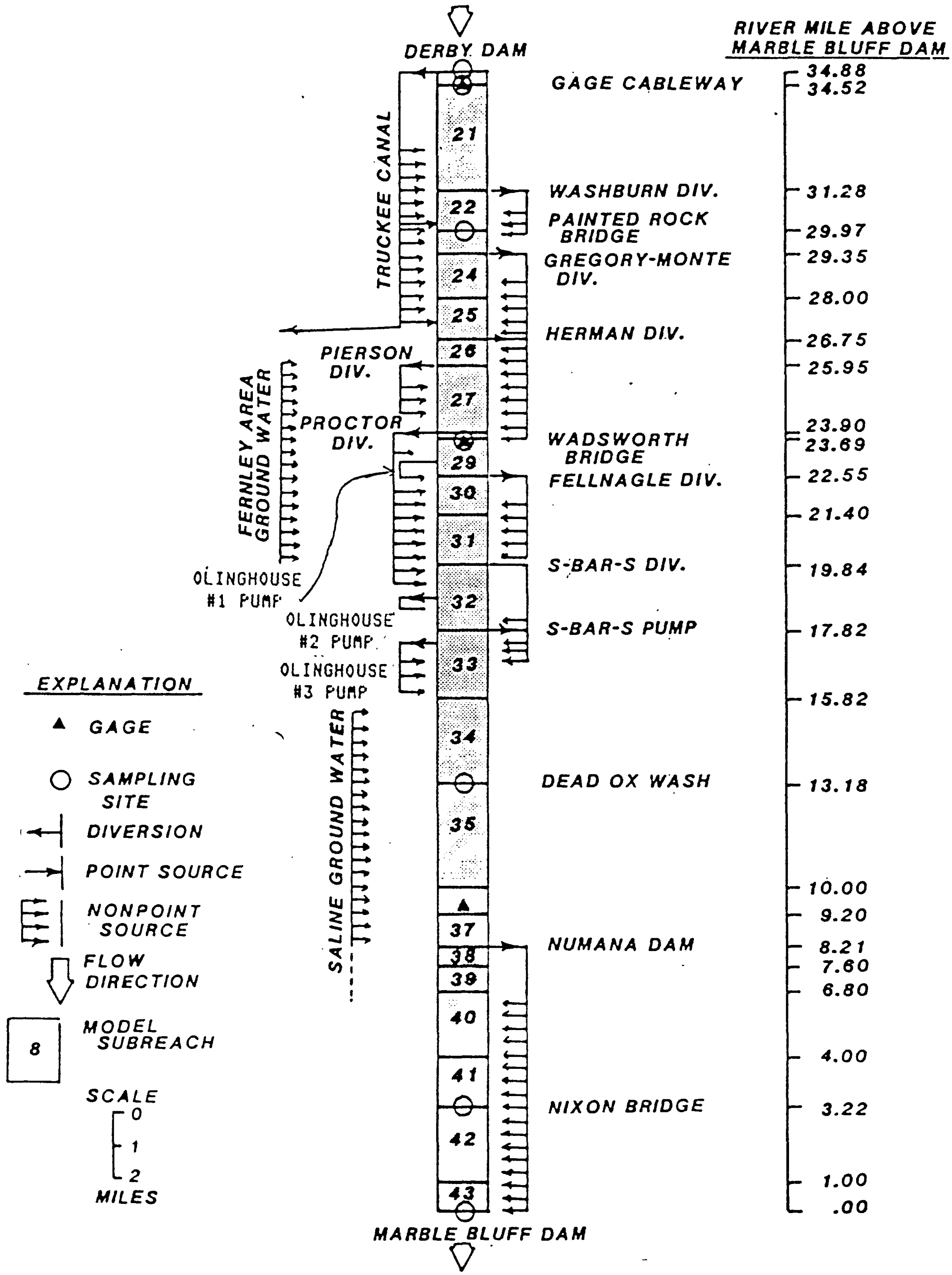


FIGURE 16.--The Truckee River below Derby Dam is divided into 24 segments for representation by the TRWQ model, based on locations of principal diversions, nonpoint returns, and significant changes in channel geometry.

TABLE 10.--Segmentation of the Truckee River, Truckee Canal, and major tributaries for water-quality modeling

Modeled stream segment	Starting river mile	Segment length (mi)	Modeled representation of tributaries, point and nonpoint sources, and Diversions[1]			Remarks[3]
			Tributaries or point sources	Diversions	Nonpoint sources or returns[2]	
MAJOR TRIBUTARIES TO THE TRUCKEE RIVER						
A. NORTH TRUCKEE DRAIN						
A1. Kleppe Lane to mouth	0.26	0.26	--	--	--	Drains agricultural returns from Spanish Springs Valley; terminus of Orr Ditch system. *10348300
B. STEAMBOAT CREEK						
B1. Kimlick Lane to STP outfall	.75	.62	--	--	--	Drains agricultural returns from south Truckee Meadows; terminus of Steamboat Ditch system. *10349980
B2. STP outfall to mouth	.13	.13	Reno-Sparks STP	--	--	*10349989 (STP outfall)
MAIN-STEM TRUCKEE RIVER						
1. McCarran Bridge to North Truckee Drain	56.12	2.46	--	--	--	*#10348200
2. North Truckee Drain to Steamboat Creek	53.66	.13	North Truckee Drain	--	--	--
3. Steamboat Creek to Vista gage	53.53	1.30	Steamboat Creek	--	--	--
4. Vista gage to Largomarsino-Noce diversion (Vista pool)	52.23	.98	--	--	--	Vista pool *#10350000
5. Largomarsino-Noce diversion to end of rapids below Laragomarsino-Murphy diversion	51.25	.35	--	Largo.-Noce and -Murphy	--	Diversions modeled at head: Murphy is at RM 50.06
6. Below Largomarsino-Murphy diversion to Lockwood Bridge	50.90	.85	--	--	SR- Noce & Murphy	--

TABLE 10.--Segmentation of the Truckee River, Truckee Canal, and major tributaries for water-quality modeling--Continued

Modeled stream segment	Starting river mile	Segment length (mi)	Modeled representation of tributaries, point and nonpoint sources, and Diversions[1]			Remarks[3]
			Tributaries or point sources	Diversions	Nonpoint sources or returns[2]	
7. Lockwood bridge to Groton diversion	50.05	.15	—	—	SR- Murphy	*10350050
8. Groton diversion to first Mustang bridge	49.90	1.65	(Long Valley Creek, RM 49.77)	Groton	SR- Murphy & Groton	—
9. First Mustang bridge to pool above McCarran diversion	48.25	1.57	—		SR- Murphy	—
10. Pool above McCarran diversion to McCarran diversion	46.68	.33	—	—	—	—
11. McCarran diversion to Patrick bridge	46.35	1.43	(gravel pit, RM 48.7)	McCarran	SR- McCarran	—
12. Patrick bridge to SP Railroad bridge	44.92	2.04	(gravel pit, RM 43.02)	—	SR- McCarran	*103500200
13. SP Railroad bridge to Hill diversion	42.88	.86	(gravel pit, RM 42.84)	—	—	—
14. Hill diversion to Tracy diversion	42.02	1.26	(gravel pit, 41.69; Tracy power returns, RM 40.78)	Hill	SR- Hill	—
15. Tracy diversion to Tracy bridge (gage)	40.76	.14	—	Tracy power	SR- Hill	*#10350400
16. Tracy bridge to Clark bridge	40.62	2.02	—	—	SR- Hill	—
17. Clark bridge to RM 37.1	38.60	1.50	—	(Eagle Pitcher pump, RM 38.44)	—	*10350500
18. RM 37.1 to oxbow cutoff at Interstate 80	37.10	1.50	—	—	—	—
19. Oxbow cutoff at Interstate 80 to Derby Dam	35.60	.72	—	—	—	Derby pool
Subtotal, McCarran bridge to Derby Dam	21.24					

TABLE 10.--Segmentation of the Truckee River, Truckee Canal, and major tributaries for water-quality modeling--Continued

Modeled stream segment	Starting river mile	Segment length (mi)	Modeled representation of tributaries, point and nonpoint sources, and Diversions[1]: Tributaries or point sources	Diversions	Nonpoint sources or returns[2]	Remarks[3]
20. Derby Dam to gage cableway	34.88	0.36	—	Truckee Canal	GW[a]	*10351000
21. Gage cableway to Washburn diversion	34.52	3.24	—	—	GW[a], SR: Canal	*#10351600
22. Washburn Dam to Painted Rock bridge	31.28	1.31	Derby Spillway, RM 30.22[b]	Washburn	SR- Washburn & Canal; GW[a]	—
23. Painted Rock bridge to Gregory-Monte diversion	29.95	.62	—	—	GW[a]	*10351619
24. Gregory-Monte diversion to RM 28.0	29.35	1.35	—	Gregory-Monte	SR- Gregory & Canal; GW[a]	—
25. RM 28.0 to Herman diversion	28.00	1.25	Gilpin Spillway, RM 27.26[b]	—	SR- Gregory GW[a]	—
26. Herman diversion to Pierson diversion	26.75	.80	—	Herman	SR- Herman; GW[a]	—
27. Pierson diversion to Proctor diversion	25.95	2.05	—	Pierson	SR- Pierson & Herman; GW[a]	—
28. Proctor diversion to Wadsworth bridge	23.90	.21	—	Proctor	SR- Herman; GW[c]	—
29. Wadsworth bridge to Fellnagle diversion	23.69	1.14	—	(Olinghouse #1 pump, RM 23.05; dam at RM 23.02)	GW[c]	*10351648 #10351650 (RM 23.11)
30. Fellnagle diversion to RM 21.4	22.55	1.15	—	Fellnagle	SR- Proctor, Fellnagle, Olinghouse #1; GW[c]	—
31. RM 21.4 to S Bar S diversion	21.40	1.56	—	—	SR- Proctor, Fellnagle; GW[c]	—
32. S Bar S diversion to S Bar S pump diversion	19.84	2.02	—	S-bar-S (Olinghouse #2 pump, RM 18.82)	SR- Proctor, S Bar S, Oling. #2; GW	—

TABLE 10.--Segmentation of the Truckee River, Truckee Canal, and major tributaries for water-quality modeling--Continued

Modeled stream segment	Starting river mile	Segment length (mi)	Modeled representation of tributaries, point and nonpoint sources, and Diversions[1]			Remarks[3]
			Tributaries or point sources	Diversions	Nonpoint sources or returns[2]	
33. S Bar S pump diversion to RM 15.82	17.82	2.00	(Gardella Wash, RM 17.40)	S Bar S pump, (Olinghouse #3 pump, RM 17.50)	SR- S Bar S, Proctor, Oling. #3; GW	—
34. RM 15.82 to Dead Ox Wash	15.82	2.64	(Hill Canyon Ranch Wash, RM 15.75; White Horse Canyon Wash, RM 15.46; Ft. Defiance Creek Wash, RM 14.99)	—	GW[d]	—
35. Dead Ox Wash to RM 10.0	13.18	3.18	(Dead Ox Wash, RM 13.08)	—	GW[d]	*10351690
36. RM 10.0 to RM 9.2	10.00	.80	—	—	GW[d]	#10351700 (RM 9.42)
37. RM 9.2 to Numana Dam	9.20	.99	—	—	GW[d]	—
38. Numana Dam to RM 7.6	8.21	.61	—	Indian Ditch	—	—
39. RM 7.6 to RM 6.8	7.60	.80	—	—	—	—
40. RM 6.8 to RM 4.0	6.80	2.80	—	—	SR- Indian	—
41. RM 4.0 to Nixon bridge	4.00	.78	—	—	SR- Indian	—
42. Nixon bridge to RM 1.0	3.22	2.22	—	—	—	*10351750
43. RM 1.0 to Marble Bluff Dam	1.00	1.00	—	—	—	Impoundment Dam
Subtotal, Derby Dam to Marble Bluff Dam		34.88				0.00)
Total, McCarran bridge to Marble Bluff Dam		56.12				

TABLE 10.--Segmentation of the Truckee River, Truckee Canal, and major tributaries for water-quality modeling—Continued

Modeled stream segment	Starting river mile	Segment length (mi)	Modeled representation of tributaries, point and nonpoint sources, and Diversions[1]: Tributaries or point sources	Diversions	Nonpoint sources or returns[2]	Remarks[3]
TRUCKEE CANAL						
C1. Derby Dam to Pyramid check dam	31.42	6.04	--	TC-T2 (Slattery 1 & 2), TC-T4 (Thornton), TC-T7 (Rocky), TC-T8 (Frosdick), Derby Spillway, canal seepage		--
C2. Pyramid Check Dam to outlet of Tunnel No. 3	25.38	2.84	—	unnamed gate, Gilpin Spillway, canal seepage		—
C3. Outlet of Tunnel No. 3 to Fernley check dam	22.54	4.52	—	TC-1 (KA), TC-T13 (Wilson), TC-T14 (Studer), TC-2,3 (KIB), TC-4 (KB), canal seepage		#10351300 *10351320 (CM 18.23)
C4. Fernley check dam to Anderson check dam	18.02	2.95	TC-5 (KB A)	TC-T17 (KBB), TC-T19 (K2C), TC-T20 (Picitti), TC-21 (Curry), canal seepage		--
C5. Anderson check dam to Allendale check dam	15.07	4.00	TC-T6, TC-T7 (KIC)	KC, TC-8 (KD), TC-9 (Anderson-Davis), TC-25 (Davis), TC-10 (KE), canal seepage		--
C6. Allendale check dam to Mason check dam	11.07	4.68	TC-T28	TC-11 (Sterni), SP, canal seepage		*10351367
C7. Mason check dam to Bango check dam	6.39	3.14	TC-12 (Mason)	canal seepage		#10351400 (pre-1981)
C8. Bango check dam to U.S. Highway 50 bridge	3.25	3.14	TC-13 (KX)	canal seepage		#10351400 (1981 and later)
C9. U.S. Highway 50 bridge to terminal weir at Lahontan Reservoir	.44	2.81	—	canal seepage		*10351590
Total, Derby Dam to Lahontan Reservoir		30.98				

TABLE 10.--Segmentation of the Truckee River, Truckee Canal, and major tributaries for water-quality modeling--Continued

[1] Tributaries and diversions at head of model segments unless otherwise noted. Only tributaries, returns, and diversions active during the 1979 and 1980 synoptic samplings are modeled. Potentially significant tributaries and diversions not active during the synoptics are listed in parentheses; locations may not coincide with heads of modeled segments. Most tributary streams and washes are ephemeral, with flow only during and shortly after precipitation events. When flowing, flow and loadings contributed by unlisted tributaries, washes, and urban storm drains (in segments 1-2) may have significant transient impacts on the quality of the Truckee River.

[2] Principal sources of nonpoint returns designated as GW (ground-water) or SR (surface returns from irrigation). Source ditches are listed for irrigation returns.

[3] Data-collection sites are denoted by * (synoptic sampling site), # (USGS gage), or @ (FWM gage); numbers correspond to site designations in table 15. Sites located at head of model segment unless other RM location specified.

[a] Ground-water returns from canal seepage.

[b] Spillways usually active; not gaged. River gains and canal losses included in estimates of nonpoint returns or seepage for the respective segments.

[c] Ground-water returns principally from irrigation in the Fernley Farm area (Truckee Canal diversions).

[d] Ground-water returns principally springs in Lahontan sediments, high in dissolved solids.

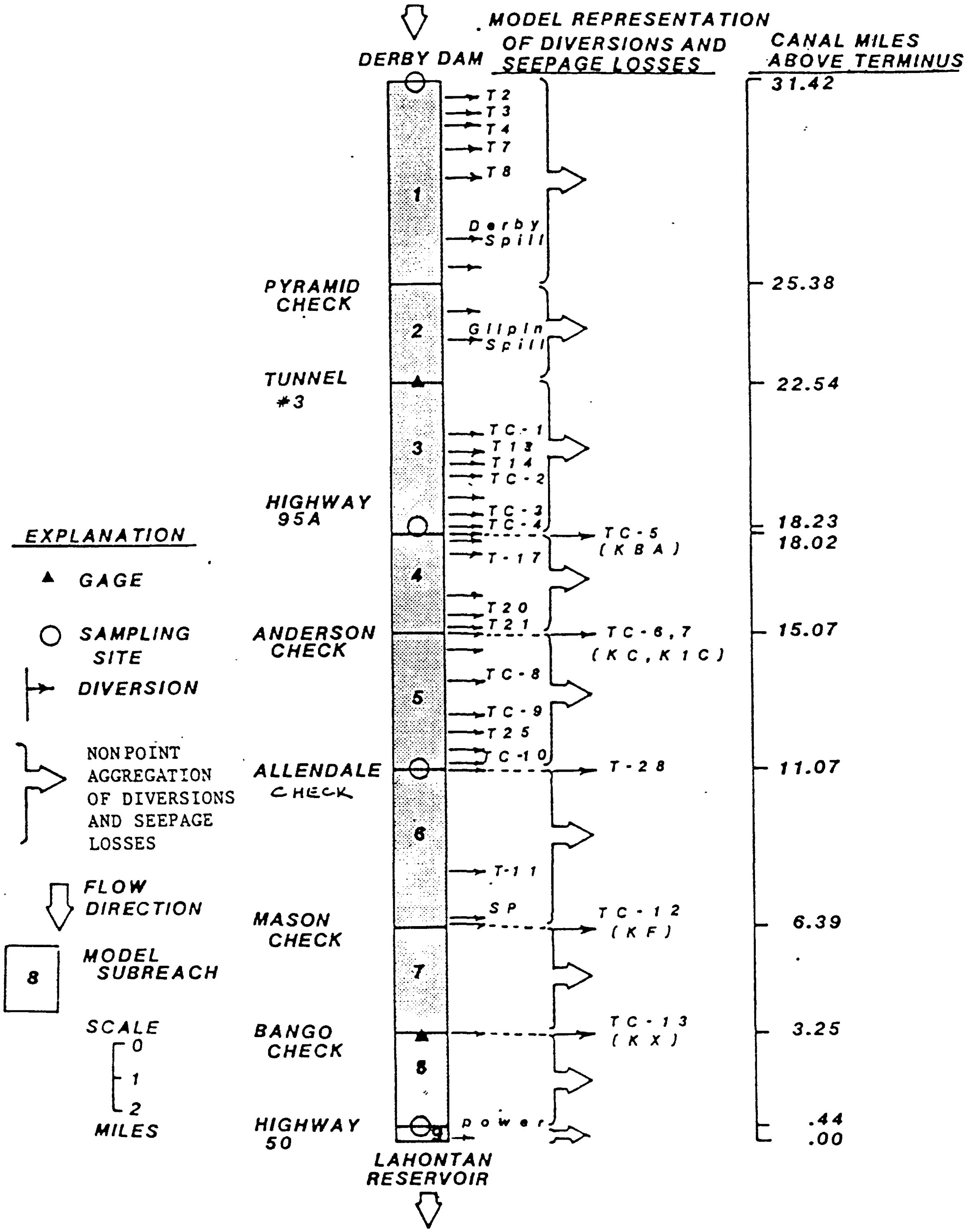


FIGURE 17.--The Truckee Canal is represented by nine segments in the TRWQ model based on locations of irrigation check dams.

Mathematical Representation

The computer program used in the TRWQ model is based on the equation for the conservation of mass:

$$\frac{dC}{dt} = -\frac{1}{A}\frac{d(QC)}{dx} \pm \Sigma S \ , \qquad (1)$$

where C = constituent concentration,

t = time,

A = stream cross-sectional area,

Q = streamflow,

x = downstream distance, and

S = the sum of source and sink terms for constituent C.

This equation does not account for effects of longitudinal dispersion, an assumption that is generally considered valid for steady-state conditions. Under steady-state conditions, the change of concentration with respect to time, dC/dt, is zero, and, in a given reach of stream, the discharge is considered constant, therefore, equation (1) reduces to

$$U\frac{dC}{dx} = \pm \Sigma S \ , \qquad (2)$$

where U = mean stream velocity (Q/A), and C, x, and S are as previously defined.

Conservative substances

Up to three conservative substances can be modeled with the computer program. For the TRWQ model, dissolved solids was selected to serve as a check on mass balance (see Appendix A). The computer program calculates concentrations of conservatives by simple mass-balance at the start of each model segment:

$$C_x = \frac{C_O Q_O + C_T Q_T + C_{PS} Q_{PS} + C_{SR} Q_{SR} + C_{GW} Q_{GW}}{Q_O + Q_T + Q_{PS} + Q_{SR} + Q_{GW}} , \quad (3)$$

where C and Q refer to the respective concentrations and discharges for:

O, river at the start of the segment,

x, river at the end of the segment,

T, input from a major tributary (submodel),

PS, input from a point source,

SR, input from surface nonpoint returns, and

GW, input from ground-water nonpoint returns.

First-order processes [simple nonconservatives such as biochemical oxygen demand (BOD)]

The model application of equation 2 to a simple nonconservative such as BOD balance for a stream is

$$U \frac{dL}{dx} = -K L , \quad (4)$$

where L = the ultimate concentration of the BOD or other nonconservative, and

K = the rate coefficient for BOD decay in the stream.

Mathematically, equation 4 is a first-order differential equation, in which the amount of material at position x is proportional to the original amount by a first-order rate coefficent (K). For boundary conditions $L = L_O$ at $x = 0$, this first-order equation integrates to

$$L_t = L_O e^{-K(t)} , \quad (5)$$

where L_O = ultimate BOD at initial time t_o,

L_t = remaining BOD at time t,

K = instream BOD decay rate coefficient (K_C for CBOD, K_N for NBOD, K_{NCR1} and K_{NCR2} for optional nonconservatives such as coliform bacteria),

t = traveltime through the calculation interval (U/x), and

e = the base of natural logarithms, approximated by 2.72.

The computer program uses equation 5, with appropriate rate coefficients, to model $CBOD_u$, NBOD (if optional modeling of nitrification is not selected), and optional nonconservatives. In the TRWQ model equation 5 was used to model phosphorus (ortho- and total) as well as $CBOD_u$.

Nitrogen Cycle

As previously stated, the computer model can optionally represent individual forms of nitrogen within the nitrogen cycle. Nitrification from ammonia to nitrate is believed to be principally due to nitrifying bacteria, in a two-step process:

(1) Ammonia oxidation (Nitrosomonas bacteria):

$$2\left(NH_4^+\right) + 3\left(O_2\right) = 2\left(NO_2^-\right) + 4\left(H^+\right) + 2\left(H_2O\right) + \text{energy} \qquad (6)$$

(2) Nitrite oxidation (Nitrobacter bacteria):

$$2\left(NO_2^-\right) + O_2 = 2\left(NO_3^-\right) + \text{energy} \qquad (7)$$

By equations 6 and 7, 3.43 mg of oxygen would be required to convert 1 mg of nitrogen from ammonia to nitrite (equation 6) and 1.14 mg of oxygen to convert 1 mg of nitrogen from nitrite to nitrate (equation 7). An interesting implication of equation 6 is the production of hydrogen ions with the oxidation of ammonia, indicating that nitrification should be accompanied by a lowering of pH. In most systems, this increase in acidity is offset by simultaneous increase in alkalinity as a consequence of photosynthesis of carbon.

Tuffey and others (1974) suggested that nitrification in rivers of sufficient intensity to cause significant oxygen depletion required either shallow "surface active" reaches with good habitat for attached growths of nitrifiers or tidal rivers or estuaries with very long detention times and high concentrations of suspended material suitable as substrate for nitrifiers. Shallow, high-gradient rivers with coarse streambed materials such as the Truckee are considered prime habitats for nitrifying bacteria given sufficient ammonia concentrations. Temperature and pH also greatly affect the nitrification process. Nitrification rates increase with temperatures above 10 °C and optimum ranges in pH have been found to be between 7.0 and 9.0 (Zison and others, 1978).

The computer program used in the TRWQ model represents the nitrification process by a set of first-order differential equations developed by Thomann and others (1971). A description of the sequential equations and their integrations is given by Bauer and others (1979). The sequence of reactions is as previously described and shown in figure 11. The reactions are represented using first-order rate coefficients for the total rate of loss (decay) of each nitrogen species and the rate of transformation (forward reaction) to the next form of nitrogen in the sequence. For each step, the total rate of loss is greater than or equal to the forward reaction rate. If the two coefficients are equal, then all loss is attributed to the forward reaction to the next step in the nitrification process. If the total rate of loss exceeds the forward reaction rate, then other sinks for nitrogen (nutrient uptake by plants, loss to bed sediments, volatilization of ammonia), are operative.

The set of first-order differential equations for the nitrogen cycle are:

Organic-nitrogen: $$\frac{\partial(ON)}{\partial t} = -K_{ONR}(ON) \ , \qquad (8)$$

Ammonia-nitrogen: $$\frac{\partial(NH_4)}{\partial t} = -K_{NH4R}(NH_4) + K_{ONF}(ON) \ , \qquad (9)$$

Nitrite-nitrogen: $$\frac{\partial(NO_2)}{\partial t} = -K_{NO2R}(NO_2) + K_{NH4F}(NH_4) \ , \qquad (10)$$

Nitrate-nitrogen: $$\frac{\partial(NO_3)}{\partial t} = -K_{NO3R}(NO_3) + K_{NO2F}(NO_2) \ , \qquad (11)$$

where t = traveltime,

ON = initial organic-nitrogen concentration,

NH_4 = initial ammonia-nitrogen concentration,

NO_2 = initial nitrite-nitrogen concentration,

NO_3 = initial nitrate-nitrogen concentration,

K_{ONR} = organic-nitrogen in-stream decay coefficient,

K_{ONF} = organic-nitrogen hydrolysis coefficient,

K_{NH4R} = ammonia-nitrogen in-stream decay coefficient,

K_{NH4F} = ammonia-nitrogen oxidation coefficient,

K_{NO2R} = nitrite-nitrogen in-stream decay coefficient,

K_{NO2F} = nitrite-nitrogen oxidation coefficient, and

K_{NO3R} = nitrate-nitrogen in-stream decay coefficient.

Through sequential substitution, equations 8-11 integrate to the following:

Organic-nitrogen: $ON = (ON)_o \, e^{-K_{ONR}(t)}$, (12)

Ammonia-nitrogen: $NH_4 = [A] \, e^{-K_{ONR}(t)} + [B] \, e^{-K_{NH4R}(t)}$, (13)

Nitrite-nitrogen: $NO_2 = [C] \, e^{-K_{ONR}(t)} + [D] \, e^{-K_{NH4R}(t)} + [E] \, e^{-K_{NO2R}(t)}$, (14)

Nitrate-nitrogen: $NO_3 = [F] \, e^{-K_{ONR}(t)} + [G] \, e^{-K_{NH4R}(t)} + [H] \, e^{-K_{NO2R}(t)} + [I] \, e^{-K_{NO3R}(t)}$, (15)

where $[A] = \dfrac{K_{ONF}}{K_{NH4R} - K_{ONR}} (ON)_o$

$[B] = (NH_4)_o - [A]$

$[C] = \dfrac{K_{NH4F}}{K_{NO2R} - K_{ONR}} [A]$

$[D] = \dfrac{K_{NH4F}}{K_{NO2R} - K_{NH4R}} (NH_4)_o - [A]$

$[E] = (NO_2)_o - \dfrac{K_{NH4F}}{K_{NO2R} - K_{NH4R}} (NH_4)_o - [C] + \dfrac{K_{NH4F}}{K_{NO2R} - K_{NH4R}} [A]$

$$[F] = \frac{K_{NO2F}}{K_{NO3R} - K_{ONR}} [C] ,$$

$$[G] = \frac{(K_{NH4F})\ (K_{NO2F})}{(K_{NO2R} - K_{NH4R})(K_{NO3R} - K_{NH4R})} [B] ,$$

$$[H] = \frac{K_{NO2F}}{K_{NO3R} - K_{NO2R}} - (NO_2)_o + [C] + \frac{K_{NH4F}}{K_{NO2R} - K_{NH4R}} [B] ,$$

$$[I] = (NO_3)_o - [F] - [G] - [H] ,$$

$(ON)_o$, $(NH_4)_o$, $(NO_2)_o$, $(NO_3)_o$ = organic-, ammonia-, nitrite-, and nitrate-nitrogen concentrations at the proceeding time step, and other terms are as defined for equations 8-11.

Un-ionized ammonia

It is generally accepted that ammonia is toxic to fish and aquatic invertebrates, and that un-ionized ammonia is the most toxic form (U.S. Environmental Portection Agency, 1976). The Nevada single-value water-quality standard for ammonia throughout the modeled reach of the Truckee River is 0.02 mg/L as un-ionized ammonia-nitrogen (NH_3-N) (Nevada Environmental Commission, 1984).

Ammonia-nitrogen exists in water both as the ammonium ion (NH_4^+) and as gaseous un-ionized ammonia (NH_3-N)[1]. The concentration of each is controlled by pH and water temperature (Thurston and others, 1974; Willingham, 1976; Yake and James, 1983):

$$NH_3 + n(H_2O) \rightleftharpoons NH_4^+ + OH^- + (n-1)H_2O \qquad (16)$$

[1] Throughout this report, the term "ammonia" and the abbreviation "NH_4-N" will represent the total ammonia in the water column (NH4+NH3).

The fraction of total ammonia-nitrogen in solution that is present in the un-ionized form has been expressed as (Yake and James, 1983):

$$f = \frac{1}{[10^{(pKa - pH)} + 1]} , \qquad (17)$$

where f = ratio of un-ionized ammonia to total ammonia (both expressed as N),

pKa = 0.09018 + 2729.92/(T + 273.18), and

T = water temperature, in degrees Celsius.

Thus the fraction of total ammonia existing in the toxic un-ionized form increases exponentially with increasing water temperature and pH. Equation 17 is used in the TRWQ model to calculate concentrations of un-ionized ammonia-nitrogen from calculated concentrations of total ammonia-nitrogen as a function of the average pH and water temperature in each modeled segment.

Dissolved oxygen

The program uses a modified Streeter-Phelps equation for representing DO that also incorporates terms for nitrogenous and benthic oxygen demands and the effects of algal photosynthesis and respiration. The DO balance is represented in the model by:

$$U \frac{d(D)}{dx} = -K_2D + K_CL + K_NN + B - P + R , \qquad (18)$$

$U \frac{d(D)}{dx}$	$-K_2D$	K_CL	K_NN	B	$-P + R$
[in-stream change in DO deficit]	[DO supplied by reaeration	[$CBOD_u$ DO demand]	[NBOD DO demand]	[Benthic DO demand]	[Photosynthetic supply and demand]

where D = DO deficit,

K_2 = atmospheric reaeration rate coefficient,

K_C = the $CBOD_u$ deoxygenation rate coefficient,

L = the ultimate CBOD,

K_N = the NBOD deoxygenation rate coefficient,

N = the ultimate NBOD,

B = sediment oxygen demand,

P = photosynthetic oxygen production, and

R = photosynthetic oxygen repiratory demand.

Equation 16 has been integrated for steady-state conditions to yield:

$$D_{(t)} = D_0 \, e^{-K_2(t)} \quad \text{(portion of initial DO deficit remaining after reaeration} \tag{19a}$$

$$+ \frac{K_C L_0}{K_2 - K_{CR}} \left(e^{-K_{CR}(t)} - e^{-K_2(t)}\right) \quad \text{(DO deficit due to CBOD)} \tag{19b}$$

$$+ \frac{K_N \, N_0}{K_2 - K_{NR}} \left(e^{-K_N(t)} - e^{-K_2(t)}\right) \quad \text{(DO deficit due to NBOD)} \tag{19c}$$

$$+ \frac{B}{K_2} \left(1 - e^{-K_2(t)}\right) \quad \text{(DO deficit due to benthic demand)} \tag{19d}$$

$$- \frac{P}{K_2} \left(1 - e^{-K_2(t)}\right) \quad \text{(DO supply from photosynthesis)} \tag{19e}$$

$$+ \frac{R}{K_2} \left(1 - e^{-K_2(t)}\right) \quad \text{(DO deficit due to respiration)} \tag{19f}$$

The NBOD term above assumes modeling nitrogeneous demand by a first-order representation. If zero-order kinetics are assumed, the term becomes:

$$+ \frac{K_{NO}}{K_2} \left(1 - e^{-K_2(t)}\right) \quad \text{(DO deficit due to nitrogenous BOD)} \tag{19g}$$

For modeling the nitrification cycle, the NBOD term (19c) is replaced by:

Ammonia Oxidation: (19h)

$$D_{NH4} = 3.43\,(K_{NH4F}) \left[\frac{[A]}{K_2 - K_{ONR}} \left(e^{-K_{ONR}(t)} - e^{-K_2(t)} \right) + \frac{[B]}{K_2 - K_{NH4R}} \left(e^{-K_{NH4R}(t)} - e^{-K_2(t)} \right) \right],$$

Nitrite Oxidation:

$$D_{NO2} = 1.14\,(K_{NO2F}) \left[\frac{[C]}{K_2 - K_{ONR}} \left(e^{-K_{ONR}(t)} - e^{-K_2(t)} \right) + \frac{[D]}{K_2 - K_{NH4R}} \left(e^{-K_{NH4R}(t)} - e^{-K_2(t)} \right) + \frac{[E]}{K_2 - K_{NO2R}} \left(e^{-K_{NO2R}(t)} - e^{-K_2(t)} \right) \right], \quad (19i)$$

where D_{NH4} = DO deficit due to oxidation of ammonia to nitrite,

D_{NO2} = DO deficit due to oxidation of nitrite to nitrate, and the other terms are as previously defined.

Phosphorus

The computer program used in the TRWQ model can optionally represent orthophosphorus as the sum of losses to the benthos and to uptake by suspended algae:

$$\frac{dLp_{t}}{dx} = - K_{PO4A}\, Lp_{0} - K_{PO4B}\, Lp_{0} CHLA \qquad (20)$$

[change in ortho- phosphorus]	[benthic exchange]	[net algal uptake]

where Lp_0 = initial orthophosphorus concentration,

Lp_t = orthophosphorus concentration at time t,

K_{PO4A} = algal orthophosphorus uptake rate coefficient,

K_{PO4B} = benthic exchange rate coefficient for orthophosphorus, and

CHLA = chlorophyll-*a* concentration.

For steady-state assumptions, equation 20 integrates to:

$$L_{p_t} = Lp_0\, e^{-K_{PO_4B}(t)} - K_{PO4A}\, CHLA\, (1-e^{-K_{PO4A}(t)}) \qquad (21)$$

Equations 20 and 21 were originally presented by Willis and others (1976) for modeling orthophosphorus in streams. The approach assumes that algal uptake can adequately be represented as a function of chlorophyll *a* concentration. This approach was developed for streams in which chlorophyll was predominately in the form of floating algae (phytoplankton), which could appropriately be represented by concentrations of chlorophyll *a* in the water column. For streams with substantial populations of attached algae (periphyton), and(or) rooted aquatic plants (macrophytes), use of equations 20 and 21 may not be appropriate. For final applications of the TRWQ model, equations 20 and 21 were not applied; phosphorus was modeled assuming a simple first-order rate of loss (equations 4 and 5), as discussed in the section on model calibration later in this report.

Nitrogen/phosphorus ratio

The ratio of nitrogen to phophorus (N/P ratio) available as nutrients to aquatic plants has been used as an indicator of which nutrient is more limiting to growth of aquatic algae. One of the outputs of the revised computer program is the N/P ratio defined by the atomic ratio of inorganic nitrogen to orthophosphorus:

$$\text{N/P ratio} = \frac{(\text{ammonia + nitrite + nitrate})}{(\text{orthophosphorus})} \text{ (moles/mole)} \qquad (22)$$

Temperature correction of reaction coefficients

The program requires all specified reaction coefficients to be entered for a standard reference temperature of 20 °C. Coefficients are corrected to the ambient temperature for calculations by assuming an Arrhenius relationship:

$$K_T = K_{20}\theta^{(T-20)} , \qquad (23)$$

where K_{20} = coefficient at the reference temperature (20 °C),

K_T = the Arrhenius (or Streeter-Phelps) coefficient at the ambient temperature, T, and

θ = the Arrhenius (or Streeter-Phelps) coefficient.

The following values for theta are used in the computer program:

Theta (θ)	Reaction coefficients	References
1.0241	K_2	Elmore and West, 1961
1.047	K_C, K_{CR}	Streeter and Phelps, 1925; Velz, 1970
1.065	BN	Thomann, 1974; Shindala, 1972
1.09	K_N, K_{NR}, K_{NOF}, K_{NOR}, K_{ONF}, K_{NH4F}, K_{NH4F}, K_{NH4R}, K_{NO2F}, K_{NO2R}, K_{NO3R}, K_{NCR1}, K_{NCR2}, K_{PO4A}, K_{PO4B}	Stratton, 1966; Shindala, 1972

Collection and Analysis of Data

Data collection required to support construction of the TRWQ model can be described in three categories: (1) channel geometry data used in defining model segments and relations between hydraulic parameters and streamflow, (2) reaeration studies to quantify reaeration rate coefficients used in the computer model, and (3) synoptic water-quality surveys to acquire data for model calibration and validation.

Channel Geometry

The computer program for the model requires accurate estimates of traveltime and cross-sectional area for calculation of decay or transformation of nonconservative substances. Average width is also required for computations of benthic phosphorus exchange if modeled. In addition, stream slopes are needed for some of the available predictive equations for reaeration rate coefficients (K_2). Collection of channel geometry data involved three major work elements (1) dye-injection traveltime studies to determine relations between traveltime and streamflow, (2) channel surveys to determine stream slopes, and (3) analysis of aerial photography to estimate relations between stream widths and flow.

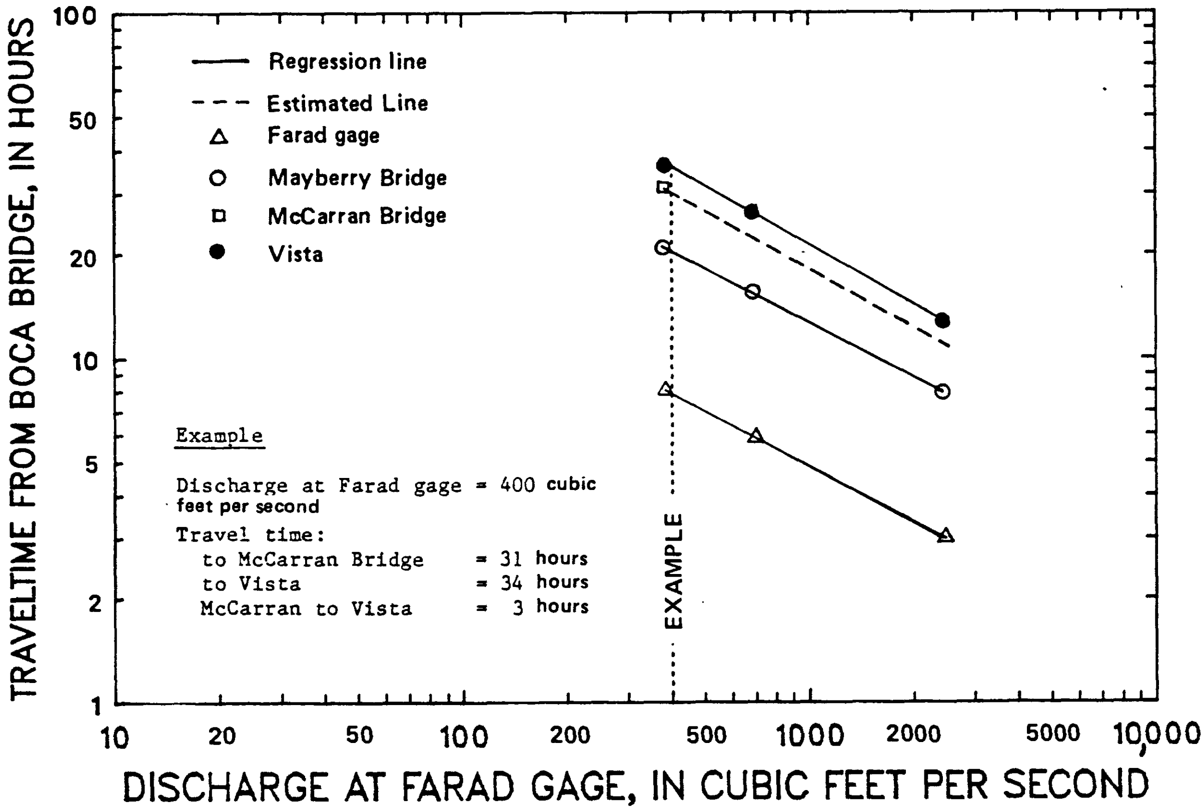
Traveltime studies

During 1979 to 1981, 14 field studies were done to determine traveltime; 10 in the Truckee River and 4 in the Truckee Canal. These studies involved injection of rhodamine WT dye in the river at the head of a subreach and measuring, by fluorometric analysis at several downstream stations, the traveltime of the resultant dye clouds. Methodologies used are described by Hubbard and others (1982; field methods) and Wilson (1968) (fluorometry and data analysis). Summary data from the studies are reported by La Camera and others (1985). Results of the studies are summarized by Brown and others (1986). These studies resulted in definition, for 11 reaches of the river and 9 reaches of the canal, of exponential relations between water discharge and mean solute traveltime as exemplified by figure 18. Summary results are published in Brown and others (1986).

Figure 18 near here

Channel surveys

River-mile locations of major hydrologic features along the river and canal were determined by digitizing data from orthophoto maps and aerial photographs (Brown and others, 1986). Preliminary stream-slope data were obtained from available topographic maps and previous surveys. In the fall of 1980, a detailed field survey was made of stream slopes for the Truckee River below McCarran Bridge. Elevations of control structures on the Truckee Canal were obtained from the files of the U.S. Bureau of Reclamation and by supplemental field surveys in the fall of 1980.



Reach from Boca Bridge to:	Estimated traveltime (T, in hours) for the following discharge ranges (Q, in cubic feet per second)	
	350-700	700-2,400
Farad gage	$T = 220Q^{-0.55}$	$T = 170Q^{-0.52}$
Mayberry Bridge	$T = 420Q^{-0.50}$	$T = 480Q^{-0.53}$
McCarran Bridge	$T = 780Q^{-0.54}$	$T = 1,000Q^{-0.58}$
Vista	$T = 870Q^{-0.54}$	$T = 1,100Q^{-0.58}$

FIGURE 18.--Traveltimes in subreaches of the Truckee River are related exponentially to discharge.

Analysis of aerial photography

Aerial photographs were obtained of the Truckee River taken on August 6, 1979. Stream lengths and surface areas were digitized from these photos and were used as a basis for estimating the relations between stream widths and stream discharges.

Data reduction for modeling

It has been observed that basic stream hydraulic parameters of velocity, depth, and width can be exponentially related to river discharge (Williams, 1978). The computer model has several options for calculation of channel hydraulic parameters. For this study, velocity and width are calculated by:

$$V = V1\ Q^{V2} \tag{24}$$

and

$$W = W1\ Q^{W2}\ , \tag{25}$$

where V = average velocity,

W = average stream width,

Q = stream discharge, and

V1, V2, W1, and W2 are empirical coefficients.

Once velocity and depth are determined the program calculates the remaining factors by:

$$A = Q/V \tag{26}$$

$$D = A/W\ , \tag{27}$$

where A = mean cross-sectional area,

D = mean depth.

The coefficients V1, V2, W1, W2, and average stream slopes for the 43 river segments and 9 canal segments modeled are listed in table 11. The velocity coefficients were determined by graphical and regression analysis of the field traveltime data (figure 18), supplemented, where appropriate[1], by regression analysis of velocity and discharge data from gaging stations. Where a subreach between data sites contained multiple model segments, interpolation was made assuming the coefficient V2 to be constant for the subreach and calculating the coefficients V1 required to match observed velocities.

Table 11 near here

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[1] Coefficients in equations 24 and 25 and the corresponding exponential equations relating depth and area to streamflow are commonly derived by regression of data from measurements of channel geometry and discharge at stream-gaging stations. Extrapolation of coefficents from such point data to longer stream subreaches for modeling can lead to significant errors in predicted channel geometry. Sites for gaging stations are selected on the basis of channel characteristics that may be atypical of upsteam and downstream cross-sections. In addition, field measurements at gaging stations may be made at more than one cross-section, depending upon flow. Low-flow wading measurements are typically made in shallow, faster-moving sections, whereas high-flow measurements are made from bridges or cableways that may have totally different cross-sectional geometries. Thus, truly reach-averaged data such as information from tracer studies are the most appropriate for derivation of velocity-discharge relationships for transport modeling.

TABLE 11.--Modeled channel-geometry characteristics for the Truckee River, Truckee Canal, and major tributaries

[Channel-geometry coefficients are for exponential equations relating velocity (V, in ft/s) and width (W, feet) to discharge (Q, ft^3/s): $V=V_1Q^{V2}$, $W=W_1Q^{W2}$]

Subreach	Starting river mile	Subreach length (mi)	Subreach slope (ft/mi)	Discharge range (ft^3/s)	Channel-geometry coefficients: Velocity V1	Velocity V2	Width W1	Width W2
MAJOR TRIBUTARIES TO THE TRUCKEE RIVER								
A. NORTH TRUCKEE DRAIN								
A1. Kleppe Lane to mouth	0.26	0.26	[e]2.3	all	0.58	0.26	5.0	[c]0.30
B. STEAMBOAT CREEK								
B1. Kimlick Lane to STP outfall	.75	.62	[e].5	all	.26	.32	14	[c].20
B2. STP outfall to mouth	.13	.13	[e].5	all	.088	.30	14	[c].20
MAINSTEM TRUCKEE RIVER, MCCARRAN BRIDGE TO DERBY DAM								
1. McCarran bridge to North Truckee Drain	56.12	2.46	5.1	≤1,000 >1,000	.0695 .085	.50 .50	50	.1
2. North Truckee Drain to Steamboat Creek	53.66	.13	1[e]	all	.0733	.50	54	.1
3. Steamboat Creek to Vista gage	53.53	1.30	[e].5	≤1,000 >1,000	.0351 .0728	.603 .50	65	.1
4. Vista gage to Largomarsino-Noce diversion	52.23	.98	[e].5				63	.1
5. Largomarsino-Noce diversion to end of rapids below Largomarsino-Murphy	51.25	.35	37 [w]19	≤1,000 >1,000	.0137 .0778	.765 .50	67	.1
6. Below Largomarsino-Murphy diversion to Lockwood bridge	50.90	.85	15				60	.1
7. Lockwood bridge to Groton diversion	50.05	.15	15				60	.1
8. Groton diversion to first Mustang bridge	49.90	1.65	14	≤1,000 >1,000	.0401 .101	.634 .50	65	.1

TABLE 11.--Modeled channel-geometry characteristics for the Truckee River, Truckee Canal, and major tributaries--Continued

Subreach	Starting river mile	Subreach length (mi)	Subreach slope (ft/mi)	Discharge range (ft^3/s)	Velocity V1	Velocity V2	Width W1	Width W2
				Channel-geometry coefficients				
9. First Mustang bridge to pool above McCarran diversion	48.25	1.57	7.0	≤1,000 >1,000	.0343 .0864	.634 .50	55	.1
10. Pool above McCarran diversion to McCarran diversion	46.68	.33	.5				68	.1
11. McCarran diversion to Patrick bridge	46.35	1.43	18 ^{w}16	≤1,000 >1,000	.0355 .0858	.634 .50	65	.1
12. Patrick bridge to SP Railroad bridge	44.92	2.04	9.8	≤1,000 >1,000	.0427 .0785	.583 .50	56	.1
13. SP Railroad bridge to Hill diversion	42.88	.86	2.3				75	.1
14. Hill diversion to Tracy diversion	42.02	1.26	7.9 ^{w}5.2	≤1,000 >1,000	.0280 .0596	.576 .50	76	.1
15. Tracy diversion to Tracy bridge	40.76	.14	29 ^{w}3.6	≤1,000 >1,000	.0518 .0754	.586 .50	71	.1
16. Tracy bridge to Clark bridge	40.62	2.02	6.4				62	.1
17. Clark bridge to river mile 37.1	38.60	1.50	11	≤1,000 >1,000	.0374 .065	.582 .50	58	.1
18. River mile 37.1 to Interstate 80 at Oxbow	37.10	1.50	5.3				54	.1
19. Interstate 80 at Oxbow to Derby Dam	35.60	.72	.8				52	.1
Subtotal, McCarran bridge to Derby Dam		21.24	8.4					

TABLE 11.--Modeled channel-geometry characteristics for the Truckee River, Truckee Canal, and major tributaries--Continued

Subreach	Starting river mile	Subreach length (mi)	Subreach slope (ft/mi)	Discharge range (ft^3/s)	Channel-geometry coefficients: Velocity V1	Velocity V2	Width W1	Width W2
MAINSTEM TRUCKEE RIVER, DERBY DAM TO MARBLE BLUFF DAM								
20. Derby Dam to gage cableway	34.88	0.36	53 11^{d}	≤500 >500	0.0231 .180	0.750 .40	53	0.1
21. Gage cableway to Washburn diversion	34.52	3.24	13				48	.1
22. Washburn diversion to Painted Rock bridge	31.28	1.31	21 $^{w}19$	≤500 >500	.0231 .180	.750 .40	44	.1
23. Painted Rock bridge to Gregory-Monte diversion	29.97	.62	6.4				57	.1
24. Gregory-Monte diversion to RM 28.0	29.35	1.35	17	≤500 >500	.0131 .202	.851 .40	40	.1
25. RM 28.0 to Herman diversion	28.00	1.25	5.6				59	.1
26. Herman diversion to Pierson diversion	26.75	.80	10 $^{w}5.6$	≤500 >500	.0131 .202	.851 .40	52	.1
27. Pierson diversion to Proctor diversion	25.95	2.05	11 $^{w}8.8$	≤500 >500	.0131 .202	.851 .40	54	.1
28. Proctor diversion to Wadsworth bridge	23.90	.21	29 $^{w}12$	≤500 >500	.0164 .151	.706 .40	36	.1
29. Wadsworth bridge to Fellnagle diversion	23.69	1.14	5.3 $^{w}3.5$				57	.1
30. Fellnagle diversion to RM 21.4	22.55	1.15	14 11^{w}	≤500 >500	.0361 .539	.706 .287	49	.1
31. RM 21.4 to S bar S diversion	21.40	1.56	7.7				50	.1
32. S Bar S dam diversion to S Bar S pump diversion	19.84	2.02	11 $^{w}11$	≤500 >500	.0262 .279	.706 .326	46	.1
33. S Bar S pump diversion to RM 15.82	17.82	2.00	7.0	≤500 >500	.0333 .353	.706 .326	45	.1

TABLE 11.--Modeled channel-geometry characteristics for the Truckee River, Truckee Canal, and major tributaries--Continued

Subreach	Starting river mile	Subreach length (mi)	Subreach slope (ft/mi)	Channel-geometry coefficients: Discharge range (ft^3/s)	Velocity: V1	Velocity: V2	Width: W1	Width: W2
34. RM 15.82 to Dead Ox Wash	15.82	2.64	6.1	≤500 >500	.0416 .253	.706 .326	52	.1
35. Dead Ox Wash to RM 10.0	13.18	3.18	5.4	≤500 >500	.0114 .254	.793 .326	61	.1
36. RM 10.0 to RM 9.2	10.00	.80	15				61	.1
37. RM 9.2 to Numana Dam	9.20	.99	1.0				74	.1
38. Numana Dam to RM 7.6	8.21	.61	26 w5.9	≤500 >500	.0304 .404	.744 .326	70	.1
39. RM 7.6 to RM 6.8	7.60	.80	11				60	.1
40. RM 6.8 to RM 4.0	6.80	2.80	6.8				52	.1
41. RM 4.0 to Nixon bridge	4.00	.78	11.5				41	.1
42. Nixon bridge to RM 1.0	3.22	2.22	9.5	≤500 >500	.0178 .189	.578 .326	41	.1
43. RM 1.0 to Marble Bluff Dam	1.00	1.00	1.5				491	.1
Subtotal, Derby Dam to Marble Bluff Dam		34.88	10 d9.6					
Total, McCarran bridge to Marble Bluff Dam		56.12	9.4					

TABLE 11.--Modeled channel-geometry characteristics for the Truckee River, Truckee Canal, and major tributaries--Continued

Subreach	Starting river mile	Subreach length (mi)	Subreach slope (ft/mi)	Discharge range (ft^3/s)	Channel-geometry coefficients: Velocity V1	Velocity V2	Width W1	Width W2
C. TRUCKEE CANAL								
C1. Derby Dam to Pyramid check dam	31.42	6.04	[n]1.0 [i].8	all	.0464	.579	7.8	[c]0.29
C2. Pyramid check dam to outlet of Tunnel No. 3	25.38	2.84	[n]1.8 [i]1.5	all	.0757	.579	9.1	[c].15
C3. Outlet of Tunnel No. 3 to Fernley check dam	22.54	4.52	[n].4 [i].1	all	.0484	.579	4.0	[c].36
C4. Fernley check dam to Anderson check dam	18.02	2.95	[n]1.4 [i].3	all	.0136	.758	21	[c].09
C5. Anderson check dam to Allendale check dam	15.07	4.00	[n]1.2 [i].5	all	.0155	.750	30	[c].04
C6. Anderson check dam to Mason check dam	11.07	4.68	[n].4 [i].02	all	.0302	.649	12	[c].23
C7. Mason check dam to Bango check dam	6.39	3.14	[n].7 [i].3	all	.0122	.810	32	[r].067
C8. Bango check dam to U.S. Highway 50 bridge	3.25	3.14	1.1	all	.267	.368	22	[r].076
C9. U.S. Highway 50 bridge to Lahontan weir	.44	2.81	[e]1	all	.239	.368	16	[r].16
Total, Derby Dam to Lahontan Weir:		30.98						

Unless otherwise noted, width coefficients based on W2 estimated to be 0.1 and W1 calculated from average widths and associated discharges from August 1979 aerial photographs.

[e] Estimated.

[d] Slope computed after subtracting effective head of Derby Dam.

[w] Slope computed after subtracting effective head of diversion dam in subreach.

[t] Velocity coefficients computed from graphical analysis of dye-injection travel time.

[g] Channel geometry coefficients from regression analysis of stream-gaging data.

[n] Average slope for non-irrigation season.

[i] Average slope between check dams for irrigation season.

[c] Width coefficients calculated from discharges, velocities, and average depths from synoptic studies.

[r] Width coefficients from regression analysis at gaging sites.

The coefficients for stream width (W1 and W2) were estimated from a combination of regression analysis at gaging stations and the analysis of aerial photographs at the 1979 low-flows. From the regression analysis of data at gaging stations, an average value of 0.1 for W2 was selected for all main-stem river segments. The coefficients W1 were then calculated from widths derived from the aerial photographs. The reliability of these coeficients decreases with higher streamflows, however, as applied in this study, TRWQ model calculations are not affected by errors in either width or the derived depth.

Reaeration Studies

The exchange of oxygen between the atmosphere and the water column is proportional to the oxygen deficit relative to saturation and a factor known as the reaeration coefficient (K_2). Although reaeration can be the most important single factor in determining the oxygen balance in a stream, it has been common in many modeling studies to use published estimates of K_2, or to predict the average value of K_2 as a function of water velocity, depth, slope, or other hydraulic parameters using one of several equations. Another approach has been to estimate or predict an initial value for K_2, and then to adjust K_2 in calibration of model simulations to fit observed DO in the assumption that all other sources and sinks of oxygen are better known than the reaeration coefficient.

In anticipation that K_2 would be a particularly important parameter in a high-gradient, relatively clean stream such as the Truckee, it was decided to conduct field studies during the RQA to experimentally determine K_2 for selected reaches, and to use the field data to select the most appropriate predictive equation for the Truckee River. Four field studies were performed in October 1979 and July 1980 in two reaches, from Lockwood to Tracy, and from

Wadsworth to Dead Ox (figure 13). The methods of Rathbun (Rathbun and others, 1975, 1977; Rathbun, 1977, 1979) were used employing ethylene gas as a tracer to determine gas exchange coefficents and rhodamine WT dye as a solute tracer. Basic data from these studies are published in La Camera and others (1985). Reaeration coefficient (K_2) in a reach has been determined experimentally (Rathbun and Grant, 1978) to be

$$K_2 = 1.15K_T \; , \qquad (28)$$

where K_T, the desorption coefficient for ethylene gas is

$$K_T = \frac{1}{t_d - t_u} \ln \frac{\left(\dfrac{C_G}{C_D}\right)_{\text{upstream}}}{\left(\dfrac{C_G}{C_D J}\right)_{\text{downstream}}} \; , \qquad (29)$$

where t_d = time of peak concentration of dye downstream,

t_u = time of peak concentration of dye upstream,

C_G = peak concentration of ethylene gas,

C_D = peak concentration of dye, and

J = ratio of upstream dye mass to downstream dye mass.

For a river without diversions, J is $(Q_u A_u / Q_d A_d)$, where A is the area under the concentration versus time curve of the dye for the upstream (A_u) and downstream (A_d) sites. For a river with diversions

$$J = \frac{Q_u A_u}{Q_d A_d + \sum_{\substack{\text{diversions} \\ \text{in reach}}} Q_i A_i} \; , \qquad (30)$$

where Q_i is the diverted flow and A_i is such that $A_u \geq A_i \geq A_d$. Q_i is measured and A_i (concentration-time area for the diversion) has to be estimated. The above calculations are for K_2 at the ambient field temperature, which can then be corrected to 20 °C by equation 23.

Results of the Truckee River reaeration studies are summarized in tables 12 and 13. These data were then combined with a similar data set from the Yampa River, a similar mountain stream in Colorado (Bauer and others, 1978), and used to test 10 equations commonly used to predict reaeration coeffcients for oxygen modeling. This analysis (table 14) indicated that the energy-dissipation model of Tsivoglou and Neal (1976) gave the best prediction (figure 19). The energy-dissipation equation expressed K_2 as a function traveltime and head loss:

$$K_2 = C \frac{\text{delta H}}{T} \qquad (31)$$

where K_2 = stream reaeration coefficient,

H = head loss in reach, in feet,

T = traveltime, in hours, and

C = oxygen escape coefficient.

Since $S = (\text{delta H})/x$

and $v = x/T$,

where S = stream slope, x = distance, and v = velocity, equation 31 can be expresed as:

$$K_2 = C\ S\ v \qquad (32)$$

Tsivoglou developed estimates of the exchange coefficient based on tracer studies in five rivers in the eastern and southeastern states. He did not propose that a single value for C existed for all rivers, but rather that the value of C varied between rivers as a function of water quality and other factors. Tsivoglou suggested a preliminary range of values to consider for C:

BOD_5	Escape coefficient (C)[1]	Stream quality
2 or less	6,500	"lightly polluted stream"
about 15	4,100	"average stream"
up to 30	2,300	"heavily polluted stream"

[1] Corrected to 20 °C and for consistent units: slope in feet per foot, velocity in feet per second.

Using a linear regression on the combined Truckee and Yampa data set resulted in C = 4,370 (r^2 = 0.84, standard error of estimate = 2.8/day), which differs by 7 percent from Tsivoglou's suggested average value of 4,100.

Figure 19 near here

Table 12, 13 and 14 near here

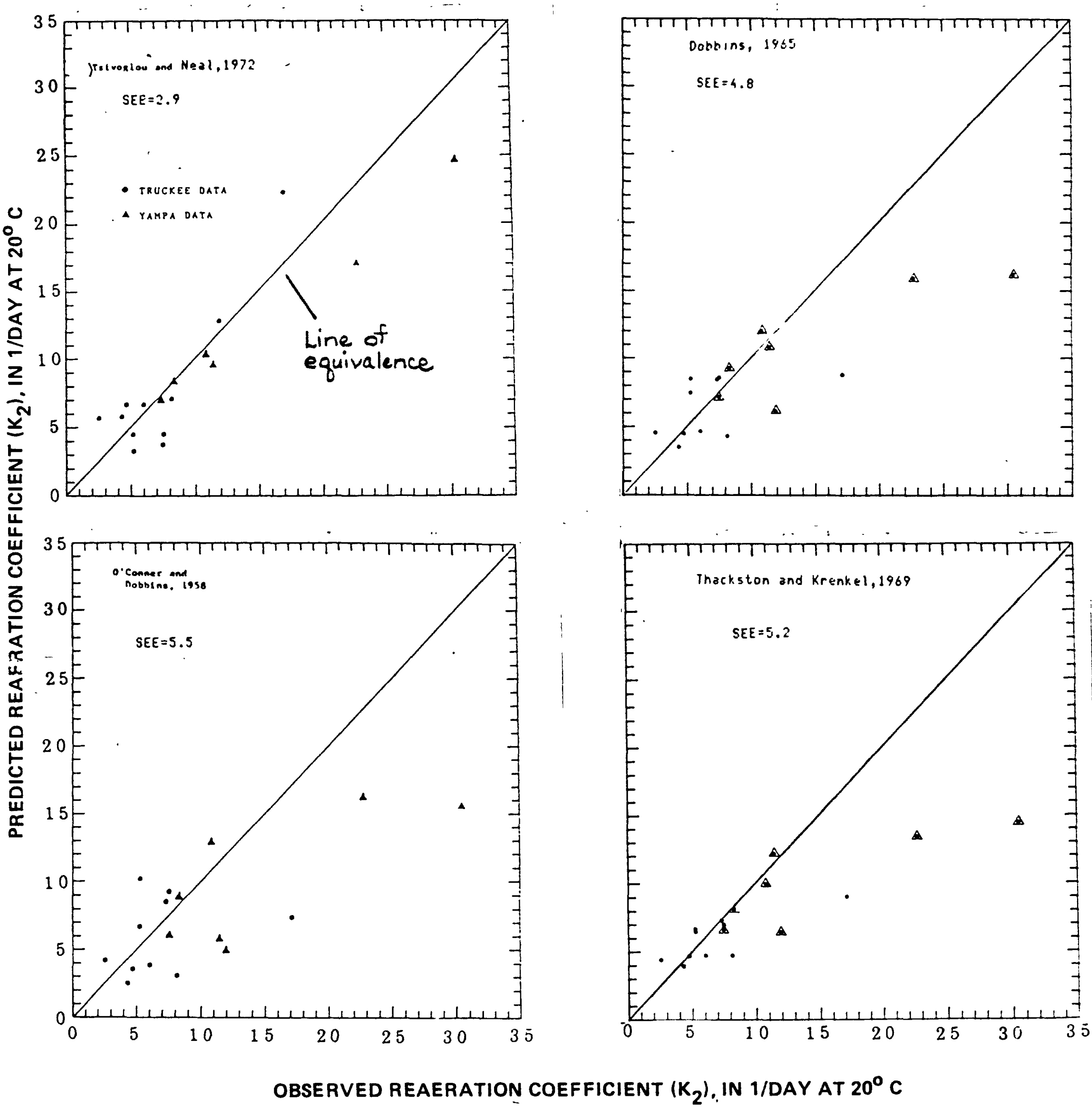


FIGURE 19.--Reaeration data from field studies were used to test the accuracy of equations used to predict reaeration rate coefficients. (Symbol: SEE, standard error of estimate for linear regression of predicted versus observed values.)

TABLE 12.--Results of gas-tracer reaeration studies for selected reaches of the Truckee River

Sub-reach	Subreach name (and inclusive site numbers)	Traveltime of dye peak (hrs)		Peak concentrations (micrograms/liter)				J factor	Mean water temper-ature (°C)	Reaeration coefficient, K_2 (1/day, base e)	
				Dye		Gas					
		Up-stream	Down-stream	Up-stream	Down-stream	Up-stream	Down-stream			At ambient temper-ature	At 20 °C
	INJECTION AT LOCKWOOD BRIDGE, 10/18/79										
1	Upper Mustang bridge to Patrick bridge (24-27)	0.123	0.248	30.4	21.4	22.0	7.8	1.48	12.5	9.92	11.9
2	Patrick bridge to Tracy bridge (27-33)	.248	.484	21.4	16.6	7.8	1.5	1.00	12.5	6.80	8.12
	INJECTION AT LOCKWOOD BRIDGE, 7/31/80										
3	Upper Mustang bridge to above McCarran diversion (24-25)	.0812	.2090	37.0	32.4	21.0	14.4	1.06	23.3	2.72	2.52
A1	Above McCarran diversion to below McCarran diversion (25-26)	.2090	.209	32.4	31.0	14.4	13.9	1.06	23.9	—	—
A2	Above McCarran diversion to Patrick bridge (25-27)	.2090	.2528	32.4	31.1	14.4	6.8	1.04	24.2	19.6	17.8
4	Below McCarran diversion to Patrick bridge (26-27)	.2090	.2528	31.0	31.1	13.9	6.8	1.00	24.2	18.9	17.1
5	Patrick bridge to above Hill diversion (27-29)	.2528	.3847	31.1	23.3	6.8	3.1	1.11	24.5	5.24	4.71
B1	Above Hill diversion to below Hill diversion	.3847	.3951 [1]	23.3	22.8	3.1	2.8	1.05	24.6	14.2	12.8
B2	Above Hill diversion to Clark bridge (29-34)	.3847	.5618	23.3	18.5	3.1	.87	1.00	24.3	6.75	6.10
6	Below Hill diversion to Clark bridge (30-34)	.3951	.5618	22.8	18.5	2.8	.87	1.00	24.1	6.62	6.01
7	Clark bridge to Derby Dam (34-36)	.5618	.7681	18.5	15.5	.87	.34	1.07	23.1	4.63	4.30

TABLE 12.--Results of gas-tracer reaeration studies for selected reaches of the Truckee River--Continued

Sub-reach	Subreach name (and inclusive site numbers)	Traveltime of dye peak (hrs)		Peak concentrations (micrograms/liter)				J factor	Mean water temperature (° C)	Reaeration coefficient, K_2 (1/day, base e)	
				Dye		Gas					
		Up-stream	Down-stream	Up-stream	Down-stream	Up-stream	Down-stream			At ambient temperature	At 20 ° C
	INJECTION AT RAILROAD BRIDGE BELOW WADSWORTH, 10/10/79										
8	Above Fellnagle diversion to RM 15.82 (47-53)	.3333	1.0236	30.0	7.8	61	.43	1.45	15.0	6.63	7.47
9	RM 15.82 to Dead Ox Wash (53-56)	1.0236	1.2576	7.8	6.8	.43	.14	1.00	15.5	4.84	5.25
	INJECTION AT RAILROAD BRIDGE BELOW WADSWORTH, 7/28/80										
C1	Above Fellnagle diversion to below Fellnagle diversion (46-47)	.2347	.2347	20.4	20.2	144	116	1.00	24.4	—	—
C2	Above Fellnagle diversion to above S Bar S diversion (46-49)	.2347	.4681	20.4	10.4	144	19	1.20	24.2	7.56	6.84
10	Below Fellnagle diversion to above S Bar S diversion (47-49)	.2347	.4681	20.2	10.4	116	19	1.02	23.9	5.74	5.23
11	Above S Bar S diversion to Dead Ox Wash (49-56)	.4681	.9847	10.4	5.0	19	.29	1.11	22.3	7.91	7.49

[1] Traveltime probably in error due to poor mixing at sampling site in pool below dam.

TABLE 13.--Results of reaeration studies and associated channel-geometry data

	Subreach	Length (mi)	Slope (ft/mi)	Mean dis-charge (ft^3/s)	Travel-time of centroid[1] (hrs)	Reaeration coefficient K_2 (1/day at 20°C)	Channel-geometry data: Velocity (ft/s)	Cross-section area (ft^2)	Top width[2] (ft)	Mean depth[3] (ft)
	INJECTION AT LOCKWOOD BRIDGE, 10/18/79									
1	Upper Mustang bridge to Patrick bridge	3.33	11.1	372	3.3	11.9	1.48	251	120	2.1
2	Patrick bridge to Tracy bridge	4.30	8.4	362	5.8	8.12	1.09	332	130	2.6
	INJECTION AT LOCKWOOD BRIDGE, 7/31/80									
3	Upper Mustang bridge to above McCarran diversion	1.85	5.9	331	2.2	2.52	1.23	269	120	2.2
A2	Above McCarran diversion to Patrick bridge	1.48	17.4	327	1.2	17.8	1.81	183	110	1.7
4	Below McCarran diversion to Patrick bridge	1.43	16.4	324	1.2	17.1	1.75	189	110	1.7
5	Patrick bridge to above Hill diversion	2.90	7.4	329	3.7	4.71	1.15	286	120	2.4
B2	Above Hill diversion to Clark bridge	3.42	8.2	327	4.4	6.10	1.14	287	120	2.4
6	Below Hill diversion to Clark bridge	3.40	7.2	327	4.2	6.01	1.19	275	120	2.3
7	Clark bridge to Derby Dam	3.72	6.8	330	5.0	4.30	1.09	303	100	3.0
	INJECTION AT RR BRIDGE BELOW WADSWORTH, 10/10/79									
8	Below Fellnagle diversion to RM 15.82	6.71	9.0	50	18.3	7.47	.53	96	73	1.3
9	RM 15.82 to Dead Ox Wash	2.64	6.1	56	5.7	5.25	.68	87	83	1.0
	INJECTION AT RR BRIDGE BELOW WADSWORTH, 7/28/80									
C2	Above Fellnagle diversion to above S Bar S diversion	2.71	10.4	60	6.1	6.84	.65	102	79	1.3
10	Below Fellnagle diversion to above S Bar S diversion	2.69	8.8	66	6.1	5.26	.65	102	79	1.3
11	Above S Bar S diversion to Dead Ox Wash	6.66	7.7	78	13.1	7.49	.74	104	91	1.1

[1] Traveltime and velocities based on centroid of dye tracer.

[2] Top width estimated from experimental width versus discharge coefficients (table 11).

[3] Mean depth calculated from area divided by width.

TABLE 14.--Comparison of field data for the reaeration coefficient (K_2) with 10 predictive equations commonly used in water-quality modeling

[Data sources--Data from gas-tracer studies on the Truckee River (11 points, K_2 from .35 to 3.5) and the Yampa River, Colo. (Bauer and others, 1979; 6 points, K_2 from 7.3 to 30.5). Abbreviations and units--H, mean depth (ft); U, mean velocity (ft/s); S, slope (ft/ft); U*, shear velocity ($\sqrt{gHS}$); F, Froude number ($\frac{U}{\sqrt{gH}}$); g, gravitional constant (ft/s^2); T, traveltime (hours).]

Equation Number	Reference	Equation for K_2 (base e, 1/day at 20°C)	Equation performance: Mean error[1] (1/day)	Rank	Standard error of estimate[2] (1/day)	Rank
(1)	Churchill and others, 1962	$.0345\ U^{2.695}\ H^{-3.085}\ S^{-.823}$	-7.5	10	9.2	9
(2)	Dobbins, 1965	$\frac{117\ (1.0 + F^2)\ H^{-1}(US)^{.375}}{(0.9 + F)^{1.5}}\ \coth\left[\frac{4.10(US)^{.125}}{(0.9 + F)^{.5}}\right]$	-1.8	2	4.8	2
(3)	Isaacs and Gaudy, 1968	$8.61\ U\ H^{-1.5}$	-4.7	5	6.7	5
(4)	Langbein and Durum, 1967	$7.61\ U\ H^{-1.33}$	-5.2	6	7.2	6
(5)	O'Connor and Dobbins, 1958	$12.3\ U^{.5}\ H^{-1.5}$	-2.5	4	5.5	4
(6)	Padden and Gloyna, 1971	$6.86\ U^{.703}\ H^{-1.054}$	5.3	7	7.7	7
(7)	Parkhurst and Pomeroy, 1972	$48.4\ (1 + 0.17\ F^2\ (US)^{.375}\ H^{-1}$	-6.6	8	8.6	8
(8)	Thackston and Krenkel, 1969	$24.9\ (1 + F^{.5})U*\ H^{-1}$	-2.4	3	5.2	3
(9)	Tsivoglou and Wallace, 1972	4100 US	-.69	1	2.9	1
(10)	Velz, 1970	$-1440m^{-1}\ \ln\ [1 - .00370H^{-1}m^{.5}]$ $m = 2.28 + .721\ H$ (for $H < 2.26$) $m = 13.9\ \ln(H)-7.45$ (for $H > 2.26$)	-6.9	9	9.4	10

[1] Mean error $= \Sigma \frac{P - O}{N}$,

where P = predicted K_2,
O = observed K_2, and
N = number of data points

[2] Standard error of estimate $= \sqrt{\Sigma \frac{(P - O)^2}{N}}$

A linear regression using just the Truckee River data resulted in C = 3360. Comparison simulations of predicted versus observed oxygen concentrations for the August 1979 synoptic data led to the incorporation of the lower value (only Truckee River data) in the TRWQ model.

Concern was expressed in the beginning of the RQA on the effect of agricultural diversion dams on the river on reaeraton. These structures are low-head (2 to 4 feet) dams composed of rocks and rubble to maintain head for diversion into agricultural ditches through fixed control gates. As a test of effect of these dams on predicted reaeration coefficients, a regression analysis was done on Truckee River data alone, divided into two data sets: (A) only those reaches containing no diversion dams, and (B) all reaches, including dams. The results are shown graphically in figure 20 and tablulated below:

Data set	C	Correlation coefficient (r^2)	Standard error of estimate
(A) all reaches	3360	0.76	2.2
(B) reaches without dams	3550	.68	2.2

Figure 20 near here

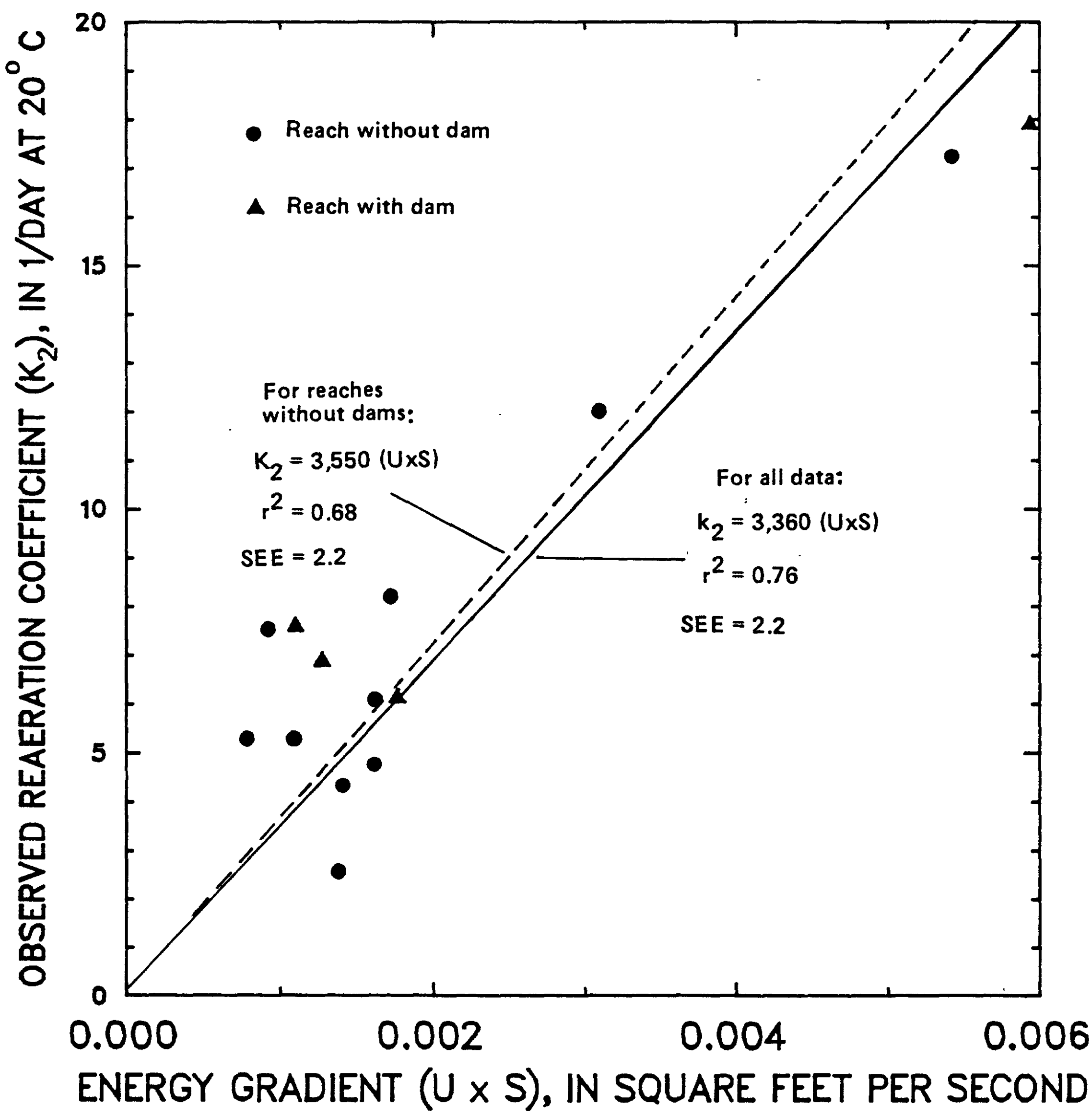


FIGURE 20.--Field data indicate that irrigation dams in the Truckee River have little effect on prediction of reaeration rate coefficients by the Tsivoglou energy-gradient equation. (Symbols: r^2, regression coefficient; SEE, standard error of estimate.)

This analysis did not indicate a significant difference in C for reaches with and without diversion dams. A working hypothesis for this lack of difference is that the the energy dissipation model includes effects of the head of the dams in the overall slope of the reach. Expressed in another way, the low-head rock rubble dams in the Truckee River can be considered to have essentially the same effect as a natural set of rapids in a reach with the same gradient. To account for the effects of the larger concrete dams in the system (Derby and Numana), the river was segmented for modeling so as to represent the dams as a short, high-gradient reach. Prediction of reaeration in the model probably decreases in reliability with higher flows. The reaeration field studies were all done at relatively low flows, which may bias the range of flows for which the derived C values are applicable. In addition, the representation of the basic channel-geometry factors may be inaccurate at higher flows.

In summary, K_2 coefficients in the model are predicted for each segment by applying equation 32 with a C value of 3,360 and estimates of velocity based on the exponential relationships to discharge (table 11). K_2 values are corrected from the 20 °C standard temperature to ambient stream temperatures using equation 23 (θ = 1.0241).

Synoptic Water-Quality Studies

Four intensive studies were conducted in June and August of 1979 and 1980 to obtain water-quality data for model calibration and validation. These sampling studies were synoptic with respect to time; that is, the entire modeled reach of river and canal was sampled during the same 1- to 3-day period. During these studies, the Truckee River and Canal, North Truckee Drain, Steamboat Creek, and the Reno-Sparks STP outfall were sampled at 2- to 4-hour intervals over 24- to 36-hour periods. These intensive field studies resulted in collection of more than 1,000 water samples and more than 20,000 individual measurements of water-quality characteristics. Raw data and details of methods used in sampling and analysis during the synoptics are presented by La Camera and others (1985). A summary of the data and methods used in data reduction are in Appendix A of this report.

Sampling sites for the synoptic studies are shown in figure 13, and listed in table 15. The Verdi and Mayberry sites were not used directly in the modeling, but were added to give information on changes in water quality through the Truckee Meadows above the modeled reach. The McCarran Bridge, Kleppe Lane, and Kimlick Lane sites define initial quality for the main-stem river and two tributary submodels. Sampling at the Reno-Sparks STP outfall established input loadings from the treatment plant. Downstream river and canal sites provided data for calibration and validation of the rate coefficients developed for the model.

Table 15 near here

TABLE 15.--Synoptic sampling sites and summary of available water-quality data

USGS site identification numbers: Station numbers used to identify sites in USGS reports and the WATSTORE and STORET data bases.

River mile: For Truckee River, mileage above the spillway at Marble Bluff Dam; for the Truckee Canal, mileage above weir and control gates to drop flume into Lahontan Reservoir; for tributaries, mileage to the confluence of the tributary with the Truckee River (mileage along the tributary above the mouth shown in parentheses).

Altitudes: Approximate water surface expressed in feet above mean sea level.

Data availability: Basic schedule for all synoptics included bihourly field determinations of water and air temperatures, barometric pressure, dissolved oxygen and percent saturation, and specific conductance, with samples taken every 4 hours for laboratory analyses for nitrogen and phosphorus species (organic-, ammonia-, nitrite-, and nitrate-nitrogen, total and ortho-phosphorus), and CBOD (20-day time-series determination of rates and concentrations). Additional samples are denoted by: A, alkalinity; DS, dissolved solids (ROE at 180 °C); BN, total and nitrogenous BOD; AGP, algal growth potential bottle test; P, phytoplankton biomass, chlorophyll *a* & *b*; PS, phytoplankton speciation and cell counts; T, turbidity; F, field measurements only. Nutrient analyses were on whole-water samples (totals) for June 1979 and on filtered samples (dissolved or soluble) for the remaining synoptics (with replicate whole-water samples at selected sites.

Map number (figure 19)	USGS site identification number	Site name	River mile	Miles below mouth of Steamboat Creek	Altitude (feet)	Data available from synoptic surveys: (A) June 6-8, 1979	(B) August 8-10, 1979	(C) June 5-6, 1980	(D) August 13-14, 1980
		Truckee River above Reno-Sparks urban area:							
1	10347050	Bridge at Crystal Peak Park at Verdi	74.30	-20.77	4852	—	—	T, BN, P, PS, AGP	T, BN, P, PS, AGP
2	10347690	Mayberry Drive bridge near Reno	65.70	-12.17	4611	—	—	T, BN, PS, AGP	T, BN, P, PS, AGP
		Truckee River at beginning of modeled reach:							
3	10348200	McCarran Ave. bridge (gage near Sparks)	56.12	-2.59	4384	A, BN	A, BN, P, PS, AGP	T, BN, P, PS, AGP	T, BN, P, PS, AGP
		Major tributaries and inputs to modeled reach:							
4	10348300	North Truckee Drain at Kleppe Lane bridge	53.66 (.26)	-.39	4375	A, BN	BN, P, PS, AGP	T, BN, P, PS, AGP	T, BN, P, PS, AGP
5	10349980	Steamboat Creek at Kimlick Lane bridge	53.53 (.75)	-.75	4375	A, BN	BN, P, PS, A, AGP, DS	T, BN, P PS, AGP	T, BN, P, PS, AGP
6	10349989	Reno-Sparks STP outfall	53.53 (.13)	-.13	4374	A, BN	BN, P, AGP, DS	T, BN, AGP	T, BN, P, AGP
								PS, AGP	AGP

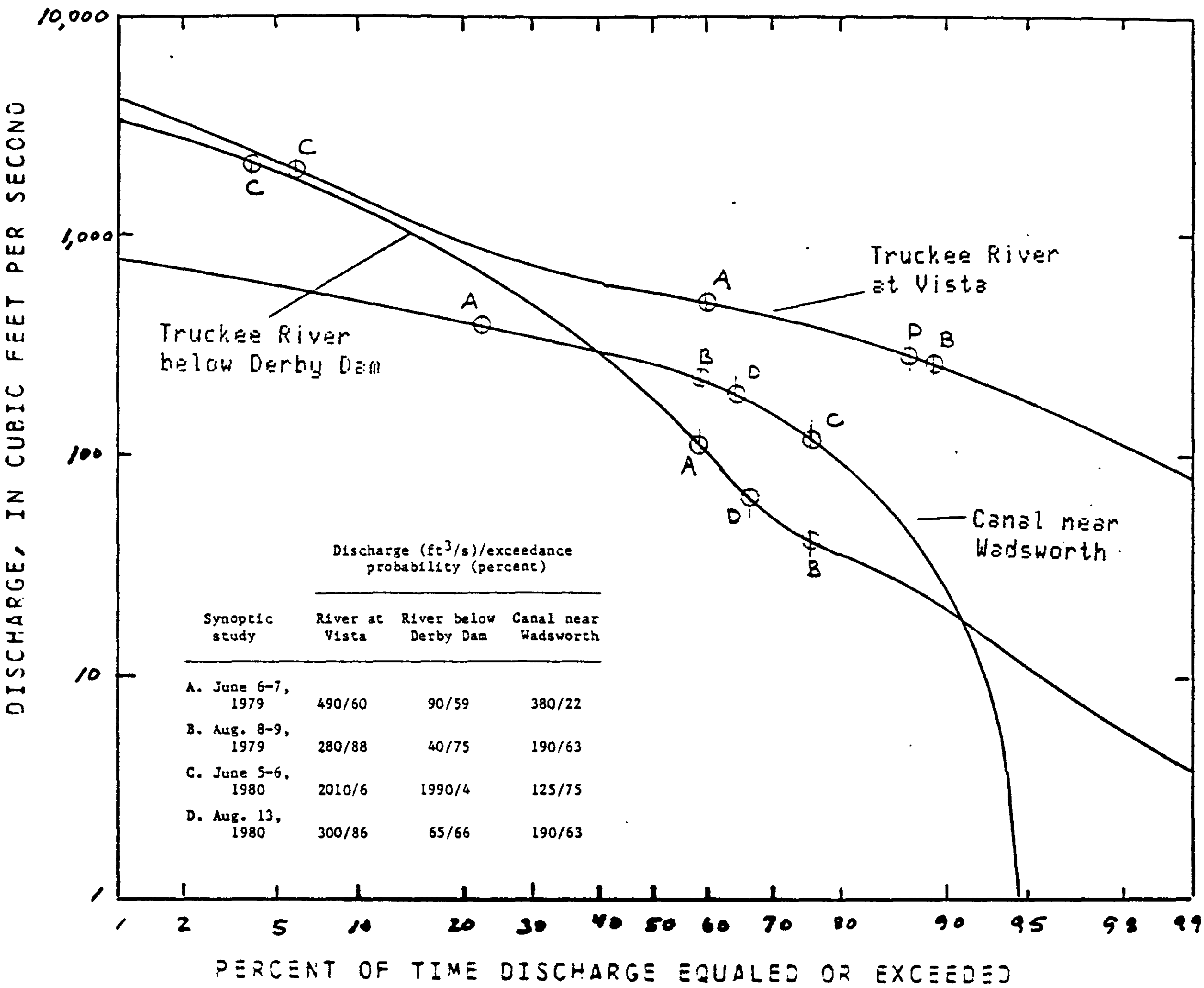
TABLE 15.—Synoptic sampling sites and summary of available water-quality data—Continued

Map number (figure 19)	USGS site identification number	Site name	River mile	Miles below mouth of Steamboat Creek	Altitude (feet)	Data available from synoptic surveys (A) June 6-8, 1979	(B) August 8-10, 1979	(C) June 5-6, 1980	(D) August 13-14, 1980
Truckee River sites between Steamboat Creek and Derby Dam:									
7	10350000	Gage at Vista	52.23	1.30	4371	A, BN	A, P, DS	T, P,	T, P, PS,
8	10350050	Bridge at Lockwood	50.05	3.48	4345	A, BN	P, PS, A, AGP	T, BN, P, PS, AGP	T,P,PS, BN, AGP
9	10350200	Bridge near Patrick (McCarran Ranch)	44.92	8.61	4279	A, BN	A, P, DS	T, PS	T, PS, P, AGP
10	10350400	Bridge at Tracy (Tracy gage)	40.62	12.91	4243	A, BN	—	T, P, PS	—
11	10350500	Bridge at Clark	38.60	14.93	4229	—	A, P, DS, AGP	—	AGP, T, P, PS
12	10351000	Derby Dam (canal gate above dam)	34.88 (canal mile 31.42)	18.65	4204	A, BN	DS, A, BN P, PS, AGP	T, BN, P, PS, AGP	T, BN, P, PS, AGP
Truckee River sites below Derby Dam:									
13	10351600	Gage below Derby Dam	34.49	19.04	4187	A, BN	DS, A, P, PS	F	F
14	10351619	Bridge at Painted Rock	29.97	23.56	4117	—	—	T, BN, P, PS, AGP	T, BN, P, PS, AGP
15	10351648	Old U.S. Highway 40 bridge at Wadsworth	23.69	29.84	4047	A, BN	DS, A, P, AGP	T, BN, P, PS, AGP	T, BN, P, PS, AGP
16	10351690	Dead Ox Wash	13.18	40.35	3960	A, BN	DS, P	T, PS	T, P, PS, AGP
17	10351750	State Highway 447 bridge at Nixon	3.22	50.31	3877	A, BN	DS, A, P, AGP	T, BN, P, PS, AGP	T, BN, P, PS, AGP
18	10351775	Marble Bluff Dam	0.00	53.53	3855	A, BN	A, P, PS, AGP	T, BN, P, PS, AGP	T, BN, P, PS, AGP
Truckee Canal:									
19	10351320	U.S. Highway 95A bridge near Fernley	18.23	31.84	4190	A, BN	DS, A, P, AGP	T, P, PS, PS, AGP	T, P, PS PS, AGP
20	10351367	Allendale check dam	11.07	39.00	4181	—	—	T, PS	T, P, PS, AGP
21	10351590	U.S. Highway 50 bridge near Lahontan Reservoir	.44	49.63	4170	A, BN	DS, A, P, PS, AGP	T, BN, P, PS, AGP	T, BN, P, PS, AGP

The synoptic studies sampled a wide range of streamflow conditions spanning discharges with probabilities of exceedance ranging from about 5 to 95 percent, as shown by the flow-duration curve in figure 21. Although the two June studies were designed to represent typical spring runoff periods, because of the 1977-79 drought in Nevada, the June 1979 data set represented much lower flows than the June 1980 data set.

Figure 21 near here

Variability of streamflow during and preceding the synoptic studies is shown by the precipitation and streamflow hydrographs in figure 22. Due to the low snowpack conditions in the Sierra Nevada in the winter of 1979, the June 1979 synoptic study sampled the end of the snowmelt period. In contrast, the June 1980 study sampled a more normal and relatively steady snowmelt runoff prior to the spring recession. Average spring flows at the Vista gage are 1,760 ft^3/s for May and 1,000 ft^3/s for June; sampled flows were 490 ft^3/s for the June 1979 study, and 2,010 ft^3/s for the June 1980 study. The two August studies sampled typical summer runoff patterns, although the flows (260 and 300 ft^3/s at Vista) were less than average for the month (440 ft^3/s, 1973-82). The only synoptic study with precipitation in the preceding 5-day period was the June 1980 study, with 0.12 inch of rainfall measured at Reno on June 4 and a trace on June 2 and 5. No overland runoff was noticed in the washes between Reno and Derby Dam following this event, although some later evidence of runoff was seen in washes between Wadsworth and Pyramid Lake that could have affected streamflow and quality in that reach of the river.



Synoptic study	Discharge (ft^3/s)/exceedance probability (percent) River at Vista	River below Derby Dam	Canal near Wadsworth
A. June 6-7, 1979	490/60	90/59	380/22
B. Aug. 8-9, 1979	280/88	40/75	190/63
C. June 5-6, 1980	2010/6	1990/4	125/75
D. Aug. 13, 1980	300/86	65/66	190/63

FIGURE 21.--The four synoptic studies spanned a wide range of expected discharges for the Truckee River and Canal.

Discussions of the water-quality characteristics of the river and canal observed during the four synoptic studies are included in a following section on model calibration and validation.

Figure 22 near here

Nonpoint Source Loadings

One potential use for a calibrated water-quality model is to evaluate the relative impact on water quality of point and nonpoint sources of pollutants. For the TRWQ model, point sources include the Reno-Sparks STP, and inputs from the two tributaries draining the Truckee Meadows, North Truckee Drain and Steamboat Creek. Nonpoint-source loadings of significant interest include surface irrigation returns and ground-water inflows below Reno. Application of a model to evaluate the nonpoint loadings required development of methods for estimating the quantity and quality of irrigation returns and ground-water inflows for both the synoptic data sets used in model calibration and for simulation of future conditions.

Surface irrigation returns

Truckee River water is cycled through 14 principal agricultural diversions between Reno and Pyramid lake (tables 4 and 7 and figures 13-16) that divert water from the river and return agricultural drainage via return ditches or direct overland runoff. In addition, diversions from the first 8 miles of the Truckee Canal are applied to fields that are adjacent to the river north of the canal.

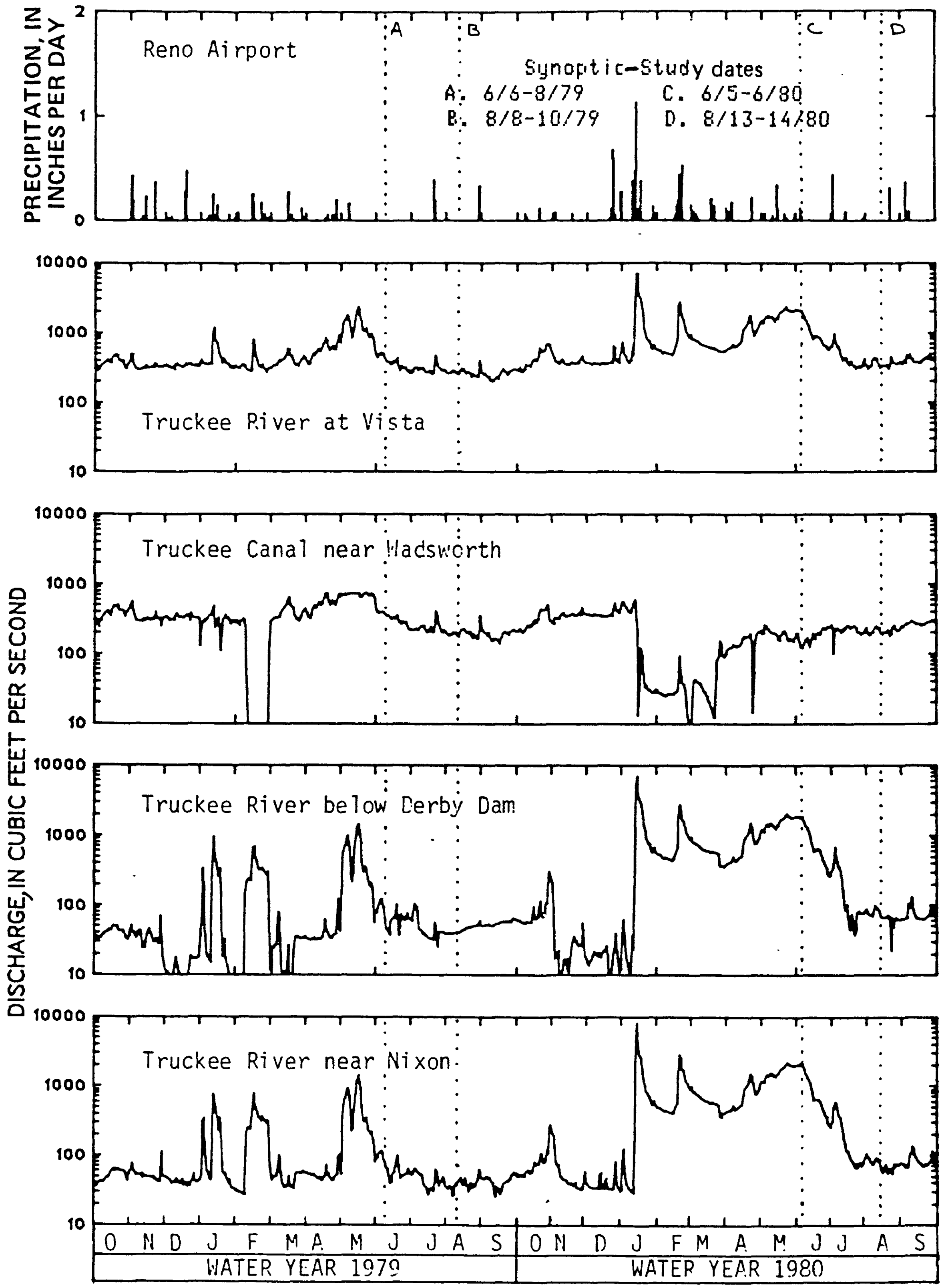


FIGURE 22.--Hydrographs for water years 1979 and 1980 show timing of synoptic studies in relation to streamflow and antecedent precipitation.

Relation of these diversions and associated returns to the TRWQ model segmentation are shown in figures 15 and 16. The diversions were represented in the model as withdrawing water at the head of the affected model segment. Surface irrrigation returns were modeled as uniformly distributed nonpoint returns for which average concentrations of constituents and total quantity of water returned over the subreach are specified as part of the input data. For segments with more than one diversion, the diversions were totaled and modeled at the head of the segment. For segments receiving returns from multiple diversions, the quantities of return flows were summed and attributed to the largest single source for that segment. Return flows are linearly distributed over the length of the receiving model segments.

Representation of the quality of irrigation return flows for 43 modeled river segments is shown in table 16 as derived from an analysis of sampled diversions and returns along the Truckee River and a statistical analysis of agricultural returns in a similar environment in Carson Valley, Nev. (see Appendix B). Estimates of the quantity of return flows were made by an initial assumption that 50 percent of the diverted water returns to the river (Claude Dukes, Federal Watermaster, 1980, oral communication) and then adjusting the estimates with an overall flow balance for the river (see "Streamflow Balance" below).

Table 16 near here

TABLE 16.--Estimates of the quality of surface irrigation-return flows used for modeling

[Estimates based on analysis of data from Carson Valley, Nevada, (Appendix B, table B1) except as noted.]

Constituents and units	Modeled concentration
Dissolved solids (mg/L)	1.2 x concentration at point of diversion
Dissolved oxygen (mg/L)	.7 x concentration at point of diversion
CBOD ultimate (mg/L)	10 (segments 1-29, 34-43)[a]
	25 (segments 30-33)[b]
Nitrogen (mg/L as N)	
organic	1.3[a]
ammonia	.1[a]
nitrite	.1[a]
nitrate	.3
Phosphorus (mg/L as P)	
ortho	.5
total	.6

a Based on Truckee River data, table B1.

b Based on model calibration, see text.

Ground-water inflows

Ground-water inflows to the river occur as discharges from regional ground-water flow systems and from ground-water returns from irrigation, especially with repect to the agricultural area near Fernley irrigated by diversions from the Truckee Canal. Estimates of the quality and quantity of ground-water inflows to the 43 model subreaches are listed in table C8. Derivation of these estimates is described in Appendix C.

Streamflow Balance

Application of the computer model assumes that, at any given point in the river, the flow is steady with respect to time. Streamflows used in calibration and validation of the model represented average flows for the duration of each synoptic study. For each of the four synoptic data sets used for model calibration, a flow-routing procedure was developed to balance estimates of diversions and return flows with measured and gaged streamflow at the sampling sites for the river and the canal. The procedures developed were generalized for developing estimates of diversions and returns for future simulations with the model. Mass balance of the estimated dissolved solids was used as a check for gross errors in the estimates of diversions and returns.

Truckee River

Data used to balance streamflows included instantaneous discharge measurements made during the synoptic studies, records at gaging stations, diversion measurements from the office of the Federal Watermaster, and independently developed estimates of ground-water return flows. At low to medium flows, precision of available flow records on the Truckee River is generally poor in relation to the magnitude of diversions and returns to an individual model segment. For example, daily discharge records for U.S. Geological Survey gages during the synoptic studies were rated in accuracy from good (±10 percent) to poor (probable error greater than ±15 percent), depending on site and study. At a river discharge of 300 ft^3/s, the probable error in daily flow at a gage could thus be in the range of 60 to 90 ft^3/s, considerably greater than the magnitude of individual diversions or returns.

Developing the flow balance for each study was an iterative process applied to model reaches between gages. Ground-water return flows were initially estimated using the methods described in Appendix C (table C7). Irrigation-return flows were estimated to be about 50 percent of the diverted quantity. Measured flow differences in a reach were then compared to the sum of estimated diversions and returns, and adjustments made to the individual estimates as deemed appropriate. Mass balance of dissolved solids was used as a guide in making the adjustments. After a reasonable match between observed and estimated flow was achieved for each of the four data sets, adjustments for each river reach were compared between data sets, and a final uniform set of rules developed for the estimates. The final procedure used is specific to reach and flow regime.

A summary of the procedures developed for balancing estimates of flow for the Truckee River is given in table 18, including specific factors used in developing the streamflow balances for the four synoptic data sets. Table 17 provides the starting estimates of surface and ground-water returns, and the final adjusted estimates used for each of the four synoptic data sets. To the extent that flow regimes and diversion practices are similar to those listed in table 17, the guidelines develped for the synoptic data sets can be used to estimate return flows for other simulations.

Tables 17 and 18 near here

Truckee Canal

The canal loses water along most of its 34-mile length between Derby Dam and Lahontan Reservoir to seepage through unlined sections, via two direct spillways back to the Truckee River, and to agricultural diversions. The only sources of inflow other than river diversions at Derby Dam are occasional flash-flood flows in ephemeral washes draining adjacent desert mountain ranges. Accurate representation of streamflow in the model for the canal thus is not required for accounting of input loads, but rather to accurately represent diminishing streamflows as a basis for calculating velocities and traveltimes for nonconservative substances.

TABLE 17.--Estimates of Truckee River tributary inflows, diversions, and returns used for modeling

[Initial estimates for irrigation returns and ground-water return flows adjusted to observed difference in streamflow between gages by procedures outlined in table 18. Origin--number of modeled segment containing diversion that is the source of the surface return flow.]

River segment modeled tributaries, diversions and returns	Starting river mile	Length (mi)	Initial estimates for flow balance (ft^3/s)	Modeled tributary, diversion, and adjusted return flows for calibration/validation data sets: (A) June 1979 (ft^3/s)	origin	(B) August 1979 (ft^3/s)	origin	(C) June 1980 (ft^3/s)	origin	(D) August 1980 (ft^3/s)	origin
1 McCarran bridge (Sparks gage)	56.12	2.46									
starting river flow:			—	375		160		1,780		155	
+ Surface return			0	0		0		0		0	
+ Ground water			0	0		0		0		0	
2 N. Truckee Drain	53.66	.13									
+ North Truckee Drain			—	40		50		50		40	
+ Surface return			0	0		0		0		0	
+ Ground water			0	0		0		0		0	
3 Steamboat Creek	53.53	1.30									
+ Steamboat Creek:			—	50		40		145		70	
+ Reno-Sparks STP:			—	25		30		35		35	
+ Surface return			0	0		0		0		0	
+ Ground water			0	0		0		0		0	
4 Vista gage	52.23	.98									
+ Surface return			0	0		0		0		0	
+ Ground water			0	0		0		0		0	
5 Largomarsino divs.	51.25	.35									
- Noce diversion (left):			*a*	-2		-4		-2		-2	
- Murphy diversion (right):			*a*	-22		-23		-18		-17	
+ Surface return			0	0		0		0		0	
+ Ground water			0	0		0		0		0	
6 Below Largo. divs.	50.90	.85									
+ Surface return			(50% Noce + 1% Murphy div.)	2.1	(5)	3.0	(5)	1.2	(5)	.8	(5)
+ Ground water			0	0		0		0		0	
7 Lockwood bridge	50.05	.15									
+ Surface return			(2% Murphy div.)	.7	(5)	.7	(5)	.4	(5)	.2	(5)
+ Ground water			0	0		0		.5		0	

TABLE 17.--Estimates of Truckee River tributary inflows, diversion, and returns used for modeling--Continued

	River segment modeled tributaries, diversions and returns	Starting river mile	Length (mi)	Initial estimates for flow balance (ft^3/s)	Modeled tributary, diversion, and adjusted return flows for calibration/validation data sets							
					(A) June 1979 (ft^3/s)	origin	(B) August 1979 (ft^3/s)	origin	(C) June 1980 (ft^3/s)	origin	(D) August 1980 (ft^3/s)	origin
8	Groton diversion	49.90	1.65									
	+ Long Valley Creek			*b*	0		0		0		0	
	- Groton diversion:			*a*	-5		-4		0		-3	
	+ Surface return			(50% Groton + 24% Murphy div.)	14	(5)	10.1	(5)	4.3	(5)	3.8	(5)
	+ Ground water			0	0		0		5.8		0	
9	Mustang bridge	48.25	1.57									
	+ Surface return			(23% Murphy div.)	9.1	(5)	7.1	(5)	4.1	(5)	2.6	(5)
	+ Ground water			0	0		0		5.7		0	
10	McCarran pool	46.68	.33									
	+ Surface return			0	0		0		0		0	
	+ Ground water			0	0		0		1.2		0	
11	McCarran div.	46.35	1.43									
	- McCarran diversion:			*a*	-22		-13		-20		-10	
	+ Surface return			(5% McCar. div.)	2.0	(11)	1.3	(11)	1.0	(11)	.3	(11)
	+ Ground water			0	0		0		5.1		0	
12	Patrick bridge	44.92	2.04									
	+ Surface return			(45 % McCar. div.)	17.1	(11)	7.8	(11)	9	(11)	3	(11)
	+ Ground water			0	0		0		7.2		0	
13	SP Railroad bridge	42.88	.86									
	+ Surface return			0	0		0		0		0	
	+ Ground water			0	0		0		3.1		0	
14	Hill diversion	42.02	1.26									
	- Hill diversion:			*a*	-4		-6		0		-7	
	+ Surface return			(6% Hill div.)	.4	(14)	.5	(14)	0		.3	(14)
	+ Ground water			0	0		0		4.5		0	
15	Tracy diversion	40.76	.14	*c*								
	- Tracy diversion			*a*	-4		-4		-4		-4	
	+ Surface return			(3% Hill div.)	.2	(14)	.3	(14)	0		.1	(14)
	+ Ground water			0	0		0		.5		0	
16	Tracy br. (gage)	40.62	2.02									
	+ Surface return			(41% Hill div.)	2.8	(14)	3.2	(14)	0		1.9	(16)
	+ Ground water			0	0		0		7.2		0	
17	Clark bridge	38.60	1.50									
	+ Surface return			0	0		0		0		0	
	+ Ground water			0	0		0		5.3		0	

TABLE 17.--Estimates of Truckee River tributary inflows, diversion, and returns used for modeling--Continued

	River segment modeled tributaries, diversions and returns	Starting river mile	Length (mi)	Initial estimates for flow balance (ft^3/s)	Modeled tributary, diversion, and adjusted return flows for calibration/validation data sets							
					(A) June 1979 (ft^3/s)	origin	(B) August 1979 (ft^3/s)	origin	(C) June 1980 (ft^3/s)	origin	(D) August 1980 (ft^3/s)	origin
18	RM37.1	37.10	1.50									
	+ Surface return			0	0		0		0		0	
	+ Ground water			0	0		0		5.3		0	
19	Derby pool	35.60	.72									
	+ Surface return			0	0		0		0		0	
	+ Ground water			0	0		0		2.6		0	
20	Derby Dam	34.88	.36									
	- Truckee Canal			*d*	-390		-220		-130		-205	
	+ Surface return			0	.4	(20)	.4	(20)	3.5	(20)	.4	(20)
	+ Ground water			.4[e]	0		0		0		0	
21	Derby cableway (Below Derby gage)	34.52	3.24									
	+ Surface return			0	3.6	(21)	3.6	(21)	31.1	(21)	3.6	(21)
	+ Ground water			3.6[e]	0		0		0		0	
22	Washburn Dam	31.28	1.31									
	- Washburn diversion:			*a*	-6		-2		-5		-1	
	+ Surface return			(50% Wash. div.)	3.5	(22)	1.6	(22)	15.0	(22)	1.8	(22)
	+ Ground water			1.4[e]	0		0		0		0	
23	Painted Rock br.	29.97	.62									
	+ Surface return			0	.7	(23)	.7	(23)	6.0	(23)	.7	(23)
	+ Ground water			.7[e]	0		0		0		0	
24	Gregory-Monte div.	29.35	1.35									
	- Gregory-Monte diversion:			*a*	-5		-8		-10		-5	
	+ Surface return			(23% Greg. div.)	2.3	(24)	1.9	(24)	15.5	(24)	2.4	(24)
	+ Ground water			1.4[e]	0		0		0		0	
25	RM 28	28.00	1.25									
	+ Surface return			(24% Greg. div.)	2.2	(25)	1.8	(25)	14.4	(25)	2.3	(25)
	+ Ground water			1.4[e]	0		0		0		0	
26	Herman diversion	26.75	.80									
	- Herman diversion:			*a*	-11		-14	0	-5		-15	
	+ Surface return			(2% Herman div.)	1	(26)	1	(26)	7.8	(26)	1.1	(26)
	+ Ground water			.9[e]	0		0		0		0	
27	Pierson diversion	25.95	2.05									
	- Pierson diversion:			*a*	-8		0		-5		-6	
	+ Surface return			(50% Pierson + 38% Herman div.)	8.2	(27)	3.5	(27)	24.1	(27)	9.1	(26)
	+ Ground water			2.3[e]	0		0		0		0	

TABLE 17.--Estimates of Truckee River tributary inflows, diversion, and returns used for modeling--Continued

River segment modeled tributaries, diversions and returns	Starting river mile	Length (mi)	Initial estimates for flow balance (ft^3/s)	Modeled tributary, diversion, and adjusted return flows for calibration/validation data sets							
				(A) June 1979		(B) August 1979		(C) June 1980		(D) August 1980	
				(ft^3/s)	origin	(ft^3/s)	origin	(ft^3/s)	origin	(ft^3/s)	origin
28 Proctor diversion	23.90	.21									
- Proctor diversion:			*a*	-8		0		-15		-6	
+ Surface return			(10% Herman div.)	1.1	(26)	.5	(28)	2.6	(28)	1.6	(26)
+ Ground water			.3[e]	0		0		0		0	
29 Wadsworth bridge (gage)	23.69	1.14									
- Olinghouse #1 div. (pump)			0[f]	0		0		0		0	
+ Surface return			0	0		0		3.7	(29)	0	
+ Ground water			4.8	4.8		4.8		4.8		4.8	
30 Fellnagle div.	22.55	1.15									
- Fellnagle diversion:			*a*	0		-6		-10		-11	
+ Surface return			(2% Proct. + 2% Fell. div.)	.1	(28)	0		4.2	(30)	.2	(30)
+ Ground water			4.9	4.9		4.9		4.9		4.9	
31 RM 21.4	21.40	1.56									
+ Surface return			(5% Proctor + 48% Fell. div.)	.3	(28)	1.1	(30)	10.6	(31)	3.1	(30)
+ Ground water			.2	.2		.2		.2		.2	.2
32 S bar S diversion	19.84	2.02									
- S Bar S diversion:			*a*	0		-4		-3		-4	
+ Surface return			(22% Proct. + 19% S Bar S div.)	1.3	(28)	.3	(32)	10.3	(32)	1.2	(28)
+ Ground water			.4	.4		.4		.4		.4	
33 S Bar S Pump	17.82	2.00									
- S Bar S, Olinghouse #2,#3 div. (pumps)			0[f]	0		0		0		0	
+ Surface return			(21% Proct. + 31% S Bar S div.)	1.2	(28)	.5	(32)	10.6	(33)	1.4	(28)
+ Ground water			.3	.3		.3		.3		.3	
34 RM 15.8	15.82	2.64									
+ Surface return			0	0		0		8.5	(34)	0	
+ Ground water			.4	.4		.4		.4		.4	
35 Dead Ox Wash	13.18	3.18									
+ Surface return			0	0		0		10.4	(35)	0	
+ Ground water			.9	.9		.9		.9		.9	

TABLE 17.--Estimates of Truckee River tributary inflows, diversion, and returns used for modeling--Continued

River segment modeled tributaries, diversions and returns	Starting River Mile	Length (mi)	Initial estimates for flow balance (ft3/s)	Modeled tributary, diversion, and adjusted return flows for calibration/validation data sets							
				(A) June 1979 (ft3/s)	Origin	(B) August 1979 (ft3/s)	Origin	(C) June 1980 (ft3/s)	Origin	(D) August 1980 (ft3/s)	Origin
36 RM 10 (Nixon gage at RM 9.42)	10.00	.80									
+ Surface return			0	0		0		2.6	(36)	0	
+ Ground water			.2	.2		.2		.2		.2	
37 RM 9.2	9.20	.99									
+ Surface return			0	0		0		0		0	
+ Ground water			.2	.2		.2		.2		.2	
38 Numana Dam	8.21	.61									
- Numana diversion:			*a*	-20		-13		-16		-20	
+ Surface return			0	0		0		0		0	
+ Ground water			.2	.2		.2		.2		.2	
39 RM 7.6	7.60	.80									
+ Surface return			0	0		0		0		0	0
+ Ground water			.2	.2		.2		.2		.2	
40 RM 6.8	6.80	2.80									
+ Surface return			(39% Numana div.)	2.7	(38)	5.1	(38)	11.3	(38)	3.5	(38)
+ Ground water			.7	.7		.7		.7		.7	
41 RM 4	4.00	.78									
+ Surface return			(11% Numana div.)	.8	(38)	1.4	(38)	3.2	(38)	1.0	(38)
+ Ground-water			.2	.2		.2		.2		.2	
42 Nixon bridge	13.22	2.22									
+ Surface return			0	0		0		0		0	
+ Ground-water			.7	.7		.7		.7		.7	
43 RM 1.00	1.00	1.00									
+ Surface return			0	0		0		0		0	
+ Ground-water			.3	.3		.3		.3		.3	
Marble Bluff Dam	.00										

a Estimated from records of Federal Watermaster

b Ephemeral stream, normally no flow.

c Estimated constant diversion for cooling water, no returns.

d Estimated from records at USGS and Federal Watermaster gages.

e Modeled as surface return.

f Not operating during synoptic studies.

TABLE 18.--Procedures used in adjusting estimates of return flows to the Truckee River from surface irrigation and ground-water inflows

[Initial estimates of return flows based on table 17. Error in estimated returns then calculated for gaged reaches as E = Q2 - (Q1 - D + SR + GW), where E is the total error in estimated returns, Q1 is the flow at the head of the reach, Q2 is the flow at the end of the reach, D is the sum of estimated diversions from all segments in the reach, SR is the sum of the estimated surface returns to receiving segments in the reach, and GR is the sum of ground-water returns to segments in the reach.]

Subreach	Model segments	Data sets	Procedure for adjusting estimates of return flows
McCarran bridge to Vista gage	1-4	All	Assumed no significant ground-water or surface irrigation returns. Differences between gaged Vista flow and sum of flows from USGS gage at McCarran Bridge, Federal Watermaster gages at Steamboat Creek and North Truckee Drain, and STP outflow records adjusted based on analysis of records at each site.
Vista gage to Derby Dam	5-19	August, June 1979	Assumed no significant ground-water returns. Flow at Derby Dam estimated from analysis of records (USGS and Federal Watermaster) for diversions through Truckee Canal and USGS gages below Derby Dam and at Tracy above Derby Dam. Errors in initial flow balance attributed to errors in estimates of surface irrigation returns. Adjustments made to return estimates by linear proration with length of segments receiving returns.
		June 1980	Error in return estimates (54 ft^3/s) much greater than could be explained by diversions. Accretions attributed to release from bank storage during falling stage and, based on mass balance of dissolved solids, modeled as ground-water returns, prorated by length to entire reach.

TABLE 18.--Procedures used in adjusting estimates of return flows to the Truckee River from surface irrigation and ground-water inflows--Continued

Subreach	Model segments	Data sets	Procedure for adjusting estimates of return flows
Derby Dam to Wadsworth bridge	20-28	August, June 1979	Assumed constant ground-water inflows (table 17). Error prorated to irrigation surface returns by length of receiving segments. Ground-water and surface returns then added for each segment and quality modeled as if all from surface returns originating in each segment.
		June 1980	Error (95 ft^3/s) much greater than could be explained by diversions. Best balance in dissolved solids achieved when error assigned to surface returns prorated by total length of reach.
Wadsworth bridge to Nixon gage	29-37	August, June 1979	Assumed constant ground-water inflows. Adjustments prorated to irrigation surface returns by length of receiving segments.
		June 1980	Error (61 ft^3/s) was much greater than could be attributed to normal surface returns. Adjustment prorated over total length of reach and, based on mass balance of dissolved solids, modeled as irrigation surface returns originating in each subreach.

Available records of daily discharge for the Truckee Canal are generally of less accuracy than for the river. The Federal Watermaster maintains a gage on the canal about 1 mile below Derby Dam. The first U.S. Geological Survey gage below the dam, Truckee Canal near Wadsworth, is about 13 miles below the dam and below several diversions and two spillways that often return water to the river (figure 17), thus records at the site may not be indicative of canal inflow. The next Geological Survey gage on the canal is Truckee Canal at Hazen, located during the synoptic studies about 25 miles below Derby Dam and about 6 miles above Lahontan Reservoir. Records at this gage are rated poor (probable error greater than ±15 percent). Estimates of discharge for the major agricultural diversions from the canal are available from the Truckee Carson Irrigation District (TCID).

About 87 percent of the length of the canal is unlined, resulting in significant losses due to seepage. Estimates of seepage losses for modeling were based on an analysis of the 16.7-mile reach between the Geological Survey gage near Wadsworth and the Hazen gage. Seepage losses were calculated by subtracting estimated diversions in the reach (TCID records) from the difference in flow between the two gages. Included with seepage in this net difference are any errors in measurements at the gages, errors in accounting of diversions, and unmeasured diversions. Figure 23 shows the relations between calculated losses for the calandar years 1967-80 and inflow to the reach as measured at the gage near Wadworth. The data indicate a general nonlinear relationship between reach inflow and estimated losses.

Figure 23 near here

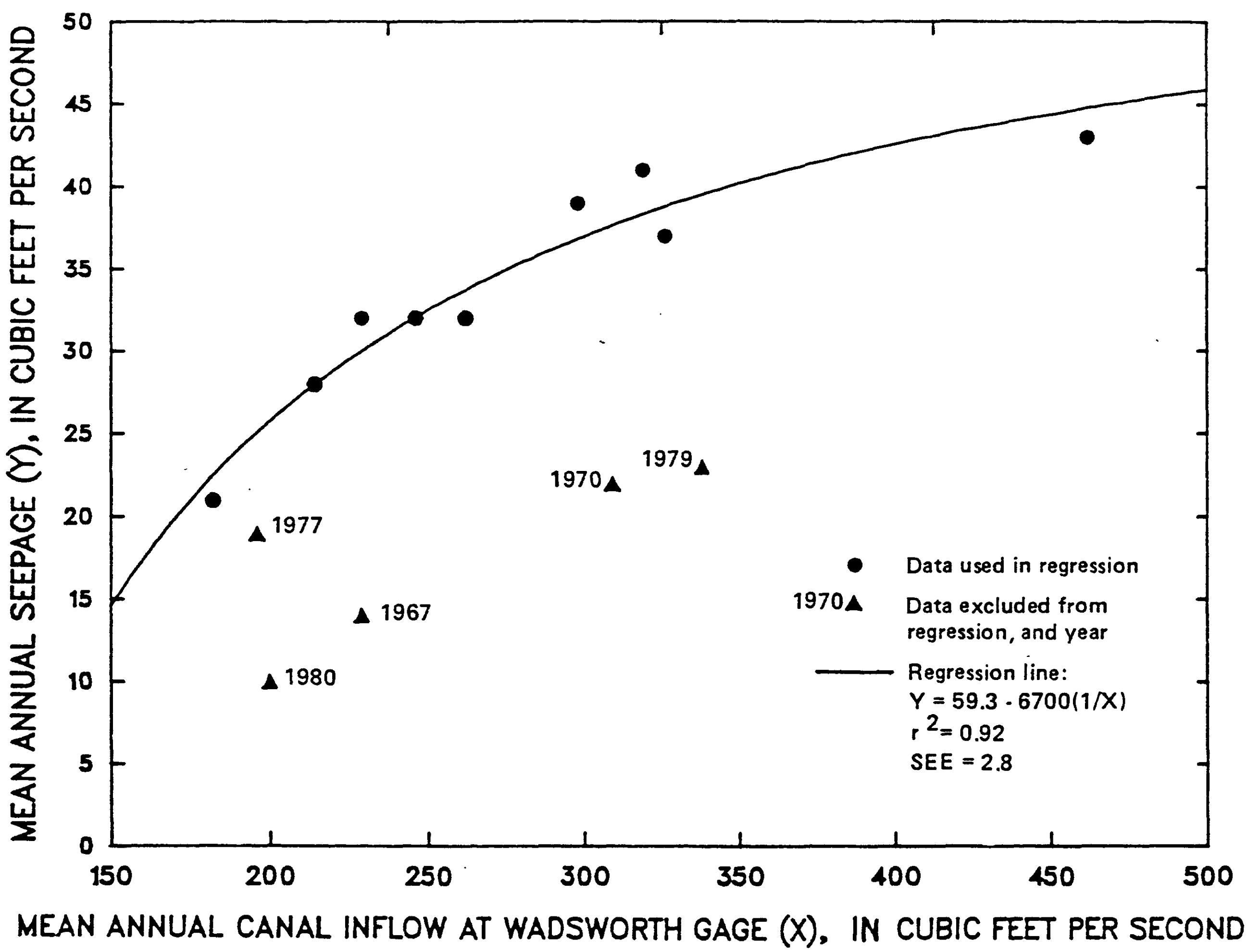


FIGURE 23.--Seepage losses in the Truckee Canal are related to the quantity of canal inflow. (Symbols: r^2, regression coefficient; SEE, standard error of estimate.)

Data for 1967, 1970, 1979, and 1980 do not follow the general trend of the data; a similar graphical analysis for estimated losses versus outflow gaged at Hazen shows the same 4 years along with 1977 do not follow the general relations. A monthly analysis of calculated losses showed that seepage calculations using data for these years had months of "negative" losses (reported diversions exceeded differences between inflow and outflow gages), indicating major errors in the data; thus the data for the years 1967, 1970, 1977, 1979, and 1980 were not considered in quantification of the relationship indicated in figure 23. For the remaining 9 years of data, annual average losses from the reach ranged from 21 to 43 ft^3/s, with an average of 33 ft^3/s. A nonlinear least-squares regression was fitted to the data of the form:

$$S = A + B/Q,$$

where S = annual losses in the reach,

Q = average annual inflow, and

A and B are regression constants.

The resulting equation is:

$$S = 59.3 - 6700/Q \; , \qquad (33)$$

in which S and Q are expressed in cubic feet per second ($r^2 = 0.92$, standard error of estimate is 2.8 ft^3/s). Seepage losses for the four synoptic studies were determined by using equation 33 to estimate the total loss in the reach from the gage near Wadsworth to Hazen. This loss was divided by 16.7, the unlined length of the reach, and the resulting rate of loss, in cubic feet per second per unlined mile, was used to estimate the loss over the unlined length of each of the nine modeled segments.

Flow balances for the canal for the four synoptic studies were developed based on the above sources of data, discharge measurements taken during the study, estimates of seepage losses, and field observations of diversions. For each study, the sum of all canal losses (diversions and seepage losses) was subtracted from the observed difference in canal flow between gaged or measured sites and the resulting difference was prorated linearly over modeled segments based on unlined length. Final distribution of diversions and seepage losses used in the calibration and validation runs for the canal are listed in table 19.

Table 19 near here

TABLE 19.--Estimates of Truckee Canal point diversions and nonpoint losses used for modeling

[Estimates based on records at USGS and Federal Watermaster gages, diversion records of the Truckee-Carson Irrigation District, and field discharge measurements. For list of individual diversions included in nonpoint losses (A), and point losses (B), see table 5.]

	Canal segment and modeled diversions	Starting canal mile	Length (mi)	Modeled losses and diversions for calibration/validation data sets (ft^3/s)			
				(A) June 1979	(B) August 1979	(C) June 1980	(D) August 1980
C1	Derby Dam (Federal Watermaster gage)	31.42	6.04				
	(A) aggregated nonpoint losses			5	10	2	10
C2	Pyramid check	25.38	2.84				
	(A) aggregated nonpoint losses			5	10	3	5
C3	Tunnel No. 3 ("near Wadsworth" gage)	22.54	4.52				
	(A) aggregated nonpoint losses			20	20	10	40
C4	Fernley check	18.02	2.95				
	(A) aggregated nonpoint losses			15	30	7	40
	(B) point diversions			0	20	0	0
C5	Anderson check	15.07	4.00				
	(A) aggregated nonpoint losses			15	15	8	25
	(B) point diversions			0	15	0	15
C6	Allendale check	11.07	4.68				
	(A) aggregated nonpoint losses			20	10	5	10
	(B) point diversions			0	0	0	5
C7	Mason check (Hazen gage, prior to Oct. 1980)	6.39	3.14				
	(A) aggregated nonpoint losses			10	10	3	10
	(B) point diversions			0	0	0	0
C8	Bango check (Hazen gage, after Oct. 1980)	3.25	2.81				
	(A) aggregated nonpoint losses			10	10	2	10
	(B) point diversions			0	10	0	15
C9	Highway 50	.44	.44				
	(A) aggregated nonpoint losses			1	1	1	1

CALIBRATION, VALIDATION, AND SENSITIVITY ANALYSIS OF THE WATER-QUALITY MODEL

The terms calibration, verification or validation, and sensitivity analysis are commonly used to describe steps in computer model construction and applications; however, the use of these terms is far from consistent in modeling literature. As used in this report, calibration refers to the process of using the model to determine the values of parameters not based on field data, or to "fine-tune" values of parameters initially based on field data. Calibration of a parameter is an iterative process of changing the parameter values until an acceptable match is achieved between predicted and observed values in the affected modeled variables. In the strictest sense, verification, or validation, is the process of testing a calibrated model against a second data set not used in the calibration to see how well simulations continue to match observed data. The term validation is preferred over verification in describing this process to avoid any implication of the ultimate "truth" of the validated model. As argued by Thomann (1982), final "verification" of a predictive model can be made only by monitoring environmental impacts after the target management practices have gone into effect. Sensitivity analysis refers to a quantification of the effect of variations of individual model parameters on the predicted variables resulting from changing one parameter at a time.

Calibration and Validation

The calibration process is guided by knowledge of the hydrology and biology of a stream system, an understanding of the specific processes being modeled, and the reasonability of calibrated values in comparison to results taken from the literature for similar systems. Although theoretically objective, the process is as much of an art as a science and has been described as being "more like tuning a violin than selecting a radio station."

For the TRWQ model, the August 1979 data were chosen for calibration for both the river and the canal. Graphical matching of the predicted concentration profiles with means and ranges of observed values at the synoptic sampling sites was used to determine acceptable calibration. No attempt was made to obtain perfect matches of simulated to observed values for each model segment. Rather, to the extent possible, a single value for each parameter was used for the entire river (or canal) or for subreaches with consistent hydraulic or biologic characteristics.

The calibrated model was then used with the remaining three sets of data to test for validation. It was initially assumed that the higher flow conditions sampled in the June synoptic studies would require a different set of rate coefficients for most constituents than the August data, and that the June 1979 data would be used for high-flow calibration and the June 1980 for high-flow validation. However, in testing data sets with the calibrated model, it was found that the calibrations, with minor adjustments, worked equally well on all four data sets and that further fine-tuning was not warranted by fundamental limitations in precision and accuracy in the field data.

A summary list of parameters and coefficents in the TRWQ model is given in table 20, indicating those defined by, or calculated from, field data and those defined by the calibration curve-matching process. The process used in calibration of each coefficient is discussed below. The results are shown in river profiles (figures 24-54) for simulated and observed values for all four synoptic studies achieved by the final calibrated and validated parameters. Numerical results of the simulations for the four studies are also tabulated for each modeled constituent. In the tables, simulation errors (differences between simulated and observed values) are presented for each sampling site and are expressed both in concentration units and as a percentage of the observed value. Simulation errors are also averaged over two major reaches of the river (McCarran Bridge to Derby Dam and below Derby Dam) and for the modeled length of the Truckee Canal. For the purposes of these discussions, the reach errors are expressed as simple arithmetic means, and thus by their signs indicate any net bias in simulations (consistent under- or over-prediction compared to the observed values).

Table 20 near here

TABLE 20.--Summary of TRWQ model parameters and variables: ranges in calibrated values and methods of determination

[Listed below are principal variables and parameters used in the TRWQ model. Where specified in column 1, units are for input data or model results. All water-quality constituents are considered to represent "totals," results that would be obtained with representative unfiltered samples. Ranges of values in column 2 are total range in input data for the four synoptic studies or for calibrated values for the Truckee River (R) and the Truckee Canal (C). Table numbers in column 3 indicate location of complete listings of data for the calibrated model. Notes on derivation give principal equations used (or appropriate equation number in text) and (or) principal references for stated values or methods of derivation.]

(1) Description		(2) Range in values	(3) Data table	(4) Derivation and remarks
MODEL INPUTS:				
Upstream river		--	21	Observed data; Appendix A
Tributary inflows		--	21	Observed data; Appendix A
Reno-Sparks effluent		--	21	Observed data: Appendix A
Nonpoint surface returns		--	16, 17	See text and Appendix B
Nonpoint ground-water returns		--	C8, 17	See text and Appendix C
MODELED WATER-QUALITY VARIABLES:				
Q	discharge (ft^3/s)	25 - 2,150(R) 15 - 380 (C)	21	Mass balance calibrated against observed data
DS	dissolved solids (mg/L at 180 °C)	74 - 390 (R) 81 - 170 (C)	A1	Mass balance
DO	dissolved oxygen (mg/L)	3.4 - 13.1 (R) 4.4 - 14.2 (C)	A1	DO_{sat} - DO_{def}
DO_{sat}	dissolved-oxygen saturation (percent of saturation)	45 - 188 (R) 58 - 206 (C)	A1	Calculated from T, BP, DO
DO_{def}	dissolved-oxyen saturation deficit (mg/L)	-6.1 - 3.7 (R) -7.3 - 3.2 (C)	--	Modified Streeter-Phelps first-order reactions
$CBOD_u$	ultimate carbonaceous biochemical oxygen demand (mg/L)	1.7 - 9.6 (R) 1.8 - 7.3 (C)	A1	Streeter-Phelps first-order reaction
Nitrogen species (mg/L as N):				
ON	organic-nitrogen	.00 - 2.4 (R) .32 - 2.0 (C)	A1	First-order sequential reactions
NH_4	ammonia-nitrogen	.00 - 1.8 (R) .00 - .34 (C)	A1	Do.
NO_2	nitrite-nitrogen	.00 - .39 (R) .01 - .39 (C)	A1	Do.
NO_3	nitrate-nitrogen	.00 - 1.4 (R) .12 - 1.3 (C)	A1	Do.
TN	total-nitrogen	.29- 3.9 (R) .62- 3.9 (C)	A1	Summation
UNH_3	un-ionized ammonia	.00- .22 (R) .00- .08 (C)	A1	Calculated from pH, T, NH_4; Eq. 17, (Willingham, 1976)
Phosphorus (mg/L as P):				
PO_4	orthophosphorus	.04- 1.4 (R) .06- .99 (C)	A1	First-order reaction
TP	total phosphorus	.06- 1.4 (R) .08- 1.1 (C)	A1	Do.

TABLE 20.--Summary of TRWQ model parameters and variables: ranges in calibrated values and methods of determination--Continued

Description (1)		Range in values (2)	Data table (3)	Derivation and remarks (4)
CHANNEL HYDRAULICS:				
V	average velocity (ft/s)	0.13 - 4.9 (R) 0.29 - 2.4 (C)	22	V = V1(Q)V2
V1	linear velocity coefficient	.01 - .54 (R) .01 - .27 (C)	11	Calculated from traveltime data From dye-tracer studies.
V2	exponential velocity coefficient	.29 - .85 (R) .37 - .81 (C)	11	Do.
W	average channel width (ft)	51 - 760 (R) 19 - 47 (C)	22	W = W1(Q)W2
W1	linear width coefficient	36 - 491 (R) 4 - 32 (C)	11	Widths from aerial photographs and W2 estimates
W2	exponential width coefficient	.1 (R) .04 - .36 (C)	11	Cross-section measurements at gaged sites
A	average channel cross-sectional area area (ft^2)	68 - 903 (R) 27 - 304 (C)	—	A = Q/V
D	average channel depth (ft)	.38 - 10 (R) .48 - 8.5 (C)	22	D = A/W
s	average channel slope (ft/ft)	.5 - 53 (R) .02 - 1.8 (C)	11	Measured in channel survey
ENVIRONMENTAL FACTORS (SEGMENT AVERAGES):				
Controls on saturation of dissolved oxygen:				
T	water temperature (°C)	10.5 - 25.0(R) 11.0 - 24.0(C)	32	Linear interpolation between observed data.
BP	barometric pressure (mm Hg)	650 - 665 (R) 650 - 655 (C)	32 32	Do.
SC	specific conductance (umhos at 25 °C)	100 - 660 (R) 120 - 270 (C)	—	Do.
Control on un-ionized ammonia:				
pH	pH (units)	7.2 - 9.1 (R) 7.3 - 9.0 (C)	32	Do.

TABLE 20.--Summary of TRWQ model parameters and variables: ranges in calibrated values and methods of determination--Continued

Description (1)		Range in values (2)	Data table (3)	Derivation and remarks (4)
REACTION RATE COEFFICIENTS:				
In-stream first-order rates (base e, 1/day at 20 °C):				
K_2	reaeration	.12 - 120 (R) .01 - 2.3 (C)	39	K_2 = CVS (Tsivoglou & Neal, 1976), escape coefficient C = 3600, from gas-tracer studies
K_{CR}	CBOD removal (Kr)	.14 - 1.7 (R) .03 - .13 (C)	24	Fitted to observed data
K_C	CBOD oxidation (K1)	.14 - 2.0 (R) .03 - .13 (C)	24	Do.
K_{ONR}	organic nitrogen removal	.10 - 1.7 (R) .05 (C)	24	Do.
K_{ONF}	organic to ammonia nitrogen	.10 - .80 (R) .05 (C)	24	Do.
K_{NH4R}	ammonia nitrogen removal	.40 - 2.4 (R) .90 (C)	24	Do.
K_{NH4F}	ammonia to nitrite oxidation	.40 - 2.4 (R) .90 (C)	24	Do.
K_{NO2R}	nitrite nitrogen removal	3.0 - 10. (R) .7 (C)	24	Do.
K_{NO2F}	nitrite to nitrate oxidation	3.0 - 10. (R) .7 (C)	24	Do.
K_{NO3R}	nitrate nitrogen removal	.3 - 2.0 (R) .18 (C)	24	Do.
K_{NCR1R}	orthophosphorus removal	.25 (R) .10 (C)	24	Do.
K_{NCR2R}	phosphorus removal	.25 (R) .25 (C)	24	Do.
P	net daily photosynthesis of oxygen (mg/L/day)	.0 - .2 (R) .5 - 2.5 (C)	41	Fitted to observed mean DO
R	respiration factor to simulate minimum DO (mg/L/day)	1 - 12 (R) 0 (C)	41	Fitted to observed minimum DO
B	benthic oxidation rate (g O_2/m^2/day)	—	--	Not applied to TRWQ model

TABLE 20.--Summary of TRWQ model parameters and variables: ranges in calibrated values and methods of determination--Continued

Description (1)		Range in values (2)	Data table (3)	Derivation and remarks (4)
Temperature-correction coefficients:				$K(t)=K(20)\theta^{(20-t)}$
θ1	theta 1	1.0241	--	For K_2 (Elmore and West, 1961)
θ2	theta 2	1.047	--	For K_C, K_{CR} (Shindala, 1972)
θ3	theta 3	1.09	--	For K_{ONR}, K_{RNF}, K_{NH3NR}, K_{NH3NF}, K_{NO2R}, K_{NO2F}, K_{NO3R} (Shindala, 1972)
θ4	theta 4	1.065	--	For B
Nitrogen oxygen demands:				
θ_{NH4}	ammonia oxidation (mg O_2/mg NH_3 oxidized)	3.43	--	Equation (6)
θ_{NO2}	nitrite oxidation (mg O_2/mg NO_2 oxidized)	1.14	--	Equation (7)

Major Point-Source and Nonpoint-Source Loadings for the Observed Data Sets

Principal and modeled sources of loadings to the Truckee River below Reno include:

1. River at McCarran bridge, the upstream model boundary.
2. North Truckee Drain (accumulated agricultural returns from Spanish Springs Valley and northside Truckee Meadows)
3. Steamboat Creek at above the STP outfall (accumulated agricultural returns from Washoe Valley and southside Truckee Meadows).
4. Effluent from the Reno-Sparks STP via Steamboat Creek.
5. Various surface irrigation return flows along the course of the river.
6. Ground-water inflows.

During, and immediately following, periods of active precipitation, the river between McCarran bridge and Steamboat Creek and the two perennial tributaries (North Truckee Drain and Steamboat Creek) could receive urban storm water from the Reno-Sparks area. In addition, the river below Steamboat Creek could receive tributary flows from any active washes and overland runoff. These additional nonpoint sources were not flowing during the synoptic studies used for model calibration and validation. Application of the TRWQ model to simulate the impact on the river from transient storm inputs would be, in fact, invalid, as transport in the model is based on steady-state assumptions.

Inputs from the upstream river, two tributaries, and the STP effluent are all grouped within the first 2.6 miles of the modeled reach of the Truckee River and have significantly different effects on river quality than the modeled nonpoint agricultural and ground-water returns that are fairly evenly distributed along the length of the river. Constituent loadings from the upstream sources have substantial initial impacts on receiving stream quality; however, the effects for nonconservative constituents may rapidly decline with downstream distance from the source due to river assimilation, the magnitude of which is a function of water temperatures and traveltime (and thus inversely related to streamflow). The effects of nonpoint inputs to the river may be minor at any point in comparison to the upstream point sources; however, the effects are cumulative and instream assimilation may be offset by the continuing accretion of loads from nonpoint sources.

The quantity and quality of major sources of constituent loadings to the river observed in the four synoptic studies in 1979 and 1980 are summarized in table 21. For the point sources, quality is described by both concentrations and loads (mass of pollutants per unit time), which are a function of the concentration and flow of the source. Nonpoint returns are summarized in terms of total inflows and loadings over two reaches, above and below Derby Dam. For surface returns, the net total loadings (returned loads minus diverted loads) are also given for the two reaches.

Table 21 near here

TABLE 21.--Summary of major inputs to the Truckee River and Canal used for model calibration and validation

[Data for river, canal, and tributaries are mean daily values from synoptic studies; values flagged with 'E' are estimates (Appendix A). Nonpoint-source data are sums of all inputs for the indicated reach based on concentration and discharge estimates (tables 16, 17, and C8). Net surface-return loads are the difference between summed surface-return loads and summed loads diverted in the indicated reach. Phosphorus loads above Derby Dam flagged with 'd' are "dummy" loadings added to calibrate observed data between Vista and Patrick (see text). Surface-return and ground-water concentrations flagged with 'c' are reach-averages computed from total loads and inflows for the reach. All loads are rounded to two significant figures; percentages may not total to 100 due to rounding.]

Constituent concentrations (mg/L), loads (lb/day), and percent of total load to reach

Discharge (ft^3/s)	Barometric pressure (mm Hg)	Water temperature (°C)	Specific conductance (µS at 25 °C)	pH units	Dissolved solids	Dissolved oxygen	Dissolved oxygen: Percent saturation	$CBOD_u$	Nitrogen as N: Organic	Nitrogen as N: Ammonia	Nitrogen as N: Nitrite	Nitrogen as N: Nitrate	Nitrogen as N: Total	Nitrogen as N: Un-ionized ammonia	Phosphorus as P: Ortho	Phosphorus as P: Total
(A) JUNE 1979																
ABOVE DERBY DAM:																
Upstream river at McCarran Bridge																
375	650	15.4	90	8.4	61	8.5	100	2.7	0.33	0.03	0.02	0.01	0.38	0.002	0.02	0.03
					123,000	17,000	--	5,500	670	61	40	20	770	--	40	61
70					38	72	--	38	43	3	11	10	20	--	4	5
North Truckee Drain																
40	650	17.8	337	8.5	235	8.8	108	4.2	.87	.05	.02	.29	1.2	.005	.10	.14
					51,000	1,900	--	910	190	11	4	63	260	--	22	30
7					16	8	--	6	12	1	1	30	7	--	2	2
Steamboat Creek																
50	650	19.1	367	--	255	7.8	99	7.6	1.2	.06	.05	.06	1.3	--	.22	.27
					69,000	2,100	--	2,000	320	16	13	16	350	--	59	73
9					22	9	--	14	20	1	4	8	9	--	6	6
Reno-Sparks STP																
25	650	22.0	524	9.6	299	7.1	94	24	.40	13	2.1	.24	15	8.4	4.9	5.8
					40,000	960	--	3,300	54	1,800	280	32	2,000	--	660	780
5					13	4	--	23	3	94	77	15	52	--	63	63
Surface-return flows:																
Total returns																
49	--	--	524	9.6	140c	5.7c	--	10	1.3	.1	.1	.3	1.8	--	.5	.6
					37,000	1,500	--	2,600	340	26	26	79	480	--	130	160
9					12	6	--	18	22	1	7	38	12	--	12	13
Net return loads:																
14					-140	-1,000	--	-1,400	210	-150	-10	14	55	--	36	40
Ground-water inflows:																
0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
					0	0	--	0	0	0	0	0	0	--	140d	140d
0					0	0	--	0	0	0	0	0	0	--	13	11
BELOW DERBY DAM:																
River at Derby Dam																
90	652	19.5	169	8.1	112	8.2	103	3.8	0.57	0.21	0.18	0.49	1.5	0.010	0.33	0.40
					54,000	4,000	--	1,800	280	100	87	240	730	--	160	190
67					42	81	--	46	57	87	83	60	64	--	64	64
Surface-return flows:																
30	--	--	524	9.6	140	5.6	--	12	1.3	.09	.11	.32	1.9	--	.51	.61
					23,000	910	--	2,000	210	15	18	51	300	--	82	99
22					18	18	--	52	43	13	17	13	26	--	33	33
Net return loads:																
-28					-20,000	-1,600	--	210	50	1	-2	-5	47	--	2	3
Ground-water inflows:																
15	--	--	--	--	640c	.5	--	1.	.0	.0	.0	1.4	1.4	--	.1	.1
					52,000	42	--	80	0	0	0	110	110	--	8	8
11					40	1	--	2	0	0	0	27	10	--	3	3
TRUCKEE CANAL:																
Diversion at Derby Dam																
390	652	19.5	169	8.1	112	8.2	103	3.8	.57	.21	.18	.49	1.5	.010	.33	.40
					236,000	17,000	--	8,000	1,200	440	380	1,000	3,200	--	690	840

TABLE 21.--Summary of major inputs to the Truckee River and Canal used for model calibration and validation--Continued

	Discharge (ft^3/s)	Barometric pressure (mm Hg)	Water temperature (°C)	Specific conductance (µS at 25 °C)	pH units	Constituent concentrations (mg/L), loads (lb/day), and percent of total load to reach: Dissolved solids	Dissolved oxygen	Dissolved oxygen: Percent saturation	$CBOD_u$	Nitrogen as N: Organic	Nitrogen as N: Ammonia	Nitrogen as N: Nitrite	Nitrogen as N: Nitrate	Nitrogen as N: Total	Un-ionized ammonia	Phosphorus as P: Ortho	Phosphorus as P: Total
(B) AUGUST 1979																	
ABOVE DERBY DAM:																	
Upstream river at McCarran Bridge																	
	160	653	20.3	127	8.3	86	7.6	98	2.4	0.33	0.03	0.01	0.04	0.41	0.002	0.08	0.04
						74,000	6,600	--	2,100	280	26	9	35	350	--	69	35
	51					28	57	--	17	20	1	15	16	9	--	4	2
North Truckee Drain																	
	50	652	19.9	359	8.1	250	7.0	90	3.9	.68	.02	.01	.41	1.1	.001	.11	.10
						67,000	1,900	--	1,100	180	5	3	110	300	--	30	27
	16					25	16	--	9	13	0	5	50	7	--	2	2
Steamboat Creek																	
	40	652	22.2	279	8.0	194	5.8	78	6.9	.90	.10	.01	.09	1.1	.004	.21	.24
						42,000	1,200	--	1,500	190	22	2	19	240	--	45	52
	13					16	10	--	12	14	1	4	9	6	--	3	3
Reno-Sparks STP																	
	30	652	24.8	509	7.8	291	6.6	92	37	3.0	14	.15	.01	17	.48	3.8	4.7
						47,000	1,100	--	6,000	480	2,300	24	2	2,800	--	620	760
	10					18	9	--	48	35	97	44	1	70	--	39	45
Surface-return flows: Total returns																	
	34	--	--	524	9.6	180c	4.6c	--	10.	1.3	.1	.1	.3	1.8	--	.5	.6
						34,000	850	--	1,800	240	18	18	55	330	--	92	110
	11					13	7	--	14	18	1	32	25	8	--	6	6
Net return loads:																	
	-20					-11,000	-1,000	--	320	66	-300	-30	-73	-330	--	-110	-110
Ground-water inflows:																	
	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
						0	0	--	0	0	0	0	0	0	--	720d	720d
	0					0	0	--	0	0	0	0	0	0	--	46	42
BELOW DERBY DAM:																	
River at Derby Dam																	
	40	656	22.8	237	8.0	150	6.3	86	4.4	.68	.11	.19	1.1	2.1	.005	.69	.78
						3,200	1,400	--	950	150	24	41	240	450	--	150	170
	51					4	67	100	43	48	66	77	62	58	100	68	67
Surface-return flows:																	
	23	--	--	--	--	270	5.3	--	9.7	1.3	.10	.10	.30	1.8	--	.50	.60
						33,000	660	--	1,200	160	12	12	37	220	--	62	74
	30					36	31	100	54	52	34	23	10	28	100	28	29
Net return loads:																	
	-24	--	--	--	--	-24,000	-1,300	--	230	22	7	5	8	42	--	-21	-18
Ground-water inflows:																	
	15	--	--	--	--	680c	.5	--	1.	0	0	0	1.4	1.4	--	.1	.1
						55,000	42	--	80	0	0	0	110	110	--	8	8
	19					60	2	100	4	0	0	0	2[illegible]	14	100	4	3
TRUCKEE CANAL:																	
Diversion at Derby Dam																	
	220	656	22.8	237	8.0	150	6.3	86	4.4	.68	.11	.19	1.1	2.1	.005	.69	.78
						180,000	7,500	--	5,200	810	130	220	1,300	2,500	--	820	930

TABLE 21.--Summary of major inputs to the Truckee River and Canal used for model calibration and validation--Continued

Discharge (ft³/s)	Barometric pressure (mm Hg)	Water temperature (°C)	Specific conductance (µS at 25 °C)	pH units	Dissolved solids	Dissolved oxygen	Dissolved oxygen: Percent saturation	$CBOD_u$	Nitrogen as N: Organic	Nitrogen as N: Ammonia	Nitrogen as N: Nitrite	Nitrogen as N: Nitrate	Nitrogen as N: Total	Unionized ammonia	Phosphorus as P: Ortho	Phosphorus as P: Total
					Constituent concentrations (mg/L), loads (lb/day), and percent of total load to reach											
					(C) JUNE 1980											
ABOVE DERBY DAM:																
Upstream river at McCarran Bridge																
1,780	648	10.3	70	7.9	47	9.7	101	1.9	0.51	0.14	0.00	0.24	0.89	0.002	0.04	0.03
					450,000	93,000	--	18,000	4,900	1,300	0	2,300	8,500	--	390	290
85					47	89	--	54	62	27	0	75	52	--	22	15
North Truckee Drain																
50	647	12.3	381	8.2	265	8.8	98	4.6	1.2	.12	.01	.44	1.8	.004	.09	.11
					71,000	2,400	--	1,200	320	32	3	120	480	--	24	30
2					7	2	--	4	4	1	3	4	3	--	1	2
Steamboat Creek																
145	648	13.1	485	8.0	337	7.9	88	5.7	1.4	.15	.01	.19	1.8	.00	.18	.20
					260,000	6,200	--	4,500	1,100	120	8	150	1,400	--	140	160
7					27	6	--	13	14	2	9	5	9	--	8	8
Reno-Sparks STP																
45	648	18.6	498	7.7	284	8.6	107	35	6E	14	.28	.23	22	.25	4.5	5.7
					69,000	2,100	--	8,500	1,500	3,400	68	56	5,300	61	1,100	1,400
2					7	2	--	25	19	70	76	2	33	--	63	71
Surface-return flows:																
Total returns																
20	--	--	--	--	93c	6.6c	--	10	1.3	.1	.1	.3	1.8	--	.5	.6
					10,000	710	--	1,100	140	11	11	32	190	--	54	65
1					1	1	--	3	2	0	12	1	1	--	3	3
Net return loads:																
-24					-8,500	-1,500	--	450	-16	-77	5	-28	-114	--	23	32
Ground-water inflows:																
54	--	--	--	--	320c	.5	--	1.	.0	.0	.0	1.4	1.4	--	.1	.1
					92,000	150	--	290	0	0	0	410	410	--	29	29
3					10	0	--	1	0	0	0	13	3	--	2	1
BELOW DERBY DAM:																
River at Derby Dam																
1,910	652	10.9	121	7.2	84	9.0	95	2.8	.64	.26	.02	.28	1.2	.001	.10	.11
					870,000	93,000	--	29,000	6,600	2,700	210	2,900	12,000	--	1,000	1,100
90					84	93	100	72	83	96	66	87	86	100	65	63
Surface-return flows:																
195	--	--	--	--	100	6.6	--	10	1.3	.10	.10	.30	1.8	--	.51	.62
					110,000	6,900	--	11,000	1,400	110	110	320	1,900	--	540	650
36					11	7	100	27	18	4	34	10	14	100	35	37
Net return loads:																
126					76,000	3,400	--	8,600	1,100	26	63	220	1,500	--	480	590
Ground-water inflows:																
15	--	--	--	--	680c	.5	--	1.	.0	.0	.0	1.4	1.4	--	.1	.1
					55,000	42	--	80	0	0	0	110	110	--	8	8
1					5	0	100	0	0	0	0	3	1	100	1	0
TRUCKEE CANAL:																
Diversion at Derby Dam																
130	652	10.9	121	7.2	84	9.0	95	2.8	.64	.26	.02	.28	1.2	.001	.10	.11
					59,000	6,300	--	2,000	450	180	14	200	840	--	70	77

TABLE 21.--Summary of major inputs to the Truckee River and Canal used for model calibration and validation--Continued

Discharge (ft³/s)	Barometric pressure (mm Hg)	Water temperature (°C)	Specific conductance (µS at 25 °C)	pH units	Constituent concentrations (mg/L), loads (lb/day), and percent of total load to reach: Dissolved solids	Dissolved oxygen	Dissolved oxygen: Percent saturation	$CBOD_u$	Nitrogen as N: Organic	Nitrogen as N: Ammonia	Nitrogen as N: Nitrite	Nitrogen as N: Nitrate	Nitrogen as N: Total	Un-ionized ammonia	Phosphorus as P: Ortho	Phosphorus as P: Total
					(D) AUGUST 1980											
ABOVE DERBY DAM:																
Upstream river at McCarran Bridge																
155	646	17.9	126	8.3	85	8.3	102	2.5	0.52	0.03	0.02	0.00	0.57	0.002	0.02	0.07
					71,000	6,900	--	2,100	440	25	17	0	477	--	17	59
50					26	53	--	16	17	1	26	0	9	--	1	4
North Truckee Drain																
40	646	17.5	348	8.0	242	8.0	99	4.0	1.0	.04	.02	.44	1.5	.001	.04	.11
					52,000	1,700	--	860	220	9	4	95	320	--	9	24
13					19	13	--	6	9	0	7	67	6	--	1	2
Steamboat Creek																
70	646	19.6	290	8.1	202	6.9	89	5.8	1.8	.06	.02	.07	2.0	.003	.09	.16
					76,000	2,600	--	2,200	680	23	8	26	760	--	34	60
22					28	20	--	17	27	1	12	19	14	--	3	4
Reno-Sparks STP																
35	646	23.3	572	7.7	327	7.6	104	39	6E	14E	.15	.00	20E	.34	3.5	4.4
					62,000	1,400	--	7,400	1,100	2,600	28	0	3,800	--	670	830
11					23	11	--	56	43	98	44	0	69	--	59	60
Surface-return flows: Total returns																
13	--	--	--	--	200c	4.7c	--	10	1.3	.1	.1	.3	1.8	--	.5	.6
					14,000	330	--	700	91	7	7	21	130	--	35	42
4					5	3	--	5	4	0	11	15	2	--	3	3
Net return loads:																
-30					-24,000	-1,200	--	-640	-180	-280	-46	-85	-590	--	-83	-110
Ground-water inflows:																
0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
					0	0	--	0	0	0	0	0	0	--	380d	380d
0					0	0	--	0	0	0	0	0	0	--	33	27
BELOW DERBY DAM:																
River at Derby Dam																
65	650	20.6	260	8.5	163	6.7	87	5.4	1.4	.25	.30	1.1	3.0	.029	.66	.72
					57,000	2,300	--	1,900	490	88	100	390	1,100	--	230	250
58					37	70	100	50	68	83	85	71	72	100	70	68
Surface-return flows: total returns																
33	--	--	--	--	230c	5.2c	--	10	1.3	.1	.1	.3	1.8	--	.5	.6
					41,000	930	--	1,800	230	18	18	53	320	--	89	110
29					27	28	100	48	32	17	15	10	21	100	27	30
Net return loads:																
-35					-37,000	-1,800	--	-20	-92	-1	-2	-21	-110	--	-30	-37
Ground-water inflows:																
15	--	--	--	--	680c	.5	--	1.	.0	.0	.0	1.4	1.4	--	.1	.1
					55,000	42	--	80	0	0	0	110	110	--	8	8
13					36	1%	100	2	0	0	0	20	7	100	2	2
TRUCKEE CANAL:																
Diversion at Derby Dam																
205	650	20.6	260	8.5	163	6.7	87	5.4	1.4	.25	.30	1.1	3.0	.029	.66	.72
					180,000	7,400	--	6,000	1,500	280	330	1,200	3,300	32	730	800

In comparing total loads from the various sources, the above distinctions between the effects of point and nonpoint sources should be kept in mind. Given equivalent total loads over the 56-mile modeled reach of river, upstream point sources will have substantially greater impact on the quality of the river in the 21 miles above Derby Dam, with impacts for nonconservative substances diminishing with distance downstream from the input. Nonpoint sources will have much less effect above Derby Dam, but the cumulative effect at low flows may become significant in the lower 36-mile reach of the river.

Interpretation of the effects on river quality of point sources requires consideration of both concentrations and corresponding rates of flow. Evaluation of sources based solely on concentrations may be misleading. In the August 1979 synoptic study (table 21B), for example, highest concentrations of dissolved solids among the point sources were observed at the STP (291 mg/L) and the lowest concentrations in the river at McCarran bridge (86 mg/L). However, the impact on river quality below Steamboat Creek is determined by the total loads and, because of the greater discharge of the river at McCarran Bridge (160 ft^3/s) compared to the STP effluent (30 ft^3/s), the modeled reach of river received about 1.5 times as much dissolved solids (74,000 lb/day) from the upstream river at the lower concentration than from the STP effluent (47,000 lb/day) at the higher concentrations.

Diversions from the river must be taken into account when evaluating the effects of agricultural loadings. Water diverted for agriculture carries with it loadings of the constituents in the river. The net effect of agriculture at any point in time thus is the difference between returned loads and diverted loads in the reach. Net loadings for surface returns are presented in table 21. Note for example, data shown for the August 1979 synoptic study (table 21B). Total flow of surface returns was 57 ft^3/s, 34 above Derby Dam and 23 below. Agricultural diversions (not counting Derby Dam) totaled 101 ft^3/s, resulting in a net loss of water of 44 ft^3/s due to agricultural diversions. For some constituents, this resulted in a net loss of loads directly attributable to agriculture (-35,000 lb/day of dissolved solids, -293 lb/day of ammonia-nitrogen); for other constituents with relatively high concentrations in the return flows, a net gain (550 lb/day of $CBOD_u$, 88 lb/day of organic-nitrogen).

Interpretation of the effects on river quality of these gains and losses in loads of potential pollutants from surface returns, however, is not straightforward. At the point of diversion, instream concentrations of substances are not changed by the diverted loadings, thus there is no direct effect on downstream quality. At the point of return, added loads, although less than the mass diverted, may be of higher concentration than in the diverted water, thus having a negative impact on instream quality.

For example, if 50 percent of the applied irrigation water is consumed by agriculture with no change in concentration of a pollutant, a 50 percent reduction in load will result, perhaps leading to the conclusion that the agriculture was beneficial to river quality. The result for conservative pollutants, however, would be that the instream river quality would be totally unaffected. For nonconservatives, river assimilation may have reduced instream concentrations between the point of diversion and the point of return. In that case the returned water would have higher concentrations than the river at the point of return and the agricultural activity would result in a deterioration of instream quality even though concentrations were unchanged by agriculture and 50 percent of the originally diverted loads were removed.

For the same assumed 50 percent consumption of water by agriculture, a net zero change in loading (diverted loads = returned loads) might lead to the conclusion that agriculture had no effect on quality. In fact, concentrations of the pollutant in the return would be doubled compared to the diverted water, which could have a serious effect on river quality during low flows. Thus evaluations of the effects of nonpoint loadings must consider both concentrations and loads in the return flow, and take into account river flows and river assimilation.

Specific analyses of the relative effects of individual point and nonpoint sources on quality of the Truckee River and Truckee Canal are discussed in following sections dealing with calibration and application of the TRWQ model.

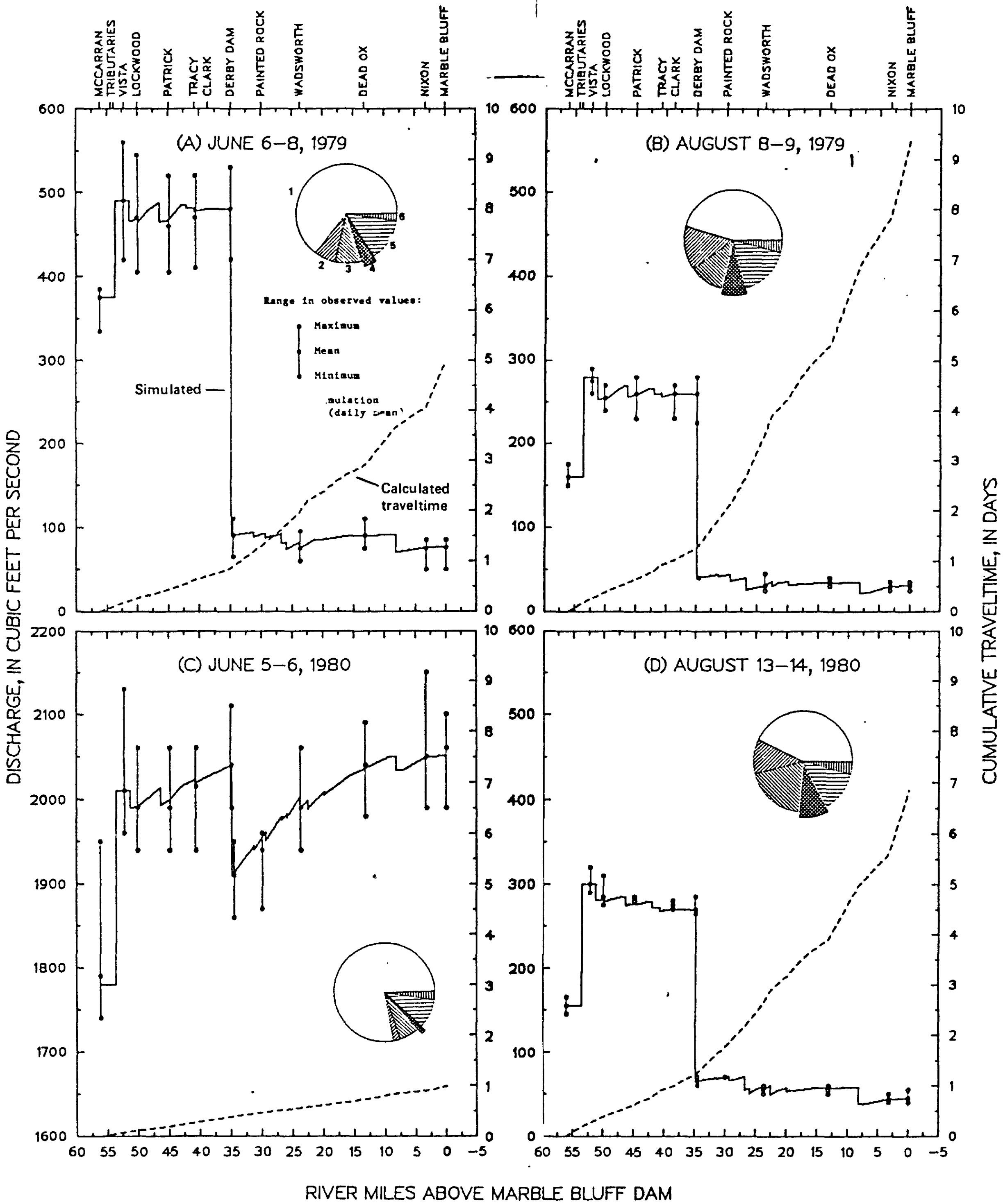
Discharge and Traveltime

Profiles of modeled streamflow and resultant cumulative traveltimes show the basic hydrologic controls on transport and decay of constituents in the Truckee River (figure 24) and the Truckee Canal (figure 25). The bar graphs of observed streamflows indicate the range and mean of flows for the four synoptic studies. The solid line indicates the modeled discharge, and the dashed line shows the calculated cumulative traveltime from McCarran Bridge as computed by the model.

Figure 24 near here

The pie diagrams accompanying each simulation profile in figure 24 show the relative contribution to the river of the major point and nonpoint sources of loadings detailed in table 21. The upstream river at the start of the model at McCarran Bridge (source 1) was the dominant source of flow, however the relative importance of the tributaries [North Truckee Drain (2), Steamboat Creek (3)], and the STP discharge (4) increases with decreasing river flow. The cumulative irrigation returns (5) and ground-water inflows (6) contributed about the same percentage of total flow to the river for all four studies.

The increase in river discharge shown at about RM 53.5 for all four profiles represents the inflow from North Truckee Drain (RM 53.66) and Steamboat Creek (RM 53.53), which includes the STP effluent. The decrease in river discharge at about RM 35 reflects the diversions into the Truckee Canal at Derby Dam, which is the starting point for the canal profiles in figure 26. Minor "sawtooth" perturbations in the discharge profile (for example, the reach between Lockwood and Patrick, RM 51 to 45) reflect the gradual increases in river flow due to agricultural returns, followed by decreases in flow due to the next downstream diversion. The larger ramps in the discharge profile



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 24.--Simulated and observed discharge and simulated traveltimes during synoptic studies, Truckee River.

for the June 1980 high flows shows the relatively large return flows modeled to match observed large increases in streamflows not accounted for in known agricultural returns and normal ground-water inflows (see preceding sections on "Nonpoint Returns" and Streamflow Balance").

Total traveltimes from McCarran Bridge to Derby Dam for the four data sets ranges from about ~~one~~ 1 day in June 1980 to about 9.5 days for August 1979. Changes in slope of the traveltime profiles reflect the major impact of the reduction in river flow at Derby Dam (increased slope) and, during low flows, the minor (but persistent) effect of diversions and returns.

Modeled flow regimes and computed traveltimes in the Truckee Canal are shown in figure 25. Traveltimes through the canal ranged from about 1.5 to 3.5 days. A comparison of figures 24 and 25 shows the lack of correlation between river and canal flow regimes. Highest river flows were in June 1980, the data set with the lowest canal flows. Diversions through the canal are managed as function of the estimated available water suppl" t Lahontan Reservoir from both the Truckee and Carson River basins as reflected in the available irrigation storage in Lahontan Reservoir, estimated future runoff in both rivers, and seasonal irrigation demands.

Figure 25 near here

Modeled streamflows are used by the TRWQ model to calculate average velocities, traveltimes, widths, and depths for each segment. The resultant simulated hydraulic data are summarized in table 22 for the four synoptic studies. Since transformations of nonconservative substances in the model are exponentially related to traveltime, any errors in simulation of velocity in the 43 river and 9 canal segments contributed to calibration errors in modeling the nonconservative water-quality constituents.

Table 22 near here

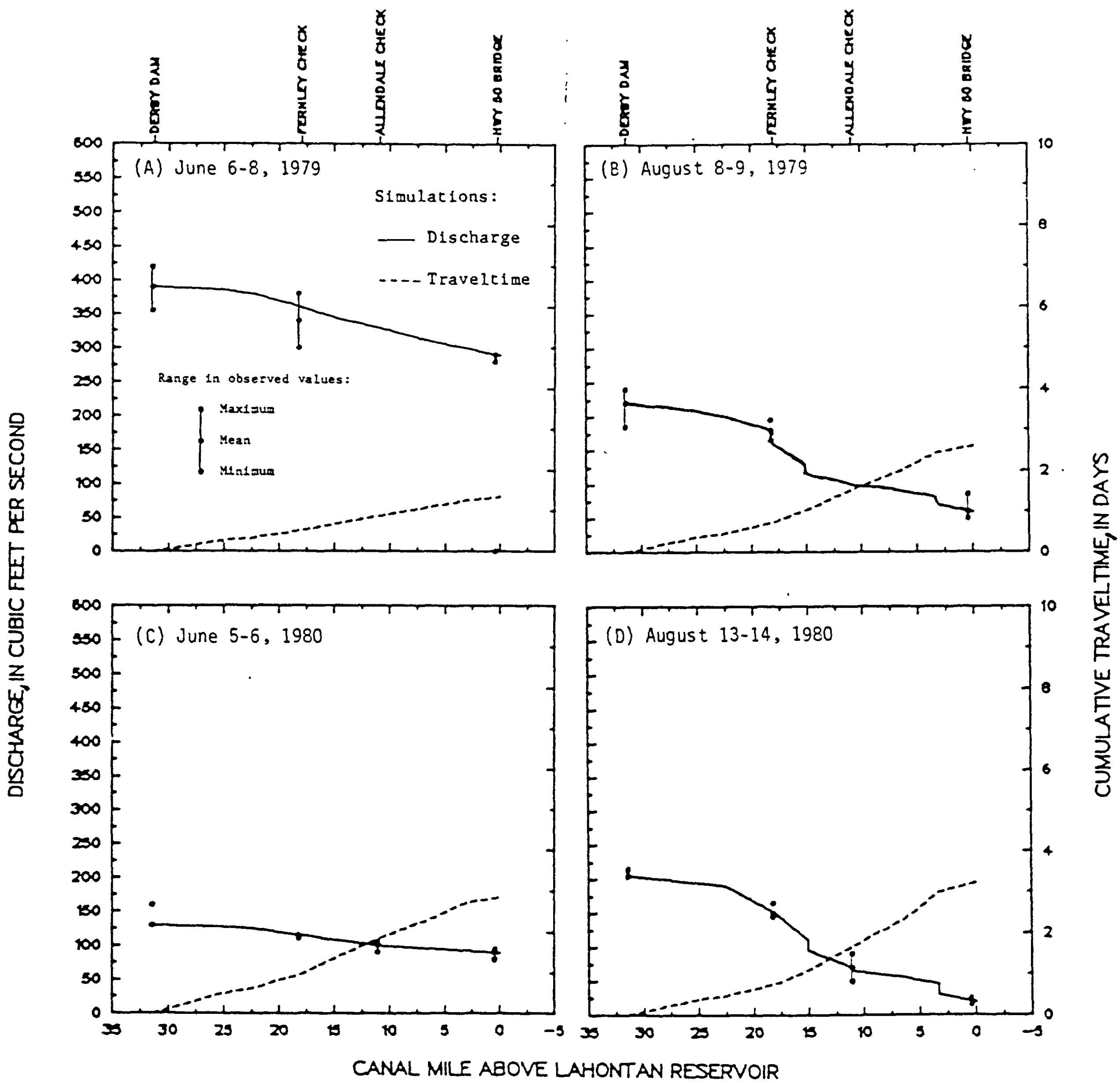


FIGURE 25.--Simulated and observed discharge and simulated traveltimes during synoptic studies, Truckee Canal.

TABLE 22.--Average discharges, velocities, widths, and depths for calibration and verification of the water-quality model

[Discharges based on mass-balance with diversions and returns (tables 17-19). Channel hydraulics data are calculated for each modeled stream segment based on exponential relationships to discharge (see text).]

Model segment	Starting river mile	Length (mile)	(A) June 1979 Discharge (ft^3/s)	(A) Velocity (ft/s)	(A) Width (feet)	(A) Depth (feet)	(B) August 1979 Discharge (ft^3/s)	(B) Velocity (ft/s)	(B) Width (feet)	(B) Depth (feet)	(C) June 1980 Discharge (ft^3/s)	(C) Velocity (ft/s)	(C) Width (feet)	(C) Depth (feet)	(D) August 1980 Discharge (ft^3/s)	(D) Velocity (ft/s)	(D) Width (feet)	(D) Depth (feet)
SUBMODELS																		
North Truckee Drain																		
1 Kleppe Lane	0.26	0.26	40	1.5	15	1.7	50	1.6	16	1.9	50	1.6	16	1.9	40	1.5	15	1.7
Steamboat Creek																		
1 Kimlick Lane	.75	.62	50	.9	31	1.8	40	.85	29	1.6	145	1.3	38	3.0	70	1.0	33	2.1
2 STP outfall	.13	.13	75	.3	33	7.0	70	.31	13	6.8	190	.42	40	11.2	105	.36	36	8.3
MAIN-STEM TRUCKEE RIVER																		
1 McCarran bridge	56.12	2.46	375	1.3	90	3.1	160	0.88	83	2.2	1,780	3.6	110	4.7	155	0.87	83	2.2
2 N. Truckee Drain	53.66	.13	415	1.5	99	2.8	210	1.1	92	2.1	1,830	3.1	110	5.1	195	1.0	91	2.1
3 Steamboat Creek	53.53	1.30	490	1.5	120	2.8	280	1.0	110	2.3	2,020	3.3	140	4.4	300	1.1	110	2.4
4 Vista gage	52.23	.98	490	1.5	120	2.8	280	1.0	110	2.4	2,020	3.3	130	4.6	300	1.1	110	2.5
5 Largomarsino divs.	51.25	.35	466	1.5	120	2.5	253	.94	120	2.3	2,000	3.5	140	4.0	281	1.0	120	2.3
6 Below Largomarsino divs.	50.90	.85	467	1.5	110	2.8	254	.95	100	2.6	2,000	3.5	130	4.5	281	1.0	100	2.6
7 Lockwood bridge	50.05	.15	468	1.5	110	2.8	256	.95	100	2.6	2,000	3.5	130	4.5	282	1.0	100	2.6
8 Groton div.	49.90	1.65	471	2.0	120	2.0	258	1.3	110	1.7	2,010	4.5	140	3.2	281	1.4	110	1.7
9 Mustang bridge	48.25	1.57	482	1.7	100	2.7	266	1.2	96	2.3	2,020	3.8	140	3.8	284	1.2	97	2.4
10 McCarran pool	46.68	.33	487	1.7	130	2.2	270	1.2	120	1.9	2,020	3.8	150	3.6	285	1.2	120	1.9
11 McCarran div.	46.35	1.43	466	1.7	120	2.2	258	1.2	110	1.9	210	3.8	130	3.8	276	1.2	110	1.9
12 Patrick bridge	44.92	2.04	476	1.5	100	3.0	262	1.1	98	2.4	2,020	3.5	120	4.8	277	1.1	98	2.5
13 SP railroad bridge	42.88	.86	485	1.6	140	2.2	266	1.1	130	1.8	2,030	3.5	160	3.6	279	1.1	130	1.9
14 Hill div.	42.02	1.26	481	1.0	140	3.5	260	.69	130	2.8	2,030	2.7	160	4.6	272	.71	130	2.9
15 Tracy div.	40.76	.14	477	1.9	130	1.9	257	1.3	120	1.6	2,030	3.4	150	3.9	268	1.4	120	1.6
16 Tracy bridge	40.62	2.02	479	1.9	110	2.2	258	1.3	110	1.8	2,030	3.4	130	4.5	269	1.4	110	1.8
17 Clark bridge	38.60	1.50	480	1.4	110	3.3	260	.95	100	2.7	2,040	2.9	120	5.6	270	.97	100	2.7
18 RM 37.1	37.10	1.50	480	1.4	100	3.5	260	.95	94	2.9	2,040	2.9	116	6.0	270	.97	95	2.9
19 Derby pool	35.60	.72	480	1.4	96	3.7	260	.95	91	3.0	2,050	2.9	111	6.2	270	.97	91	3.1
20 Derby Dam	34.88	.36	90	.68	83	1.6	40	.37	77	1.4	1,920	3.7	113	4.6	65	.53	80	1.5

TABLE 22.--Average discharges, velocities, widths, and depths used in calibration and verification data sets

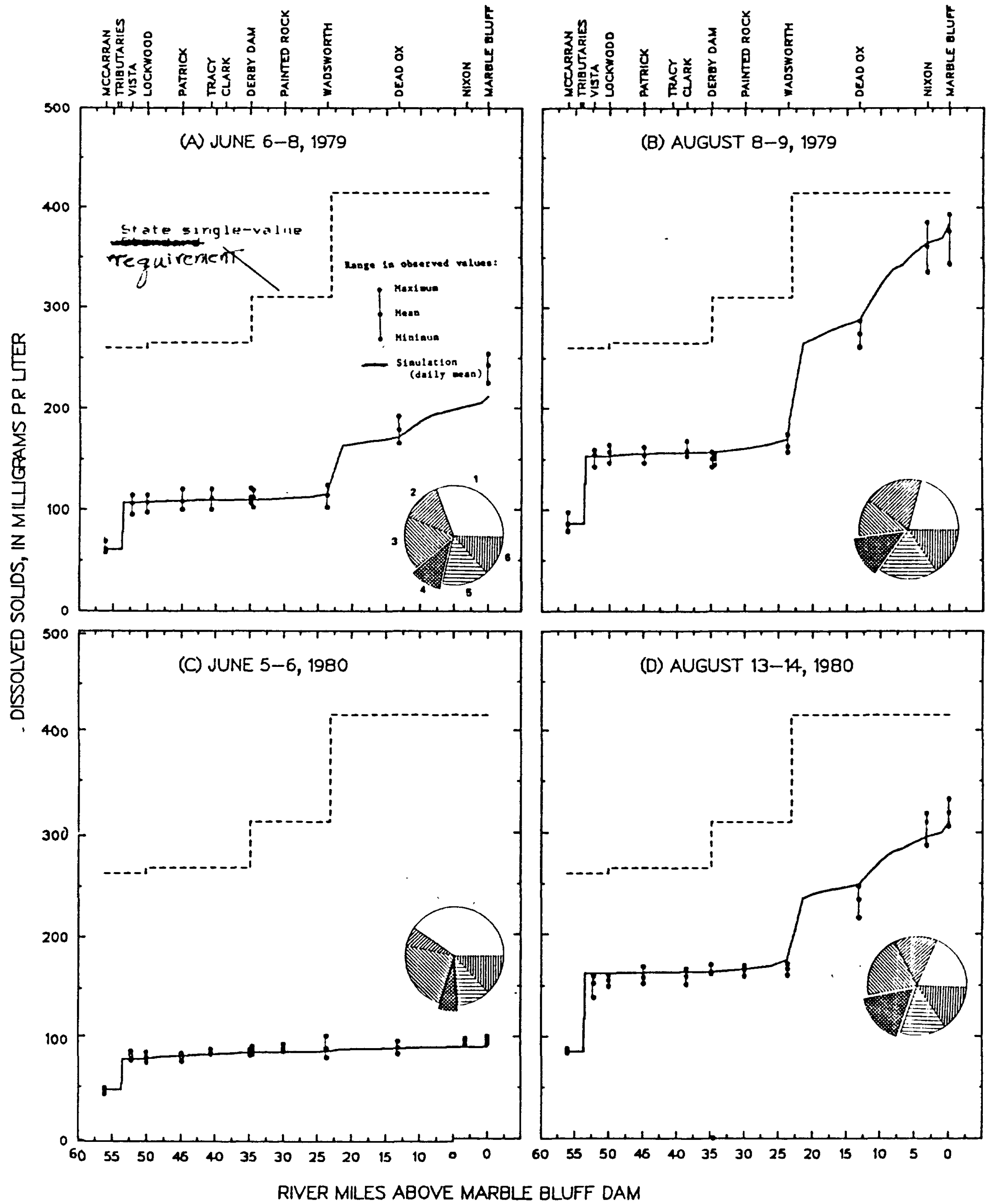
Model segment		Starting river mile	Length (mile)	(A) June 1979				(B) August 1979				(C) June 1980				(D) August 1980			
				Dis- charge (ft^3/s)	Ve- loc- ity (ft/s)	Width (feet)	Depth (feet)	Dis- charge (ft^3/s)	Ve- loc- ity (ft/s)	Width (feet)	Depth (feet)	Dis- charge (ft^3/s)	Ve- loc- ity (ft/s)	Width (feet)	Depth (feet)	Dis- charge (ft^3/s)	Ve- loc- ity (ft/s)	Width (feet)	Depth (feet)
21	Derby cableway	34.52	3.24	92	.69	75	1.8	42	.38	70	1.6	1,940	3.7	102	5.1	67	.54	73	1.7
22	Washburn Dam	31.28	1.31	90	.67	69	1.9	43	.39	64	1.7	1,960	3.7	94	5.6	69	.55	67	1.9
23	Painted Rock bridge	29.97	.62	92	.69	90	1.5	44	.39	83	1.3	1,970	3.7	122	4.3	70	.56	87	1.4
24	Gregory-Monte div.	29.35	1.35	88	.59	63	2.4	37	.28	57	2.3	1,970	4.2	85	5.5	67	.47	61	2.3
25	RM 28.0	28.00	1.25	91	.61	93	1.6	39	.30	85	1.5	1,980	4.2	126	3.7	69	.48	90	1.6
26	Herman div.	26.75	.80	81	.55	81	1.8	26	.21	72	1.7	1,990	4.2	111	4.2	56	.40	78	1.8
27	Pierson div.	25.95	2.05	78	.53	83	1.7	29	.23	76	1.7	2,000	4.2	115	4.1	55	.40	81	1.7
28	Proctor div.	23.90	.21	74	.34	55	3.9	31	.18	51	3.3	2,000	3.2	77	8.2	54	.27	54	3.7
29	Wadsworth bridge	23.69	1.14	77	.35	88	2.5	33	.20	81	2.1	2,000	3.2	122	5.2	57	.29	85	2.3
30	Fellnagle div.	22.55	1.15	82	.81	76	1.3	32	.42	69	1.1	2,000	4.8	105	4.0	51	.58	73	1.2
31	RM 21.4	21.40	1.56	85	.83	78	1.3	35	.45	71	1.1	2,010	4.8	107	3.9	56	.62	75	1.2
31	RM 21.4	21.40	1.56	85	.83	78	1.3	35	.45	71	1.1	2,010	4.8	107	3.9	56	.62	75	1.2
32	S Bar S div.	19.84	2.02	86	.61	72	2.0	32	.31	65	1.6	2,020	3.3	98	6.2	54	.44	69	1.8
33	S Bar S pump	17.82	2.00	88	.79	70	1.6	33	.39	64	1.3	2,030	4.2	96	5.0	56	.57	67	1.5
34	RM 15.8	15.82	2.64	90	.99	82	1.1	34	.50	74	.9	2,040	3.0	111	6.0	57	.72	78	1.0
35	Dead Ox Wash	13.18	3.18	90	.41	96	2.3	34	.19	87	2.1	2,050	3.0	131	5.1	57	.28	91	2.2
36	RM 10.0	10.00	.80	91	.41	96	2.3	35	.19	87	2.1	2,060	3.1	131	5.2	58	.28	92	2.2
37	RM 9.2	9.20	.99	91	.41	120	1.9	35	.19	110	1.7	2,060	3.1	159	4.2	58	.29	110	1.8
38	Numana Dam	8.21	.61	71	.73	110	.9	22	.31	95	.8	2,044	4.8	150	2.8	38	.46	100	.8
39	RM 7.6	7.60	.80	71	.73	92	1.1	22	.31	82	.9	2,044	4.8	129	3.3	38	.46	86	1.0
40	RM 6.8	6.80	2.80	73	.74	80	1.2	25	.34	72	1.0	2,051	4.8	111	3.8	41	.48	75	1.1
41	RM 4.0	4.00	.78	75	.76	63	1.6	29	.37	57	1.4	2,060	4.9	88	4.8	43	.50	60	1.4
42	Nixon bridge	3.22	2.22	76	.22	63	5.5	30	.13	58	4.1	2,060	2.3	88	10.3	44	.16	60	4.6
43	RM 1.0	1.00	1.00	77	.22	760	.5	31	.13	690	.3	2,060	2.3	105	.9	45	.16	720	.4
	TRUCKEE CANAL																		
C1	Derby Dam	31.42	6.04	387	1.5	44	6.0	215	1.0	37	5.6	130	0.77	32	0.77	200	1.0	36	5.5
C2	Pyramid check	25.38	2.84	382	2.4	22	7.3	205	1.6	20	6.1	130	1.2	19	1.25	192	1.6	20	6.0
C3	Tunnel 3	22.54	4.52	370	1.5	34	7.4	190	1.0	26	7.1	120	.77	22	.77	170	.95	25	7.1
C4	Fernley check	18.02	2.95	352	1.2	36	8.5	145	.59	33	7.5	110	.48	32	.48	130	.54	33	7.3
C5	Anderson check	15.07	4.00	337	1.2	38	7.3	108	.52	36	5.7	100	.50	36	.50	82	.42	36	5.4
C6	Allendale check	11.07	4.68	320	1.3	45	5.5	95	.58	34	4.8	97	.59	34	.59	60	.43	31	4.5
C7	Mason check	6.39	3.14	305	1.2	47	5.2	85	.45	43	4.4	93	.48	43	.48	50	.29	42	4.1
C8	Bango check	3.25	2.81	295	2.2	34	4.0	65	1.2	30	1.7	91	1.4	31	1.40	25	.87	28	1.0
C9	Highway 50	.44	.44	289	1.9	40	3.8	60	1.1	31	1.8	89	1.2	33	1.25	19	.71	26	1.1

Dissolved Solids

Major loadings of DS to the modeled reaches of the river are tabulated in table 21 and illustrated in the pie diagrams in figure 26. Although the concentrations of DS in the river at McCarran Bridge were low compared to concentrations in Steamboat Creek, North Truckee Drain, and the STP, the upstream river was the largest source of DS loads to the reach above Derby Dam for three of the four synoptic studies. Highest concentrations of DS were observed in the STP effluent (about 300 mg/L), which contributed from 7 to 22 percent of the loadings to the reach. Surface irrigation returns contributed from 1 to 13 percent of the DS loads above Derby Dam. Ground-water returns above Derby Dam were actively modeled only for the June 1980 data set, and were attributed to bank-storage releases from preceding higher stages.

Figure 26 near here

The degree of agreement between simulated and observed DS for the Truckee River (figure 26) is largely determined by the accuracy of estimations of concentrations and magnitudes of nonpoint return flows. The profiles show a continuous small increase in DS from McCarran Bridge to Derby Dam in response to recycling of diversions and returns along the river. Concentrations of DS increased markedly in the area of Wadsworth in response to inflows of ground-water derived from the Fernley Farms area, and increase again near Dead Ox Wash in response to inflow of saline springs with low (less than 1 ft^3/s) discharge but high salinities (see Appendix C). The effects of nonpoint returns on the concentrations of DS increases with decreasing flow among the four data sets.



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 26.--Simulated and observed concentrations of dissolved solids during synoptic studies, Truckee River.

The simulations of DS were "calibrated" by way of procedures used in estimating sources and magnitudes of return flows (see "Streamflow Balance" above). Simulation errors are listed in table 23; the average error for all four data sets was less than 1 percent for the reach from McCarran Bridge to Derby Dam and about -2 percent from Derby Dam to Marble Bluff Dam. The greatest errors below Derby Dam were for the June 1979 data, where concentrations were underestimated below Dead Ox, indicating an underestimation of nonpoint loadings. Comparisons of all four simulations show errors to be fairly randomly distributed from site to site and data set to data set, indicating no consistent bias in the representation of the return flows.

Table 23 near here

Since the Truckee Canal has no inputs other than the river diversion at Derby Dam, concentrations of dissolved solids would be expected to be constant, as shown in the simulations in figure 27. Contrary to expectations and simulation, a uniform downstream decrease in dissolved solids was observed in the canal in the August 1980 synoptic. This trend is not believed to be an artifact of sampling or analytical errors. One possible explanation is that, since traveltime through the reach (3.5 days) exceeded the span of sampling (1 day), the apparent decrease may be a reflection of quality existent in the upstream river prior to the start of the synoptic. Average error for the canal for all four data sets was less than 1 percent.

Figure 27 near here

TABLE 23.—Results of calibration and validation for mean daily dissolved solids

[Observed and simulated results for synoptic studies, in milligrams per liter; Percent error calculated by [(observed − simulated)/observed] X 100.]

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	61	—	—	—	47	—	—	—	86	—	—	—	85	—	—	—
Vista (52.23)	106	107	+1	1	81	78	-3	-4	154	153	-1	1	152	161	9	6
Lockwood (50.05)	107	107	0	0	79	78	-1	-1	157	153	-4	-2	155	161	6	4
Patrick (44.92)	108	108	0	0	79	81	-2	2	154	155	1	1	158	162	4	2
Tracy (40.62)	111	109	-2	-2	84	83	-1	-1	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	158	156	-2	-1	159	163	4	2
Derby (34.88)	112	109	-3	-3	84	85	1	1	150	156	6	4	163	163	0	0
Reach average error:	—	—	-1	-1	—	—	-1	-1	—	—	0	1	—	—	5	3
Truckee River below Derby Dam																
Below Derby (34.52)	112	109	-3	3	86	85	1	-1	151	157	6	4	—	—	—	—
Painted Rock (29.97)	—	—	—	—	88	85	-3	-3	—	—	—	—	165	166	1	1
Wadsworth (23.69)	114	115	+1	+1	88	86	-2	-2	163	170	7	4	166	175	9	5
Dead Ox (13.18)	179	166	-13	-7	89	89	0	0	274	288	14	5	234	249	15	6
Nixon (3.22)	244	196	-48	-20	96	91	-5	-5	361	364	3	1	310	295	-15	-5
Marble Bluff (0.00)	243	206	-37	-15	97	91	-6	-6	376	383	7	2	319	310	-9	-3

TABLE 23.--Results of calibration and validation for mean daily dissolved solids

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Reach average error:	—	—	-20	-8	—	—	-3	-3	—	—	7	3	—	—	0	1
Average error for river:	—	—	-10	-4	—	—	-2	-2	—	—	3	2	—	—	2	2
Truckee Canal																
Derby Dam (31.42)	112	—	—	—	84	—	—	—	150	—	—	—	163	—	—	—
Highway 95A (18.23)	114	112	-2	-2	89	84	-5	-6	155	150	-5	-3	155	163	8	5
Allendale (11.07)	—	—	—	—	88	84	-4	-4	—	—	—	—	149	163	14	9
Highway 50 (3.25)	110	112	2	+2	89	84	-5	-6	155	150	-5	-3	139	163	24	17
Reach average error:	—	—	0	0	—	—	-5	-5	—	—	-5	-3	—	—	15	10

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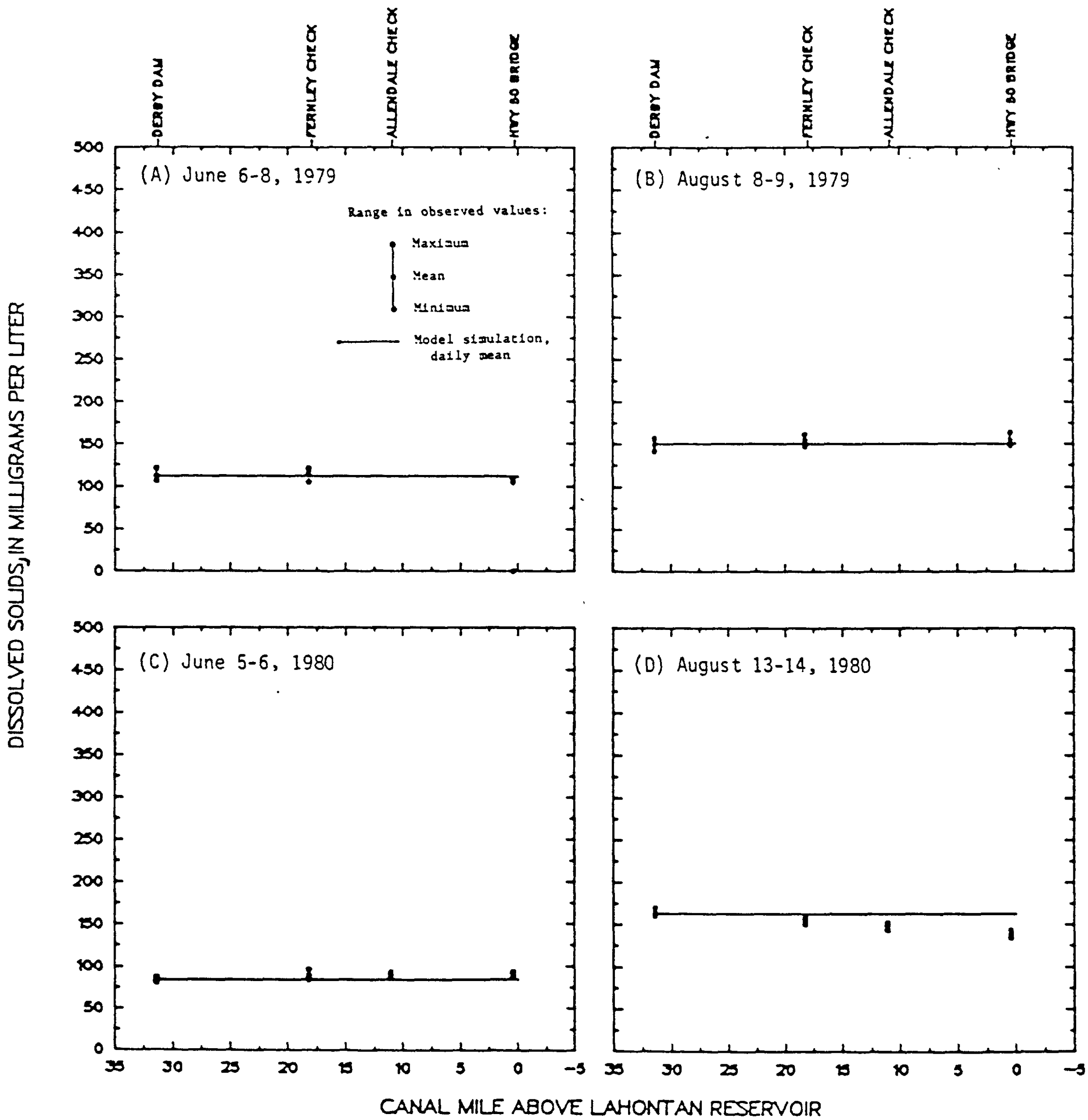


FIGURE 27.--Simulated and observed concentrations of dissolved solids during synoptic studies, Truckee Canal.

$CBOD_u$

Factors affecting instream $CBOD_u$ removal coefficients (K_{CR}) include the nature of the source effluents, sedimentation of organic material, scour, volatilization and chemical reaction, mixing, and available biological habit (Zison and others, 1978, pages 169-186). It should be kept in mind in evaluating and applying river-quality models addressing BOD and oxygen dynamics, that all these complex and interrelated processes are usually represented by a very simplistic first-order reaction (equations 4 and 5).

Laboratory values of K_1, the $CBOD_u$ bottle decay coefficient, for the four studies ranged from 0.03 to 0.32 per day and averaged 0.13. Some investigators use observed laboratory K_1 values as initial estimates of the river removal coefficient. Using laboratory values of K_1 as direct estimators of instream CBOD removal assumes that the processes removing carbonaceous material from the river are adequately represented by the biological processes in the BOD bottle in the laboratory, and that the environment in the bottle, such as the ratio of volume to surface area, is comparable to that of the river.

River removal coefficients for the four studies may also be estimated from graphical analysis of the log of $CBOD_u$ concentrations plotted against river traveltimes. In theory, the slope of such a plot gives the instream removal coefficients for the plotted constituent (Velz, 1970); however, this type of analysis assumes that there are no significant tributary or nonpoint sources in the reach under consideration. Using loads rather than concentrations as a basis for the analysis compensates for dilution effects (Thomann, 1974), but does not compensate for inputs from nonpoint sources.

For both the Truckee River and canal, the calibration process for the instream $CBOD_u$ removal coefficients, K_{CR}, was to start with all segments set to the average bottle coefficient of 0.13 and then to adjust coefficients for segments until a reasonable match was obtained between observed and simulated values. Adjustment of coefficients was made with the assumption that there should be a uniform overall coefficient for major reaches or the entire river, and that physical and biological factors might result in subreaches or individual segments with higher coefficients. Channel hydraulics, observations of aquatic habitat, and the preliminary graphical analyses of instream concentrations were used as guides in selecting segments for adjustment of coefficients. Coefficents were calibrated on the August 1979 data set and then tested against the remaining three data sets. Only minor adjustments were required after calibration to achieve an accceptable fit to all four data sets.

For the Truckee River, validated coefficients are 0.20 per day for most segments (table 24). The $CBOD_u$ removal coefficent was increased to 1.7 per day in the Vista pool and adjacent backwater into the lower reach of Steamboat Creek (segments 2, 3, and B2), where increased depths and decreased slope and velocity would be expected to lead to some sedimentation of suspended organic matter. The $CBOD_u$ removal coefficient remains somewhat elevated at 0.70 per day in segments 5 and 6, then drops back to a consistent coefficient of 0.20 per day for the balance of the river. Segment 5 contains a short, but deep, pool above the Largomarsino Murphy diversion dam in which sedimentation of organic particulate matter could also be expected. The two rock-rubble diversion dams at low flow provide a large shallow surface area as potential habitat for attached organisms involved in the degradation of CBOD.

Segment 6 is a high-gradient reach containing both the Murphy diversion dam and a swift rapids below the dam in which the turbulence and resulting mixing would be expected to contribute to a higher rate of CBOD removal.

Table 24 near here

Relative sources of $CBOD_u$ loadings for the four studies are shown in figure 28. During the lower August flows, the STP was the major source; however, at high June flows, loads from the upstream river exceeded those from the STP even though $CBOD_u$ concentrations in the STP effluent were 9 to 18 times higher than in the river at McCarran bridge. Nonpoint sources above Derby Dam were relatively minor, contributing from 4 to 18 percent of the total loads to the reach. Below Derby Dam, modeled nonpoint surface returns contributed loads of $CBOD_u$ about equivalent to those released to the river through the dam.

Figure 28 near here

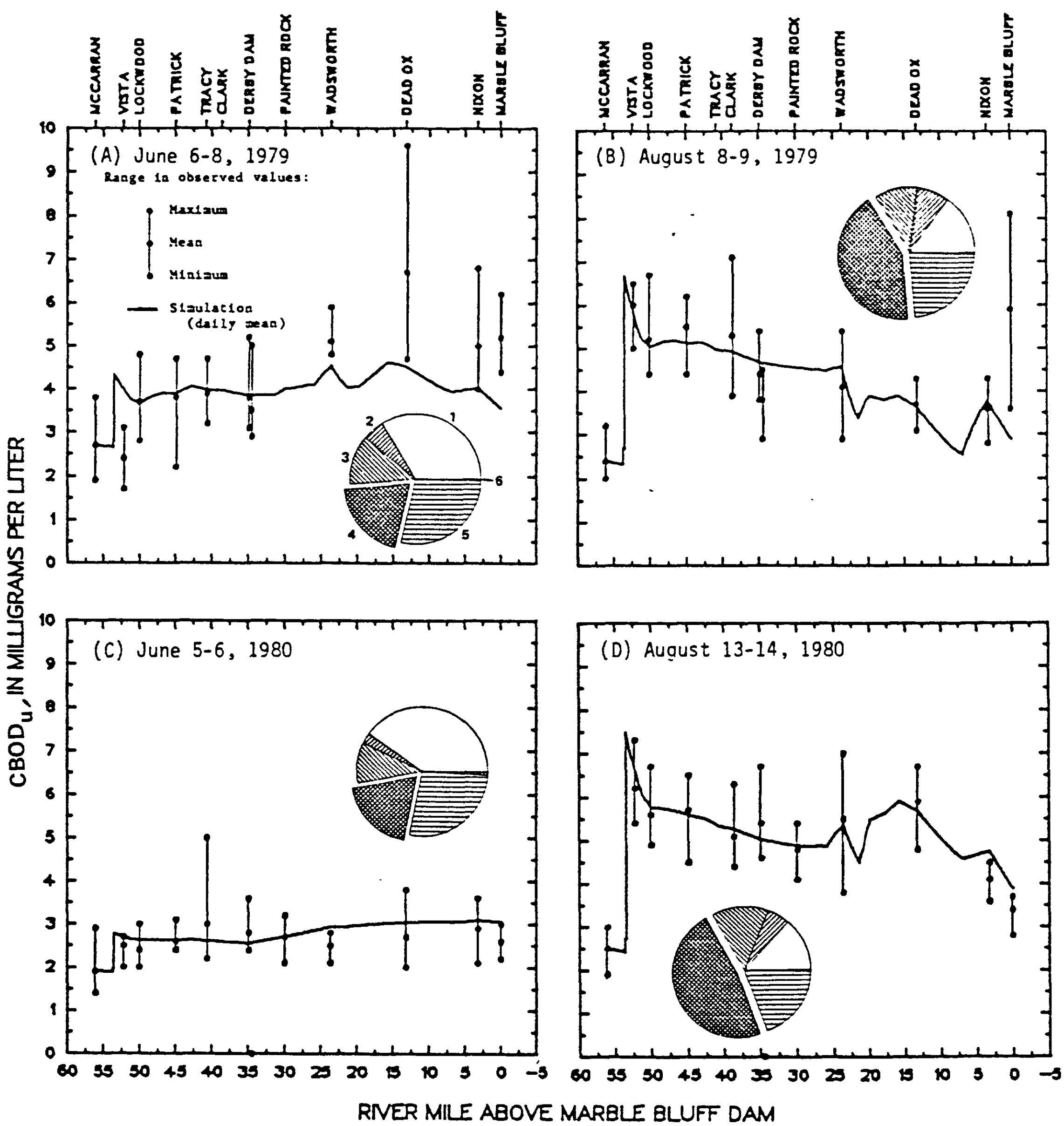
River profiles of observed and simulated concentrations of $CBOD_u$ for the four synoptic data sets are shown in figure 28. Simulation errors for the reach above Derby Dam averaged (arithmetic means) 4.5 percent for all four data sets and 2.5 percent for the reach below Derby Dam (table 25). The greatest error in simulation is at Vista for June 1979, where sampling errors are suspected (the mean observed value for $CBOD_u$ at Vista, below the inputs of North Truckee Drain, Steamboat Creek, and the Reno-Sparks STP, was actually lower than the starting value at McCarran Bridge). There is more variation between observed and simulated concentrations of $CBOD_u$ above Derby Dam for the June 1980 data than the other three studies; however, the average error of 14 percent for the reach represents only 0.4 mg/L.

TABLE 24.—Calibrated and validated reaction rate coefficients for CBODu, nitrogen, and phosphorus for the ~~TRQMOD~~ TRWQ model

Model segment		Starting river mile	Length (mile)	Reaction coefficients at 20 °C (1/day, base e): CBOD$_u$ K_{CR}	CBOD$_u$ K_C	Organic-N K_{ONR}	Organic-N K_{ONF}	Ammonia-N K_{NH4R}	Ammonia-N K_{NH4F}	Nitrite-N K_{NO2R}	Nitrite-N K_{NO2F}	Nitrate-N K_{NO3R}	Phosphorus: Ortho K_{NCR1}	Phosphorus: Total K_{NCR2}
	SUBMODELS													
	North Truckee Drain													
A1	Kleppe Lane	0.26	0.26	0.20	0.20	0.10	0.10	0.40	0.40	1.0	1.0	0.30	0.25	0.25
	Steamboat Creek													
B1	Kimlick Lane	.75	.62	.20	.20	.10	.10	.40	.40	1.0	1.0	.30	.25	.25
B2	STP outfall	.13	.13	1.7	.20	1.7	.80	.40	.40	10	10	.30	.25	.25
	MAINSTEM TRUCKEE RIVER													
1	McCarran bridge	56.12	2.46	0.20	0.20	0.10	0.10	0.40	0.40	1.0	1.0	0.30	0.25	0.25
2	N. Truckee Drain	53.66	.13	.20	.20	.10	.10	.40	.40	1.0	1.0	.30	.25	.25
3	Steamboat Creek	53.53	1.30	1.70	.20	1.70	.80	.40	.40	10	10	.30	.25	.25
4	Vista gage	52.23	.98	1.70	.20	1.70	.80	.40	.40	10	10	.30	.25	.25
5	Largomarsino divs.	51.25	.35	.70	.20	.10	.10	2.4	2.4	10	10	.30	.25	.25
6	Below Largo(m)arsino divs.	50.90	.85	.70	.20	.10	.10	2.4	2.4	10	10	.30	.25	.25
7	Lockwood bridge	50.05	.15	.20	.20	.10	.10	2.4	2.4	10	10	.30	.25	.25
8	Groton div.	49.90	1.65	.20	.20	.10	.10	2.4	2.4	10	10	.30	.25	.25
9	Mustang bridge	48.25	1.57	.20	.20	.10	.10	2.4	2.4	6.0	6.0	.30	.25	.25
10	McCarran pool	46.68	.33	.20	.20	.10	.10	2.4	2.4	6.0	6.0	.30	.25	.25
11	McCarran div.	46.35	1.43	.20	.20	.10	.10	2.4	2.4	5.0	5.0	.30	.25	.25
12	Patrick bridge	44.92	2.04	.20	.20	.10	.10	2.4	2.4	3.0	3.0	.30	.25	.25
13	SP railroad bridge	42.88	.86	.20	.20	.10	.10	2.4	2.4	3.0	3.0	.30	.25	.25
14	Hill div.	42.02	1.26	.20	.20	.10	.10	2.4	2.4	3.0	3.0	.30	.25	.25
15	Tracy div.	40.76	.14	.20	.20	.10	.10	2.4	2.4	3.0	3.0	.30	.25	.25
16	Tracy bridge	40.62	2.02	.20	.20	.10	.10	2.4	2.4	3.0	3.0	.30	.25	.25
17	Clark bridge	38.60	1.50	.20	.20	.10	.10	2.4	2.4	3.0	3.0	.30	.25	.25
18	RM 37.1	37.10	1.50	.20	.20	.10	.10	2.4	2.4	3.0	3.0	.30	.25	.25
19	Derby pool	35.60	.72	.20	.20	.10	.10	2.4	2.4	3.0	3.0	1.5	.25	.25
20	Derby Dam	34.88	.36	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
21	Derby cableway	34.52	3.24	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
22	Washburn Dam	31.28	1.31	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
23	Painted Rock bridge	29.97	.62	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
24	Gregory-Monte div.	29.35	1.35	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
25	RM 28.0	28.00	1.25	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25

TABLE 24.—Calibrated and validated reaction rate coefficients for CBODu, nitrogen, and phosphorus for the ~~TRQMOD~~ TRWQ model—Continued

	Model segment	Starting river mile	Length (mile)	Reaction coefficients at 20 °C (1/day, base e): CBOD$_u$		Organic-N		Ammonia-N		Nitrite-N		Nitrate-N	Phosphorus	
				K_{CR}	K_C	K_{ONR}	K_{ONF}	K_{NH4R}	K_{NH4F}	K_{NO2R}	K_{NO2F}	K_{NO3R}	Ortho K_{NCR1}	Total K_{NCR2}
26	Herman div.	26.75	.80	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
27	Pierson div.	25.95	2.05	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
28	Proctor div.	23.90	.21	.20	.20	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
29	Wadsworth bridge	23.69	1.14	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
30	Fellnagle div.	22.55	1.15	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
31	RM 21.4	21.40	1.56	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
32	S Bar S div.	19.84	2.02	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
33	S Bar S pump	17.82	2.00	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
34	RM 15.8	15.82	2.64	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
35	Dead Ox Wash	13.18	3.18	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
36	RM 10.0	10.00	.80	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
37	RM 9.2	9.20	.99	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
38	Numana Dam	8.21	.61	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
39	RM 7.6	7.60	.80	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
40	RM 6.8	6.80	2.80	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
41	RM 4.0	4.00	.78	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
42	Nixon bridge	3.22	2.22	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
43	RM 1.0	1.00	1.00	.14	.14	.10	.10	2.4	2.4	3.0	3.0	2.0	.25	.25
	Marble Bluff Dam	.00												
	TRUCKEE CANAL													
C1	Derby Dam	31.42	6.04	0.13	0.13	0.05	0.05	0.90	0.90	0.70	0.70	0.18	0.10	0.10
C2	Pyramid check	25.38	2.84	.13	.13	.05	.05	.90	.90	.70	.70	.18	.10	.10
C3	Tunnel 3	22.54	4.52	.13	.13	.05	.05	.90	.90	.70	.70	.18	.10	.10
C4	Fernley check	18.02	2.95	.13	.13	.05	.05	.90	.90	.70	.70	.18	.10	.10
C5	Anderson check	15.07	4.00	.13	.13	.05	.05	.90	.90	.70	.70	.18	.10	.10
C6	Allendale check	11.07	4.68	.13	.13	.05	.05	.90	.90	.70	.70	.18	.10	.10
C7	Mason check	6.39	3.14	.13	.13	.05	.05	.90	.90	.70	.70	.18	.10	.10
C8	Bango check	3.25	2.81	.03	.03	.05	.05	.90	.90	.70	.70	.18	.10	.10
C9	Highway 50	.44	.44	.03	.03	.05	.05	.90	.90	.70	.70	.18	.10	.10
	Terminal weir	.00												



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 28.--Simulated and observed concentrations of CBOD during synoptic studies, Truckee River.

Table 25 near here

The accuracy of simulations decreases below Derby Dam as nonpoint source loadings become more significant. For August 1979, the predictions are good down to Nixon. The observed increase in $CBOD_u$ concentrations between Nixon and Marble Bluff Dam, however, is not reflected in the simulations, as the only inputs modeled in the reach were ground-water inflows with low BOD concentrations. In contrast, the model overpredicts $CBOD_u$ from Dead Ox Wash to Marble Bluff for the August 1980. Concentrations are consistently underpredicted below Derby Dam for June 1979, when, as for dissolved solids, significant nonpoint loadings of $CBOD_u$ are not accounted for in the modeled inputs. Simulations are more accurate for the June 1980 high flows, with a small consistent overprediction in the reach.

The simulation profiles for the four synoptic studies demonstrate the relative importance of nonpoint sources of $CBOD_u$ below Derby Dam in comparison to the loads of $CBOD_u$ transported from the Reno-Sparks area (figure 28). Modeled transport, decay, and nonpoint sources are accurately represented above Derby Dam, and, although precision decreases below the Dam, the trends in concentration are reasonably represented by the simulations. $CBOD_u$ simulations could be improved by more accurate representation of nonpoint loadings, however, the variations in sign and magnitude of model errors from site to site and data set to data set indicate that there is no single representation of these nonpoint loadings that would satisfy all modeled river environments.

TABLE 25.—Results of calibration and validation for mean daily $CBOD_u$

[Observed and simulated results for synoptic studies, in milligrams per liter; Percent error calculated by [(observed - simulated)/observed] x 100.]

Site (River or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	2.7	—	—	—	1.9	—	—	—	2.4	—	—	—	2.5	—	—	—
Vista (52.23)	2.4	4.0	1.6	66	2.5	2.9	0.4	16	6.0	5.8	-0.2	-3	6.2	6.6	0.4	6
Lockwood (50.05)	3.7	3.7	0	0	2.4	2.8	.4	17	5.2	5.0	-.2	-4	5.6	5.8	.2	3
Patrick (44.92)	3.8	3.9	.1	3	2.6	2.8	.2	8	5.5	5.1	-.4	-7	5.7	5.6	-.1	-2
Tracy (40.62)	3.9	4.0	.1	3	3.0	2.8	-.2	-7	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	5.3	4.9	-.4	-7	5.1	5.3	.2	4
Derby (34.88)	3.8	3.8	0	0	2.8	2.7	-.1	-3	4.4	4.7	.3	7	5.4	5.0	-.4	-7
Reach average error:	—	—	.36	14	—	—	.14	6	—	—	-.2	-3	—	—	-.1	1
Truckee River below Derby Dam																
Below Derby (34.52)	3.5	3.9	0.4	11	—	—	—	—	3.8	4.7	0.9	24	—	—	—	—
Painted Rock (29.97)	—	—	—	—	2.7	2.8	0.1	4	—	—	—	—	4.8	4.9	0.1	2
Wadsworth (23.69)	5.1	4.5	-.6	-12	2.5	3.1	.6	24	4.1	4.6	.5	12	5.5	5.4	-.1	-2
Dead Ox (13.18)	6.7	4.5	-2.2	-33	2.7	3.2	.5	18	3.7	3.6	-.1	-3	5.8	5.7	-.1	-2

TABLE 25.—Results of calibration and validation for mean daily $CBOD_u$—Continued

Site (River or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Nixon (3.22)	5.0	4.0	-1.0	-20	2.9	3.2	.3	10	3.6	3.8	.2	5	4.1	4.8	.7	17
Marble Bluff (0.00)	5.2	3.5	-1.7	-33	2.6	3.2	.6	23	5.9	2.9	-3	-51	3.4	3.9	.5	15
Reach average error:	—	—	-1.0	-17	—	—	.4	16	—	—	-.3	-3	—	—	.2	6
Average error for river:	—	—	-.32	-1	—	—	.27	11	—	—	-.2	-3	—	—	.05	3
							Truckee Canal									
Derby Dam (31.42)	3.8	—	—	—	2.8	—	—	—	4.4	—	—	—	5.4	—	—	—
Highway 95A (18.23)	3.4	3.6	0.2	6	2.8	2.6	-0.2	-7	4.4	3.9	-.5	-11	4.3	4.9	0.6	14
Allendale (11.07)	—	—	—	—	2.1	2.4	.3	14	—	—	—	—	4.8	4.3	-.5	-10
Highway 50 (3.25)	4.1	3.3	-.8	-19	2.3	2.2	-.1	-4	6.1	3.2	-2.9	-48	3.9	3.5	-.4	-10
Reach average error:	—	—	-.3	-6	—	—	0	1	—	—	-1.7	-30 ~~-29~~	—	—	-.1	-2

Profiles of observed and simulated $CBOD_u$ concentrations in the Truckee Canal are shown in figure 29. Simulations in the canal are generally less accurate than the river; average error for all four data sets is -11 percent. The observed increases in $CBOD_u$ in all data sets (Fernley to Highway 50 in June and August 1979, Allendale to Highway 50 in June 1980, and Fernley to Allendale in August 1980) cannot be explained by unmodeled external point or nonpoint loadings as the canal had no known external inputs during the four studies. The most likely explanation is that decay of algae and aquatic weeds in the canal creates an internal CBOD source. As with the lower river reach, errors in prediction in the canal are fairly randomly distributed from site to site and data set to data set.

Figure 29 near here

The $CBOD_u$ removal coefficients in table 24 can be compared to results from previous modeling studies on the Truckee River. O'Connell and others (1962) developed estimates of K_{CR} based on an intensive field survey in July 1962. At that time, Reno and Sparks had separate treatment plants with a lower level of treatment (average BOD_5 was 23 mg/L at Reno and 68 at Sparks) than the current Reno-Sparks plant. Using the method of graphical analysis described above, an instream decay coefficient of 0.21 per day (base e) was obtained between the Reno and Sparks plant (TRWQ model segments 1-2) and 0.31 from Steamboat Creek to Derby Dam (segments 3-19). In a subsequent analysis of the same data, O'Connor and Di Toro (1970) obtained coefficients of 0.49 per day (base e) above Steamboat Creek (segments 1-2) and 1.3 from Steamboat Creek to Clark (segements 3 to 16). The higher coefficients calculated in that analysis compared to this current study may be a function of the higher concentrations of BOD in the effluents at

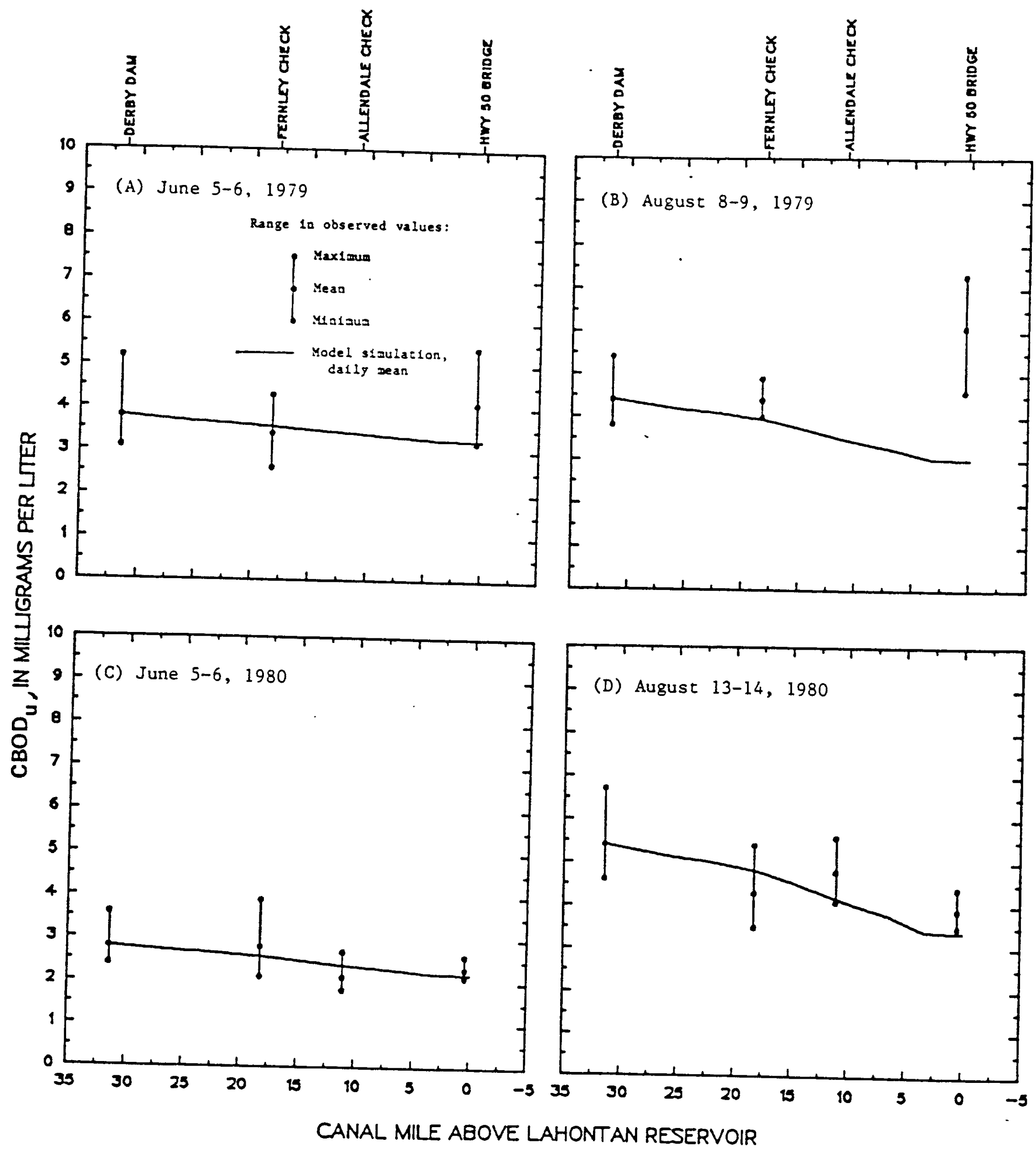


FIGURE 29.--Simulated and observed concentrations of CBODu during synoptic studies, Truckee Canal.

the 1962 level of sewage treatment compared to 1979 and 1980. Willis and others (1976) used a uniform coefficient of 0.11 for the entire river from Lake Tahoe to Pyramid Lake in a model based on water-quality surveys conducted in 1972 (Kaiser Engineers, 1973) and records from the Nevada Department of Environmental Health. The model did not consider nonpoint inputs and the author noted severe limitations as to the reliability of estimates of the quality and quantity of tributary inflows used in the study.

Phosphorus

Phosphorus in the Truckee River is of interest as an essential nutrient for the growth of aquatic plants both in the river and the receiving bodies of Pyramid Lake and Lahontan Reservoir. In the river, stimulation of growth of aquatic plants is important with respect to nighttime low DO concentrations due to plant respiration. Algal stimulation also can cause high DO demands and nuisance odors during periods of algal decay. Algal stimulation in Pyramid Lake and Lahontan Reservoir is of concern with respect to potential DO depletion due to decaying algal blooms. In addition, the asthetics of large-scale algal blooms are a concern with respect to aquatic recreation in Lahontan Reservoir.

Phosphorus can occur in water in the dissolved ionic form (orthophosphorus, or PO_4-P), as organic detritus, as complexes with metal ions, and as colloidal particulate material (Hem, 1970). In the four synoptic studies about 90 percent of the phosphorus below Vista was found as orthophosphorus (see Appendix A), which is the form most readily available as a nutrient. Total phosphorus determinations, however, are also important as suspended and bottom sediments may be significant pathways for the transport and cycling of phosphorus. Both ortho- and total phosphorus were included as variables in the model.

The occurrence of phosphorus in a stream is controlled by complex cycling between solution, transport by suspended sediments, biological uptake and release by both aquatic plants and invertebrate grazers, and storage in and release from benthic sediments. Webster (1975) pointed out that nutrients in a stream do not cycle in a two-dimensional pattern through these transformations, but are also displaced by transport in a downstream direction as they cycle between components of the aquatic ecosystem. This coupling of cycling and transport of nutrients has been described as spiraling. It has been demonstrated that the spiraling of phosphorus in small streams from water transport to particulates, to consumers, and back to water transport can take place over relatively small distances (about 600 feet), and that the complex spiraling can be adequately represented as a first-order decay process (Newbold and others, 1981).

The computer program used for the TRWQ model provided options to model phosphorus by simulation of two pathways: (1) removal of phosphorus in response to algal uptake as represented by chlorophyll-*a* concentrations, and (2) loss or gain in phosphorus from exchange with bottom materials (figure 10, equation 25). In adaptation of the model to the Truckee River, however, a more simplistic approach of modeling both ortho- and total phosphorus as simple first-order loss was adopted for two reasons: (1) concentrations of chlorophyll *a* in the water column were not believed to be indicative of algal uptake of phosphorus in the Truckee River ecosystem, which was dominated during this study by attached algae and rooted aquatic plants, and (2) detailed field studies to determine rates for phosphorus exchange with bottom sediments were not conducted during the RQA.

Calibrated removal coefficients for both ortho- and total phosphorus were finalized as 0.25 for the entire river and 0.10 for the canal (table 24). Calibration was complicated by the fact that, in three of the four data sets, observed phosphorus concentrations increased between Lockwood and Patrick in quantities in excess of what could be explained by estimates of nonpoint irrigation returns and ground-water inflows (figures 30A, B, and D). In an examination of historical monitoring data from the Nevada Division of Environmental Protection for the period 1978 to 1981, it was determined that similar trends of phosphorus accretion commonly occurred in the reach between Vista and Clark or, when data have been available, between Lockwood and Tracy. Potential sources of this phosphorus input include:

(a) sampling errors (missing bed loads and near-bottom transport of particulate phosphorus),

(b) recycling of phosphorus from sediments and (or) aquatic plants,

(c) undocumented sources of agricultural waste,

(d) abnormally high phosphorus concentrations in agricultural returns,

(e) mineralized ground waters, and

(f) undocumented point or nonpoint sources of residential or industrial contamination in the reach.

Figure 30 near here

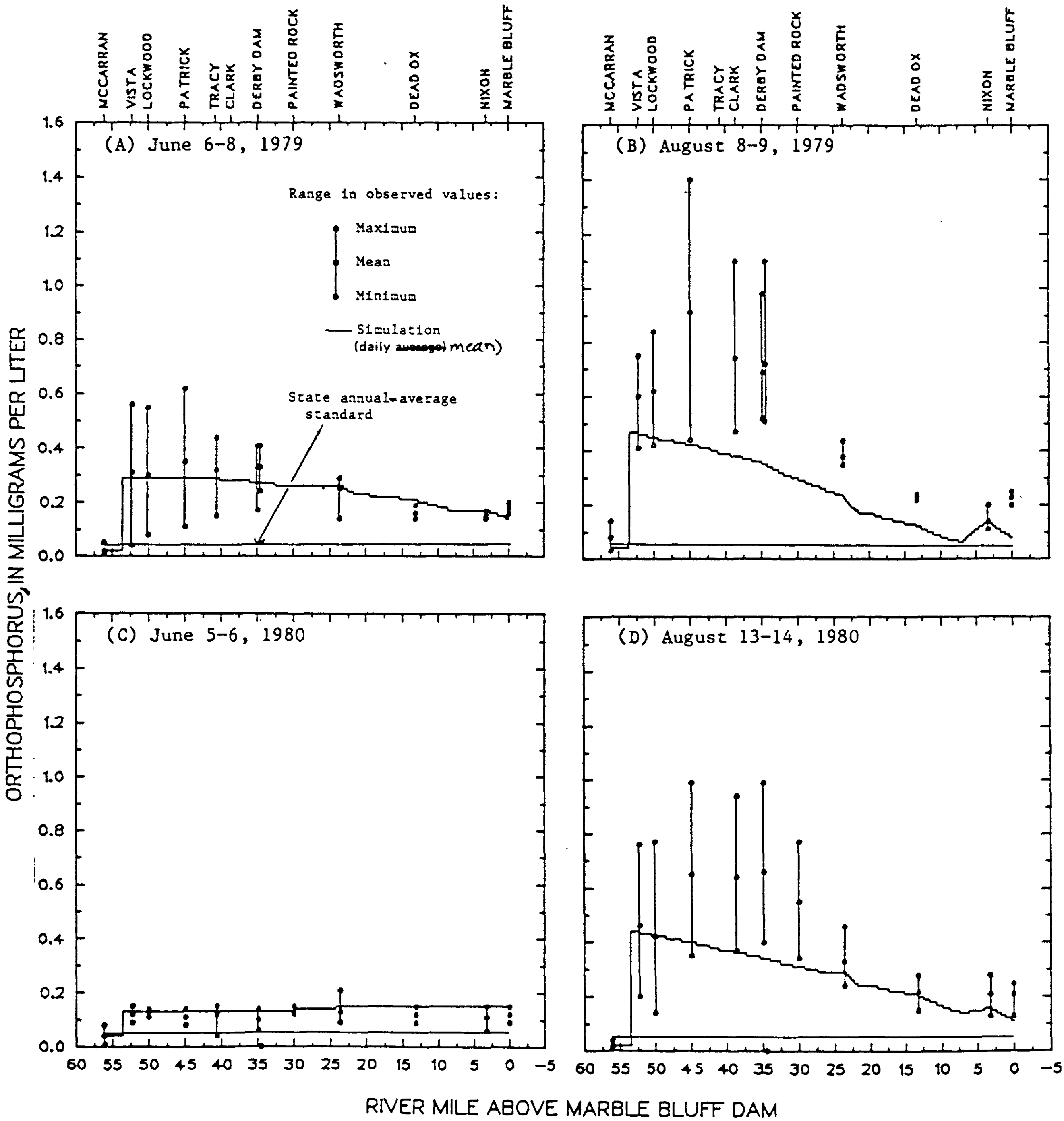


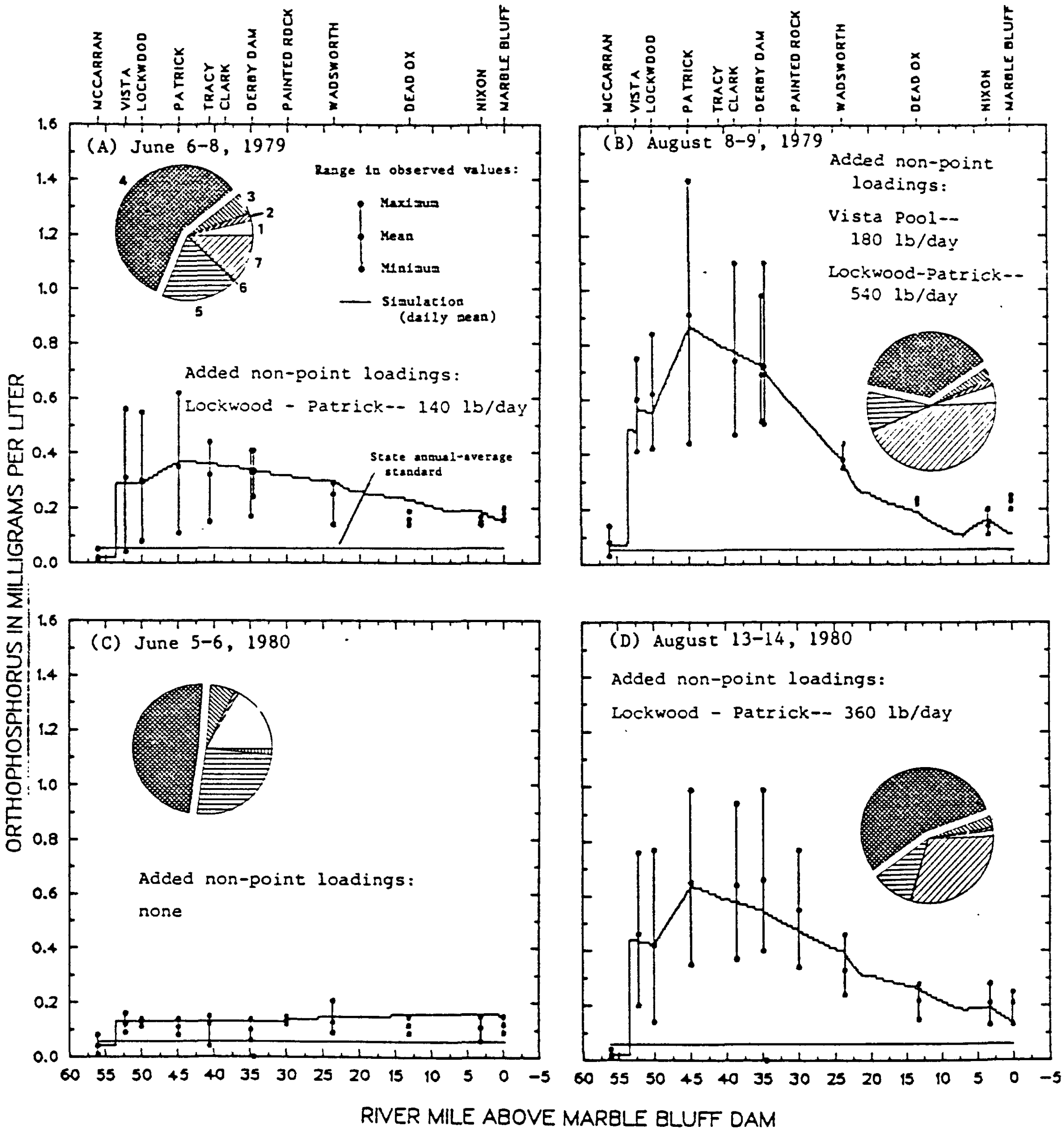
FIGURE 30.--Observed concentrations of orthophosphorus during synoptic studies in the Truckee River and simulation without addition of "dummy" nonpoint loadings of phosphorus.

To quantify the magnitude of the source or sources, it was assumed that a uniform nonpoint source of phosphorus existed between Lockwood and Patrick (segments 7-12). The magnitude of this source then was calibrated to the observed concentrations at and below Patrick using a uniform decay coefficient of 0.25. For the August 1979 data, the observed values of both orthophosphorus and total phosphorus at Vista and Lockwood were significantly greater than simulated concentrations based on the measured inputs. For this data set, additional phosphorus was added to the model as a point source at Vista to raise the concentrations at Lockwood. Relative magnitudes of these simulated sources of phosphorus to the river are illustrated in the pie diagrams in figures 31 and 32.

The results of the calibration of "dummy" phosphorus loads to match the observed concentrations at Patrick is reflected in the linear increase in phosphorus between Lockwood and Patrick in figures 31 (orthophosphorus) and 32 (total phosphorus). Given the uncertainties of nonpoint phosphorus loadings, the uniform decay coefficient of 0.25 gives a good average fit to observed data throughout most of the modeled reach. A notable exception is in the reach between Nixon and Marble Bluff Dam, in which the simulations show a phosphorus decrease; whereas the observed concentrations increased. The observed increase may be due to unmodeled nonpoint sources of phosphorus or to internal cycling of phosphorus within the pond above Marble Bluff Dam. Average simulation errors for the four data sets were 5 percent for orthophosphorus and 14 percent for total phosphorus (tables 26 and 27).

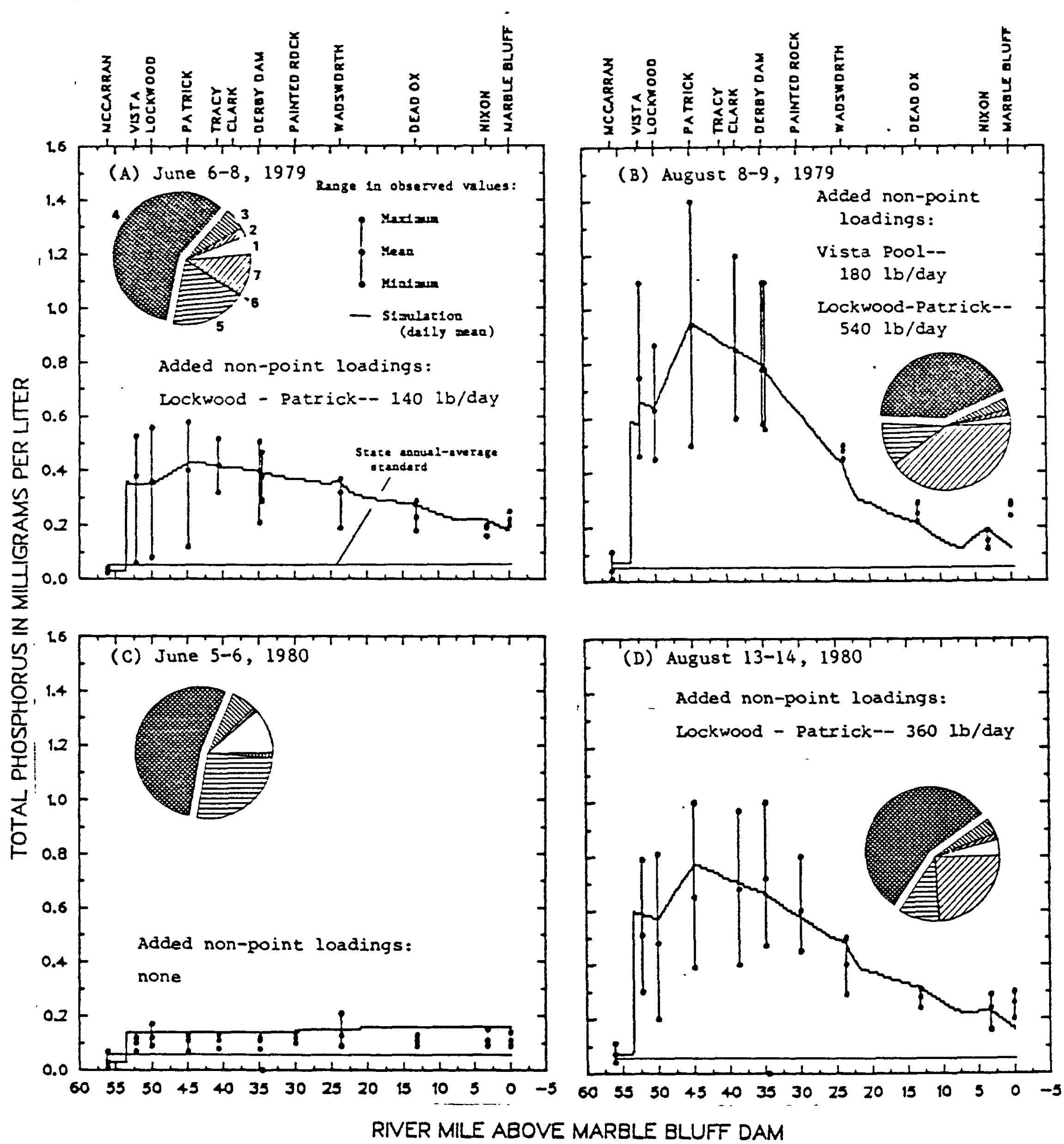
Figures 31 and 32 near here

Tables 26 and 27 near here



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, (6) total ground-water inflows, and (7) "dummy" distributed nonpoint loadings of phosphorus required for calibration at Patrick.]

FIGURE 31.--Observed concentrations of orthophosphorus during synoptic studies in the Truckee River and calibration with addition of "dummy" nonpoint loadings of phosphorus.



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, (6) total ground-water inflows, and (7) "dummy" distributed nonpoint loadings of phosphorus required for calibration at Patrick.]

FIGURE 32.--Observed concentrations of total phosphorus during synoptic studies in the Truckee River and calibration with addition of "dummy" nonpoint sources of phosphorus.

TABLE 26.—Results of calibration and validation for mean daily orthophosphorus

[Observed and simulated results for synoptic studies, in milligrams per liter as P; Percent error calculated by [(observed - simulated)/observed] x 100]

Site (River or Canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	0.02	—	—	—	0.04	—	—	—	0.08	—	—	—	0.02	—	—	—
Vista (52.23)	.31	.29	-.02	-6	.12	.15	.03	25	.60	.61	-.01	-2	.46	.43	-.03	-6
Lockwood (50.05)	.30	.29	-.01	-3	.13	.15	.02	15	.62	.58	-.04	-6	.42	.42	0	0
Patrick (44.92)	.35	.34	-.01	-3	.11	.15	.04	36	.91	.90	-.01	-1	.65	.62	-.03	-5
Tracy (40.62)	.32	.33	.01	3	.12	.15	.03	25	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	.74	.79	.05	7	.64	.56	-.08	-12
Derby (34.88)	.33	.32	-.01	-3	.10	.15	.05	50	.69	.73	.04	6	.66	.53	-.13	-20
Reach average error:	—	—	.01	-2	—	—	.03	30	—	—	.01	1	—	—	-.05	-9
Truckee River below Derby Dam																
Below Derby (34.52)	0.33	0.32	-0.01	-3	—	—	—	—	0.72	0.72	0	0	—	—	—	—
Painted Rock (29.97)	—	—	—	—	.13	.15	.02	15	—	—	—	—	.55	.46	-.09	-16
Wadsworth (23.69)	.25	.29	.04	16	.13	.16	.03	23	.38	.36	.02	5	.33	.38	.05	15
Dead Ox (13.18)	.16	.22	.06	37	.12	.17	.05	42	.23	.17	-.06	-26	.22	.25	.03	14

TABLE 26.—Results of calibration and validation for mean daily orthophosphorus—Continued

Site (River or Canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Nixon (3.22)	.15	.18	.03	20	.11	.17	.06	54	.14	.15	.01	7	.21	.18	-.03	-14
Marble Bluff (0.00)	.18	.15	-.03	-17	.12	.17	.05	42	.23	.09	-.14	-61	.21	.13	-.08	-38
Reach average error:	—	—	.02	11	—	—	.04	35	—	—	.03	-15	—	—	-.02	-8
Average error for river:	—	—	.01	4	—	—	.03	32	—	—	-.01	-7	—	—	-.03	-8
Truckee Canal																
Derby Dam (31.42)	0.33	—	—	—	0.10	—	—	—	0.69	—	—	—	0.66	—	—	—
Highway 95A (18.23)	.31	.32	.01	3	.11	.10	-.01	-9	.75	.63	-.12	-16	.56	.61	.05	9
Allendale (11.07)	—	—	—	—	.12	.09	-.03	-25	—	—	—	—	.45	.54	.09	20
Highway 50 (3.25)	.30	.30	0	0	.12	.09	-.03	-25	.67	.50	-.17	-25	.30	.47	.17	57
Reach average error:	—	—	0	0	—	—	-.02	-20	—	—	-.14	-20	—	—	.10	29

TABLE 27.—Results of calibration and validation for mean daily total phosphorus

[Observed and simulated results for synoptic studies, in milligrams per liter as P; Percent error calculated by [(observed − simulated)/observed] X 100]

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	0.03	—	—	—	0.03	—	—	—	0.04	—	—	—	0.07	—	—	—
Vista (52.23)	.38	.35	−.03	−8	.10	.17	.07	70	.75	.68	−.07	−9	.51	.59	.08	16
Lockwood (50.05)	.36	.35	−.01	−3	.12	.17	.05	42	.63	.66	.03	5	.48	.57	.09	19
Patrick (44.92)	.40	.40	0	0	.11	.17	.06	54	.94	.97	.03	3	.65	.76	.11	17
Tracy (40.62)	.42	.39	−.03	−7	.11	.17	.06	54	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	.85	.85	0	0	.68	.69	.01	1
Derby (34.88)	.40	.37	−.03	−7	.11	.17	.06	54	.78	.79	.01	1	.72	.65	−.07	−10
Reach average error:	—	—	−.02	−5	—	—	.06	55	—	—	0	0	—	—	.04	9
Truckee River below Derby Dam																
Below Derby (34.52)	0.38	0.37	−0.01	−3	—	—	—	—	0.78	0.78	0	0	—	—	—	—
Painted Rock (29.97)	—	—	—	—	.12	.18	.06	50	—	—	—	—	.60	.56	−.04	−7
Wadsworth (23.69)	.32	.35	.03	9	.13	.19	.06	46	.48	.40	−.08	−17	.40	.46	.06	15
Dead Ox (13.18)	.23	.27	.04	17	.11	.19	.08	73	.25	.19	−.06	−24	.28	.30	.02	7

TABLE 27.—Results of calibration and validation for mean daily total phosphorus—Continued

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Nixon (3.22)	.19	.22	.03	16	.11	.19	.08	73	.15	.17	.02	13	.24	.22	-.02	-8
Marble Bluff (0.00)	.22	.18	-.04	-18	.11	.19	.08	73	.28	.10	-.18	-64	.26	.15	-.11	-42
Reach average error:	—	—	.01	4	—	—	.07	63	—	—	-.06	-18	—	—	-.02	-7
Average error for river:	—	—	.005	-.5	—	—	.06	59	—	—	-.03	-9	—	—	.01	1
Truckee Canal																
Derby Dam (31.42)	0.40	—	—	—	0.11	—	—	—	0.78	—	—	—	0.72	—	—	—
Highway 95A (18.23)	.38	.32	-.06	-16	.10	.11	.01	10	.82	.71	-.11	-13	.60	.66	.06	10
Allendale (11.07)	—	—	—	—	.10	.10	0	0	—	—	—	—	.52	.59	.07	13
Highway 50 (3.25)	.35	.30	-.05	-14	.11	.10	-.01	-10	.79	.56	-.23	-29	.35	.51	.16	46
Average error:	—	—	-.05	-15	—	—	0	0	—	—	-.17	-21	—	—	.10	23

The dummy phosphorus loads required for calibration of phosphorus are summarized in table 28. Listed are the apparent input loads, that is the simple differences between upstream and downstream observed loads assuming conservative transport, and the calibrated loads assuming a uniformly distributed nonpoint source and a decay coefficient of 0.25. Note that for the August 1979 data, phosphorus had to be added in the Vista Pool to bring calculated loads at Lockwood up to observed levels. No loads were required to calibrate the June 1980 concentrations. At the high discharges during the June 1980 study (2,020 ft^3/s at Vista), load differences of 200 lb/day are represented by small changes in concentration (±0.01 mg/L), and are not significant to calibration.

Alternative hypotheses for sources of the phosphorus accretion in this reach were explored by examining available monitoring data. Historical data show accretions during the winter non-irrigation season, eliminating irrigation returns or algal recycling as the primary source of phosphorus. Release of phosphorus from bed sediments was tested as a potential source by calculating release rates required to produce the observed gains during the synoptic studies. These estimates were minimized by assuming bed sediments over the entire reach were contributing phosphorus (much of the streambed in the Lockwood to Patrick reach actually consists of coarse sediments that would be unlikely to provide significant capacity for phosphorus exchange). Results of these estimates are included in table 28, and indicate that the minimum rates of bed exchange required to provide the observed phosphorus accretion are orders of magnitude greater than phosphorus exchange rates observed by other investigators (table 29), thus suggesting direct exchange with bed sediments is not likely to be the principal source of phosphorus accretion.

Tables 28 and 29 near here

TABLE 28.--Phosphorus accretions in the reach from Vista to Patrick, synoptic data sets

Apparent load accretion: Simple difference between downstream and upstream loads based on observed data for the reach.

Calibrated nonpoint dummy load: Required additional load to achieve calibration for the reach with a uniform first-order decay rate of 0.25 per day (base e at 25°C) and with diversions, surface returns, and ground-water inflows modeled as specified in tables 16-19 and C8.

Maximum equivalent bottom sediment release rate: Bottom sediment release rate to produce calibrated nonpoint loads assuming entire bed surface of reach is releasing phosphorus.

Synoptic data set		Reach	Model segments	Apparent load accretion (lb/day)		Calibrated nonpoint dummy load (lb/day)	Reach length (miles)	Estimated total bed area ($ft^2 \times 10^6$)	Maximum equivalent bottom sediment release rate ($mg/day/m^2$)
				Ortho-P	Total P				
(A)	6/79	Lockwood-Patrick	7-11	110	80	140	5.13	3.1	220
(B)	8/79	Vista Pool	3	130	240	180	1.30	.83	1,060
		Lockwood-Patrick	7-11	430	450	540	5.13	2.9	910
(C)	6/80	No adjustment--predicted concentrations within 0.03 mg/L of observed	--	0	0	0	0	0	0
(D)	8/80	Lockwood-Patrick	7-11	330	240	360	5.13	2.9	610

Notes: Average apparent load accretions for State monitoring data for Vista to Tracy for 5/82 - 8/83:
All data--Ortho-P = 13 lb/day, Total P = 250 lb/day.
Censored data--Ortho-P = 205 lb/day, Total P = 505 lb/day (data excluded based on concentration differences of 0.02 mg/L or less.
Load accretion = (Tracy concentration - Vista concentration) x Tracy discharge x 5.394.

Conversion factor: $(lb/day/ft)^2 \times 4.88 \times 10^{-6} = mg/day/m^2$

TABLE 29.—Published rates of phosphorus release from aquatic sediments

Release rate (mg/d)/m² as P	Qualifications	Type or area of study	Reported by
154	(maximum anaerobic)	Simulated sludge	Fillos and Molof, 1972[a]
3	(average aerobic)		
91	(maximum anaerobic)	Muddy River, Mass.	Capaccio, 1971[a]
3	(average aerobic)		
9–10	(average aerobic)	Lake Baldeggersee (*in situ*)	Vollenweider, 1968[a]
.031	(estimated)	Doboy Sound	Pomeroy and others, 1965[a]
96	(maximum anaerobic)	Muddy River, Mass. (eutrophic)	Fillos and Swanson, 1975
9.6	(average aerobic)		
26	(maximum anaerobic)	Lake Warren, Mass. (eutrophic)	do.
1.2	(average aerobic)		
.03		Potomac Estuary (*in situ*)	Callender and Hammond, 1982
1.1–1.5	(aerobic, filtered native water)	Lahontan Reservoir, Nev.	Richard-Haggard, 1983
7.9–8.6	(anaerobic, filtered native water)		
12–15	(aerobic, distilled water)		
19–22	(anaerobic, distilled water)		
15	(estimated, anaerobic)	Lahontan Reservoir, Nev.	Bryce, 1981[b]
6–30		—	Holdren, 1977[b]
Total P:		Liberty Lake, Wash.	Mawson and others, 1983
1.3/.045	(anaerobic/aerobic, organic muck)		
3.0/.096	(anaerobic/aerobic, silt)		
Dissolved P:			
.65/.002	(anaerobic/aerobic, muck)		
1.7/.073	(anaerobic/aerobic, silt)		
Soluble Reactive P:			
.74/.004	(anaerobic/aerobic,) muck)		
.66/2.3x10⁻⁵	(anaerobic/aerobic, silt)		
4.0–10.8	(anoxic)	5 lakes	Sonzogni and others, ~~1977~~ 1982[c]

[a] Reported by Fillos and Swanson, 1975.
[b] Reported by Richard-Haggard, 1983.
[c] Reported by Mawson and others, 1983.

Although the source of phosphorus accretion in the Lockwood to Patrick reach is not known, the existance of similar increases in concentrations in other data collected both before (Pacific Environmental Laboratory, 1979) and after (Nevada Division of Environmental Protection Truckee River monitoring data) the 1979-80 synoptic studies indicates that the accretion is persistent and needs to be accounted for in simulations of phosphorus in the river. The relative magnitude of this unknown source (or sources) of phosphorus in the Lockwood to Patrick reach in comparison with other sources is illustrated in the pie diagrams in figure 31 and 32. For two of the three studies, the dummy phosphorus loads (pie segment 7) exceeded the sum of all agricultural returns to the river from Vista to Marble Bluff (segment 5), and for the August 1979 study, the total dummy loading was near the loading from the STP effluent (segment 4).

On the basis of the dummy loads required to calibrate observed data at Patrick and monitoring data collected during 1982 and 1983, an average dummy nonpoint load of 280 lb/day (with a concurrent assimilation rate coefficient of 0.25) is suggested for realistic modeling accretion in the reach of both ortho- and total phosphorus in the Lockwood to Patrick reach. Given the significant magnitude of this source in relation to other phosphorus sources in the model, and the possibility that the source is related to historic, relatively high discharges of phosphorus from the STP, model simulations in this report will be made both with, and without, the dummy source being included.

To summarize the above discussion of phosphorus calibration:

1. The removal (assimilation) coefficient of 0.25 for phosphorus (ortho and dissolved) was calibrated and verified from data collected for the four independent synoptic studies for the river starting at Patrick (RM 44.9) and thus is independent of any consideration of sources in the reach from Steamboat Creek to Patrick.

2. Using the calibrated removal coefficients, the measured loads of phosphorus at known upstream sources were insufficient to reproduce the phosphorus concentrations observed at Patrick in three of the four synoptic studies. The imbalance was equivalent to an average distributed nonpoint loading of 280 lb/day of phosphorus for the reach from Lockwood to Patrick. Future phosphorus simulations in this report will be made both with, and without, this "dummy" loading required to reproduce the observed conditions in the synoptic studies.

3. Using the "dummy" loading to simulate the observed phosphorus concentrations allows questions regarding potential causes of the anomaly to be addressed external of the calibrated river assimilation rates. The external phosphorus loadings to the model, including the "dummy" loads, can be changed without changing the internal simple first-order formulation of phosphorus dynamics.

4. If future investigations determine the causes of the phosphorus anomaly, the rate coefficients for phsophorus removal in the reach from Vista to Patrick should be re-evaluated.

Calibration of phosphorus removal coefficients for the canal was more straightforward, with uniform value of 0.10 derived as an average for all data sets (table 24). For the August 1979 data set, the observed phosphorus concentrations in the canal actually increased between Derby Dam and Highway 95A near the Fernley Check (figures 33 and 34). A similar trend can be seen for the June 1979 data set. Since the canal has no known inputs other than the diversions at Derby Dam, and similar increases between observation points have been noted for other constituents such as $CBOD_u$, no attempt was made to quantify these increase in concentrations. Possible explanations include release from bed sediments, release from decaying algae or rooted aquatic plants, and sampling errors.

Figures 33 and 34 near here

Although the precision of predicted phosphorus concentrations in the canal for the two August data sets is not as good as for other variables, the predictions generally follow observed trends rather well. Average errors for the four data sets were -3 percent for both ortho- and total phosphorus. More precise calibration would have to account for the algal cycling of phosphorus and would likely result in seasonally dependent calibration coefficients.

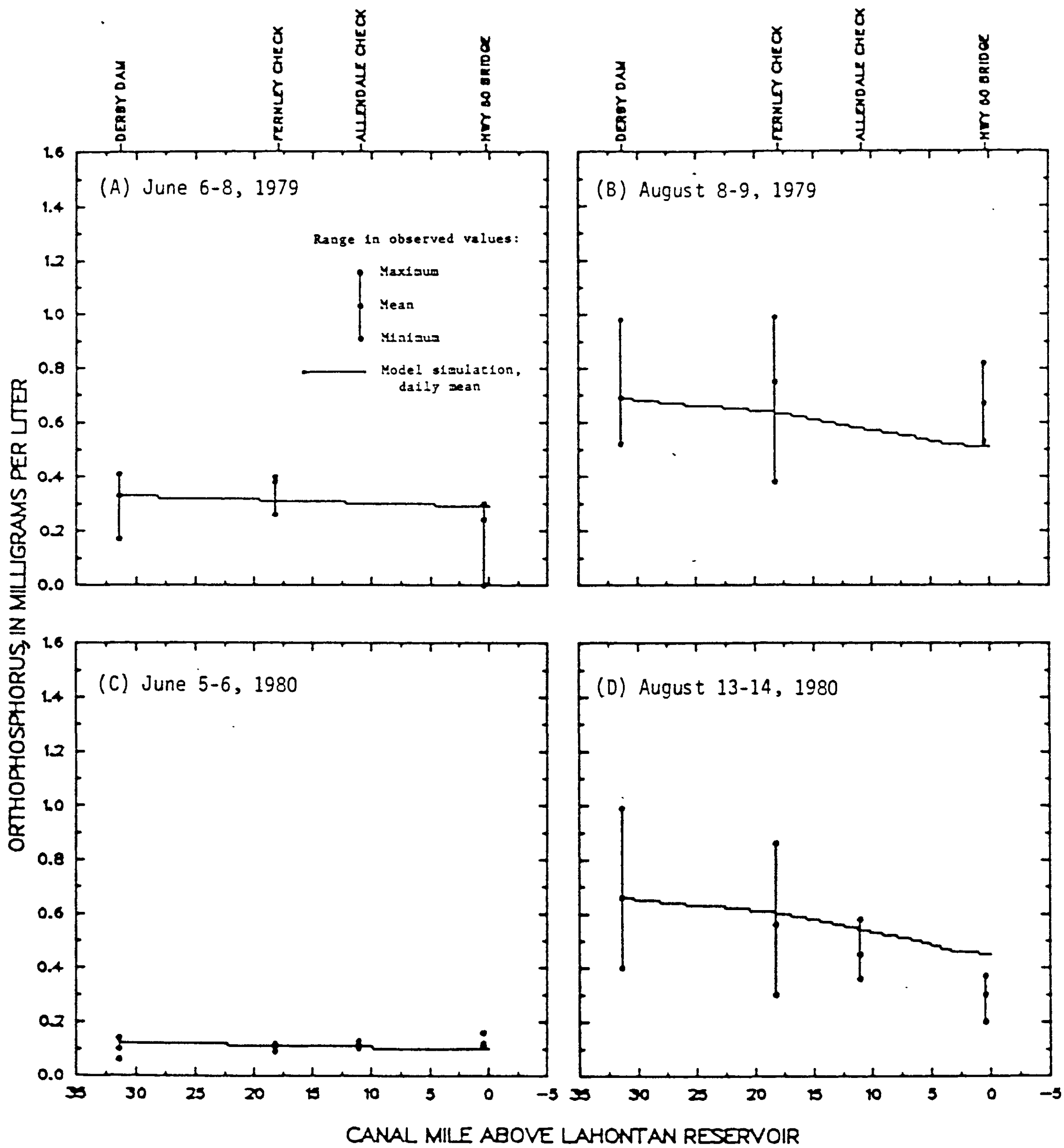


FIGURE 33.--Simulated and observed concentrations of orthophosphorus during synoptic studies, Truckee Canal.

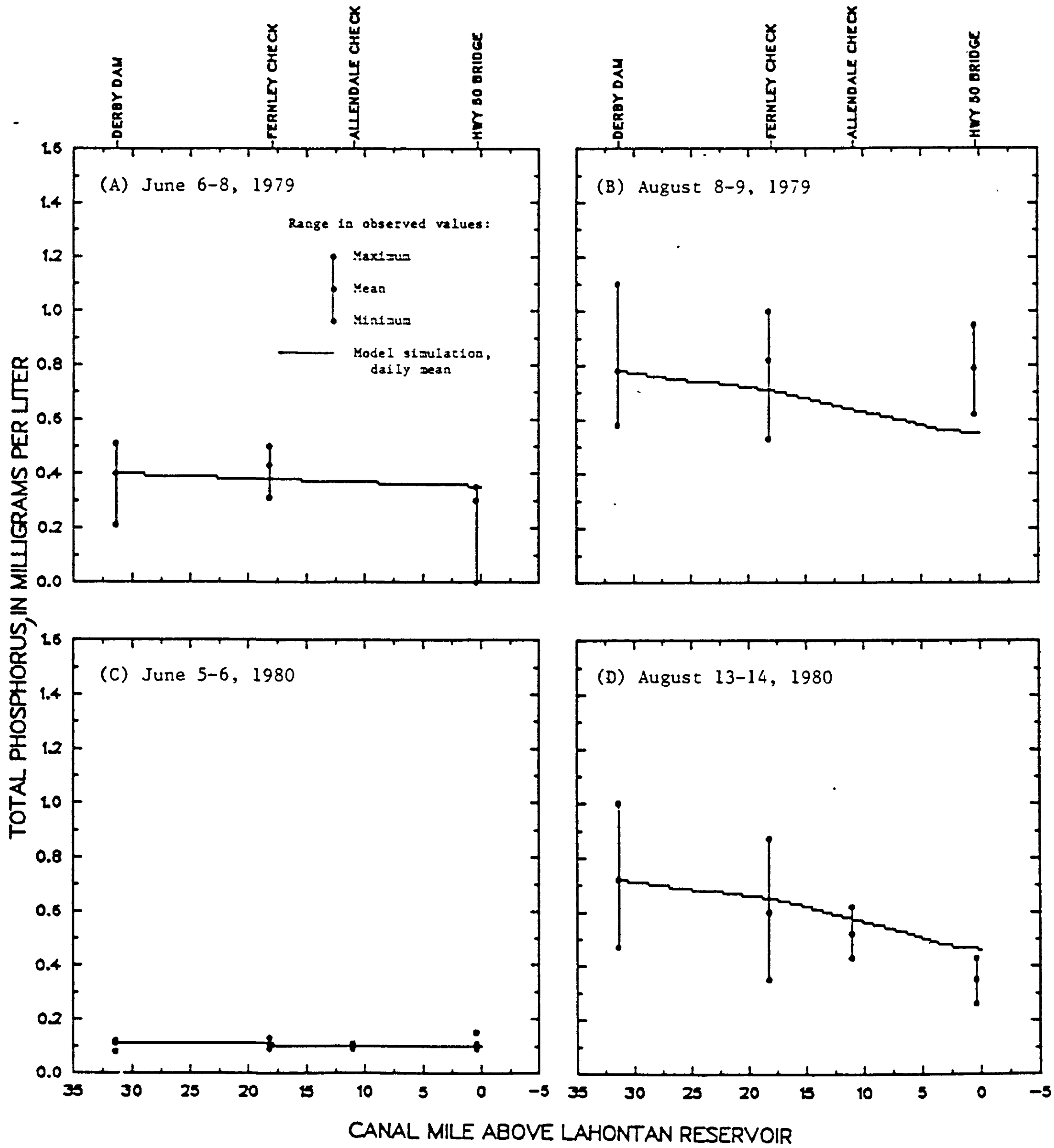


FIGURE 34.--Simulated and observed concentrations of total phosphorus during synoptic studies, Truckee Canal.

Nitrogen Cycle

Modeling the nitrogen cycle involves a set of reactions following the sequence of transformations from organic-nitrogen to nitrate-nitrogen (figure 11). For all nitrogen species except nitrate, there are two reaction coefficients to calibrate, the total instream removal and a coefficient for the forward reaction to the next species in the cycle. Calibration of coefficients for the nitrogen cycle was an iterative process starting with organic-nitrogen and working sequentially to nitrate. For each species, the instream decay coefficient was first calibrated to observed values, with the forward rate coefficient set equal to the total decay coefficient, using an uniform value for the entire river and canal. Thus all organic-nitrogen was assumed to transform to ammonia, all ammonia to nitrite, etc. Once the process had been completed for all species, forward coefficients were fine-tuned by fitting the shape of the resultant profiles to observed values. Changes to forward coefficients sometimes required changes to the total removal coefficients, resulting in another pass through the process.

Organic-nitrogen

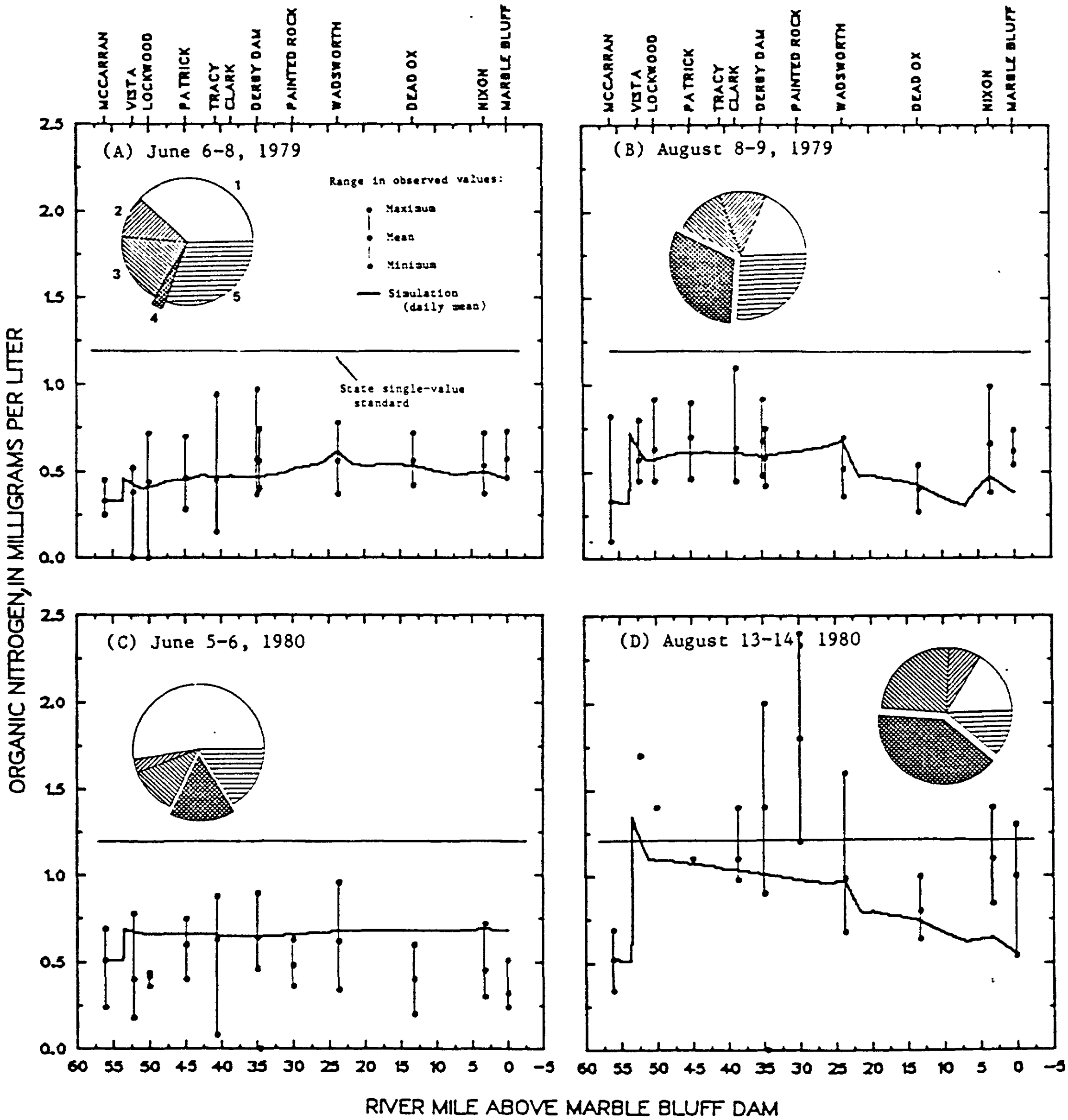
The upstream river was the major source of organic-nitrogen in the June synoptic studies and the STP during the August studies (figure 35). Below Derby Dam, modeled loadings from surface irrigation returns contribute from about 20 to 50 percent of the total loads to the reach (table 21).

Organic-nitrogen concentrations in the model are controlled by the instream removal coefficient, K_{ONR}. Initial estimates of K_{ONR} were obtained by graphical analysis in a manner similar to that described previously for CBOD. Coefficients were then adjusted to obtain an adequate fit to observed data. Final coefficients are given in table 24, and the results shown graphically for the river in figure 35 and for the canal in figure 36.

Organic-nitrogen is generally the least precise analysis for nitrogen parameters, as reflected in the relatively wide range in observed values shown in figure 35 and 36. Given the variability and lack of precision in the field data, little attempt was made to fine-tune the calibration. An average value of 0.10 was used for most of the river, with the coefficient increased to 1.7 through the Vista pool. The best average fit for the Truckee Canal was obtained with a removal coefficient of 0.05. Forward coefficients for all segments except in the Vista pool (segments 3 and 4) were set equal to the decay coefficient, implying total conversion to ammonia. In the Vista pool, the difference between K_{ONR} (1.7) and the forward coefficient K_{ONF} (0.8) indicates that about half the organic-nitrogen is lost to sinks within the pool, probably due to sedimentation in this low-velocity reach.

Figures 35 and 36 near here

The match between simulated and observed values for organic-nitrogen in the river was generally best above Derby Dam, where the effects of nonpoint returns are less than below the Dam. The best fit was obtained for the June and August 1979 data sets, with average prediction errors of -6 and -10 percent (table 30). Concentrations below Derby Dam were over-predicted for June 1980, suggesting that the estimated inputs for nonpoint returns were too high for the sampled conditions. In contrast, simulated concentrations at, and below, Derby Dam were lower than observed at most sites for the August 1980 data set. Given the relatively large scatter of values for this data set, the relatively poor fit may be due to analytical errors as much as to errors in estimations of nonpoint returns. The relative low coefficients for the rate of hydrolysis of organic-nitrogen to ammonia removal in comparison to



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 35.--Simulated and observed concentrations of organic nitrogen during synoptic studies, Truckee River.

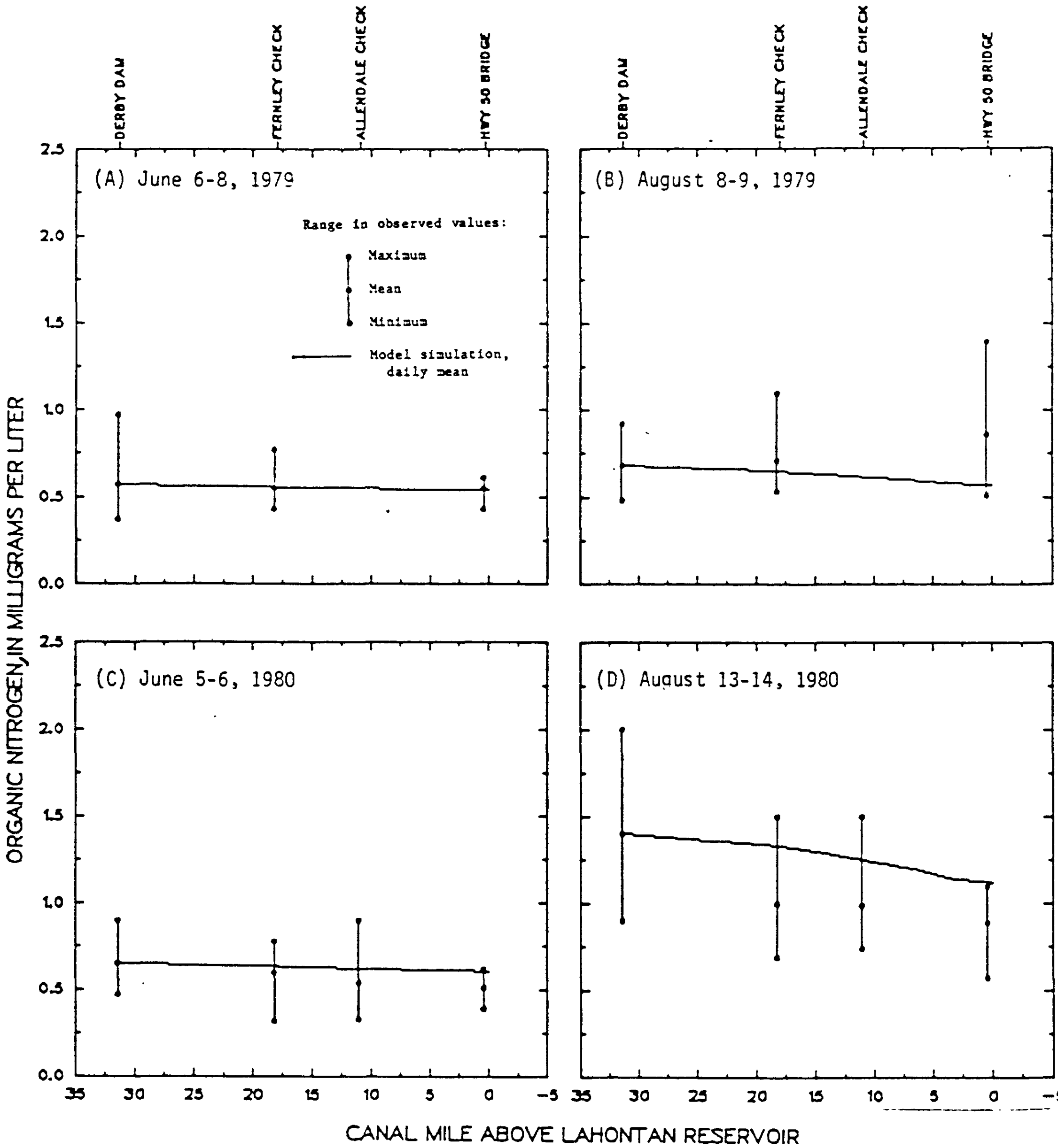


FIGURE 36.--Simulated and observed concentrations of organic nitrogen during synoptic studies, Truckee Canal.

the coefficients for ammonia for most river segments indicate that errors in the prediction of organic-nitrogen will have little effect on simulated concentrations of other nitrogen species.

Table 30 near here

In the Truckee Canal, the best matches of simulated to observed concentrations for organic-nitrogen were obtained with the two June data sets (table 30). For the August 1979 data, the observed concentration at the Highway 50 sampling site near the end of the canal was higher than at the upstream site near Fernley. This could be due to decay of algae in the canal, to sampling or analytical errors, or to errors from sampling periods being significantly less than traveltimes for the canal. In the August 1980 data set, the consistent overprediction below Derby Dam is probably due to errors in sampling or analysis at Derby Dam; the amount of error is about the same as the underprediction for the river at Derby Dam.

Ammonia-nitrogen

The STP was the dominant source of ammonia-nitrogen to the river above Derby Dam for all four synoptic studies, contributing from 70 to 98 percent of the total loading (figure 38). Modeled concentrations in irrigation returns were relatively low (0.1 mg/L); irrigation returns composed from 4 to 33 percent of the total load to the river below the dam.

Figure 37 near here

Simulated concentrations of ammonia-nitrogen in the river agree well with observed data except for the August 1980 data in the reach from the tributaries to Tracy (figure 37). As explained in Appendix A, the observed data shown for Vista to Patrick for this data set are single estimated values due to laboratory errors with the total kjeldahl (organic plus ammonia-nitrogen) determinations. The good fit below Tracy and the good fit of

TABLE 30.—Results of calibration and validation for mean daily organic nitrogen

[Observed and simulated results for synoptic studies, in milligrams per liter as N; Percent error calculated by [(observed - simulated)/observed] x 100.]

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	0.33	—	—	—	0.51	—	—	—	0.33	—	—	—	0.52	—	—	—
Vista (52.23)	.38	0.43	0.05	13	.40	0.69	0.29	72	.57	0.63	0.06	10	1.7	1.3	-0.4	-23
Lockwood (50.05)	.44	.41	-.03	-7	.42	.68	.26	62	.63	.57	-.06	-9	1.4	1.2	-.2	-14
Patrick (44.92)	.46	.45	-.01	-2	.60	.68	.08	13	.70	.61	-.09	-13	1.1	1.2	.1	9
Tracy (40.62)	.45	.48	.03	7	.63	.67	.04	6	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	.64	.61	-.03	-5	1.1	1.1	0	0
Derby (34.88)	.57	.47	-.10	-17	.64	.66	.02	3	.68	.59	-.09	-13	1.4	1.1	-.3	-21
Reach average error:	—	—	-.01	-1	—	—	.14	31	—	—	-.04	-6	—	—	-.2	-10
Truckee River below Derby Dam																
Below Derby (34.52)	0.56	0.47	-.09	-16	—	—	—	—	0.58	0.60	0.02	3	—	—	—	—
Painted Rock (29.97)	—	—	—	—	0.48	0.68	0.20	42	—	—	—	—	1.8	1.0	-0.8	-44
Wadsworth (23.69)	.56	.62	.06	11	.62	.70	.08	13	.52	.68	.16	31	.99	1.0	.1	10
Dead Ox (13.18)	.56	.53	-.03	-5	.40	.70	.30	75	.40	.42	.02	5	.80	.77	-.3	-37

TABLE 30.—Results of calibration and validation for mean daily organic nitrogen—Continued

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Nixon (3.22)	.53	.50	-.03	-6	.45	.70	.25	55	.66	.47	-.19	-29	1.1	.67	-.43	-39
Marble Bluff (0.00)	.57	.45	-.12	-21	.32	.70	.38	119	.62	.37	-.25	-40	1.0	.57	-.43	-43
Reach average error:	—	—	-.04	-7	—	—	.24	61	—	—	-.05	-6	—	—	.37	-31
Average error for river:	—	—	-.02	-4	—	—	.19	46	—	—	-.04	-6	—	—	-.28	-20
Truckee Canal																
Derby Dam (31.42)	0.57	—	—	—	0.64	—	—	—	0.68	—	—	—	1.4	—	—	—
Highway 95A (18.23)	.55	0.56	0.01	2	.60	0.63	0.03	5	.70	0.65	-0.05	-7	1F0	1.3	0.3	30
Allendale (11.07)	—	—	—	—	.54	.61	.07	13	—	—	—	—	.99	1.3	.4	40
Highway 50 (3.25)	.55	.54	-.01	-2	.51	.60	.09	15	.86	.58	-.28	-32	.88	1.2	.32	36
Reach average error:	—	—	0	0	—	—	.06	11	—	—	-16	-19	—	—	.34	35

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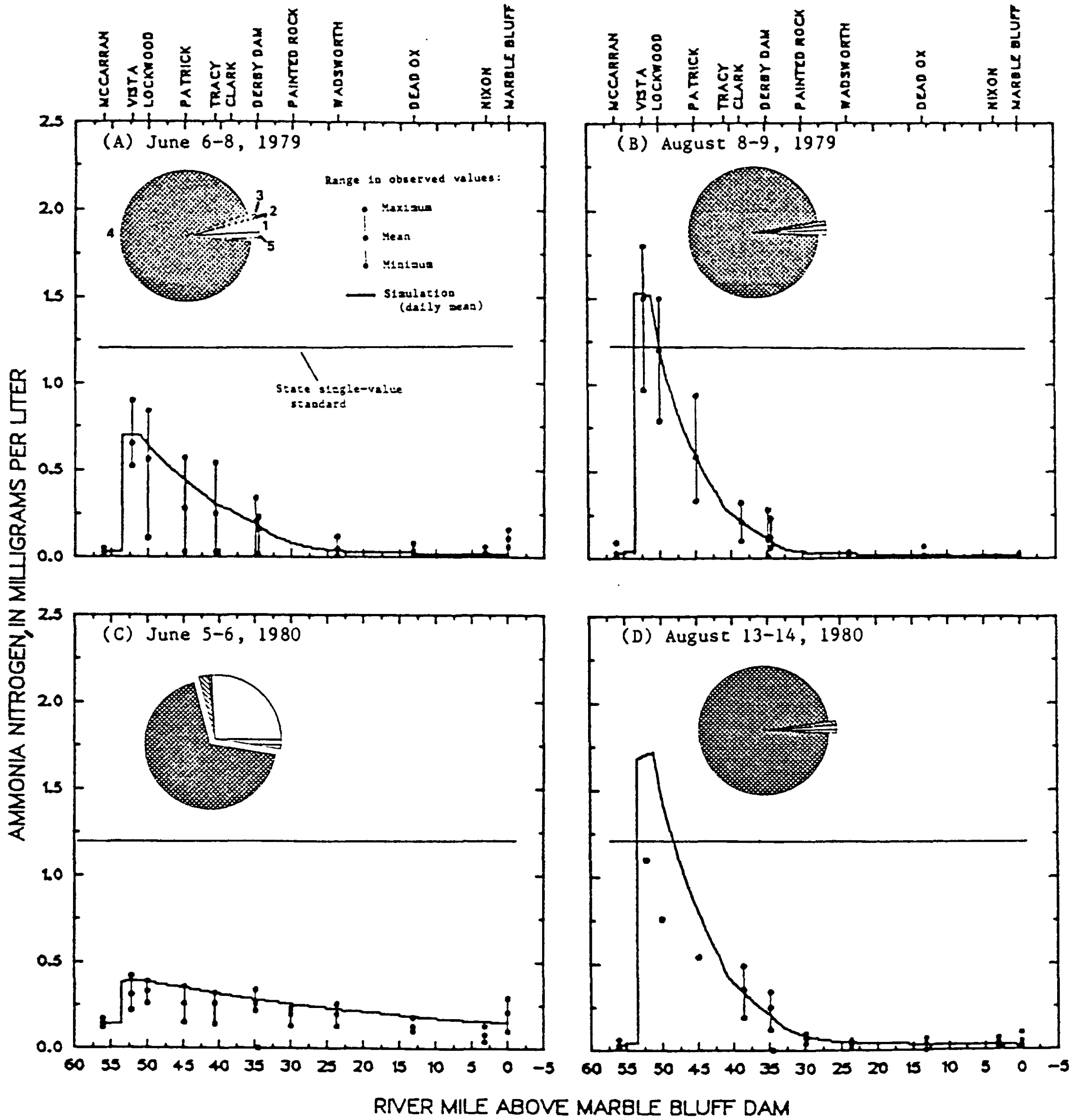


[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 37.--Simulated and observed concentrations of ammonia nitrogen during synoptic studies, Truckee River.

resultant nitrite and nitrate predictions resulted in these three suspect data points being ignored in the calibration for ammonia. Final rate coefficients for ammonia removal (K_{NH3R}) and oxidation to nitrite (K_{NH3F}) were equal and set to 0.40 for model segments 1 through 4 (RM 51.25) and to 2.4 for the remainder of the river. The change in values at segment 5 is reasonable in consideration that the food source for the nitrifying bacteria (STP effluent) is absent above Steamboat Creek. Raising the values of coefficients for nitrification below the Vista pool fits with the known channel morphology; more suitable habitat exists for the nitrifying bacteria in the shallow, faster downstream reach than in the deeper, low-velocity pool. Simulation errors for ammonia averaged 24 percent (0.12 mg/L) above Derby Dam and 18 percent (0.05 mg/L) below (table 31).

The rate coefficient of 2.4 for ammonia oxidation for the river below the Vista pool (segment 4, RM 51.25) is within the upper limit of ranges of reported nitrification coefficients from other river studies (O'Connor and DiToro, 1970; Bansal, 1976; Bowie and others, 1985). The only previous study resulting in a calculated nitrification coefficient of 2.4 (base e) from observations of ammonia, nitrite, nitrate, and traveltime. This rate is widely quoted in summaries of rate constants, including the above references; however, it is not clear from the original reference whether the rate was referenced to ambient temperature or corrected to a standard reference temperature (and, if so, what temperature coefficient was used). The original reference gives the ambient temperature for the survey as 21.8 °C (all subsequent references have misquoted the temperature as 27.8 °C). If the coefficients were calculated at ambient temperature, the coefficient at 20 °C would be 2.1, compared to the coefficient of 2.4 used in the TRWQ model. In modeling studies of the Arkansas River in Colorado using an earlier version of the TRWQ model computer program, ~~an~~ ammonia oxidation coefficients (KNH4F) were calibrated at 2.0 to 2.5 with a total removal coefficient (K_{NH4R}) of a rate of 2.5 for the 42-mile reach modeled (Cain and others, 1980).

Table 31 near here

A relatively low ammonia oxidation rate coefficient of 0.9 was calibrated for the entire length of the Truckee Canal. The fit between simulated and observed values was good for all sites in all four data sets (figure 38). The lower values for the canal in comparison to the river are consistent with the lack of expected habitat for nitrifying bacteria in the deeper, lower-velocity cross-sections in the canal.

Figure 38 near here

Un-ionized ammonia

Un-ionized ammonia concentrations are a function of total ammonia, pH, and water temperature (Willingham, 1976), and are calculated by the model from simulated total-ammonia concentrations (equations 17). A comparison of simulated to observed concentrations of un-ionized ammonia is shown in figure 39 for the river and figure 40 for the canal; results are tabulated in table 33. The accuracy of the simulated values are a function of the precision of calibration of total ammonia and the representativeness of the average pH and temperature values used for the model segments (table 32). Of interest is the wide range in un-ionized ammonia exhibited in the three data sets with low to medium flows (August 1979 and 1980, June 1979). For these studies, large daily ranges in pH were observed, principally due to the high maximum daytime pH values from photosynthesis, resulting in concomitant increases in the percentage of ammonia in un-ionized form, which varies exponentially with pH. Both the observed data and the simulations indicate that instream concentrations of un-ionized ammonia in reaches with high rates of algal

TABLE 31.—Results of calibration and validation for mean daily ammonia nitrogen

[Observed and simulated results for synoptic studies, in milligrams per liter as N; Percent error calculated by [(observed-simulated)/observed] X100.]

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	0.03	—	—	—	0.14	—	—	—	0.03	—	—	—	0.03	—	—	—
Vista (52.23)	.65	0.70	0.05	8	.31	0.45	0.14	45	1.5	1.5	0	0	1.1E	1.7	0.6	54
Lockwood (50.05)	.56	.64	.08	14	.33	.45	.12	36	1.2	1.2	0	0	.76E	1.5	.74	97
Patrick (44.92)	.28	.45	.17	61	.26	.41	.15	58	.58	.58	0	0	.54E	.80	.26	48
Tracy (40.62)	.25	.30	.05	20 ~~60~~	.26	.37	.11	42	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	.21	.21	0	0	.35	.34	-.01	-3
Derby (34.88)	.21	.19	-.02	-10	.26	.33	.07	27	.11	.12	-0.01	-9	.25	.21	-.04	-16
Reach average error:	—	—	.07 ~~.09~~	19 ~~27~~	—	—	.12	42	—	—	0	-2	—	—	.29	36
Truckee River below Derby Dam																
Below Derby (34.52)	0.16	0.18	0.02	12	—	—	—	—	0.12	0.10	-0.02	-17	—	—	—	—
Painted Rock (29.97)	—	—	—	—	0.20	0.30	0.10	50	—	—	—	—	0.07	0.08	0.01	14
Wadsworth (23.69)	.05	.04	.01	20	.20	.26	.06	30	.02	.03	.01	50	.04	.05	.01	25
Dead Ox (13.18)	.04	.03	-.01	-25	.13	.22	.09	69	.02	.02	0	0	.04	.03	-.01	-25

TABLE 31.—Results of calibration and validation for mean daily ammonia nitrogen--Continued

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Nixon (3.22)	.03	.02	-.01	-33	.08	.18	.10	125	.01	.02	.01	100	.04	.03	-.01	-25
Marble Bluff (0.00)	.11	.02	-.09	-82	.21	.17	-.04	-19	.02	.02	0	0	.05	.03	-.02	-40
Reach average error:	—	—	-.02	-22	—	—	.06	51	—	—	0	27	—	—	0	-10
Average error for river:	—	—	-.02	-1.5	—	—	.09	46	—	—	0	12	—	—	.14	13
Truckee Canal																
Derby Dam (31.42)	0.21	—	—	—	0.26	—	—	—	0.11	—	—	—	0.25	—	—	—
Highway 95A (18.23)	.09	0.15	0.06	67	0.19	0.18	-0.01	-5	0.06	0.07	0.01	17	.11	0.16	0.05	45
Allendale (11.07)	—	—	—	—	.19	.14	-.05	-26	—	—	—	—	.03	.10	.07	233
Highway 50 (3.25)	.04	.10	.06	150	.08	.10	.02	25	.01	.04	.03	300	.03	.08	.05	167
Reach average error:	—	—	.06	108	—	—	-.01	-2	—	—	.02	158	—	—	.06	148

E, estimated.

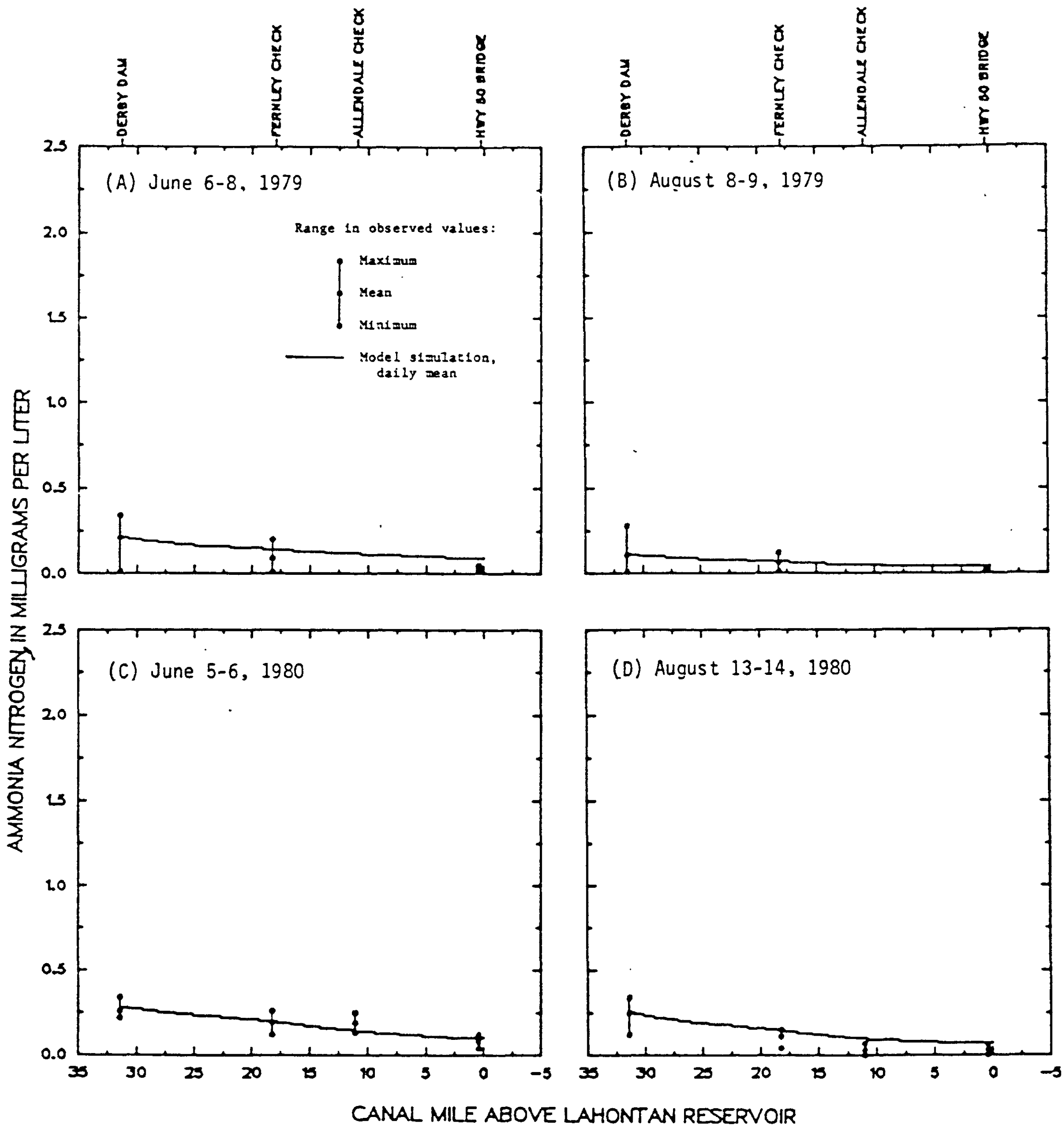


FIGURE 38.--Simulated and observed concentrations of ammonia nitrogen during synoptic studies, Truckee Canal.

productivity are likely to exceed the Nevada standard of 0.016 mg/L (based on fish toxicity) even with relatively low concentrations of total ammonia.

Tables 32 and 33 near here

Figures 39 and 40 near here

Nitrite-nitrogen

STP loads were the major source of nitrite to the river during the four synoptic studies, contributing from 43 to 77 percent of the total external loads above Derby Dam (figure 41 and table 21).

Figure 41 near here

Calibrated coefficients for nitrite oxidation (K_{NO2F}) were equal to the total removal coefficient (K_{NO2R}) for all segments of the river and canal (table 24), indicating complete nitrification of nitrite. Calibrated values for the coefficients were 1.0 in the river and tributaries above Steamboat Creek, 3.0 in the river below Patrick, and 0.70 through the Truckee Canal. In order to obtain a reasonable match to observed data for the August 1979 data set, coefficients were set to 10 for an approximately 5-mile reach below Steamboat Creek, and then dropped stepwise for about 3 miles to the base value of 3 at Patrick Bridge. The calibrated coefficients were then applied without change to the other three data sets. Calibration generally held for the June 1979 and August 1980 data sets, with the exception that nitrite concentrations were generally under-predicted from Vista to Clark in August 1980 (figure 41, table 34). Given the other uncertainties in nitrogen observations in that data set as noted above, no further attempt was made to fine-tune the calibration.

Table 34 near here

TABLE 32.—Water temperatures, barometric pressures, and pH's used in model calibration and validation

Model segment	Starting river mile	Length (mile)	(A) June 1979 Barometric pressure (mm Hg)	(A) June 1979 Water temperature (°C)	(A) June 1979 pH (units)	(B) August 1979 Barometric pressure (mm Hg)	(B) August 1979 Water temperature (°C)	(B) August 1979 pH (units)	(C) June 1980 Barometric pressure (mm Hg)	(C) June 1980 Water temperature (°C)	(C) June 1980 pH (units)	(D) August 1980 Barometric pressure (mm Hg)	(D) August 1980 Water temperature (°C)	(D) August 1980 pH (units)
(A) SUBMODELS:														
North Truckee Drain														
1 Kleppe Lane	0.26	0.26	650	18.0	8.5	650	20.0	7.9	645	12.5	8.1	645	17.5	7.8
Steamboat Creek														
1 Kimlick Lane	.75	.62	650	19.0	8.0	650	22.0	8.0	650	13.0	8.0	645	19.5	8.0
2 STP outfall	.13	.13	650	20.0	8.5	650	23.5	7.9	650	14.0	7.9	645	21.0	8.0
(B) MAINSTEM TRUCKEE RIVER:														
1 McCarran bridge	56.12	2.46	650	15.5	8.4	655	20.5	8.0	650	10.5	7.9	645	18.0	8.1
2 N. Truckee Drain	53.66	.13	650	15.5	8.4	655	20.0	8.2	645	10.5	7.9	645	18.0	8.2
3 Steamboat Creek	53.53	1.30	650	16.5	8.4	655	21.0	8.0	645	11.0	7.9	645	19.0	8.1
4 Vista gage	52.23	.98	650	17.0	8.1	655	21.0	7.7	645	11.0	7.8	645	19.5	8.0
5 Largomarsino diversion	51.25	.35	650	17.0	8.0	655	21.0	7.6	650	11.0	7.7	645	20.0	8.0
6 Below Largomarsino diversion	50.90	.85	650	17.0	8.0	655	21.5	7.5	650	10.5	7.7	645	20.0	7.9
7 Lockwood bridge	50.05	.15	650	17.5	8.0	655	21.5	7.4	650	10.5	7.6	645	20.0	7.9
8 Groton diversion	49.90	1.65	650	17.5	7.9	655	21.5	7.5	650	10.5	7.6	645	20.0	7.9
9 Mustang bridge	48.25	1.57	650	17.0	7.8	655	21.5	7.6	650	10.5	7.6	650	20.5	7.8
10 McCarran pool	46.68	.33	650	17.0	7.7	655	21.5	7.7	650	10.5	7.6	650	20.5	7.7
11 McCarran div.	46.35	1.43	650	17.0	7.6	655	21.5	7.8	650	10.5	7.6	650	20.5	7.7
12 Patrick bridge	44.92	2.04	650	17.5	7.7	655	22.0	7.8	650	10.5	7.5	650	20.5	7.7
13 SP Railroad bridge	42.88	.86	650	17.5	7.8	655	22.0	7.8	650	11.0	7.4	650	20.5	7.8
14 Hill diversion	42.02	1.26	650	18.0	7.9	655	22.0	7.8	650	11.0	7.3	650	21.0	7.8
15 Tracy diversion	40.76	.14	655	18.0	8.0	655	22.0	7.8	650	11.0	7.2	650	21.0	7.8
16 Tracy bridge	40.62	2.02	655	18.5	8.0	655	22.0	7.8	650	11.0	7.2	650	21.0	7.8
17 Clark bridge	38.60	1.50	650	19.0	8.0	655	22.0	7.8	650	11.0	7.2	650	21.0	7.9
18 RM 37.1	37.10	1.50	650	19.0	8.1	655	22.5	7.9	650	11.0	7.2	650	20.5	8.2
19 Derby pool	35.60	.72	650	19.5	8.1	655	22.5	8.0	650	11.0	7.2	650	20.5	8.4
20 Derby Dam	34.88	.36	655	19.5	8.0	655	23.0	8.0	650	11.0	7.2	650	21.0	8.5
21 Derby cableway	34.52	3.24	660	19.5	8.0	655	23.0	8.0	655	11.0	7.3	650	21.0	8.5
22 Washburn Dam	31.28	1.31	660	19.5	8.0	655	23.0	8.0	655	11.0	7.3	650	21.0	8.4
23 Painted Rock bridge	29.97	.62	660	19.5	8.1	660	23.0	8.0	655	11.5	7.4	650	21.5	8.4
24 Gregory-Monte diversion	29.35	1.35	660	19.5	8.2	660	23.0	8.1	655	11.5	7.5	650	21.5	8.4
25 RM 28.0	28.00	1.25	660	20.0	8.2	660	23.0	8.1	655	11.5	7.5	650	21.5	8.4

TABLE 32.—Water temperatures, barometric pressures, and pH's used in model calibration and validation—Continued

Model segment	Starting river mile	Length (mile)	(A) June 1979			(B) August 1979			(C) June 1980			(D) August 1980		
			Baro-metric pressure (mm Hg)	Water temper-ature (°C)	pH (units)	Baro-metric pressure (mm Hg)	Water temper-ature (°C)	pH (units)	Baro-metric pressure (mm Hg)	Water temper-ature (°C)	pH (units)	Baro-metric pressure (mm Hg)	Water temper-ature (°C)	pH (units)
26 Herman diversion	26.75	.80	665	20.0	8.3	660	23.0	8.1	655	11.5	7.6	650	22.0	8.4
27 Pierson diversion	25.95	2.05	665	20.0	8.3	660	23.0	8.1	655	11.5	7.6	650	22.0	8.4
28 Proctor diversion	23.90	.21	665	20.0	8.3	660	23.0	8.1	655	11.5	7.6	650	22.0	8.4
29 Wadsworth bridge	23.69	1.14	665	20.0	8.3	660	23.0	8.1	655	11.5	7.6	650	22.0	8.4
30 Fellnagle div.	22.55	1.15	665	20.0	8.4	660	23.0	8.2	655	11.5	7.6	650	22.0	8.4
31 RM 21.4	21.40	1.56	665	20.0	8.6	660	23.5	8.2	655	11.5	7.6	655	21.5	8.4
32 S Bar S diversion	19.84	2.02	665	19.5	8.8	660	24.0	8.3	660	12.0	7.7	655	21.5	8.5
33 S Bar S pump	17.82	2.00	665	19.5	9.0	660	24.0	8.4	660	12.0	7.7	660	21.5	8.5
34 RM 15.8	15.82	2.64	665	19.5	9.1	660	24.5	8.4	660	12.0	7.7	660	21.5	8.5
35 Dead Ox Wash	13.18	3.18	665	19.0	9.1	660	24.5	8.4	660	12.0	7.7	660	21.5	8.4
36 RM 10.0	10.00	.80	665	19.0	9.1	660	24.5	8.4	660	12.0	7.7	660	21.5	8.4
37 RM 9.2	9.20	.99	665	19.0	9.1	660	24.5	8.4	660	12.0	7.8	660	21.5	8.4
38 Numana Dam	8.21	.61	665	19.0	9.1	660	25.0	8.4	660	12.0	7.8	660	21.5	8.3
39 RM 7.6	7.60	.80	665	19.0	9.1	665	25.0	8.4	660	12.0	7.8	660	21.5	8.3
40 RM 6.8	6.80	2.80	665	19.0	9.1	665	25.0	8.4	660	12.0	7.8	660	21.5	8.2
41 RM 4.0	4.00	.78	665	19.0	9.1	665	25.0	8.4	660	12.0	7.8	660	21.5	8.2
42 Nixon bridge	13.22	2.22	665	18.5	9.1	665	24.0	8.6	660	12.0	7.8	660	21.0	8.2
43 RM 1.0	1.00	1.00	665	18.0	9.1	665	23.0	8.8	660	12.0	7.7	660	20.5	8.3
(C) TRUCKEE CANAL:														
C1 Derby Dam	31.42	6.04	650	19.0	8.0	655	23.0	8.1	655	11.0	7.3	650	21.0	8.2
C2 Pyramid check	25.38	2.84	655	19.0	7.9	655	23.0	8.2	655	11.5	7.5	650	21.0	7.9
C3 Tunnel No. 3	22.54	4.52	655	18.5	7.8	655	23.5	8.2	655	11.5	7.7	650	21.5	7.6
C4 Fernley check	18.02	2.95	655	18.5	7.7	655	23.5	8.3	655	11.5	7.8	650	21.5	7.4
C5 Anderson check	15.07	4.00	655	18.5	7.8	655	23.5	8.5	655	12.5	7.7	650	22.0	7.9
C6 Allendale check	11.07	4.68	655	18.5	8.0	660	23.5	8.8	655	13.0	7.8	650	22.0	8.2
C7 Mason check	6.39	3.14	655	18.5	8.1	660	24.0	8.9	655	13.5	8.0	650	22.0	8.3
C8 Bango check	3.25	2.81	655	19.0	8.1	660	24.0	9.0	655	13.5	8.2	650	21.5	8.4
C9 Highway 50	.44	.44	655	19.0	8.1	660	24.0	9.0	655	13.5	8.3	650	21.5	8.5

TABLE 33.—Results of calibration and validation for mean daily un-ionized ammonia

[Observed and simulated results for synoptic studies, in milligrams per liter as N; Percent error calculated by [(observed - simulated)/observed] x100.]

Site (River or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	0.002	—	—	—	0.002	—	—	—	0.002	—	—	—	0.002	—	—	—
Vista (52.23)	—	—	—	—	.005	0.007	0.002	40	.049	0.062	0.013	26	.051E	0.076	0.025	49
Lockwood (50.05)	.018	0.020	0.002	11	.003	.004	.001	33	.016	.017	.001	6	.023E	.044	.021	91
Patrick (44.92)	.006	.006	0	0	.002	.003	.001	50	.020	.016	-.004	-20	.017E	.016	-.001	-6
Tracy (40.62)	.013	.010	-.003	-23	.001	.001	0	0	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	.007	.006	-.001	-14	.014	.009	-.005	-36
Derby (34.88)	.012	.009	-.003	-25	.001	.001	0	0	.006	.005	-.001	-17	.029	.020	-.009	-31
Reach average error:	—	—	-.001	-9	—	—	.001	25	—	—	.002	4	—	—	.006	13
Truckee River below Derby Dam																
Below Derby (34.52)	0.005	0.006	0.001	20	—	—	—	—	.007	0.005	-0.002	-29	—	—	—	—
Painted Rock (29.97)	—	—	—	—	0.002	0.001	-0.001	-50	—	—	—	—	0.013	0.008	-0.005	-38
Wadsworth (23.69)	.025	.003	-.022	-88	.002	.002	0	0	.002	.002	0	0	.005	.005	0	0
Dead Ox (13.18)	.015	.008	-.007	-47	.002	.002	0	0	.003	.002	-.001	-33	.007	.004	-.003	-43

TABLE 33.—Results of calibration and validation for mean daily un-ionized ammonia—Continued

Site (River or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Nixon (3.22)	—	—	—	—	.001	.002	.001	100	.002	.003	.001	100	.003	.002	-.001	-33
Marble Bluff (0.00)	—	—	—	—	.002	.002	0	0	.007	.004	-.003	-43	.005	.002	-.003	-60
Reach average error:	—	—	-.009	-38	—	—	0	50	—	—	-.001	-1	—	—	-.002	35
Average error for river:	—	—	-.005	-23	—	—	.0005	37	—	—	.0005	1	—	—	.002	24
Truckee Canal																
Derby Dam (31.42)	0.012	—	—	—	0.001	—	—	—	0.006	—	—	—	0.029	—	—	—
Highway 95A (18.23)	.002	0.003	0.001	50	.002	0.002	0	0	.006	0.005	-0.001	-17	.001	0.003	0.002	200
Allendale (11.07)	—	—	—	—	.002	.002	0	0	—	—	—	—	.002	.004	.002	100
Highway 50 (3.25)	.002	.004	.002	100	.004	.002	-.002	-50	.003	.011	.008	267	.004	.006	.002	50
Reach average error:	—	—	.001	75	—	—	0	-17	—	—	.003	125	—	—	.002	117

E, estimated.

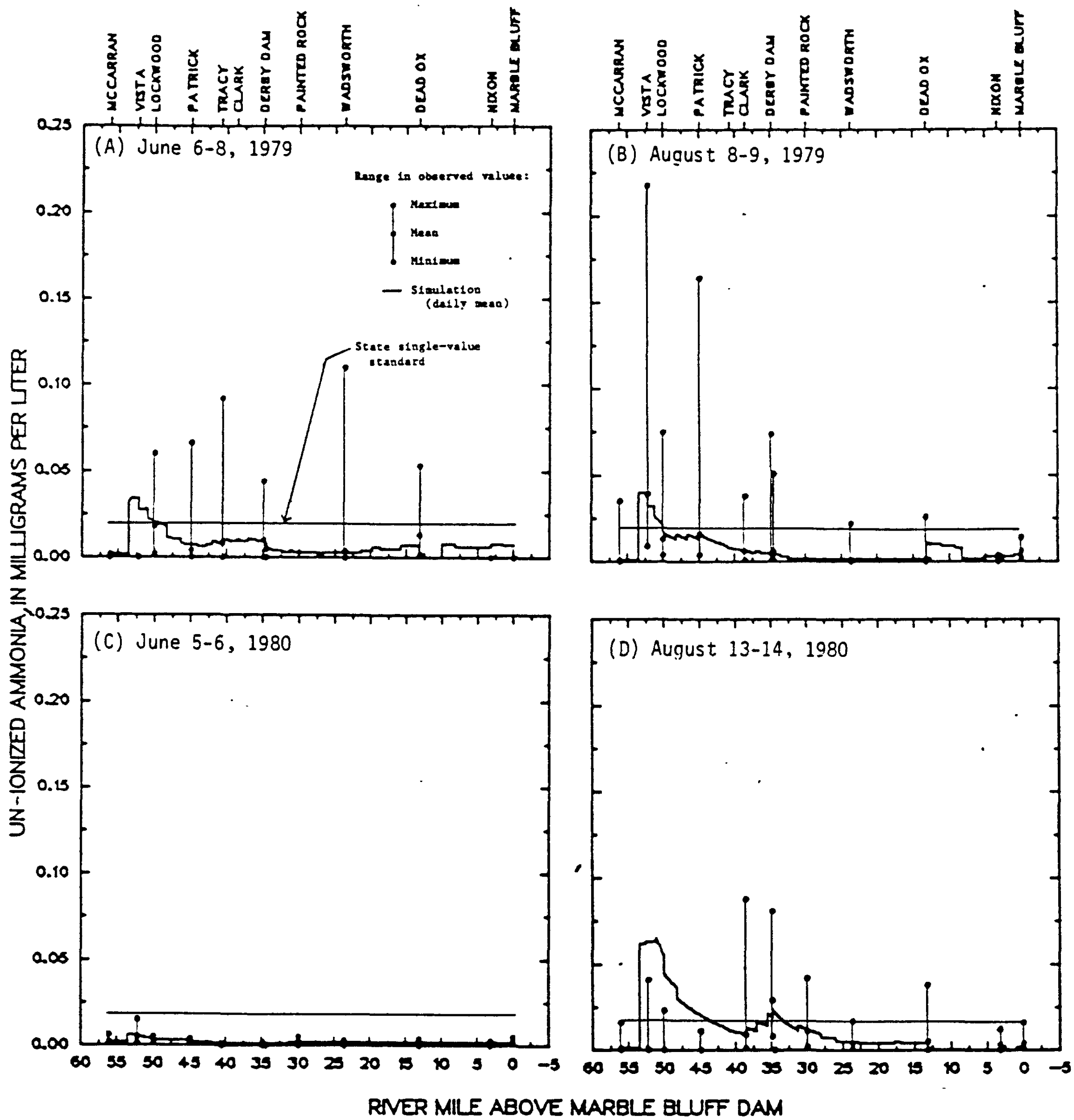


FIGURE 39.--Simulated and observed concentrations of un-ionized ammonia nitrogen during synoptic studies, Truckee River.

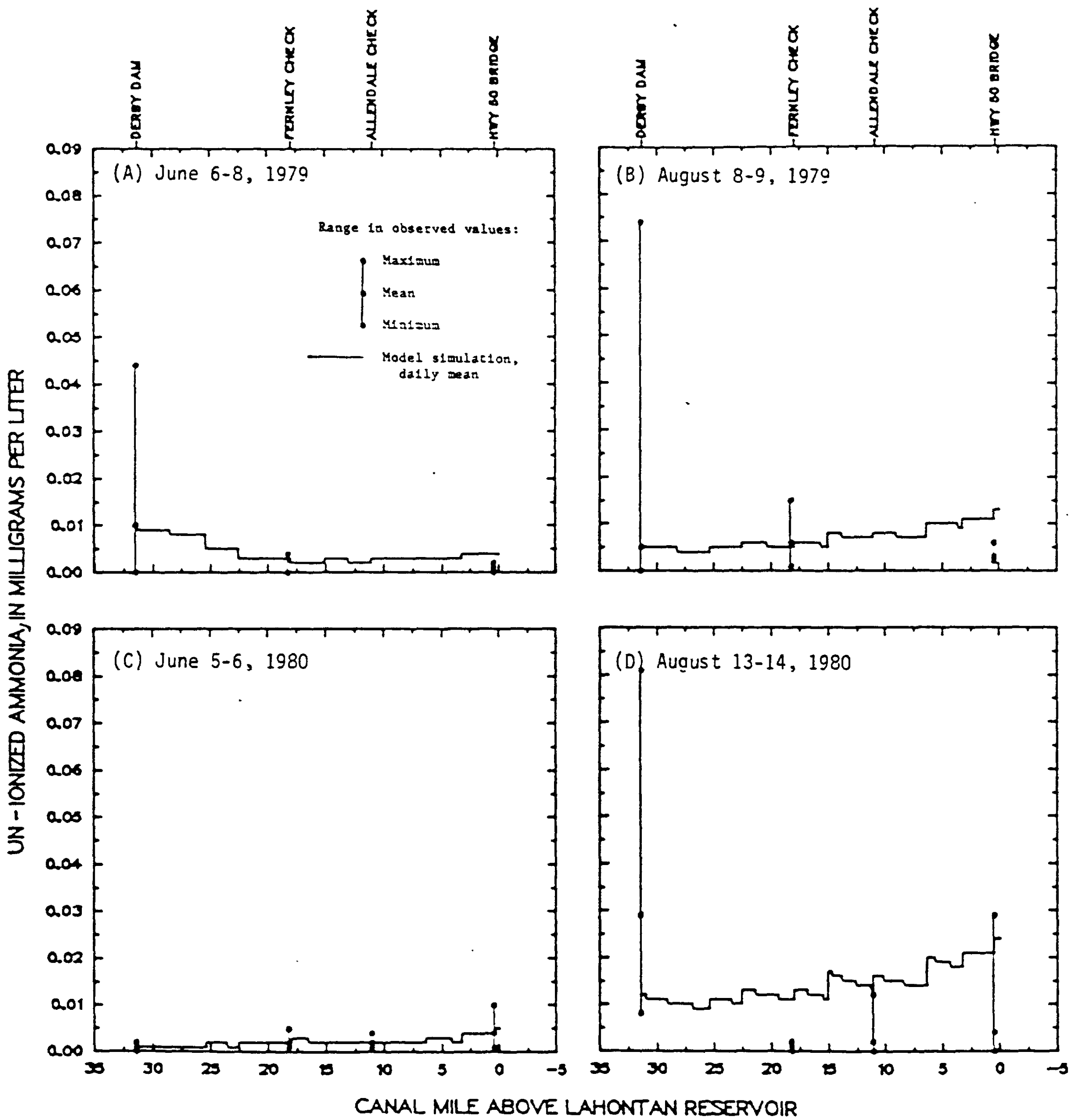
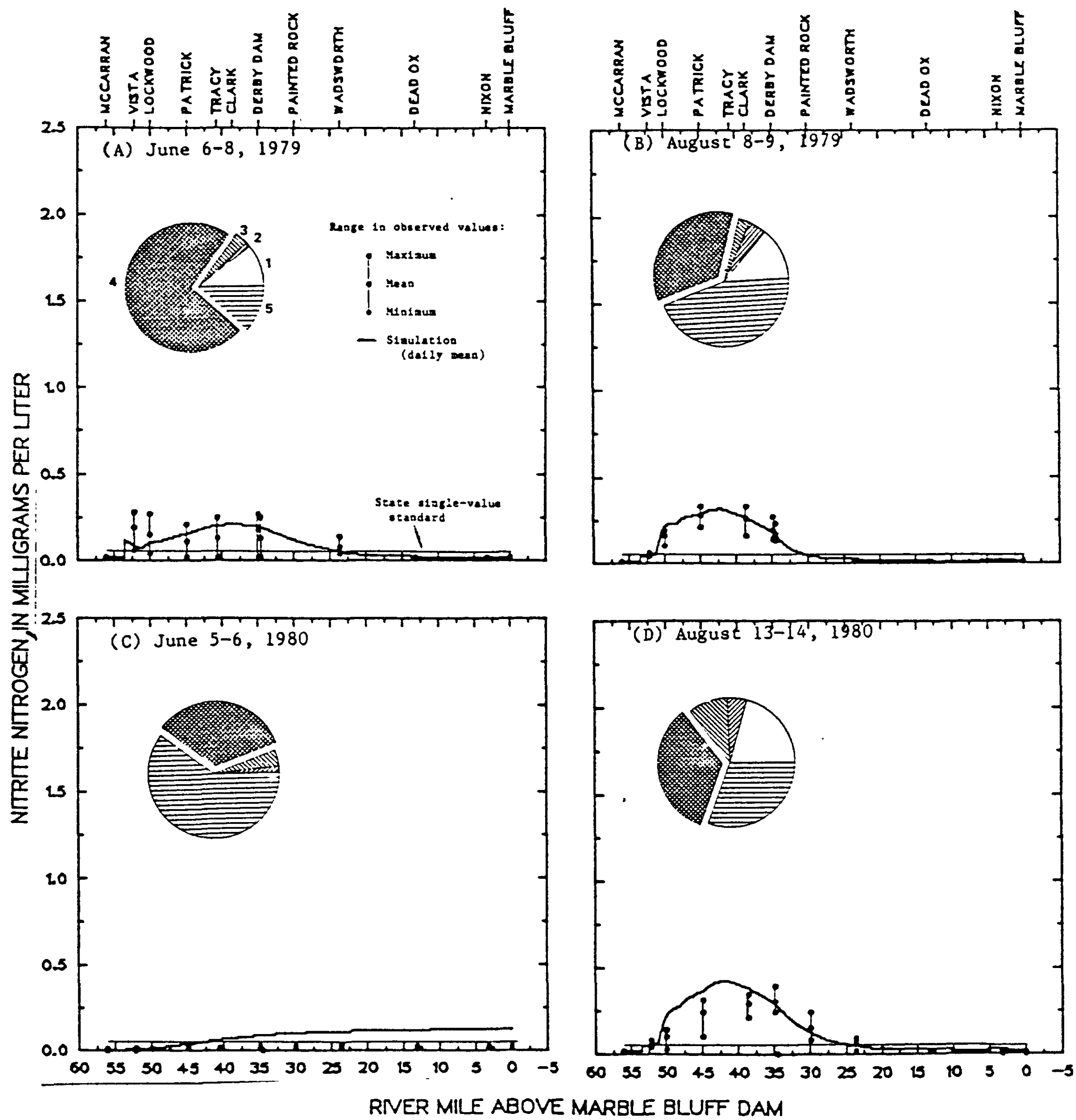


FIGURE 40.--Simulated and observed concentrations of un-ionized ammonia nitrogen during synoptic studies, Truckee Canal.



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 41.--Simulated and observed concentrations of nitrite nitrogen during synoptic studies, Truckee River.

TABLE 34.—Results of calibration and validation for mean daily nitrite nitrogen

[Observed and simulated results for synoptic studies, in milligrams per liter as N; Percent error calculated by [(observed - simulated)/observed] x 100.]

Site (River or Canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	0.02	—	—	—	0.00	—	—	—	0.01	—	—	—	0.02	—	—	—
Vista (52.23)	.19	0.09	−0.10	−53	0.01	0.01	0	0	0.05	.05	0	0	0.06	0.06	0	0
Lockwood (50.05)	.15	.10	−.05	−33	.01	.02	−0.01	100	.16	.21	0.05	31	.10	.22	0.12	120
Patrick (44.92)	.11	.15	.04	36	.01	.05	.04	400	.28	.28	0	0	.24	.36	.12	50
Tracy (40.62)	.13	.20	.07	54	.02	.07	.05	250	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	.26	.26	0	0	.29	.38	.09	31
Derby (34.88)	.18	.20	.02	11	.02	.10	.08	400	.19	.18	−.01	−5	.30	.29	−.01	−3
Reach average error:	—	—	0	3	—	—	.03	230	—	—	.01	5	—	—	.06	40
Truckee River below Derby Dam																
Below Derby (34.52)	0.13	0.19	0.06	46	—	—	—	—	0.17	0.16	−0.01	−6	—	—	—	—
Painted Rock (29.97)	—	—	—	—	0.02	0.12	0.10	500	—	—	—	—	0.15	0.12	−0.03	−20
Wadsworth (23.69)	.08	.05	−.03	−37	.03	.13	.10	333	.01	.03	.02	200	.07	.05	−.02	−28
Dead Ox (13.18)	.01	.02	.01	100	.02	.14	.12	600	.01	.02	.01	100	.01	.03	.02	200

TABLE 34.--Results of calibration and validation for mean daily nitrite nitrogen--Continued

Site (River or Canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Nixon (3.22)	.02	.02	0	0	.02	.15	.13	433	.01	.02	.01	100	.01	.03	.02	200
Marble Bluff (0.00)	.02	.02	0	0	.03	.14	.11	367	.01	.01	0	0	.00	.02	.02	0
Reach average error:	—	—	.01	22	—	—	.11	447	—	—	.006	79	—	—	0	70
Average error for river:	—	—	.005	12	—	—	.07	338	—	—	.008	42	—	—	.03	55
Truckee Canal																
Derby Dam (31.42)	0.18	—	—	—	0.02	—	—	—	0.19	—	—	—	0.30	—	—	—
Highway 95A (18.23)	.14	0.19	0.05	36	.02	0.09	0.07	350	.14	0.15	0.01	7	.23	0.28	0.05	22
Allendale (11.07)	—	—	—	—	.02	.12	.10	500	—	—	—	—	.19	.22	.03	16
Highway 50 (3.25)	.13	.18	.05	38	.02	.13	.11	550	.12	.08	-.04	-33	.09	.14	.05	55
Reach average error:	—	—	.05	37	—	—	.09	467	.15	—	-.01	-13	—	—	.04	31

For the June 1980 high-flow data, nitrite concentrations were consistently overpredicted below Vista. Average prediction errors for these data were very high, expressed as a percentage of the observed concentration (230 percent above Derby, 340 percent below); however, the average errors in concentration (0.03 and 0.07 mg/L) are not as significant. Contributing factors to the inaccuracy of the calibration for these data may be errors in the temperature correction (equation 23) for the rate coefficients in these cold (10 to 12 °C) waters, the loss of nitrite due to oxidation during sample shipping, and to analytical imprecision at the relatively low (0.00 to 0.03 mg/L) observed concentrations. Results of simulations for the canal are shown in figure 42. Nevada single-value water-quality standards for nitrite-nitrogen are 0.04 mg/L throughout the modeled reach of the river. Both observed data and the calibrated simulations indicate that, with the observed inputs of ammonia and nitrite, nitrite standards are likely to be exceeded above Painted Rock at most low to medium river flows (figure 41).

Figure 42 near here

Nitrate-nitrogen

The relative magnitudes of sources of loads of nitrate-nitrogen to the river changed with streamflow for the four synotpic studies (figure 43). For the two August studies, North Truckee Drain was the largest single source, contributing from 50 to 67 percent of the total loads above Derby Dam; however, during the June 1980 high flows, the upstream river contributed 73 percent of the total loads to the reach (table 21). Concentrations of nitrate in irrigations returns were modeled at a constant 0.3 mg/L, and were the largest single source for the June 1979 data set with 38 percent of the total loads.

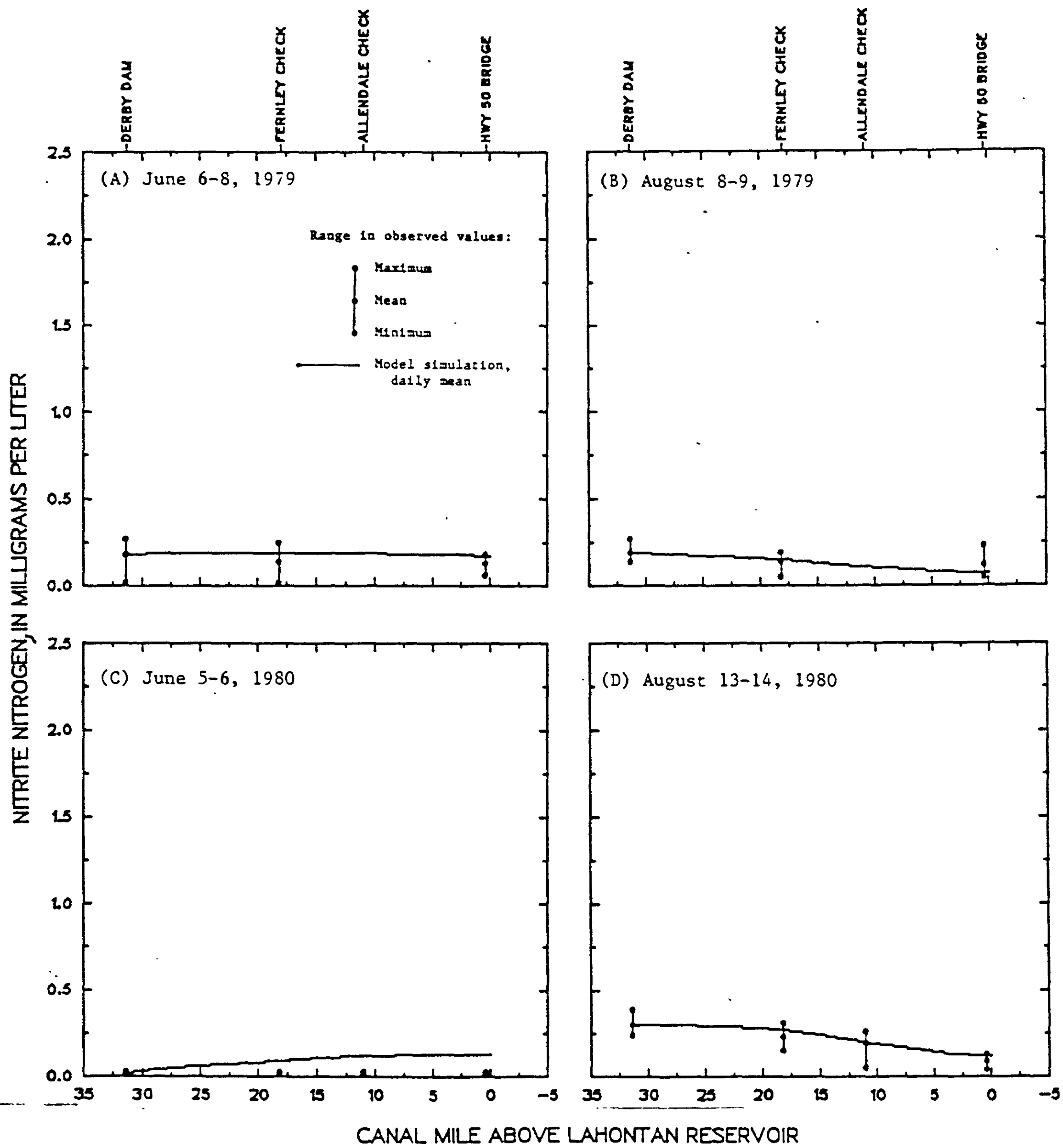


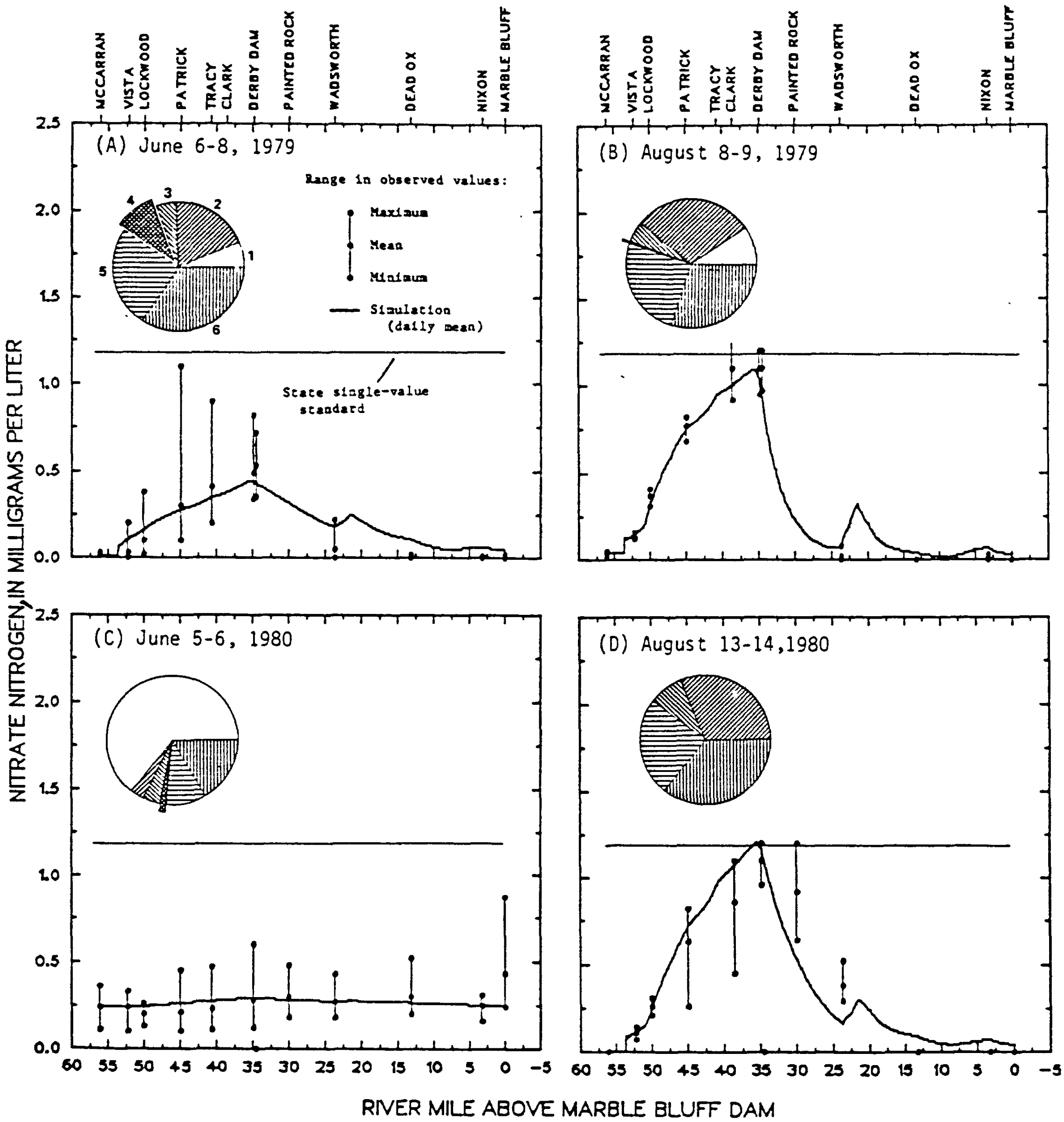
FIGURE 42.--Simulated and observed concentrations of nitrite nitrogen during synoptic studies, Truckee Canal.

Figure 43 near here

Below Derby Dam, nitrate in the river, principally from the oxidation of ammonia loadings from the STP, contributed from 60 to 87 percent of the loading to the lower river. At low to medium flows, nonpoint sources contributed from 30 to 40 percent of the total nitrate loads, with ground water contributing about twice as much as irrigation return flows.

Nitrate concentrations in the model are controlled by the nitrate generation from oxidation of ammonia and loss to assimilation by aquatic plants as represented by the instream removal rate. Calibrated nitrate removal coefficients (K_{NO3R}) for the river were 0.3 above the pool at Derby Dam, 1.5 through the pool, and 2.0 below Derby Dam. The change in values is consistent with field observations of more abundant growths of periphytic (attached) algae in the lower-flow reaches below Derby Dam. Calibration was made on the August 1979 data and was validated above Derby Dam by the other three data sets (figure 43 and table 35). Trends in simulated concentrations of nitrate below Derby Dam followed the trends in observed values for all four data sets; however, simulated values were generally greater than observed for the June and August 1979 data and below the observed for the August 1980 data. This may be due to varying concentrations of nitrate in return flows, and(or) changes in the aquatic algal communities between the 2 years.

Although the Nevada single-value water-quality standard for nitrate-nitrogen in the modeled reach is 2.0 mg/L, the effective standard is the lower value of 1.2 mg/L for total-nitrogen based on criteria for protecting fish and aquatic life as the most restrictive beneficial use. Both the observed data and simulations indicate that the standard was exceeded during the two August low flows near Derby Dam due to nitrification of ammonia from the STP (figure 43).



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 43.--Simulated and observed concentrations of nitrate nitrogen during synoptic studies, Truckee River.

Nitrate simulations match observed values rather well in the canal (figure 44); the greatest errors were at the downstream Highway 50 site for the two August data sets which over-predicted nitrate relative to the observed values. The average error for the four data sets was about 1 percent.

Figure 44 near here

Table 35 near here

Total-nitrogen

The model calculates total-nitrogen by addition of the four modeled species. Relative sources of total-nitrogen loadings are shown in figure 45; for low to medium flows, the STP is the dominant source. Comparisons of simulated to observed concentrations of total-nitrogen (table 36) are shown in figure 45 for the river and figure 46 for the canal. Simulations followed the observed profiles rather well for all data sets. In general, simulation errors for organic-nitrogen were the greatest contributors to the errors in calculated total-nitrogen.

Figure 45 near here

Inputs of relatively refractory organic-nitrogen from the upstream river and the STP and ammonia-nitrogen from the STP resulted in both observed and simulated total-nitrogen concentrations exceeding the single-value standard of 1.2 mg/L above Derby Dam for all four data sets (figure 46).

Table 36 near here

Figure 46 near here

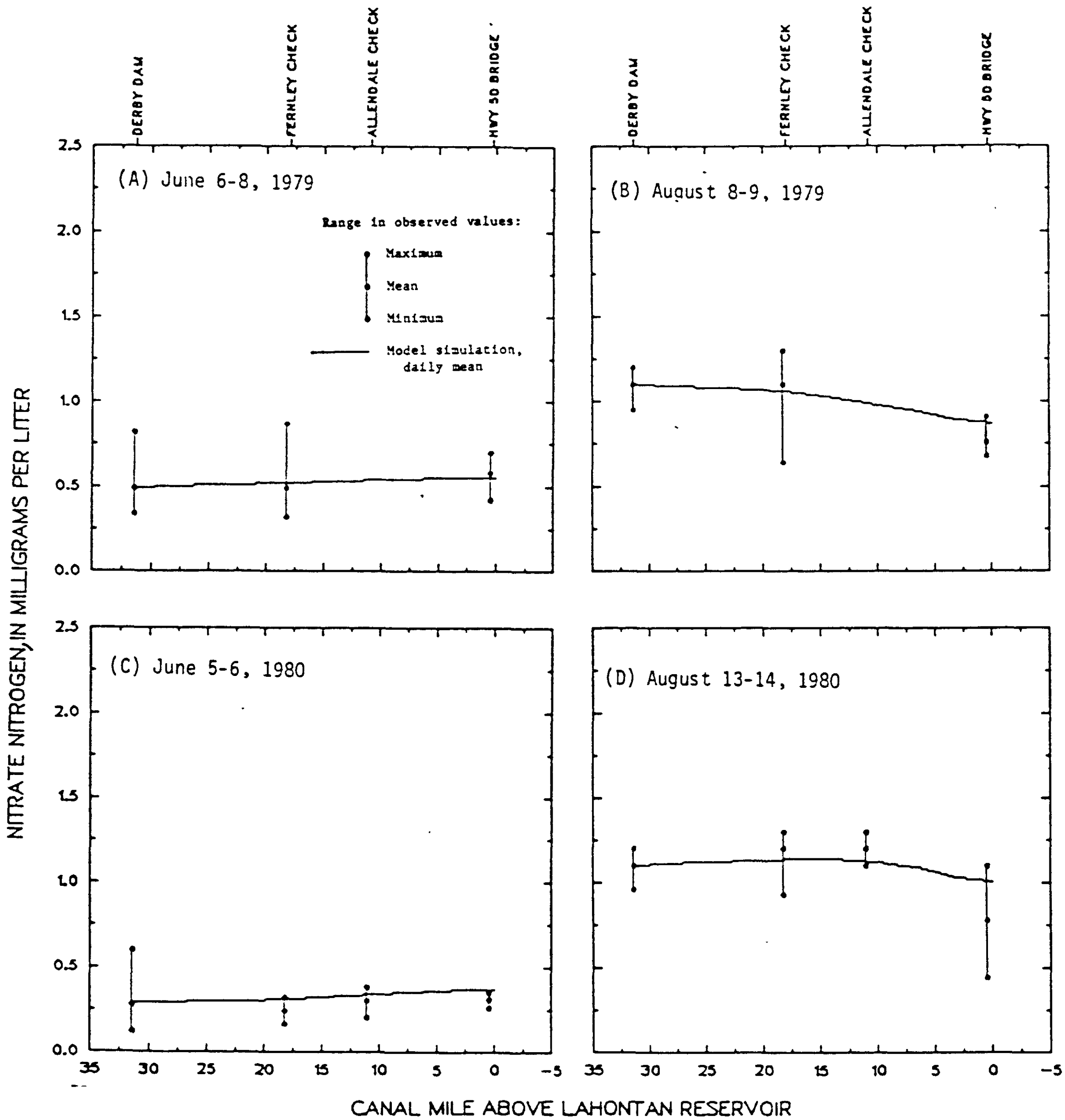


FIGURE 44.--Simulated and observed concentrations of nitrate nitrogen during synoptic studies, Truckee Canal.

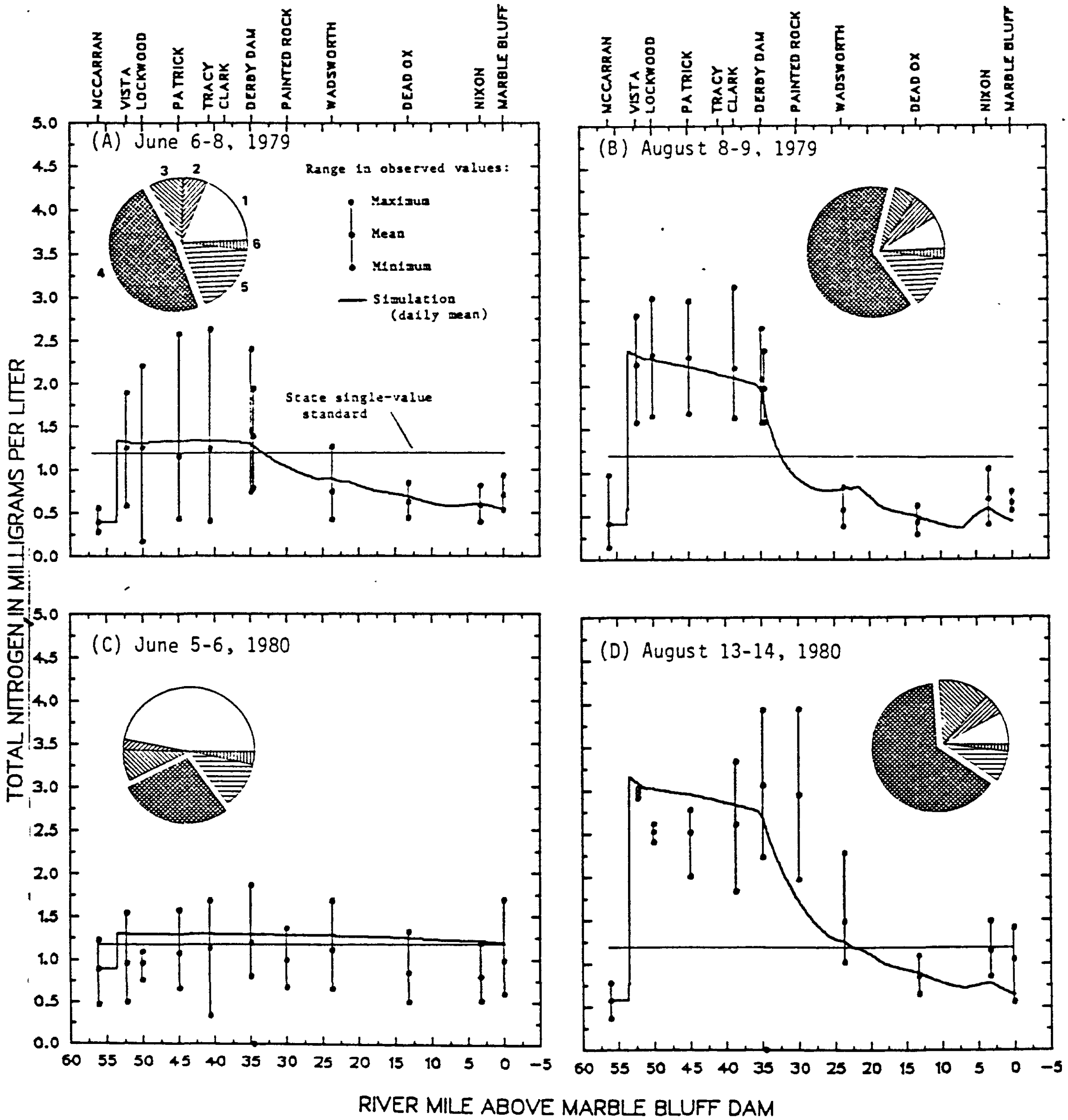
TABLE 35.—Results of calibration and validation for mean daily nitrate nitrogen

[Observed and simulated results for synoptic studies, in milligrams per liter as N; Percent error calculated by [(observed - simulated)/observed] × 100.]

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	0.01	—	—	—	0.24	—	—	—	0.04	—	—	—	0.00	—	—	—
Vista (52.23)	.03	0.11	0.08	267	.24	0.24	0	0	.13	0.15	0.02	15	.11	0.11	0	0
Lockwood (50.05)	.10	.16	.06	60	.20	.24	.04	20	.37	.31	-.06	-16	.26	.25	-.01	-4
Patrick (44.92)	.37	.28	-.09	-24	.21	.26	.05	24	.77	.75	-.02	-2	.63	.72	.09	14
Tracy (40.62)	.41	.35	-.06	-15	.23	.28	.05	22	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	1.1	1.0	-.1	-9	.06	1.1	.24	22
Derby (34.88)	.49	.44	-.05	-10	.28	.30	.02	7	1.1	1.0	-.1	-9	1.1	1.2	-.1	-9
Reach average error:	—	—	-.01	56	—	—	.03	15	—	—	-.05	-4	—	—	.04	5
Truckee River below Derby Dam																
Below Derby (34.52)	0.53	0.43	-0.10	-19	—	—	—	—	1.1	0.92	-0.18	-16	—	—	—	—
Painted Rock (29.97)	—	—	—	—	0.30	0.29	-0.01	-3	—	—	—	—	0.92	0.52	-0.40	-43
Wadsworth (23.69)	.05	.17	.12	240	.27	.28	.01	4	.02	.07	.05	250	.38	.16	-.22	-58
Dead Ox (13.18)	.01	.11	.10	1,000	.30	.27	-.03	-10	.00	.04	.04	0	.00	.09	.09	0

TABLE 35.—Results of calibration and validation for mean daily nitrate nitrogen--Continued

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Nixon (3.22)	.00	.07	.07	0	.25	.27	.02	8	.01	.07	.06	600	.00	.07	.07	0
Marble Bluff (0.00)	.00	.04	.04	0	.43	.26	-.17	-40	.00	.03	.03	0	.00	.04	.04	0
Reach average error:	—	—	.05	244	—	—	-.04	-8	—	—	0	167	—	—	-.08	-20
Average error for river:	—	—	.02	150	—	—	-.005	3	—	—	-.02	81	—	—	-.02	-7
Truckee Canal																
Derby Dam (31.42)	0.49	—	—	—	0.28	—	—	—	1.1	—	—	—	1.1	—	—	—
Highway 95A (18.23)	.49	0.51	0.02	4	.24	0.28	0.04	17	1.1	1.0	-0.1	-9	1.2	1.1	-0.1	-8
Allendale (11.07)	—	—	—	—	.30	.29	-.01	-3	—	—	—	—	1.2	1.1	-.1	-8
Highway 50 (3.25)	.58	.53	-.05	-9	.31	.30	-.01	-3	.76	.82	.06	8	.78	.98	.20	26
Reach average error:	—	—	-.01	-2	—	—	.01	3.7	—	—	-.02	0	—	—	0	3



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 45.--Simulated and observed concentrations of total nitrogen during synoptic studies, Truckee River.

TABLE 36.—Results of calibration and validation for mean daily total nitrogen

[Observed and simulated results for synoptic studies, in milligrams per liter; Percent error calculated by [(observed-simulated)/observed]x100.]

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	0.38	—	—	—	0.89	—	—	—	0.41	—	—	—	0.57	—	—	—
Vista (52.23)	1.2	1.3	0.1	8	.97	1.4	0.43	44	2.2	2.4	0.2	9	3.0	3.2	0.2	7
Lockwood (50.05)	1.3	1.3	0	0	.96	1.4	.44	46	2.4	2.3	-.1	-4	2.5	3.1	.6	24
Patrick (44.92)	1.2	1.3	.1	8	1.1	1.4	.30	27	2.3	2.2	-.1	-4	2.5	3.0	.5	20
Tracy (40.62)	1.2	1.3	.1	8	1.1	1.4	.30	27	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	2.2	2.1	-.1	-4	2.6	2.9	.3	11
Derby (34.88)	1.5	1.3	-.2	-13	1.2	1.4	.20	17	2.1	1.9	-.2	-9	3.0	2.8	-.2	-7
Reach average error:	—	—	0	2	—	—	.33	32	—	—	-.1	-2	—	—	.3	11
Truckee River below Derby Dam																
Below Derby (34.52)	1.4	1.3	-0.1	-7	—	—	—	—	2.0	1.8	-0.2	-10	—	—	—	—
Painted Rock (29.97)	—	—	—	—	1.0	1.4	0.40	40	—	—	—	—	2.9	1.8	-1.1	-38
Wadsworth (23.69)	.73	.89	.16	22	1.1	1.4	.30	27	.57	.81	.24	42	1.5	1.3	-.2	-13
Dead Ox (13.18)	.62	.69	.07	11	.85	1.3	.45	53	.43	.50	.07	16	.85	.93	.08	9

TABLE 36.—Results of calibration and validation for mean daily total nitrogen—Continued

Site (river or canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob- served	Simu- lated	Dif- ference	Error (%)	Ob- served	Simu- lated	Dif- ference	Error (%)	Ob- served	Simu- lated	Dif- ference	Error (%)	Ob- served	Simu- lated	Dif- ference	Error (%)
Nixon (3.22)	.59	.61	.02	3	.80	1.3	.50	63	.69	.59	-.10	-14	1.2	.80	-.40	-33
Marble Bluff (0.00)	.70	.53	-.17	-24	.99	1.3	.31	31	.65	.43	-.22	-34	1.0	.66	-.34	-34
Reach average error:	—	—	.01	1	—	—	.39	43	—	—	-.04	0	—	—	-.40	-22
Average error for river:	—	—	.005	1	—	—	.36	37	—	—	-.07	-1	—	—	-.05	-5
								Truckee Canal								
Derby Dam (31.42)	1.5	—	—	—	1.2	—	—	—	2.1	—	—	—	3.0	—	—	—
Highway 95A (18.23)	1.3	1.4	0.1	8	1.0	1.2	0.20	20	2.0	1.9	-0.1	-5	2.5	2.9	0.4	16
Allendale (11.07)	—	—	—	—	1.1	1.2	.10	9	—	—	—	—	2.4	2.7	.3	12
Highway 50 (3.25)	1.3	1.3	0	0	.92	1.3	.38	41	1.8	1.5	-.3	-17	1.8	2.4	.6	33
Reach average error:	—	—	0	4	—	—	.23	23	—	—	-.2	-11	—	—	.4	20

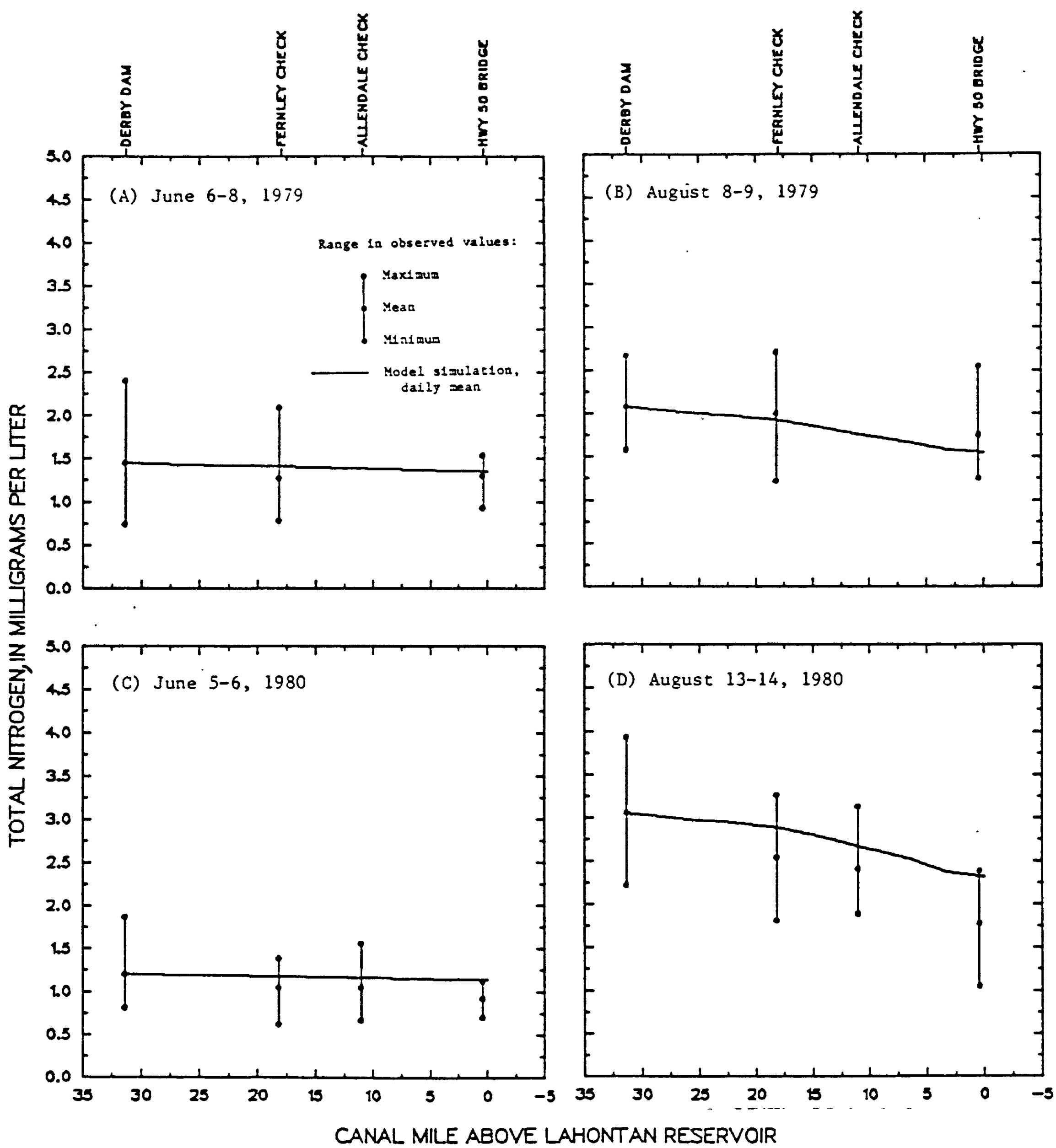


FIGURE 46.--Simulated and observed concentrations of total nitrogen during synoptic studies, Truckee Canal.

Nitrogen/phosphorus ratio

The atomic (moles/mole) ratio of inorganic-nitrogen to orthophosphorus is calculated by the model (equation 22) and shown for the four synoptic studies in figure 47 for the river and figure 48 for the canal. This ratio has been used by some investigators as an index of whether nitrogen or phosphorus is the limiting nutrient for stimulation of algal growth. Based on the stoichiometry of the photosynthetic reaction, algae are assumed to consume a relatively fixed ratio of nitrogen to phosphorus (N/P) of about 16:1 (Redfield, 1958; Stumm and Morgan, 1970; Ryther and Dunstan, 1971). Phosphorus is assumed to be the limiting nutrient for algal growth when the ratio exceeds 15, and nitrogen when the ratio is less than 15. The critical ratios found in field investigations seem to depend to some extent on algal species and environment, and have been reported as high as 30:1 (Rhee, 1978). Allowing some variation from the theoretical 16, ratios above 20 may be considered indicative of phosphorus limitation and ratios below 10 to imply nitrogen limitation.

Field studies in this investigation found N/P ratios for all four synoptic data sets that indicate that nitrogen was the limiting nutrient for both the river and the canal. Ratios are less than 15 for all sites below Vista and are less than 10 for the two August and the June 1979 synoptics. Similar results have been found in previous and succeeding investigations of the river (Pacific Environmental Laboratory, 1979; Cooper and others, 1984). Average daily concentrations of orthophosphorus exceeded 0.10 mg/L (3.0 micromoles), well above what could be considered to be a limiting concentration for algal growth (Lider and others, 1980, found algal stimulation active at concentrations of orthophosphorus as low as 0.03 mg/L in Truckee River studies).

Average daily concentrations of inorganic-nitrogen in the river during the four synoptic studies were generally greater than 0.05 mg/L (3.6 micromoles), reported to indicate nitrogen-limiting conditions for southwestern streams (Grimm and others, 1983). However, concentrations for the August data sets may have approached nitrogen-limiting values below Wadsworth. Grimm and others (1983) proposed the hypothesis that noncultural sources (soil and bed-sediment mineralogy) of phosphorus in southwestern streams are commonly more than adequate to maintain instream phosphorus concentrations above limiting values for algal growth. These natural sources of phosphorus, coupled with the effects of irrigation return flows, may also be dominant in the Truckee system, indicating that nitrogen control of sewage effluents may be the only practical way to limit growth of aquatic plants in the Truckee River.

Figures 47 and 48 near here

Dissolved Oxygen

Results of calibration for DO for the river and canal are shown in figures 50 and 52 (concentrations) and figures 51 and 53 (percent saturation). The DO budget for the river is controlled by exchange with the atmosphere, oxygen production by daytime plant photosynthesis, and oxygen demands from the oxidation of CBOD, ammonia, and nitrite, and plant respiration. Observed DO concentrations were generally above applicable Nevada water-quality standards except for nighttime minimums in the two August data sets. Average daily DO concentrations for the June 1979 data (medium flows) and the two August data sets (low flows) were depleted below saturation from Steamboat Creek to about Painted Rock due to oxidation of CBOD and ammonia, and were above saturation from about Wadsworth to Marble Bluff Dam due to photosynthetic inputs from

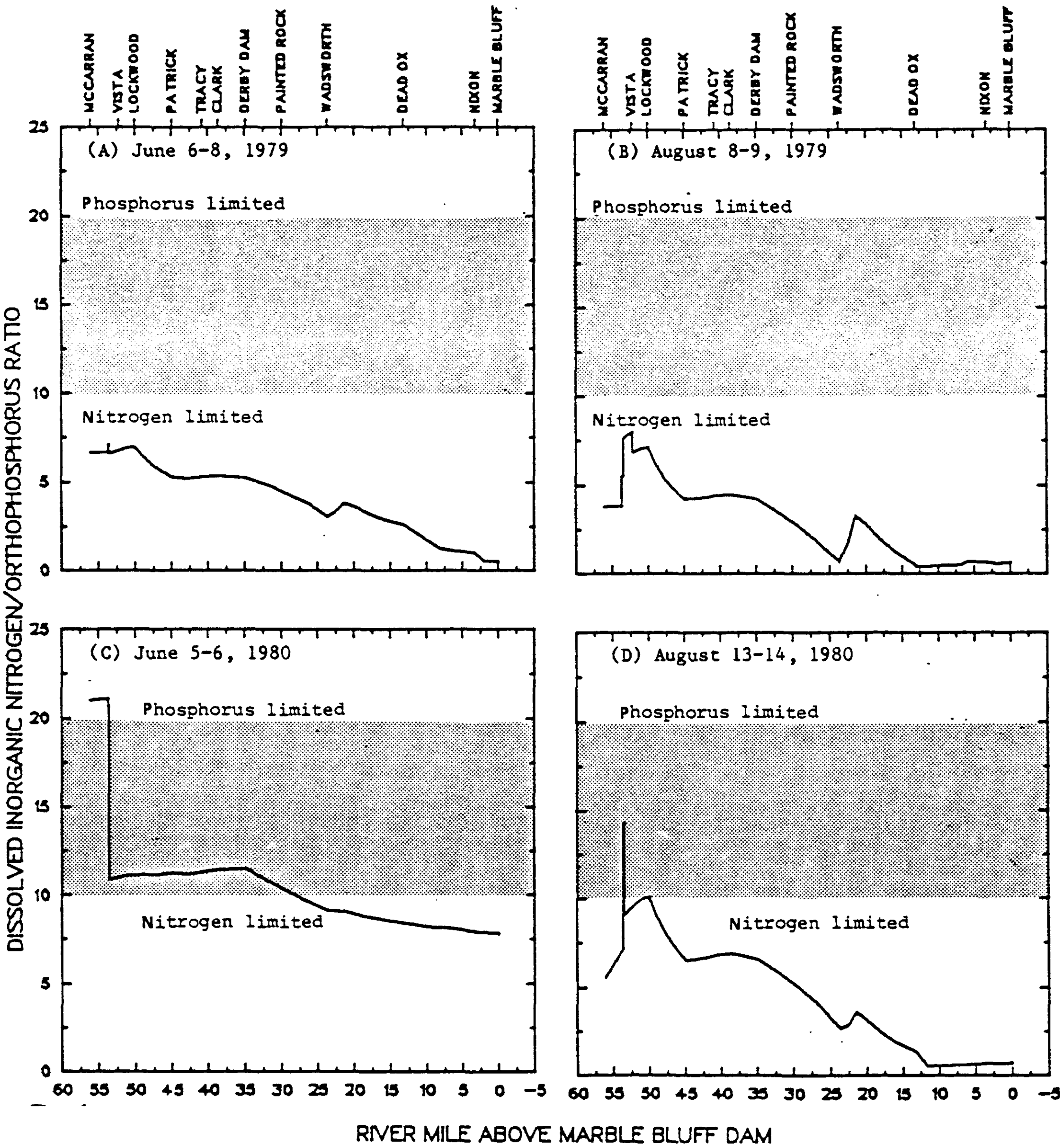


FIGURE 47.--Simulated N/P ratio during synoptic studies, Truckee River.

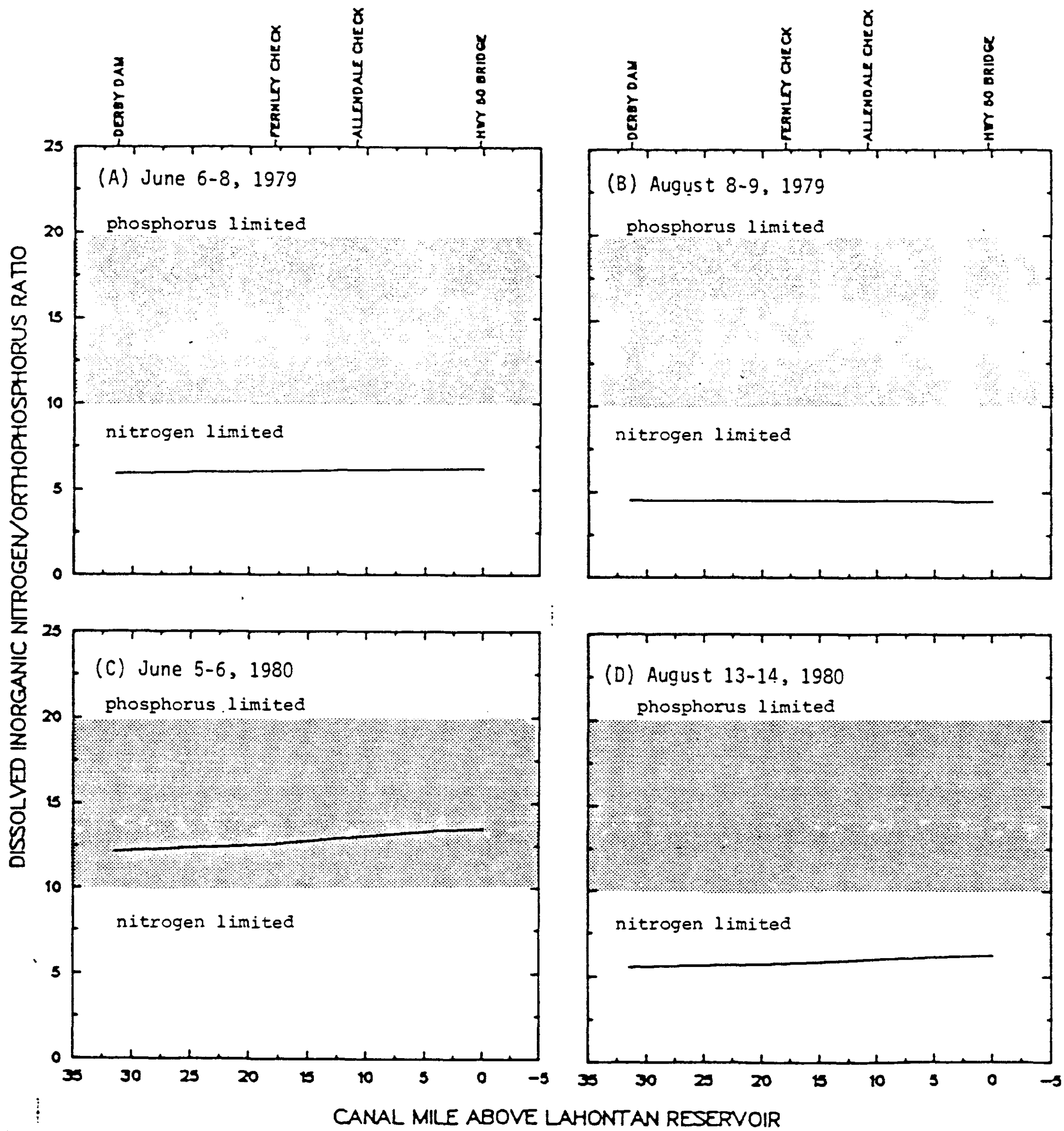


FIGURE 48.--Simulated N/P ratio during synoptic studies, Truckee Canal.

algae and rooted aquatic plants. The higher productivity of the river below Derby Dam is also reflected by the greater differences between maximum daytime and minimum nighttime oxygen concentrations. During the June 1980 high-flow study, short traveltimes, high reaeration rate coefficients, and lower plant productivity resulted in average DO levels at or very near saturation throughout the river.

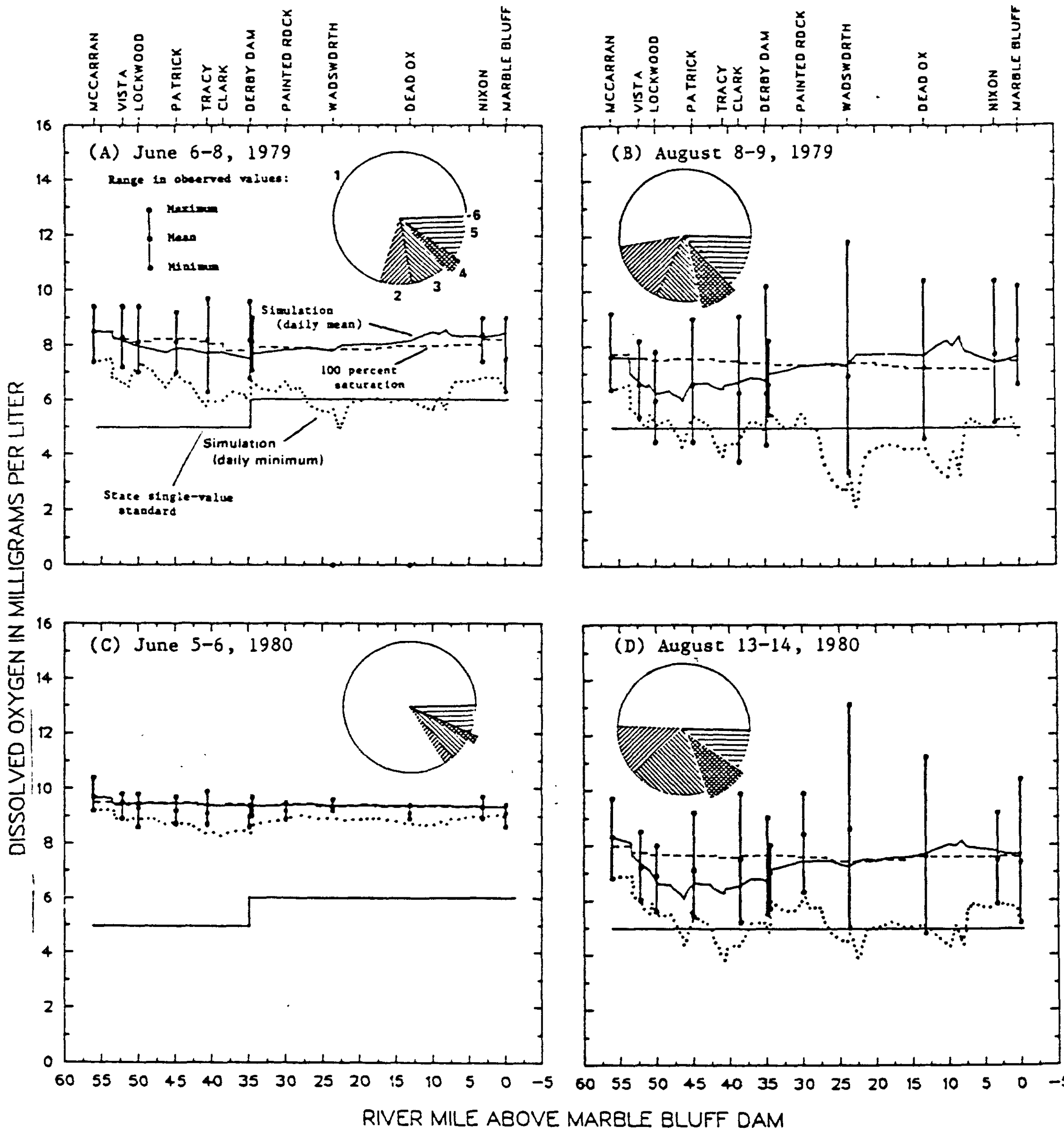
Single-value Nevada DO standards for the modeled reach of the river are 6.0 mg/L from November through March and 5.0 mg/L from April through September. Both observed data and the simulations indicated minimum DO concentrations were lower than standards during nighttime periods for the two August data sets (figure 49B, D).

Figures 49-52 near here

Figure 50 shows the same effects in terms of percent saturation (a function of barometric pressure and water temperature). During the nighttime periods, DO levels fell to 50 to 60 percent of saturation throughout much of the river during the August studies, whereas during daytime periods of peak photosynthesis, DO in the entire reach exceeded 100 percent saturation and was over 150 percent of saturation below Derby Dam.

The TRWQ model was configured to simulate both mean and minimum daily DO concentrations, and the results of calibration for both are included in figures 49 to 52. Net photosynthesis was used as the only calibration factor for DO, as discussed in the following sections. Overall calibration for the river was excellent; average errors were -1 percent for daily mean DO and 2 percent for daily minima (tables 37 and 38).

Tables 37 and 38 near here



[Pie diagrams show relative contributions of external loadings to the modeled reach of river. Sources are: (1) River upstream from McCarran Bridge, (2) North Truckee Drain, (3) Steamboat Creek upstream from the STP outfall, (4) Reno-Sparks STP, (5) total irrigation-return flows, and (6) total ground-water inflows.]

FIGURE 49.--Simulated and observed DO concentrations during synoptic studies, Truckee River.

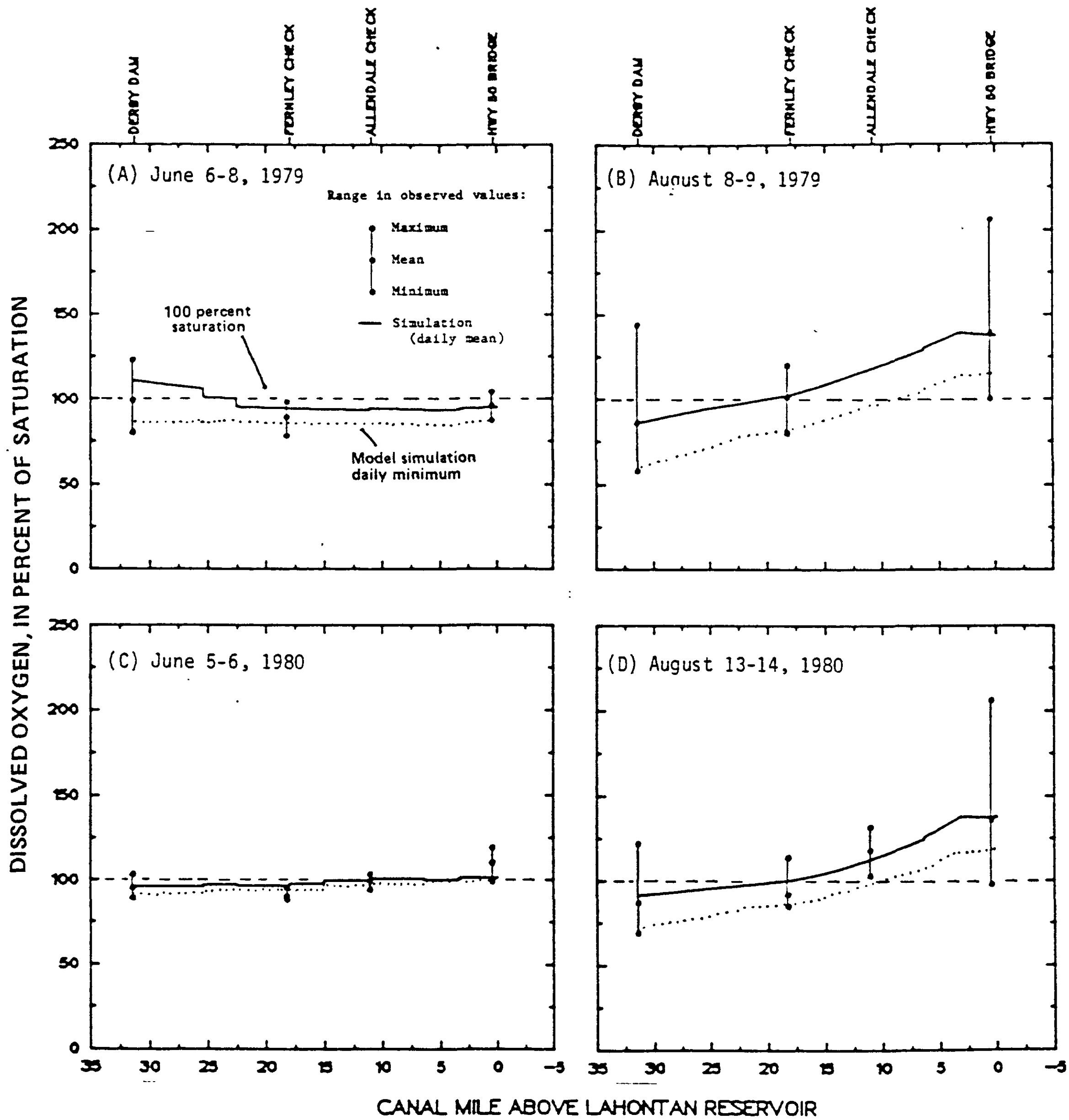


FIGURE 50.--Simulated and observed DO saturation percentages during synoptic studies, Truckee River.

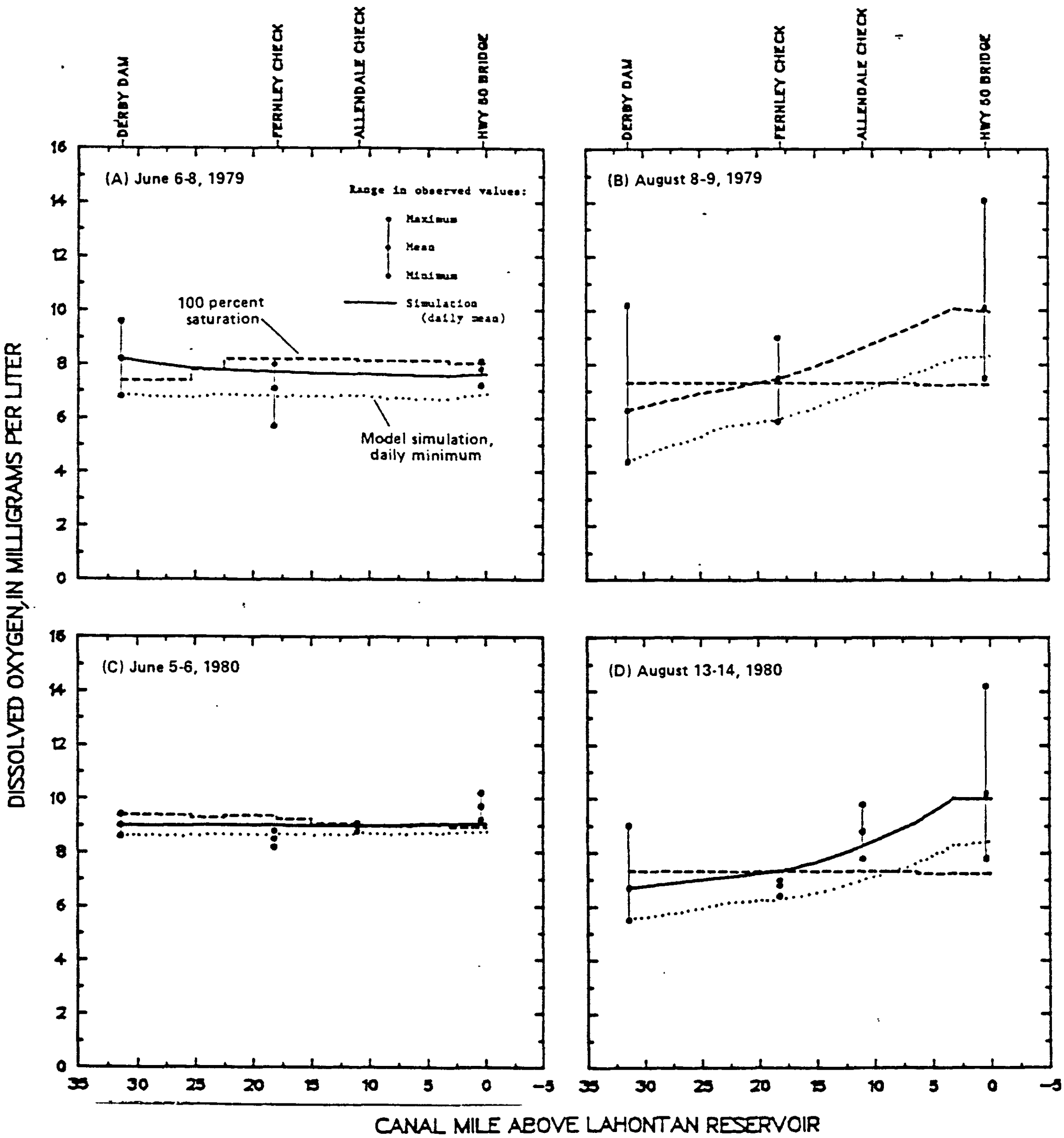


FIGURE 51.--Simulated and observed DO concentrations during synoptic studies, Truckee Canal.

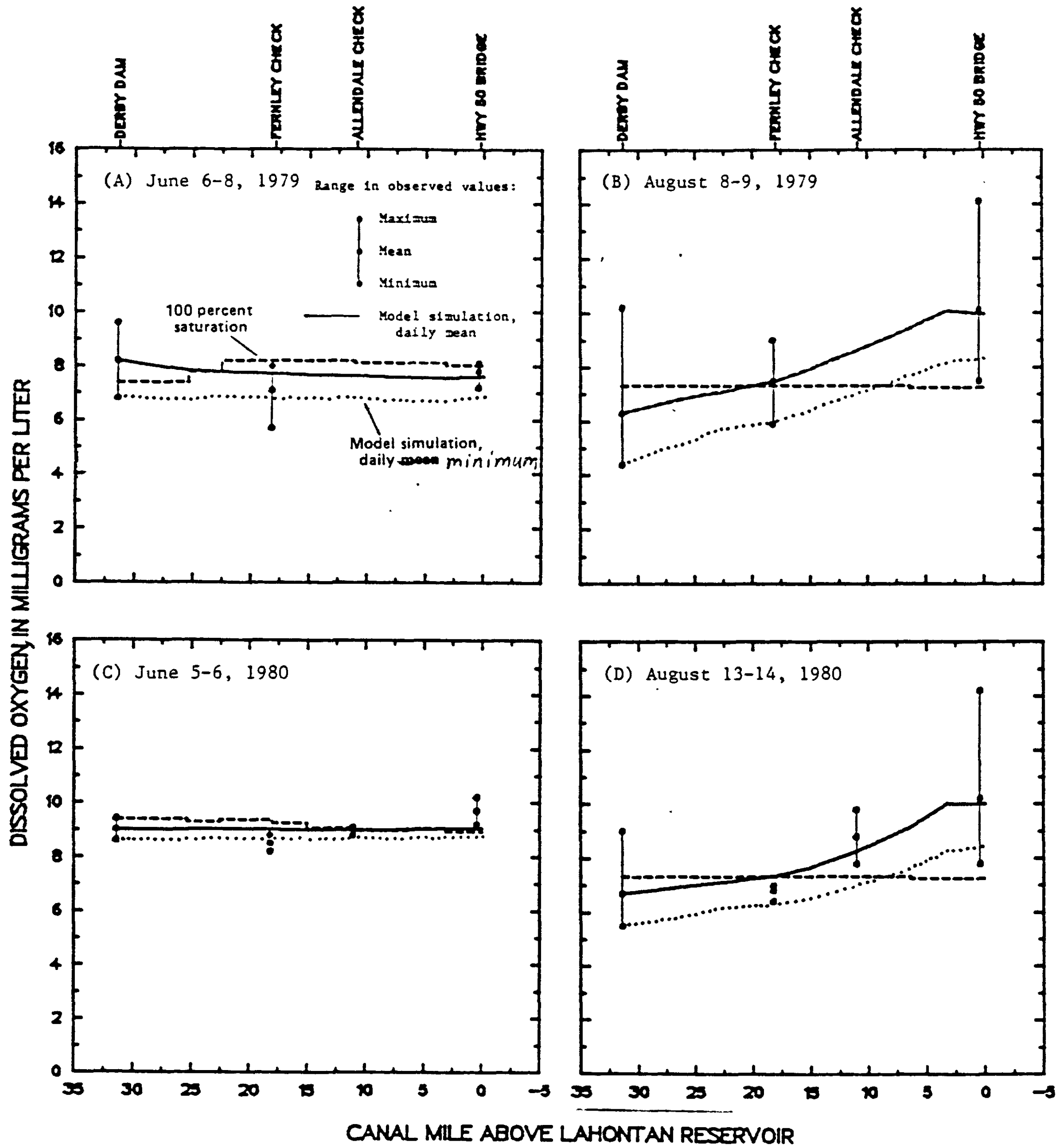


FIGURE 52.--Simulated and observed DO concentrations during synoptic studies, Truckee Canal.

TABLE 37.—Results of calibration and validation for mean daily dissolved oxygen

[Observed and simulated results for synoptic studies, in milligrams per liter; Percent error calculated by [(observed - simulated)/observed] x100.]

Site (River or Canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Truckee River above Derby Dam																
McCarran bridge (56.12)	8.5	—	—	—	9.7	—	—	—	7.6	—	—	—	8.3	—	—	—
Vista (52.23)	8.3	8.2	−0.1	-1	9.5	9.4	−0.1	-1	6.6	6.7	0.1	1	7.2	7.4	0.2	3
Lockwood (50.05)	8.1	8.0	-.1	-1	9.3	9.4	.1	1	6.0	6.4	.4	7	6.9	6.7	-.2	-3
Patrick (44.92)	8.1	7.9	-.2	-2	9.2	9.4	.2	2	6.6	6.7	.1	1	7.1	6.6	-.5	-7
Tracy (40.62)	8.2	7.7	-.5	-6	9.1	9.4	.3	3	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	6.3	6.7	.4	6	7.5	6.5	-1	-13
Derby (34.88)	8.2	7.5	-.7	-8	9.0	9.3	.3	3	6.3	6.7	.4	6	6.7	6.6	-.1	-1
Reach average error:	—	—	-.3	-4	—	—	.2	2	—	—	.3	4	—	—	-.1	-4
Truckee River below Derby Dam																
Below Derby (34.52)	8.1	7.7	−0.4	-5	—	—	—	—	6.6	7.0	0.4	6	7.0	7.1	0.1	1
Painted Rock (29.97)	—	—	—	—	9.2	9.4	0.2	2	—	—	—	—	8.4	7.4	-1	-12
Wadsworth (23.69)	—	—	—	—	9.3	9.3	0	0	6.9	7.4	.5	7	8.6	7.2	-1.4	-16
Dead Ox (13.18)	—	—	—	—	9.1	9.3	.2	2	7.2	7.6	.4	5	7.6	7.7	.1	1

TABLE 37.--Results of calibration and validation for mean daily dissolved oxygen--Continued

Site (River or Canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Nixon (3.22)	8.4	8.3	-.1	-1	9.3	9.3	0	0	7.7	7.4	-.3	-4	7.5	7.8	.3	4
Marble Bluff (0.00)	7.5	8.4	.9	12	9.1	9.3	.2	2	8.2	7.5	-.7	-8	7.4	7.8	.4	5
Reach average error:	--	--	.1	2	--	--	.1	1	--	--	.1	1	--	--	-.1	-3
Average error for river:	--	--	-.1	-1	--	--	.1	1	--	--	.2	2	--	--	-.1	-3
Truckee Canal																
Derby Dam (31.42)	8.2	--	--	--	9.0	--	--	--	6.3	--	--	--	6.7	--	--	--
Highway 95A (18.23)	7.1	7.9	0.8	11	8.5	9.0	0.5	6	7.5	7.5	0	0	6.8	7.6	0.8	12
Allendale (11.07)	--	--	--	--	9.0	9.0	0	0	--	--	--	--	8.8	8.5	-.3	-3
Highway 50 (3.25)	7.8	7.6	-.2	-2	9.7	9.0	-.7	-7	10.1	9.4	-.7	-7	10.2	10.4	.2	2
Reach average error:	--	--	.3	4	--	--	-.1	0	--	--	0	-2	--	--	0	4

TABLE 38.--Results of calibration and validation for minimum daily dissolved oxygen

[Observed and simulated results for synoptic studies, in milligrams per liter;
Percent error calculated by [(observed - simulated)/observed] x 100]

Site (River or Canal mile)	June 1979				June 1980				August 1979				August 1980			
	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)	Observed	Simulated	Difference	Error (%)
Truckee River above Derby Dam																
McCarran Bridge (56.12)	7.4	—	—	—	9.2	—	—	—	6.4	—	—	—	6.8	—	—	—
Vista (52.23)	7.2	6.6	-0.6	-8	8.9	8.9	0	0	5.4	5.3	-0.1	-10	6.0	5.8	-0.2	-3
Lockwood (50.05)	7.0	7.4	.4	6	8.6	8.9	.3	3	4.5	5.2	.7	15	5.6	5.5	-.1	-2
Patrick (44.92)	7.0	6.9	-.1	-1	8.7	8.8	.1	1	4.5	5.5	1	22	5.4	5.5	.1	2
Tracy (40.62)	6.3	5.9	-.4	-6	8.7	8.4	-.3	-3	—	—	—	—	—	—	—	—
Clark (38.60)	—	—	—	—	—	—	—	—	3.8	4.5	.7	70	5.2	4.3	-.9	-17
Derby (34.88)	6.8	6.0	-.8	-12	8.6	8.3	-.3	-3	4.4	4.8	.4	40	5.5	4.8	-.7	-13
Reach average error:	—	—	-.3	-4	—	—	0	0	—	—	.5	27	—	—	-.4	-7
Truckee River below Derby Dam																
Below Derby (34.52)	7.1	6.7	-0.4	-6	9.0	8.7	-0.3	-3	5.5	5.8	0.3	5	5.7	6.0	0.3	5
Painted Rock (29.97)	—	—	—	—	8.9	9.0	.1	1	—	—	—	—	6.3	6.1	-.2	-3
Wadsworth (23.69)	—	—	—	—	9.2	8.9	-.3	-3	3.4	3.4	0	0	5.0	4.7	-.3	-6
Dead Ox (13.18)	—	—	—	—	8.9	8.6	-.3	-3	4.6	9.2	-.4	-9	4.8	5.1	.3	6

TABLE 38.--Results of calibration and validation for minimum daily dissolved oxygen--Continued

Site (River or Canal mile)	June 1979				June 1980				August 1979				August 1980			
	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)	Ob-served	Simu-lated	Dif-ference	Error (%)
Nixon (3.22)	7.4	6.9	-.5	-7	8.9	9.0	.1	1	5.2	5.3	-.1	-2	5.9	5.9	0	0
Marble Bluff (0.00)	6.3	6.4	.1	1	8.6	9.0	.4	5	6.6	4.6	-2	-30	5.2	5.2	0	0
Reach average error:	—	—	-.3	-4	—	—	0	0	—	—	.4	-7	—	—	0	0
Average error for river:	—	—	-.3	-4	—	—	0	0	—	—	.4	10	—	—	-.2	3
								Truckee Canal								
Derby Dam (31.42)	6.8	—	—	—	8.6	—	—	—	4.4	—	—	—	5.5	—	—	—
Highway 95A (18.23)	5.7	6.6	0.9	16	8.2	8.3	-0.1	-1	5.9	4.7	-1.2	-20	6.4	5.1	-1.3	-20
Allendale (11.07)	—	—	—	—	8.8	9.1	.3	3	—	—	—	—	7.8	4.2	-3.6	-46
Highway 50 (3.25)	7.2	6.2	-1	-14	9.2	8.9	-.3	-3	7.5	3.8	-3.7	-49	7.8	3.0	-4.8	-62
Average error:	—	—	0	1	—	—	0	0	—	—	-2.4	-34	—	—	-3.2	-43

The oxygen balance for the canal was dominated by photosynthesis and respiration for the two August studies (figures 51 and 52). Initial concentrations at Derby Dam were below saturation due to residual CBOD, ammonia and nitrite loadings from the river and low (in relation to the river) reaeration rate coefficients. By the Highway 95A sampling site, photosynthetic productivity of algae in the canal had raised DO concentrations to, or near, saturation. At the downstream canal site at Highway 50, observed average August DO concentrations were about 140 percent of saturation, maximum concentrations were about 200 percent of saturation, and even the nighttime minima were about 100 percent of saturation. Algal productivity was lower for the June data, resulting in average and extreme DO concentrations much closer to saturation.

As with the river calibration, net photosynthesis was the only calibration parameter for DO in the canal. Unlike the river and for any of the other modeled constituents, two calibrations had to be made, one for the August data sets, and one for the June data sets. Simulated DO concentrations matched observed mean and minimum concentrations very well for the canal; average errors were 2 percent for daily mean DO and -19 percent for daily minima.

Individual components to the oxygen budgets for the river and canal are discussed in the following sections.

Reaeration

Reaeration rate coefficients (K_2) for the river and the canal were calculated for each model segment as a function of slope and average velocity as discussed in preceeding sections of this report. Values for K_2 for the four data sets are given in table 39 and shown graphically in figures 53 and 54. Calculated values for the river ranged from as low as 0.12 per day (base e, 20 °C) in the slow, relative flat reaches (pools in segments 37 and 43) in August 1979 to as high as 120 per day in the high flows of June 1980 for the segment containing Derby Dam. The relative changes in calculated K_2 values from segment to segment seem realistic with respect to field observations of the river hydraulics. It is believed that this realistic segment-to-segment modeling of K_2 (as opposed to applications of literature values or equations based on rivers with differing hydraulics) has contributed greatly to the excellent match of simulated to observed DO profiles for the river.

Table 39 and Figures 53 and 54 near here

Values of K_2 for the canal were much lower than for most river segments, as expected due to the differing hydraulics. Calculated values for K_2 ranged from 0.01 to 2.3 for the four data sets. The low values directly relate to the enhanced effects of photosynthetic production of oxygen in the canal as compared to the river. When oxygen production in the water column exceeds 100 percent saturation, the exchange with the atmosphere reverses direction, and the excess oxygen is outgassed at a rate proportional to K_2. In the river, relatively high reaeration results in a more rapid exchange of supersaturated oxygen with the atmosphere than in the canal. Lower reaeration coefficients in the canal result in a net accumulation of DO in reaches of high algal productivity; the accumulated excess oxygen is reflected in the observed supersaturation of oxygen through the lower half of the canal.

TABLE 39.—Reaeration coefficients (K_2) used in model calibration and verification

[Reaeration coefficients calculated from average velocities (table 22) and slopes (table 11) by a modification of the Tsivoglou energy-gradient equation (equation [redacted] 32); reaeration coefficients at 20°C converted to ambient stream temperature using theta = 1.[redacted] 0241 (equation [redacted] 23)]

Model segment	Starting river mile	Length (mile)	(A) June 1979			(B) August 1979			(C) June 1980			(D) August 1980		
			Water temper-ature (°C)	Reaeration rate (1/day)		Water temper-ature (°C)	Reaeration rate (1/day)		Water temper-ature (°C)	Reaeration rate (1/day)		Water temper-ature (°C)	Reaeration rate (1/day)	
				At 20 °C	Ambient temper-ature		At 20 °C	Ambient temper-ature		At 20 °C	Ambient temper-ature		At 20 °C	Ambient temper-ature
(A) SUBMODELS:														
North Truckee Drain														
1 Kleppe Lane	0.26	0.26	18.0	2.2	2.1	20.0	2.4	2.4	12.5	2.4	2.0	17.5	2.2	2.1
Steamboat Cr.														
1 Kimlick Lane	.75	.62	19.0	.29	.28	22.0	.27	.28	13.0	.41	.34	19.5	.32	.32
2 STP outfall	.13	.13	20.0	.10	.10	23.5	.00	.00	14.0	.14	.12	21.0	.11	.12
(B) MAINSTEM TRUCKEE RIVER:														
1 McCarran bridge	56.12	2.46	15.5	4.4	3.9	20.5	2.8	2.9	10.5	12	9.3	18.0	2.8	2.7
2 N. Truckee Drain	53.66	.13	15.5	.95	.85	20.0	.68	.68	10.5	2.0	1.6	18.0	.65	.62
3 Steamboat Creek	53.53	1.30	16.5	.47	.43	21.0	.33	.34	11.0	1.0	.84	19.0	.35	.34
4 Vista gage	52.23	.98	17.0	.47	.44	21.0	.33	.34	11.0	1.0	.84	19.5	.35	.34
5 Largomarsino divs.	51.25	.35	17.0	35	33	21.0	22	23	11.0	82	66	20.0	24	24
6 Below Largomarsino divs.	50.90	.85	17.0	36	33	21.5	9.0	9.4	10.5	33	26	20.0	9.8	9.8
7 Lockwood bridge	50.05	.15	17.5	36	34	21.5	9.1	9.4	10.5	33	26	20.0	9.8	9.8
8 Groton div.	49.90	1.65	17.5	18	17	21.5	12	12	10.5	40	32	20.0	13	13
9 Mustang bridge	48.25	1.57	17.0	7.7	7.2	21.5	5.3	5.5	10.5	17	14	20.5	5.5	5.6
10 McCarran pool	46.68	.33	17.0	.55	.51	21.5	.38	.39	10.5	1.2	.97	20.5	.39	.4
11 McCarran div.	46.35	1.43	17.0	20	19	21.5	14	14	10.5	44	35	20.5	14	14
12 Patrick bridge	44.92	2.04	17.5	9.7	9.1	22.0	6.8	7.2	10.5	22	18	20.5	7.1	7.2
13 SP Railroad bridge	42.88	.86	17.5	2.3	2.2	22.0	1.6	1.7	11.0	5.2	4.1	20.5	1.7	1.7
14 Hill div.	42.02	1.26	18.0	4.9	4.7	22.0	3.5	3.6	11.0	14	11	21.0	3.6	3.6
15 Tracy div.	40.76	.14	18.0	35	34	22.0	25	26	11.0	63	51	21.0	25	26
16 Tracy bridge	40.62	2.02	18.5	7.8	7.6	22.0	5.5	5.7	11.0	14	11	21.0	5.6	5.7
17 Clark bridge	38.60	1.50	19.0	9.5	9.2	22.0	6.7	7.0	11.0	20	17	21.0	6.8	7.0
18 RM 37.1	37.10	1.50	19.0	4.6	4.5	22.5	3.2	3.4	11.0	9.9	8.0	20.5	3.3	3.3
19 Derby pool	35.60	.72	19.5	.69	.68	22.5	.48	.51	11.0	1.5	1.2	20.5	.50	.50
20 Derby Dam	34.88	.36	19.5	23	23	23.0	12	13	11.0	120	100	21.0	18	18

TABLE 39.—Reaeration coefficients (K_2) used in model calibration and verification—Continued

Model segment	Starting river mile	Length (mile)	(A) June 1979 Water temperature (°C)	(A) Reaeration rate (1/day) At 20 °C	(A) Reaeration rate (1/day) Ambient temperature	(B) August 1979 Water temperature (°C)	(B) Reaeration rate (1/day) At 20 °C	(B) Reaeration rate (1/day) Ambient temperature	(C) June 1980 Water temperature (°C)	(C) Reaeration rate (1/day) At 20 °C	(C) Reaeration rate (1/day) Ambient temperature	(D) August 1980 Water temperature (°C)	(D) Reaeration rate (1/day) At 20 °C	(D) Reaeration rate (1/day) Ambient temperature
21 Derby cableway	34.52	3.24	19.5	5.7	5.6	23.0	3.2	3.4	11.0	31	25	21.0	4.5	4.6
22 Washburn Dam	31.28	1.31	19.5	9.0	8.9	23.0	5.2	5.6	11.0	50	40	21.0	7.4	7.6
23 Painted Rock bridge	29.97	.62	19.5	2.8	2.8	23.0	1.6	1.7	11.5	15	12	21.5	2.3	2.4
24 Gregory—Monte diversion	29.35	1.35	19.5	6.4	6.4	23.0	3.1	3.3	11.5	45	37	21.5	5.1	5.2
25 RM 28.0	28.00	1.25	20.0	2.2	2.2	23.0	1.1	1.1	11.5	15	12	21.5	1.7	1.8
26 Herman div.	26.75	.80	20.0	3.5	3.5	23.0	1.4	1.5	11.5	27	22	22.0	2.6	2.7
27 Pierson div.	25.95	2.05	20.0	3.7	3.7	23.0	1.6	1.7	11.5	30	24	22.0	2.8	2.9
28 Proctor div.	23.90	.21	20.0	6.4	6.4	23.0	3.4	3.6	11.5	58	48	22.0	5.1	5.3
29 Wadsworth bridge	23.69	1.14	20.0	1.2	1.2	23.0	.66	.71	11.5	11	8.7	22.0	.97	1.0
30 Fellnagle div.	22.55	1.15	20.0	7.2	7.2	23.0	3.7	4.0	11.5	43	35	22.0	5.2	5.4
31 RM 21.4	21.40	1.56	20.0	4.1	4.1	23.5	2.2	2.4	11.5	23	19	21.5	3.0	3.1
32 S Bar S diversion	19.84	2.02	19.5	4.3	4.2	24.0	2.1	2.4	12.0	23	19	21.5	3.1	3.2
33 S Bar S pump	17.82	2.00	19.5	3.5	3.5	24.0	1.8	1.9	12.0	19	16	21.5	2.5	2.6
34 RM 15.8	15.82	2.64	19.5	3.9	3.8	24.5	1.9	2.2	12.0	12	9.7	21.5	2.8	2.9
35 Dead Ox Wash	13.18	3.18	19.0	1.4	1.4	24.5	.65	.72	12.0	10	8.7	21.5	.97	1.0
36 RM 10.0	10.00	.80	19.0	3.9	3.8	24.5	1.8	2.0	12.0	29	24	21.5	2.7	2.8
37 RM 9.2	9.20	.99	19.0	.26	.25	24.5	.12	.14	12.0	1.9	1.6	21.5	.18	.19
38 Numana Dam	8.21	.61	19.0	12	12	25.0	5.1	5.7	12.0	80	66	21.5	7.6	7.8
39 RM 7.6	7.60	.80	19.0	5.1	5.0	25.0	2.2	2.4	12.0	34	28	21.5	3.2	3.3
40 RM 6.8	6.80	2.80	19.0	3.2	3.1	25.0	1.5	1.6	12.0	21	17	21.5	2.1	2.2
41 RM 4.0	4.00	.78	19.0	5.6	5.4	25.0	2.7	3.1	12.0	36	29	21.5	3.7	3.8
42 Nixon bridge	3.22	2.22	18.5	1.3	1.3	24.0	.77	.85	12.0	14	11	21.0	.96	.99
43 RM 1.0	1.00	1.00	18.0	.21	.20	23.0	.12	.13	12.0	2.2	1.8	20.5	.15	.15
(C) TRUCKEE CANAL:														
C1 Derby Dam	31.42	6.04	19.0	.74	.73	23.0	.53	.57	11.0	.39	.32	21.0	.51	.52
C2 Pyramid check	25.38	2.84	19.0	2.3	2.2	23.0	1.6	1.7	11.5	1.2	.97	21.0	1.5	1.6
C3 Tunnel no. 3	22.54	4.52	18.5	.09	.09	23.5	.06	.07	11.5	.05	.04	21.5	.06	.06
C4 Fernley check	18.02	2.95	18.5	.22	.21	23.5	.11	.12	11.5	.09	.08	21.5	.10	.11
C5 Anderson check	15.07	4.00	18.5	.39	.37	23.5	.16	.18	12.5	.16	.13	22.0	.14	.14
C6 Allendale check	11.07	4.68	18.5	.02	.02	23.5	.01	.01	13.0	.01	.01	22.0	.01	.01
C7 Mason check	6.39	3.14	18.5	.24	.23	24.0	.09	.09	13.5	.09	.08	22.0	.06	.06
C8 Bango check	3.25	2.81	19.0	1.5	1.5	24.0	.87	.96	13.5	.98	.84	21.5	.61	.63
C9 Highway 50	.44	.44	19.0	1.2	1.2	24.0	.68	.75	13.5	.80	.68	21.5	.45	.47

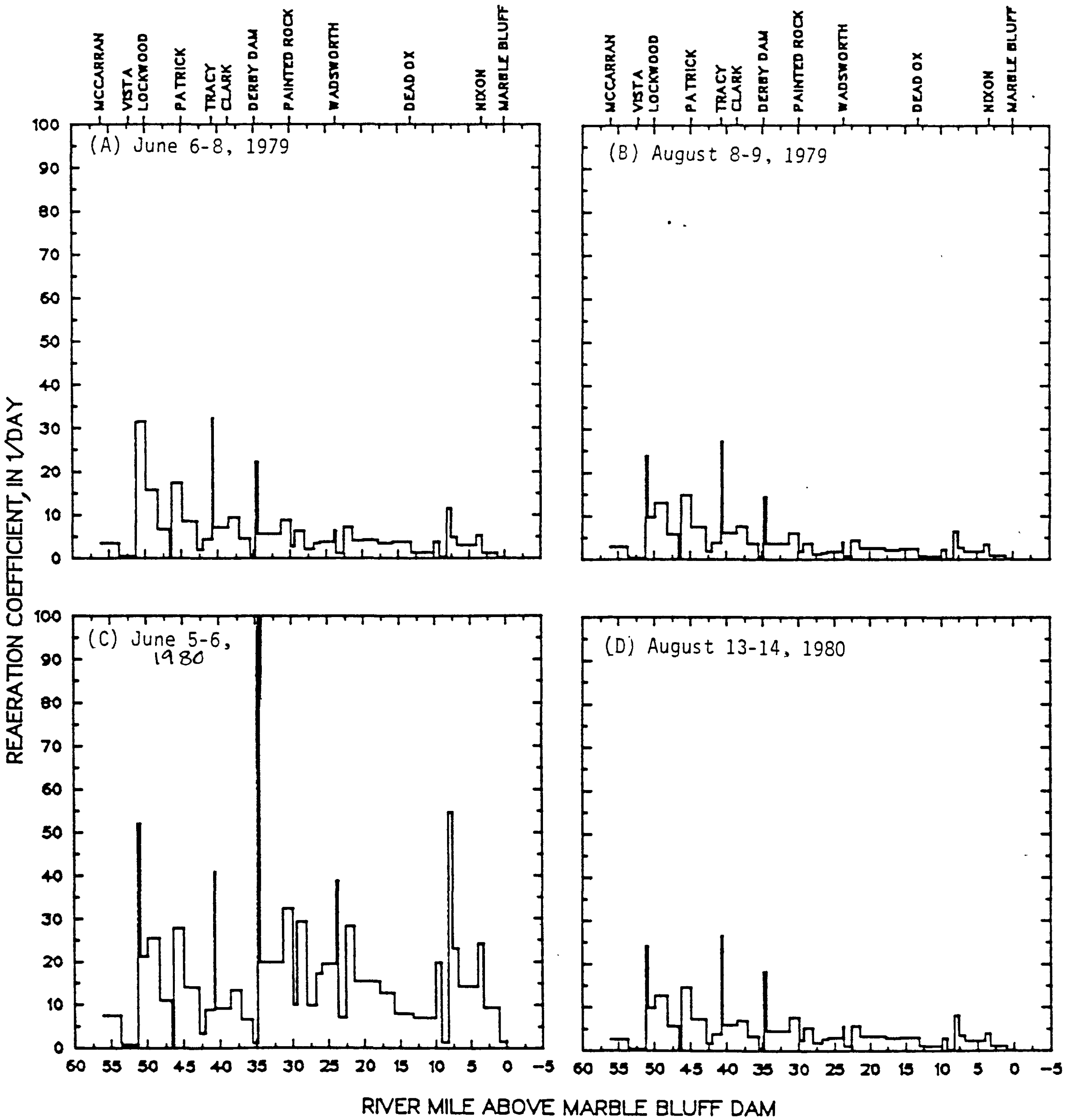


FIGURE 53.--Simulated and observed reaeration coefficients (K_2) [redacted] during synoptic studies, Truckee Canal.

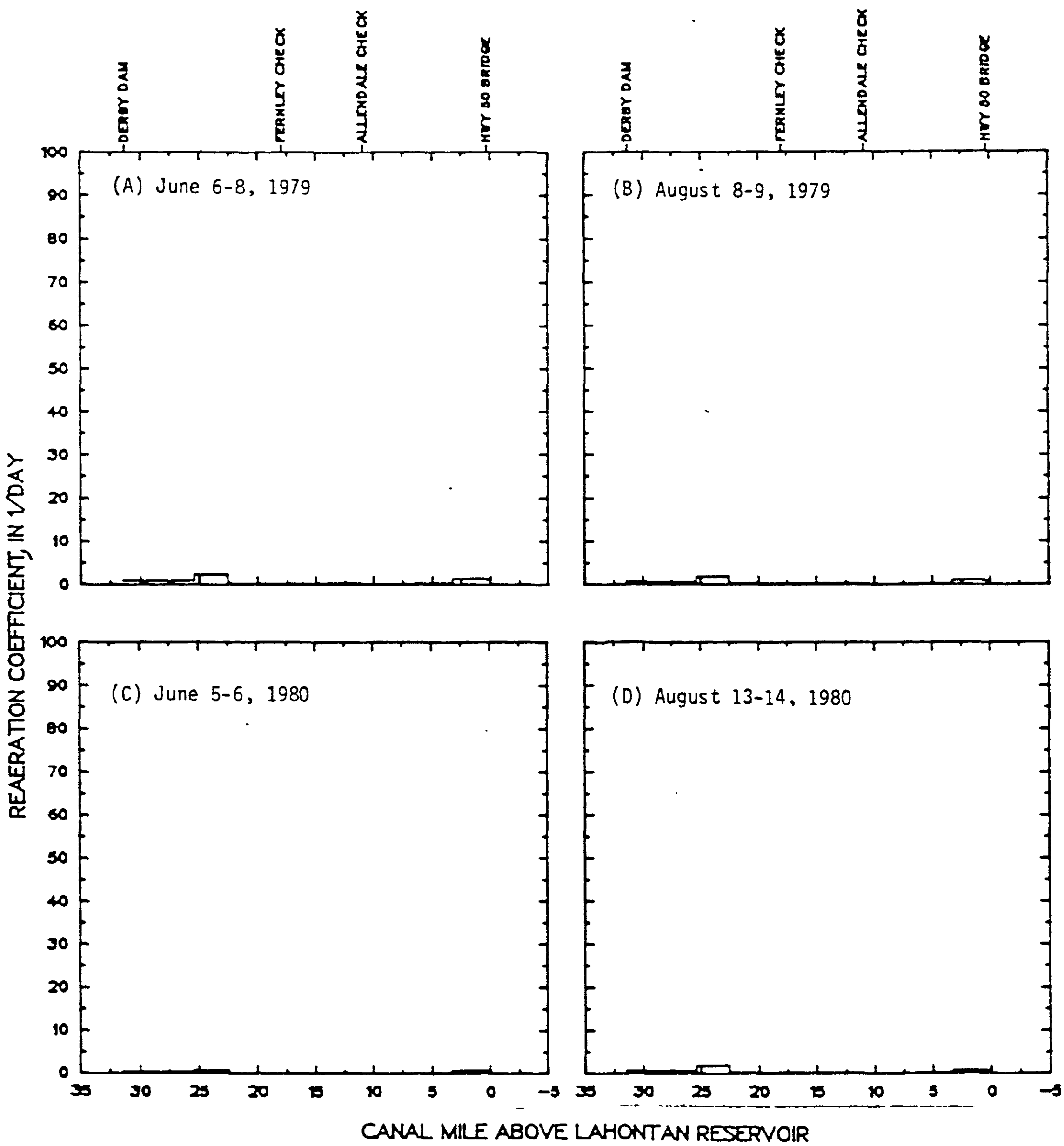


FIGURE 54.--Simulated reaeration coefficients (K_2) during synoptic studies, Truckee River.

Photosynthesis and respiration of aquatic plants

The observed large fluctuations in DO concentrations through a 24-hour cycle indicate that the metabolism of aquatic plants in the river and canal strongly impact the overall oxygen budget. Field observations indicate that productivity in much of the Truckee River below Reno is dominated by attached algae, with localized reaches of intense growth of rooted aquatic plants. In contrast, the greater depths, slower velocities, and reduced transparency in the canal promote planktonic algae, with localized reaches of rooted plants.

Several methods were used to estimate oxygen productivity from field data collected during the synoptic studies. Light-dark bottle instream incubations were attempted, and observed diel DO data were analyzed by a variety of techniques. All methods were found to have limitations that affected their applicability to the quantitative modeling of oxygen, and the final calibration of the net photosynthetic production of oxygen was by curve fitting.

The basic process of photosynthesis can be represented by:

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2 \qquad (34)$$

The rate of photosynthesis (primary productivity) in water is often estimated by measuring the amount of DO produced in a 24-hour period. Net photosynthetic oxygen production has also been estimated from other indicators of productivity such as concentrations of chlorophyll *a* as an indicator of algal biomass. Methods employed in analyzing DO data in this study assume that the net change in oxygen concentration in a volume of water under daytime illumination is from production (P) by chlorophyll-containing plants and simultaneous consumption in respiration (R) by plants, animals, and bacteria.

In the dark, only respiration occurs. Thus, the rate of oxygen production in light is an estimate of net primary productivity (P-R), and the rate of oxygen consumption in dark estimates respiration (R). Assuming the rate of respiration is uniform, addition of net production in light and respiration in dark will estimate gross primary productivity (P).

The above assumptions are employed in the light-bottle/dark-bottle technique to estimate values for P and R from simultaneous instream incubation of transparent and opaque BOD bottles (Greeson and others, 1977, page 247). Light-bottle/dark-bottle studies of planktonic algal production were performed at 15 locations in the river and canal in June and August 1980, with indeterminate results. For many sites, the dissolved oxygen measured in light bottles at the end of the incubation period (3 or 4 hours) was less than in the dark bottles. In retrospect, it was concluded that the shallow depths (1 to 2 feet) of implacement of the bottles may have resulted in inhibition of photosynthesis, or photoxidation due to intense solar radiation (Vollenweider, 1974).

The same assumptions may be applied to analysis of hourly oxygen data in a 24-hour cycle, as indicated in figure 55. In this analysis, first applied to streams by Odum (1956, 1957), periodic measurements of dissolved oxygen and water temperature are made over a 24-hour period (figure 55A, B). From the measured water temperatures and barometric pressure, the oxygen concentrations are converted to a net deficit from saturation (figure 55C). Oxygen deficits are corrected for diffusion to and from the atmosphere, resulting in a net productivity curve (figure 55D). In a graphical analysis (Greeson and others, 1977, page 271), the curve is divided into daytime and nighttime portions (figure 55E). The area under the curve during daytime is assumed to be the gross production (P), and the total area that is negative (including an estimated baseline during the day) is assumed to be the gross daily respiration (R). Net community productivity is defined as P - R. A computer program (Stephens and Jennings, 1976) is available for a similar analysis. This program, with modifications, assumes that the net community metabolism (P - R) is approximated by the net daytime production (Pd) minus the nighttime respiration (Rn) (figure 55F). Assuming respiration to be constant, gross respiration (R) can be calculated from the ratio of nighttime hours to 24, and P is estimated by the net community metabolism minus R.

Figure 55 near here

Diel DO data also may be analyzed by assuming a basic symmetry to the oxygen cycle. O'Connor (1967) noted that the photosynthetic production is dependent upon the hourly change in solar radiation supplying energy to the algae, which may approximated by a half-cycle sine wave:

$$\text{for } tsr<t<tss: \quad Pt = Pm \text{ sine } [\frac{2\pi}{24} (t-tsr)] \tag{35}$$

$$\text{for } tss<t<tsr: \quad Pt = 0$$

where Pt = photosynthetic oxygen production at time t, in milligrams per liter per day,

Pm = maximum production, amplitude of the productivity curve, in milligrams per liter per day,

t = time of day, in hours (0 to 24),

tsr = time of sunrise, in hours,

tsr = time of sunset, in hours,

$2(\pi)/24$ = conversion of hours to radians.

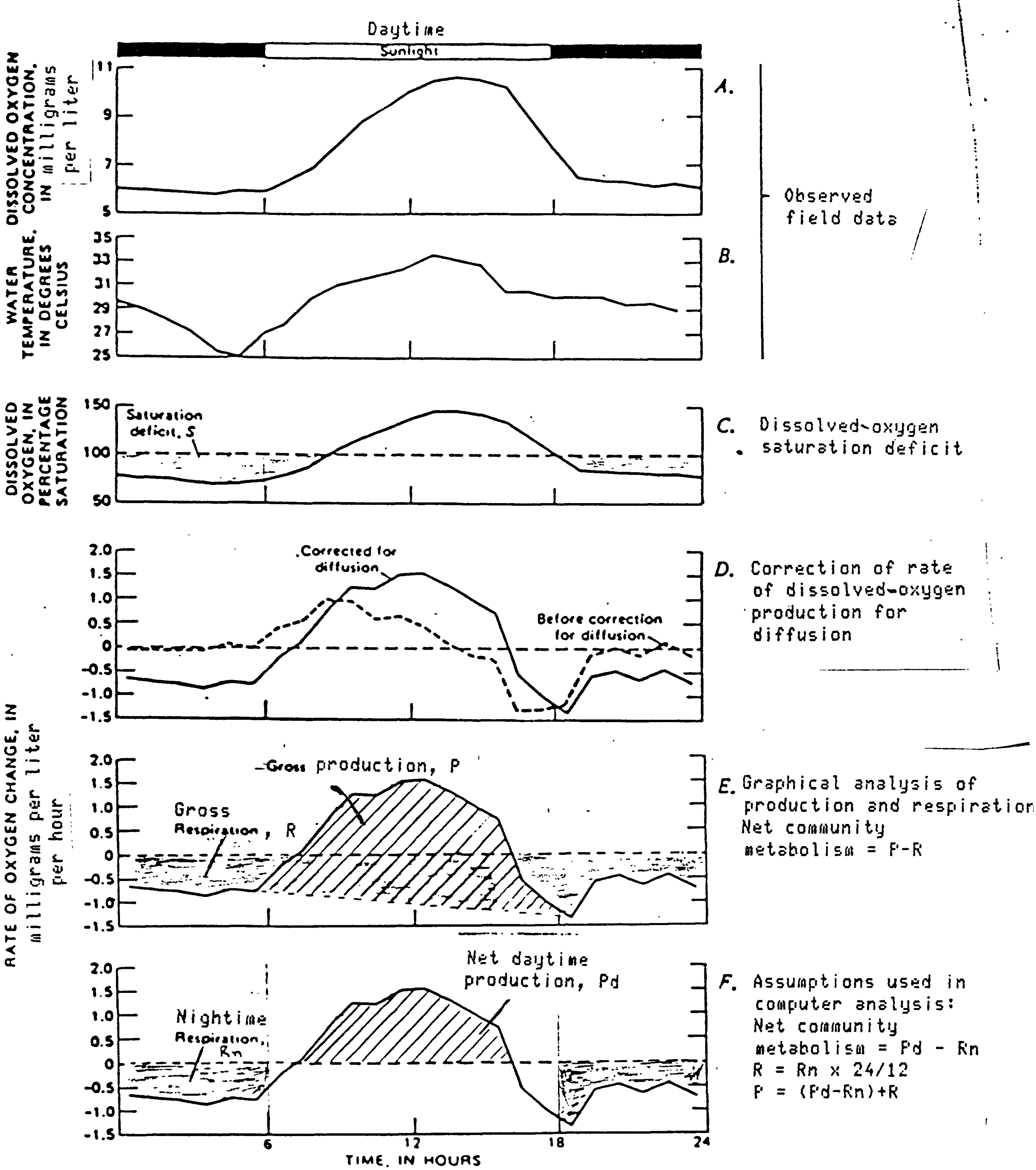


FIGURE 55.--Estimates of photosynthesis and respiration by aquatic biota may be obtained from diel dissolved-oxygen data (after Greeson and others, 1977).

For steady-state assumptions, the average oxygen production from photosynthesis for a day is:

$$P = Pm/\pi \qquad (36)$$

The relations in equations 32 and 33 are shown in figure 56. Equation 35 describes the time-varying response of algal production of oxygen, Pt, during daylight hours. Respiration, R, is assumed to be constant. The resultant net community metabolism (Pt-R) is approximated by a truncated sine curve (figure 56A). Oxygen diffussion to and from the atmosphere dampens the resulting changes in deficit with respect to saturation and changes the timing of minimum and peak values (figure 56B). The resulting DO concentrations cycle above and below the saturation concentration over a day as shown in figure 56C. The relations shown assume that no oxygen deficits other than the effects of photosynthesis exist, daylight and nighttime hours are equal, diel temperature changes do not affect atmospheric diffusion, and there are no residual photosynthetic deficits from upstream.

Figure 56 near here

The full effects of photosynthetic production on steady-state transport of oxygen as illustrated in figures 56A and B have been described by O'Connor and Di Torro (1970). They have shown that the effect of photosynthesis on the oxygen deficit can be represented by:

$$Dp = -(P-R) + Pm[G] \qquad (37)$$

where Dp = the net oxygen deficit due to photosynthesis and respiration,

P-R = net daily algal productivity,

Pm = maximum photosynthetic production

G = a Fourier series of sine functions describing time-varying net photosynthesis at the site and residual effects from upstream.

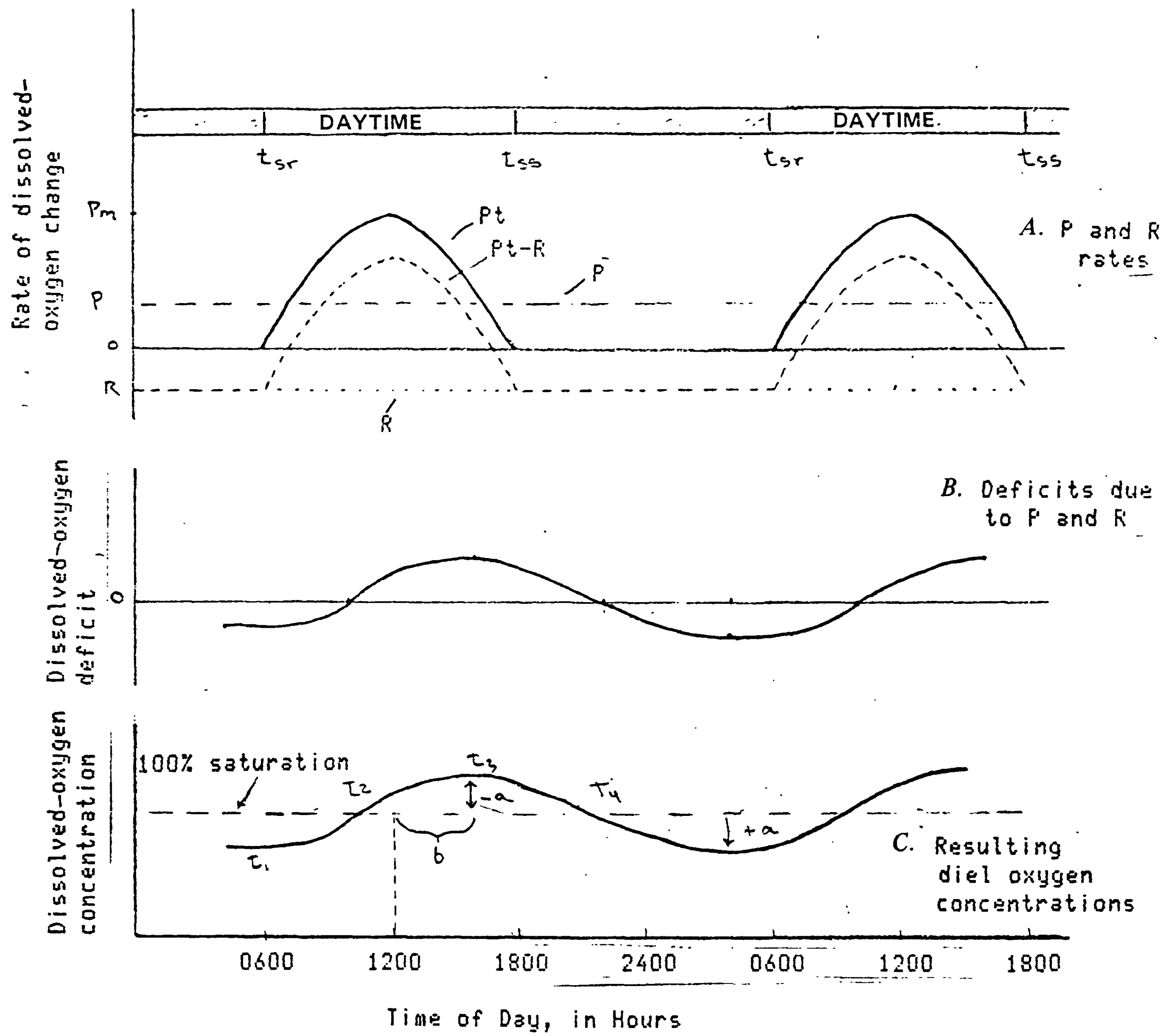


FIGURE 5b.--A simple sine curve may be used to quantify diel oxygen cycles caused by algal photosynthesis and respiration.

The similarity between the shape of the curves in figures 56B and C and observed field data suggest that a simple sine function may approximate hourly oxygen variations in streams with significant diel fluctuations. Under steady-state assumptions for modeling average daily DO, all deficits are considered to be constant with time, including P and R (equation 34). Shelton and others (1978) proposed simulation of the time-varying effects of net photosynthesis by:

$$Dt = Da - a \text{ sine}\left[\frac{2\pi}{24} (t+b)\right] \quad , \tag{38}$$

where Dt = total oxygen deficit (milligrams per liter) at time t (hours),

Da = the average daily deficit from all sources, in milligrams per liter,

a = amplitude of the daily change in deficit (milligrams per liter), and,

b = lag between noon and time of peak productivity, in hours.

Since the average daily DO concentration is simply the concentration at saturation minus the average deficit, maximum and minimum daily DO concentrations may be predicted from the mean concentration and the amplitude, a:

$$DOmax = DOmean + a \tag{38a}$$

$$DOmin = DOmean - a \tag{38b}$$

$$a = DOmean - DOmin = DOmax - DOmean = (DOmax - DOmin)/2 \tag{38c}$$

$$b = 0600 - t1 = 1200 - t2 = 1800 - t3 = 2400 - t4 \quad , \tag{38d}$$

where t1 = time of minium concentration,

t2 = time of average concentration in morning,

t3 = time of maximum concentration,

t4 = time of average concentration in evening.

Equation 38 may be fit to observed diel DO data by simple linear regression. To do so, let

t = time, in decimal hours,

$x1 = \sin(0.2618(t))$,

$x2 = \cos(0.2618(t))$,

y = observed DO concentration at time t.

The linear equation corresponding to equation 38 is

$$y = I + S1(x1) + S2(x2) \quad (39)$$

where I is the intercept, and S1 and S2 are regression coefficients. Once I, S1, and S2 are determined by standard regression techniques,

$$a = (S1^2 + s2^2)^{0.5} \quad (39a)$$

$$b = \arctan(s2/s1)/0.2618 \quad (39b)$$

Negative values for b can be corrected to a 24 hour cycle by adding 24.

Estimates of the effects of P and R and results of a harmonic analysis of diel variations in DO for the river and canal are presented in table 40 and shown graphically for the two August synoptic studies in figure 57. Observed DO means and ranges (figure 57A) show the river to have an average net deficit with respect to saturation from Vista to Derby Dam. Average DO concentrations exceed saturation in the August conditions somewhere between Derby Dam and Wasdsworth. Data for the canal (shown in equivalent river miles below Derby Dam) start with an initial average deficit at the point of diversion and begin to exceed saturation near the Highway 95A sampling site at Fernley. Similar trends are seen in the calculated P and R data from the modifed Odum analysis (figure 57E). Respiration (R) exceeds gross production (P) from Vista to below Derby Dam. Between Derby and Wadsworth, the balance shifts to a positive net metabolism with P exceeding R. In considering these trends, one must remember that the Odum method includes all oxygen demands in the estimated R values, thus the relatively high respiration rates above Derby Dam are due mainly to bacterial respiration in the consumption of carbonaceous and nitrogenous material rather than to algae. Interestingly, estimated P values for the canal obtained by the Odum method are less than in corresponding reaches of the river (figure 57E) even though observed supersaturation is much greater in the canal than in the river (figure 57A). This is due to the much higher K_2 coefficients in the river resulting in a faster outgassing of photosynthetic oxygen than in the canal, where low K_2 values result in photosynthetic oxygen remaining at concentrations exceeding saturation during transport to downstream sites.

Table 40 and Figure 57 near here

TABLE 40.—Estimates of effects of photosynthesis and respiration on oxygen budgets for the Truckee River and Canal

Observed data: Dissolved-oxygen (DO) means and extremes based on total observed record for each synoptic; N, number of analyses for DO per study;

Phytoplankton data are mean values per study.

Diel analyses: Estimates of gross photosynthetic production (P), gross daily respiration (R), and net community metabolism (P-R) from computer analysis of observed data.

Harmonic analyses: Based on fitting observed data to the equation:

$$DO_t = M + a \{sine[(2\pi/24)(t+b)]\} ,$$

by linear regression, where DO_t = DO concentration at time t (hours).

R^2: Correlation coefficient

SE: Standard error of estimate for the regression analysis (95 percent or greater confidence except where flagged by *).

Predicted minimum DO: M −a, percent error gives difference between observed and predicted minima. Time for minima is Pacific Daylight Savings Time.

		Observed data						Diel analysis (mg/L)			Harmonic analysis					Predicted minimum DO		
						Phytoplankton												
Site	Synoptic study	N	Mean water temperature (°C)	Mean DO (mg/L)	Maximum DO (mg/L)	Minimum DO (mg/L)	Chlorophyl *a* (mg/L)	Cells	P	R	P-R	Mean DO (M) (mg/L)	Amplitude (a) (mg/L)	Phase angle (b) (hrs)	R^2	SE of est. (mg/L)	(mg/L)	Error (percent)	Time (hours)
								Truckee River above Reno-Sparks urban area											
Crystal Peak Park	June 80	13	9.6	9.5	9.9	9.3	0.8	521	—	—	—	9.5	0.2	1.2	0.78	0.1	9.3	0	0450
	Aug. 80	14	16.1	8.4	9.2	7.8	.2	46	—	—	—	8.3	.6	4.5	.88	.2	7.7	−1	0130
Mayberry Ave.	June 80	12	9.9	9.6	11.5	9.0	—	33	—	—	—	9.5	.3	2.9	.84	.1	9.2	2	0300
	Aug. 80	13	17.2	8.7	9.8	7.6	.2	210	—	—	—	8.6	1.2	5.2	.94	.2	7.4	3	0050
								Truckee River at start of modeled reach											
McCarran Blvd. RM 56.12	June 79	13	15.4	8.5	9.4	7.4	—	—	−0.8	0.9	−1.7	8.3	.7	5.4	.62	.4	7.6	3	0040
	Aug. 79	13	20.3	7.6	9.2	6.4	1.2	360	2.9	3.8	−.9	7.5	1.3	4.9	.93	.3	6.2	−3	0110
	June 80	12	9.6	9.7	10.2	9.4	1.4	410	−1.2	−2.4	1.2	9.6	.6	12.4	.73	.2	9.0	−4	1740
	Aug. 80	14	16.1	8.3	9.7	6.8	.2	390	−1.8	−2.0	.2	8.1	1.5	4.8	.96	.2	6.6	−3	0110
								Tributary inputs											
North Truckee Drain	June 79	16	17.8	8.8	12.2	5.0	—	—	9.8	9.8	0	7.7	3.9	3.2	.97	.5	3.8	−24	0250
	Aug. 79	12	19.9	7.0	11.0	4.4	2.0	400	11.1	13.0	−1.9	7.0	3.1	3.0	.95	.6	3.9	−11	0300
	June 80	11	12.3	8.7	10.3	7.2	1.3	1,760	6.5	7.9	−1.4	8.3	1.5	3.9	.82	.5	6.8	−6	0210
	Aug. 80	14	17.5	8.0	10.8	5.6	.9	1,630	.0	.7	− .7	7.8	2.0	3.1	.95	.5	5.8	4	0300

TABLE 40.—Estimates of effects of photosynthesis and respiration on oxygen budgets for the Truckee River and Canal—Continued

			Observed data				Phytoplankton		Diel analysis (mg/L)			Harmonic analysis					Predicted minimum DO		
Site	Synoptic study	N	Mean water temper-ature (°C)	Mean DO (mg/L)	Max-imum DO (mg/L)	Min-imum DO (mg/L)	Chlo-rophyl *a* (mg/L)	Cells	P	R	P-R	Mean DO (M) (mg/L)	Amp-litude (a) (mg/L)	Phase angle (b) (hrs)	R^2	SE of est. (mg/L)	(mg/L)	Error (percent)	Time (hours)
Steam-boat Creek	June 79	15	19.1	7.8	10.3	4.6	—	—	4.1	4.4	.3	6.9	2.5	2.1	.76	.9	4.4	-4	0350
	Aug. 79	11	22.2	5.8	8.2	4.0	1.7	2,170	7.6	8.1	- .5	5.7	2.2	1.4	.96	.4	3.5	-13	0440
	June 80	11	13.1	7.9	8.8	6.7	1.7	1,420	4.8	5.2	- .4	7.9	.9	2.7	.78	.4	7.0	4	0320
	Aug. 80	14	19.6	6.9	9.0	5.0	1.8	1,750	2.4	2.5	- .1	6.8	2.1	1.6	.98	.2	4.7	-6	0420
Reno-Sparks STP	June 79	12	22.0	7.1	7.6	5.0	—	—	—	—	—	7.1	.3	3.1	.15*	.7	6.8	30	0250
	Aug. 79	11	24.8	6.5	6.8	6.3	.5	—	—	—	—	6.6	.2	12.4	.56	.1	6.5	3	1740
	June 80	11	18.6	8.6	9.0	8.3	—	—	—	—	—	8.6	.1	2.9	.06*	.1	8.5	2	0300
	Aug. 80	14	23.3	7.6	8.5	7.2	.3	—	—	—	—	7.6	.2	3.5	.19*	.4	7.4	3	0230
Truckee River, Vista to Derby Dam																			
Vista gage RM 52.23	June 79	16	16.8	8.3	9.4	7.2	—	—	2.0	1.7	.3	7.8	1.1	2.8	.67	.4	6.7	-7	0310
	Aug. 79	13	21.0	6.6	8.2	5.4	.5	—	3.8	4.2	- .4	6.7	1.2	1.8	.94	.2	5.5	2	0410
	June 80	12	10.9	9.5	9.8	8.9	.6	480	1.2	1.4	- .2	9.5	.3	5.4	.58	.2	9.2	3	0040
	Aug. 80	13	19.5	7.1	8.5	6.0	.4	1,040	1.8	2.3	- .5	7.1	1.3	1.1	.95	.2	5.8	-3	0450
Lockwood RM 50.05	June 79	18	17.3	8.1	9.4	7.0	—	—	8.7	19.7	-11.0	7.7	1.2	3.6	.67	.5	6.5	-7	0220
	Aug. 79	13	21.4	5.9	7.8	4.5	1.5	610	13.7	29.3	-15.6	5.6	1.6	4.0	.93	.4	4.0	-11	0200
	June 80	13	10.7	9.3	9.8	8.6	1.3	480	13.7	25.9	-12.2	9.2	.4	4.9	.65	.2	8.8	2	0100
	Aug. 80	12	20.0	6.9	8.0	5.6	.5	1,170	9.8	20.1	-10.3	6.7	1.1	3.5	.89	.3	5,6	0	0230
Patrick RM 44.94	June 79	16	17.2	8.1	9.2	7.0	—	—	8.2	17.9	- 9.7	7.8	1.0	2.7	.84	.3	6.8	-3	0320
	Aug. 79	10	21.7	6.6	9.0	4.5	1.1	—	24.0	41.5	-17.5	6.4	2.2	3.1	.95	.4	4.2	-7	0300
	June 80	13	10.7	9.2	9.7	8.7	—	510	17.8	34.3	-16.5	9.1	.4	4.9	.70	.2	8.7	0	0110
	Aug. 80	14	20.6	7.1	9.2	5.4	1.0	1,440	26.7	37.8	-11.1	7.0	1.8	2.7	.97	.3	5.2	-4	0320
Tracy RM 40.62	June 79	18	18.2	8.1	9.7	6.3	—	—	9.0	12.8	- 3.8	7.8	1.4	2.2	.84	.4	6.4	2	0350
	June 80	14	10.8	9.1	9.9	8.7	—	540	7.4	15.2	- 7.8	9.1	.3	4.7	.62	.2	8.8	1	0120
Clark RM 38.60	Aug. 79	10	22.1	6.3	9.1	3.8	1.4	—	14.3	23.0	- 8.7	6.1	2.6	2.9	.94	.6	3.5	-8	0304
	Aug. 80	14	20.9	7.5	9.9	5.2	.8	1,960	11.9	14.6	- 2.7	7.3	2.2	2.5	.97	.3	5.1	-2	0330
Derby Dam RM 34.88	June 79	16	19.5	8.2	9.6	6.8	—	—	5.4	6.8	- 1.4	7.7	1.3	1.2	.82	.4	6.4	-6	0450
	Aug. 79	16	22.8	6.3	10.2	4.4	1.4	1,030	9.3	9.7	- .4	6.7	2.8	1.8	.95	.5	3.9	-11	0410
	June 80	12	10.9	9.0	9.4	8.6	.8	500	8.8	16.2	7.4	8.9	.4	3.9	.89	.1	8.5	-1	0210
	Aug. 80	13	20.6	6.7	9.0	5.5	.8	2,630	-1.8	2.5	4.3	6.8	1.7	1.3	.89	.4	5.1	-7	0440

TABLE 40.—Estimates of effects of photosynthesis and respiration on oxygen budgets for the Truckee River and Canal—Continued

Site	Synoptic study	N	Observed data: Mean water temperature (°C)	Mean DO (mg/L)	Maximum DO (mg/L)	Minimum DO (mg/L)	Phytoplankton: Chlorophyl *a* (mg/L)	Cells	Diel analysis (mg/L): P	R	P–R	Harmonic analysis: Mean DO (M) (mg/L)	Amplitude (a) (mg/L)	Phase angle (b) (hrs)	R^2	SE of est. (mg/L)	Predicted minimum DO: (mg/L)	Error (percent)	Time (hours)
Truckee River below Derby Dam																			
Below Derby Dam RM 34.49	June 79	15	19.2	8.1	9.0	7.1	—	—	3.0	6.3	-3.3	7.8	.7	4.9	.61	.3	7.1	0	0110
	Aug. 79	17	23.2	6.6	8.2	5.5	1.0	—	9.5	17.1	-7.6	6.7	1.2	2.3	.90	.3	5.5	0	0340
	June 80	13	10.9	9.2	9.7	9.0	—	—	17.5	33.7	-16.2	9.2	.3	4.9	.70	.1	8.9	-1	0100
	Aug. 80	13	—	7.0	8.0	5.7	—	—	—	—	—	7.0	.9	1.7	.78	.4	6.1	7	0420
Painted Rock RM 29.97	June 80	8	11.2	9.2	9.5	8.9	1.0	450	11.0	20.4	-9.4	9.3	.2	1.5	.64	.1	9.1	2	0430
	Aug. 80	11	21.7	8.5	9.9	6.3	1.0	2,710	2.0	.5	1.5	7.7	2.1	3.8	.95	.3	5.6	-11	0210
Wads-worth RM 23.69	Aug. 79	12	23.0	6.9	11.8	3.4	1.3	—	19.0	18.0	1.0	7.8	4.3	.2	.99	.3	3.5	3	0550
	June 80	11	11.7	9.3	9.6	9.2	1.1	560	3.9	5.0	1.1	9.3	.1	4.2	.25*	.1	9.2*	0	0150*
	Aug. 80	14	21.8	8.5	13.1	5.0	2.7	3,230	4.0	2.5	1.5	8.3	4.1	2.0	.96	.7	4.2	-16	0400
Dead Ox RM 13.18	Aug. 79	12	24.5	7.2	10.4	4.6	1.5	—	12.7	12.8	-.1	7.2	3.0	1.9	.97	.4	4.2	-9	0410
	June 80	12	11.8	9.1	9.4	8.9	—	390	5.5	9.8	-4.3	9.1	.2	2.0	.53	.1	8.9	0	0400
	Aug. 80	14	21.5	7.6	11.2	4.8	1.1	3,560	12.2	11.8	.4	7.6	3.1	1.0	.97	.4	4.5	-6	0500
Nixon RM 3.22	June 79	16	18.9	8.3	9.0	7.4	—	—	2.6	2.4	.2	8.1	.8	3.9	.85	.2	7.3	-1	0200
	Aug. 79	12	24.9	7.7	10.4	5.2	2.2	—	13.5	11.5	2.0	7.6	2.8	3.5	.97	.4	4.8	-8	0230
	June 80	14	11.8	9.3	9.7	8.9	1.2	400	8.5	13.8	-5.3	9.3	.2	2.8	.94	.1	9.1	2	0320
	Aug. 80	14	21.5	7.5	9.2	5.9	.6	4,230	1.2	2.3	-1.1	7.4	1.9	3.8	.95	.3	5.5	-7	0210
Marble Bluff RM 0.00	June 79	12	17.9	7.5	9.0	6.3	—	—	5.6	6.1	- .5	7.5	1.0	3.1	.83	.4	6.5	3	0300
	Aug. 79	12	22.8	8.2	10.2	6.6	6.4	4,820	2.5	3.6	-1.1	8.2	1.5	2.6	.78	.7	6.7	-2	0320
	June 80	14	11.9	9.1	9.4	8.6	.7	320	3.9	7.3	-3.4	9.1	.4	3.7	.90	.1	8.7	1	0220
	Aug. 80	12	20.6	7.4	10.4	5.2	1.1	4,390	11.4	11.2	.2	7.7	2.2	2.6	.85	.7	5.5	6	0320
Truckee Canal																			
Highway 95A CM 18.23	June 79	25	18.3	7.1	8.0	5.7	—	—	.4	.5	- .1	7.0	.5	.7	.37	.4	6.5	14	0520
	Aug. 79	12	23.6	7.5	9.0	5.9	1.9	160	-2.2	-2.3	.1	7.5	1.5	16.1	.96	.3	6.0	2	1400
	June 80	13	11.6	8.5	8.8	8.2	.8	360	- .7	- .7	.0	8.5	.2	15.0	.66	.1	8.3	1	1500
	Aug. 80	12	21.6	6.8	7.0	6.4	.7	2,990	.9	.7	.2	6.8	.2	17.1	.56	.1	6.6	3	1250
Allen-dale check CM 11.07	June 80	11	12.8	9.0	9.1	8.8	—	580	- .2	- .2	.0	9.0	.2	3.7	.93	.04	8.8	0	0220
	Aug. 80	14	22.2	8.8	9.8	7.8	2.1	8,950	2.9	2.7	.2	8.9	1.0	1.7	.88	.3	7.9	1	0420
Highway 50 CM 0.44	June 79	16	18.8	7.8	8.1	7.2	—	—	1.0	1.5	.5	7.7	.4	1.8	.81	.1	7.3	1	0410
	Aug. 79	12	23.8	10.1	14.1	7.5	17.7	12,050	9.9	7.0	2.9	10.2	3.0	1.8	.88	.9	7.2	-4	0410
	June 80	10	13.7	9.7	10.2	9.2	1.1	1,220	1.8	1.2	.6	9.6	.6	3.2	.87	.2	9.0	-2	0250
	Aug. 80	13	21.5	10.2	14.2	7.8	1.5	3,950	1.3	- .6	1.9	10.1	3.0	1.3	.83	1.1	7.1	-9	0440

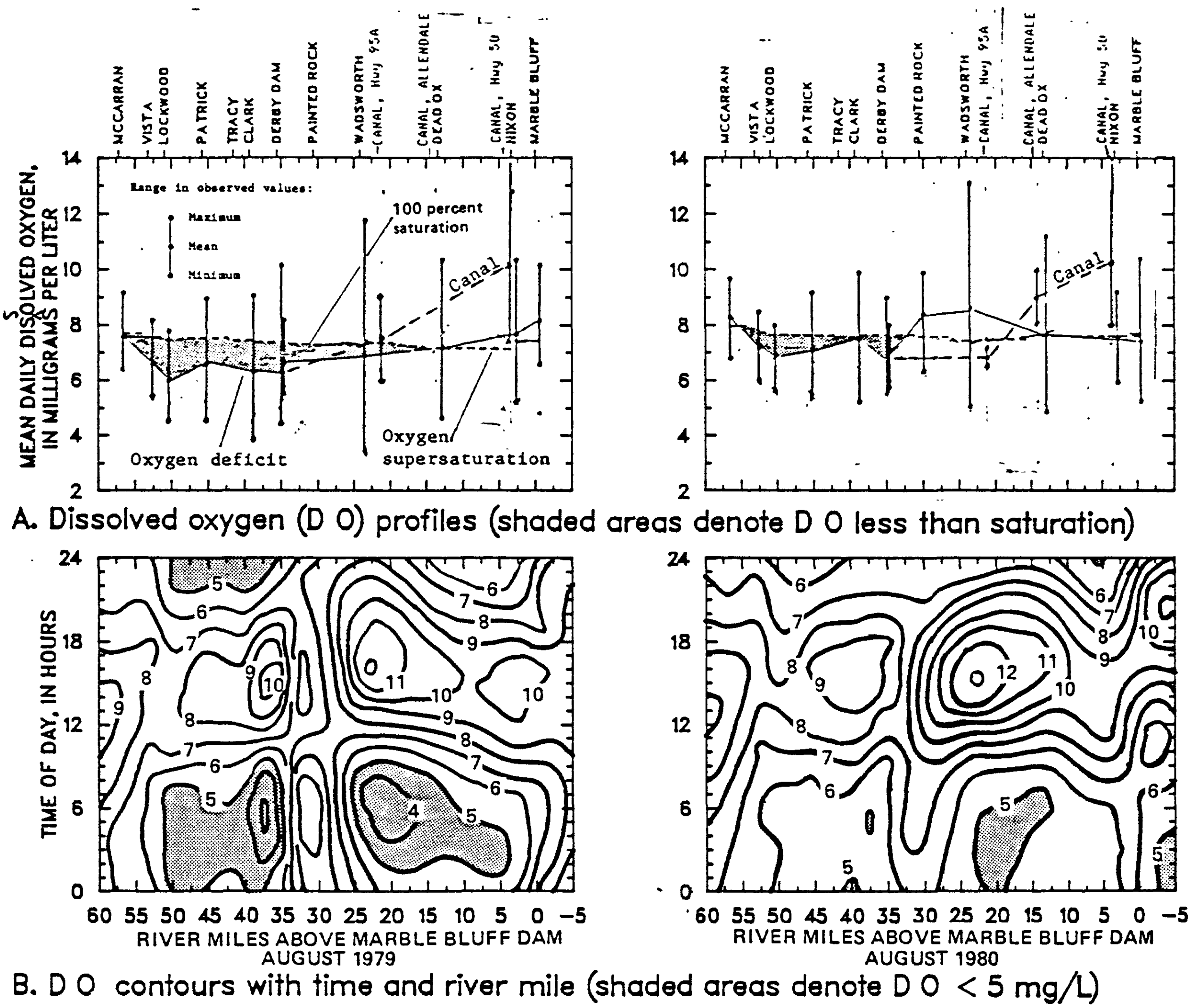
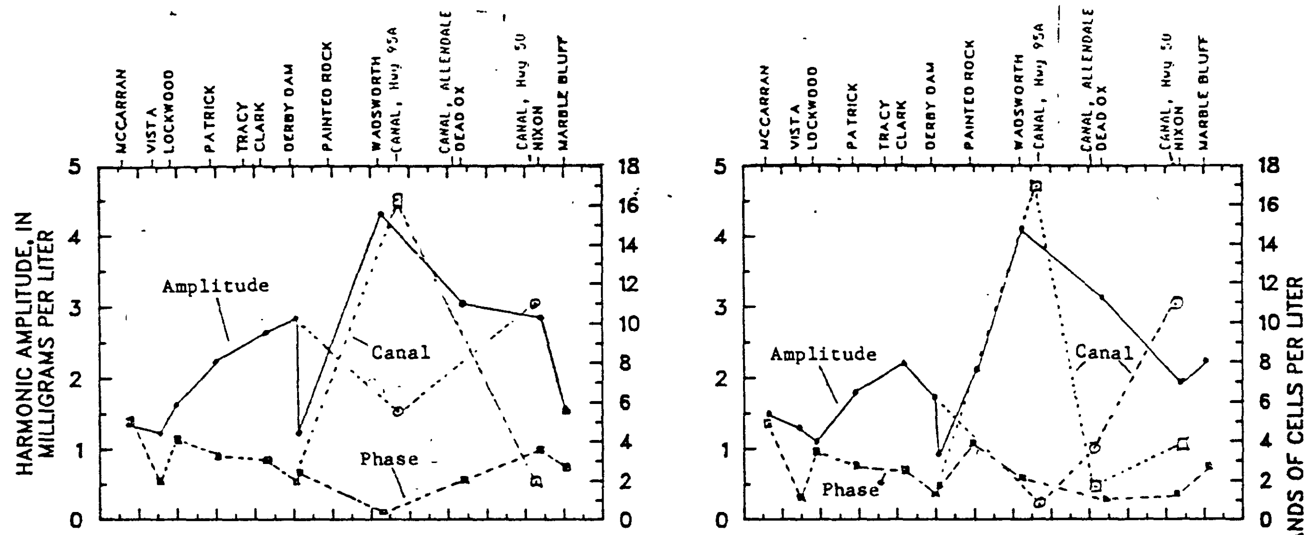
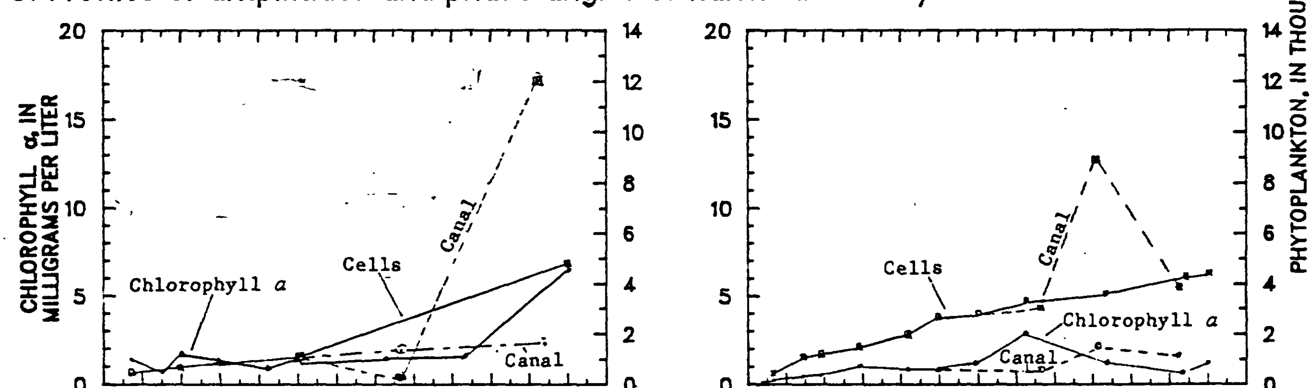


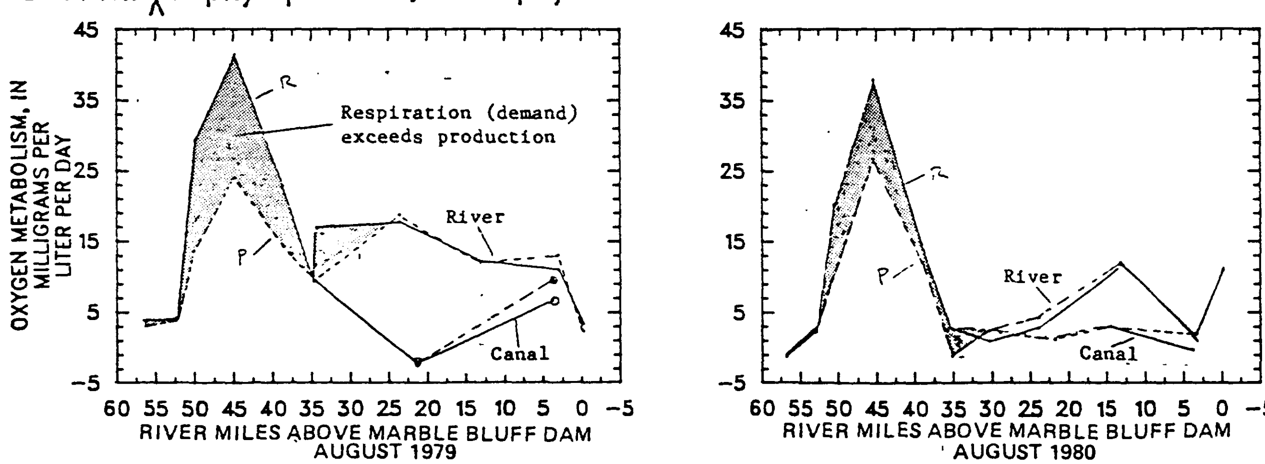
FIGURE 57.--Hourly variations in dissolved oxygen in the Truckee River are determined by the effects of algal photosynthesis.



C. Profiles of amplitudes and phase angles of harmonic D O cycles



D. Profiles of phytoplankton, chlorophyll *a* and cell counts



E. Profiles of estimated D O respiration and production

FIGURE 57.--Continued.

Results of a harmonic analysis of diel DO data from the four synoptic studies are given in table 40 and illustrated for the two August studies in figures 57 and 58. Values of m, a, and b shown were determined by linear regression of the observed data. The resultant high correlation coefficients (r^2) and low standard errors of estimate (average of 0.3 mg/L for all river sites) indicate that the simple harmonic analysis provides excellent simulations of the diel fluctuations in DO. Since minimum oxygen concentrations are of particular importance to meeting water-quality standards and managing fishery resouces, predicted minimum daily DO concentrations and hour of occurrence are included in the table. Average error of prediction of the minimum DO concentrations (with respect to the observed minima with a 2-hour sampling interval) was 2 percent for all the river data.

Figure 58 near here

Although mean daily DO concentrations were above the Nevada water-quality standards of 5 or 6 mg/L at all sites, minimum DO's were less than standards at most sites below Steamboat Creek. At most sites, minimum DO occurred between 2 a.m. and 4 a.m. (b = 2 to 4 hours). The relatively small variation in b from site to site is indicative of the predominance of local photosynthesis in the control of daily variations of DO at most sites. A notable exception is at the Highway 95A sampling site near Fernley on the Truckee Canal. The phase of the daily cycle at this site was about 12 hours out of synchronization with other sites for the two August and June 1980 synoptics, with minimum DO occurring at 1 to 2 in the afternoon, the normal time of high oxygen production from photosynthesis. This may be due to relatively low production in upper reaches of the canal as the algal population shifts from the attached communities typical for the shallow, swift

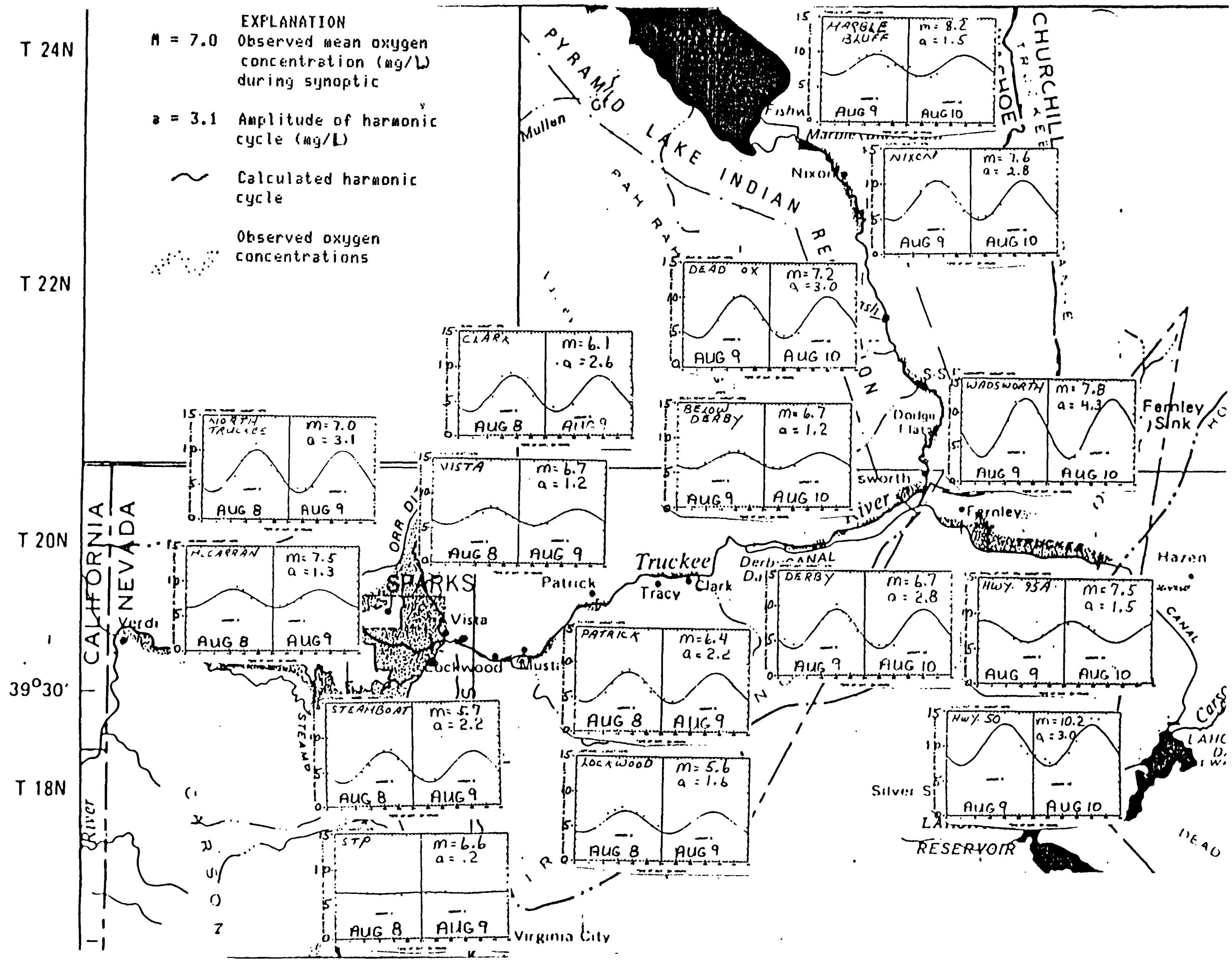


FIGURE 58.--Hourly variations in dissolved oxygen in the Truckee River and Canal are represented well by sine curves.

flowing river to planktonic algae in the deeper, more turbid and sluggish canal. Low productivty at the Highway 95A site results in the oxygen cycle being dominated by translated effects from upstream more productive reaches of the river above Derby Dam. Productivity in the canal increases by the Allendale and Highway 50 sites, at which dominance of local photosynthesis once again establishes the normal cycle of minima occurring from 2 a.m. to 4 a.m.

These excellent results for harmonic analysis of diel DO cycles have important implications for efficiency in future programs for monitoring DO. Round-the-clock samplings such as the four USGS synoptics are expensive with respect to required manpower. The above analysis suggests that 24-hour studies could be replaced by samplings over a significantly reduced period such as 12 hours with extension of the results by harmonic analysis to a full 24-hour period with little error in the resulting predictions of minimum daily DO concentrations.

Unfortunately for predictive modeling, both the harmonic and Odum techniques for reduction of diel DO data are, at best, descriptive in nature, and do not provide techniques for modeling DO extremes as a function of other model parameters such as nutrients. The results of the Odum analysis are influenced by oxygen demands other than algal respirations and thus should not be used for more than very general indications of the P and R factors to be used in model calibration (equation 18). Although the original U.S. Geological Survey steady-state DO model provided estimates of R from chlorophyll-*a* data (Bauer and others, 1979; Shindala, 1972), such an approach is inappropriate for streams dominated by attached algae such as the Truckee.

Given the above limitations, the net effects of photosynthesis and respiration on mean DO in the TRWQ model were quantified by simple calibration of a net P factor against the observed data. Calibrated values of net P for the river and canal are given in table 41.

Table 41 near here

For the river, one set of values was used for all four data sets, and net P values for the 43 model segments ranged from 0 mg/L/day in and above the Vista pool to 2 mg/L/day below Derby Dam. These values seem consistent with the observed downstream variations in productivity as discussed above. Resultant average errors in simulated mean DO concentrations were -0.6 percent above Derby Dam and +0.5 percent below.

For the canal, calibration of all four data sets could not be made with one set of net P values. Instead, calibration resulted in a uniform P value for all nine canal segments of 0.5 mg/L/day for the June data and 2.5 mg/L/day for the August data. Average errors in simulated mean DO concentrations in the canal were +2 percent for the June and +1 percent for the August data sets.

Since simulation of minimum DO concentrations is of as much, or more, importance to water-quality and fishery mangement of the Truckee River than mean concentrations, the TRWQ model was also calibrated against observed DO minima for the four synoptic studies. The method used was based on the results of the above analyses of diel DO cycles that indicated, for most sites in the river and canal, daily DO extremes are more a function of local photosynthetic activity than transport of upstream time-varying DO deficits or excesses.

TABLE 41.--Photosynthesis and respiration calibration coefficients for daily mean and minimum dissolved oxygen (DO)

Model segment		Starting river mile	Length (mile)	Net daily DO photosynthetic production (P) (mg/L/day)	Calibration factor (R) for minimum daily DO (mg/L/day)
		SUBMODELS			
		North Truckee Drain			
1	Kleppe Lane	0.26	0.26	0.0	2
		Steamboat Creek			
1	Kimlick Lane	.75	.62	.0	2
2	STP outfall	.13	.13	.0	2
		MAINSTEM TRUCKEE RIVER			
1	McCarran bridge	56.12	2.46	.0	2
2	N. Truckee Drain	53.66	.13	.0	2
3	Steamboat Creek	53.53	1.30	.0	2
4	Vista gage	52.23	.98	.0	2
5	Largomarsino divs.	51.25	.35	.0	12
6	Below Largomarsino divs.	50.90	.85	.0	12
7	Lockwood bridge	50.05	.15	1.	12
8	Groton div.	49.90	1.65	1.	12
9	Mustang bridge	48.25	1.57	1.	12
10	McCarran pool	46.68	.33	1.	12
11	McCarran div.	46.35	1.43	1.	12
12	Patrick bridge	44.92	2.04	1.	12
13	SP railroad bridge	42.88	.86	1.	12
14	Hill div.	42.02	1.26	1.	12
15	Tracy div.	40.76	.14	1.	12
16	Tracy bridge	40.62	2.02	1.	12
17	Clark bridge	38.60	1.50	1.	6
18	RM 37.1	37.10	1.50	1.	6
19	Derby pool	35.60	.72	1.	6
20	Derby Dam	34.88	.36	2.	7
21	Derby cableway	34.52	3.24	2.	7
22	Washburn Dam	31.28	1.31	2.	7
23	Painted Rock bridge	29.97	.62	2.	7
24	Gregory-Monte div.	29.35	1.35	2.	7
25	RM 28.0	28.00	1.25	2.	7

TABLE 41.—Photosynthesis and respiration calibration ~~parameters~~ coefficients for daily mean and minimum dissolved oxygen (DO)—Continued

	Model segment	Starting river mile	Length (mile)	Net daily DO photosynthetic production (P) (mg/L/day)	Calibration factor (R) for minimum daily DO (mg/L/day)
26	Herman div.	26.75	.80	2.	7
27	Pierson div.	25.95	2.05	2.	7
28	Proctor div.	23.90	.21	2.	7
29	Wadsworth bridge	23.69	1.14	2.	6
30	Fellnagle div.	22.55	1.15	2.	6
31	RM 21.4	21.40	1.56	2.	6
32	S Bar S div.	19.84	2.02	2.	6
33	S Bar S pump	17.82	2.00	2.	6
34	RM 15.8	15.82	2.64	2.	6
35	Dead Ox Wash	13.18	3.18	2.	3
36	RM 10.0	10.00	.80	2.	3
37	RM 9.2	9.20	.99	2.	3
38	Numana Dam	8.21	.61	2.	3
39	RM 7.6	7.60	.80	2.	3
40	RM 6.8	6.80	2.80	2.	3
41	RM 4.0	4.00	.78	2.	3
42	Nixon bridge	3.22	2.22	1.	1
43	RM 1.0	1.00	1.00	1.	1
	Marble Bluff Dam	.00			
		TRUCKEE CANAL			
C1	Derby Dam	31.42	6.04	.5, 2.5[a]	.0, -2.1[b]
C2	Pyramid check	25.38	2.84	.5, 2.5[a]	.0, -2.1[b]
C3	Tunnel No. 3	22.54	4.52	.5, 2.5[a]	.0, -2.1[b]
C4	Fernley check	18.02	2.95	.5, 2.5[a]	.0, -2.1[b]
C5	Anderson check	15.07	4.00	.5, 2.5[a]	.0, -2.1[b]
C6	Allendale check	11.07	4.68	.5, 2.5[a]	.0, -2.1[b]
C7	Mason check	6.39	3.14	.5, 2.5[a]	.0, -2.1[b]
C8	Bango check	3.25	2.81	.5, 2.5[a]	.0, -2.1[b]
C9	Highway 50	.44	.44	.5, 2.5[a]	.0, -2.1[b]
	Terminal weir	.00			

[a] P for daily mean DO calibrated to 0.5 mg/L/d for June data sets, 2.5 mg/L/d for August data sets with higher algal productivity.

[b] R for daily minimum DO calibrated to 0.0 mg/L/d for June data sets, -2.1 mg/L/d for August data sets.

Thus it was assumed that, starting with an initial minimum DO, a steady-state simulation of minimum DO may be made for the length of the stream by calibrating an effective respiration value for R in equation 18. A simple analogy would be the effects of a total solar eclipse lasting several days where P throughout the system would be shut off and the resulting steady-state mean DO would be purely a function of gross R. A similar approach has been used in other applications of steady-state oxygen models (Terry and others, 1983, 1984). In the TRWQ model, calibration was achieved by setting initial values at McCarran Bridge, Steamboat Creek, North Truckee Drain, and the STP to the observed minimum DO concentrations, and then calibrating against observed downstream river and canal minima by adjusting R with P set to 0. As with the calibration for net P, one set of R values was obtained for all four synoptic data sets for the river (table 41). For the canal, acceptable calibration on minimum DO was obtained for the June data by setting both P and R to zero. For the high-productivity and very low reaeration environments observed in the August data, calibration of minimum DO resulted in uniform negative R values (-2.1 mg/L/d). The negative R values reflect the continued residual effect of daytime DO supersaturation. Errors in simulated DO minima were greater than for the simulations of daily mean DO: +4 percent for the river above Derby Dam, -3 percent below Derby Dam, and -20 percent for the canal (table 38).

Sensitivity Analyses

Sensitivity analysis refers to the process of determining the effect of individual model parameters (input data, rate coefficients) on simulations of specific water-quality variables; for example, evaluating the effect of changes in coefficients for reaeration rates on predicted dissolved-oxygen concentrations.

A sensitivity analysis for a water-quality model serves several purposes. The effects of uncertainties in the values of various model parameters on the accuracy of predictions may be quantitatively determined. The process indicates the relative importance of various input data to model results, allowing cost-effectiveness decisions to be made regarding data collection for model calibration or validation. Given some knowledge of probable errors in the input data sets, a sensitivity analysis will allow an estimation of the precision of model simulations. In terms of model applications, a sensitivity analysis can provide cost-effectiveness information for decisions on water-quality management and pollution control. For example, if instream DO concentrations are found to be relatively insensitive to CBOD concentrations in sewage effluent but to be very sensitive to ammonia concentrations, control of ammonia at a sewage-treatment plant may be more effective in terms of impact on DO than control of CBOD.

The August 1979 data set was chosen for sensitivity analysis of the TRWQ model. Runs of the model were made with relatively large (plus and minus 20 percent) changes in key inputs and reaction-rate coefficients. Resultant impacts were evaluated for the Truckee River from McCarran Bridge to Marble Bluff Dam.

The four major inputs to the river were individually assessed:

(1) Truckee River at the start of the modeled reach (McCarran Bridge),

(2) North Truckee Drain (Kleppe Lane Bridge),

(3) Steamboat Creek (Kimlick Lane Bridge), and

(4) Reno-Sparks STP effluent.

Model runs were made changing the following variables one at a time by plus and minus 20 percent from the values used in calibration of the August 1979 data set:

(a) Water discharge (Q) (run for the river only),

and concentrations of

(b) carbonaceous oxygen demands ($CBOD_u$),

(c) orthophosphorus (OP),

(d) ammonia-nitrogen (NH_4-N), and

(e) dissolved oxygen (DO).

Independent sensitivity analyses were made for rate coefficients by testing the August 1979 data set with plus and minus 20 percent changes in the following coefficients:

(a) $CBOD_u$ oxidation and assimilation (K_C, K_R),

(b) orthophosphorus assimilation (K_{NCR1R}),

(c) organic-nitrogen hydrolysis and assimilation (K_{ONF}, K_{ONR}),

(d) ammonia-nitrogen oxidation and assimilation (K_{NH4F}, K_{NH4R}),

(e) nitrite-nitrogen oxidation and assimilation (K_{NO2F}, K_{NO2R}),

(f) nitrate-nitrogen assimilation (K_{NO3R}), and

(g) reaeration (K_2).

Additional tests were made for model sensitivity to environmental and biological factors:

(a) stream temperatures (T),

(b) plant net photosynthetic production (P), and

(c) calibration factor for plant respiration effects on dissolved oxygen (R).

The results of the sensitivity tests are discussed below by parameter tested and shown graphically in figures 59 to 70. In the graphs, the relative effects of changes in model parameters are indicated by the shaded range in simulated values in the water-quality profiles.

The results of the testing are summarized in table 42, listing for six key sites on the river simulated values for selected model outputs (such as DO concentrations) resulting from each changed input parameter. In addition, the relative importance of various model parameters to each predictor variable is indicated for two major reaches of the river: McCarran Bridge to Derby Dam, and Wadsworth to Marble Bluff Dam. For each reach, a relative ranking factor (1 indicating the greatest effect) is given on all six sites for each sensitivity test. For example, the start of table 42 summarizes the sensitivity testing for simulation of dissolved solids with respect to independently varying discharges and concentrations of dissolved solids of the principal tributaries and the river at McCarran Bridge, the start of the modeled reach. For simulations at sites in the reach from Vista to Derby Dam, the greatest impact (ranking of 1) was from changing the concentrations of dissolved solids in the river at McCarran Bridge; the least was from changing the concentration of dissolved solids in Steamboat Creek (ranking of 5). For the reach below Derby Dam from Wadsworth to Marble Bluff, changes in the river discharge at McCarran Bridge had the greatest impact on simulated dissolved solids (ranking of 1), and as with the reach upstream of Derby Dam, changing dissolved solids concentrations in Steamboat Creek had the least effect (ranking of 5).

Model Sensitivity to Upstream River Flows

Sensitivity runs on the effects of Truckee River streamflow were made to illustrate the impacts of changes in upstream river flow on selected modeled variables. For the changed upstream river flow at McCarran Bridge, sensitivity runs assumed that all diversions and returns were equal to those in the August 1979 calibration run except for the Truckee Canal Diversion at Derby Dam. For the low-flow run (calibrated flow at McCarran Bridge minus 20 percent), the 32-ft^3/s reduction in river flow would have resulted in a release from Derby Dam to the lower river of only 8 ft^3/s, whereas the Federal Watermaster tries to maintain minimum releases to 30 ft^3/s to the river below Derby Dam. Thus, for the reduced-flow simulation, canal diversions were reduced from 220 to 198 ft^3/s to maintain the 30-ft^3/s mimimum river flow.

Three competing processes need to be considered in evaluating the impacts of changing river flows:

1. Concentration/dilution effects.--An increased flow in the river has the effect of diluting all other inputs to the river, resulting in uniformly lower instream concentrations of constituents. Conversely, a reduced river flow results in increased instream concentrations.

2. Loadings from nonpoint sources.--Total loads of those constituents modeled as being of constant concentration in agricultural returns ($CBOD_u$, nitrogen, and phosphorus) will decrease for the lower river flow, resulting in lower instream concentrations after mixing in the river.

3. Instream assimilation and transformations.--A decrease in streamflow results in decreased velocities and increased traveltimes in the TRWQ model (equation 24). This has an exponential impact on the rate of transformation and assimilation of modeled nonconservative substances (equation 5). Given the same initial instream concentration of a nonconservative, the increased traveltime results in increased assimilation or transformation in a given reach of stream. Conversely, increased streamflow results in decreased traveltime and exponentially decreased assimilation.

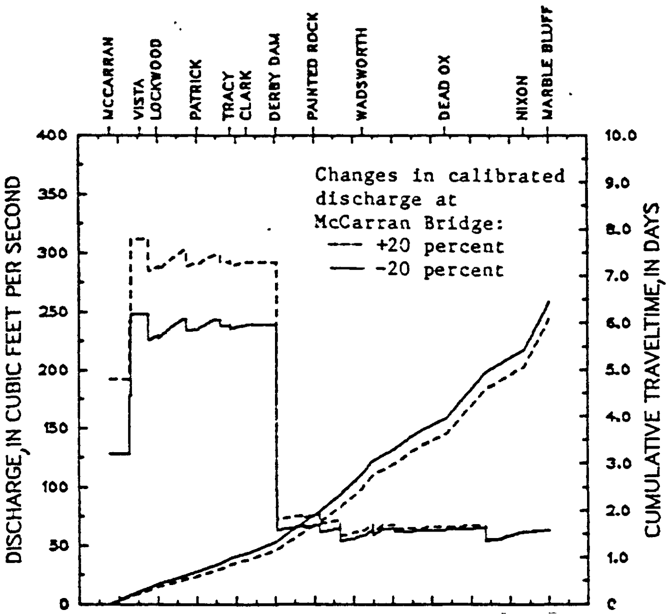
Streamflow and traveltime

The changed flows and resultant traveltimes for the changes in Truckee River streamflow at McCarran Bridge are shown in figure 59A. Initial streamflows for the two simulations are 192 and 128 ft^3/s, compared to 160 ft^3/s for the calibration data set. Resultant traveltimes ranged from 1.2 to 1.4 days to Derby Dam and from 4.9 days to 5.1 days from Derby Dam to Pyramid Lake. The effects of changed upstream river flows as McCarran Bridge have less of an impact below Derby Dam due to the relatively large diversion at Derby Dam; flows below Derby Dam for the two runs are 72 and 63 ft^3/s.

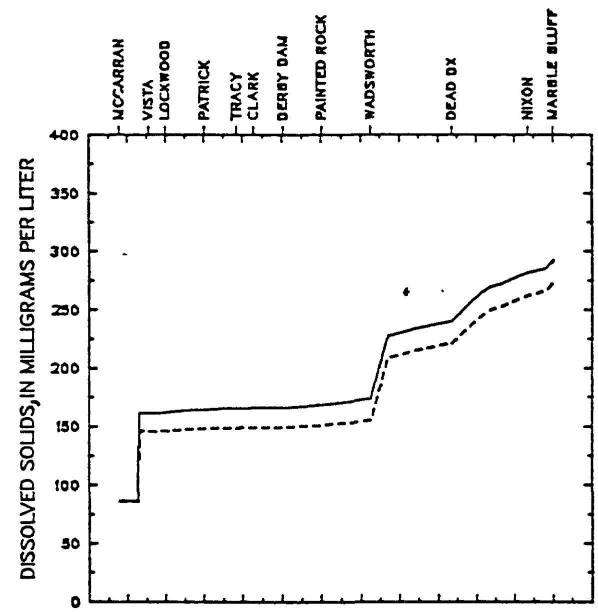
Figure 59 near here

Dissolved solids

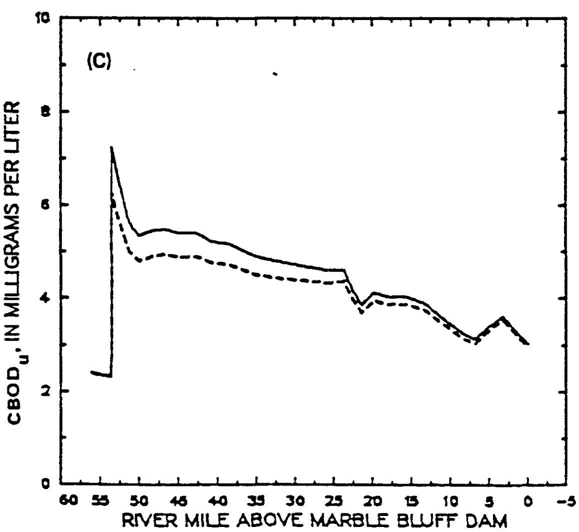
Concentrations of dissolved solids in the river (figure 59B) are sensitive to changes in discharge due to the concentration/ dilution effects of the changed flows on the impacts of added point and nonpoint loads, resulting in parallel profiles throughout the length of the river.

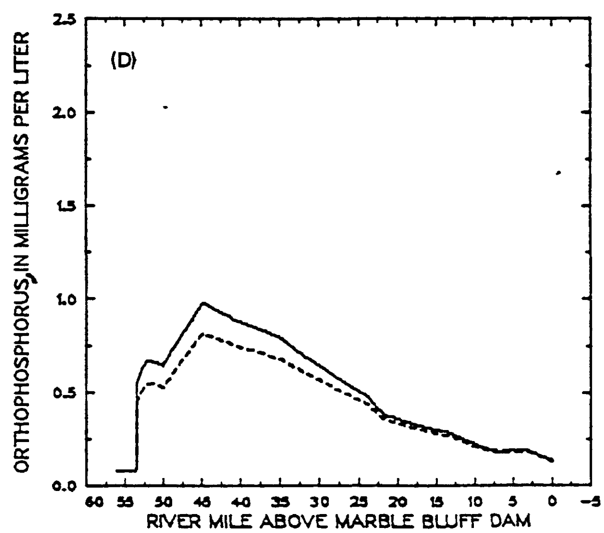


(A) Traveltime in the river are inversely related to stream flow.



(B) Changes in streamflow result in uniform dilution effects on concentrations of dissolved solids.





(C,D) The effects of changes in streamflow on concentrations of CBODu and orthophosphorus diminish with downstream distance from the major inputs.

FIGURE 59.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in upstream Truckee River flow at McCarran Bridge: (A) Discharge and traveltime, (B) dissolved solids, (C) CBODu, and (D) orthophosphorus.

$CBOD_u$

Simulated $CBOD_u$ concentrations in the river vary with discharge (figure 59C). The principal source of $CBOD_u$ to the river is the STP. The initial difference in instream $CBOD_u$ concentrations for the two modeled flows is due to the concentration/dilution effects of river flow; the lower flows result in higher $CBOD_u$ concentrations after mixing of the STP loadings. Lower flows also result in longer traveltimes and increased assimilations. In addition, the total oxidation of $CBOD_u$ is proportional to the initial concentration (equation 5), thus amount of $CBOD_u$ oxidized in a reach is greater for the lower river flows, resulting in a convergence of the two curves with distance down the river. This convergence of the two curves is common to all simulations of substances modeled as first-order reactions.

Orthophosphorus

The effects of changes in streamflow on concentrations of orthophosphorus are shown in figure 59D. As with CBOD, the phosphorus profiles are the result of the competing effects of increased initial concentrations at lower flows balanced by increased traveltimes and higher concentrations resulting in more assimilation for a given reach of stream. Initial differences between the two profiles are due to the effects of concentration/dilution on the modeled phosphorus loads from the STP. For the August 1979 data set, dummy nonpoint loadings of phosphorus were added in the segment of the Vista Pool and the reach from Lockwood to Patrick to calibrate against the observed data. The concentration/dilution effects on the dummy nonpoint loadings added between Vista and Patrick result in the divergence of the two profiles for the reach; however, the differences in assimilation rates predominate below Patrick and the profiles again begin to converge.

Organic-nitrogen

The effects of changing river flows on simulated concentrations of organic-nitrogen (figure 60A) are similar, in nature and cause, to the changes in the other simple nonconservatives, CBOD and orthophosphorus.

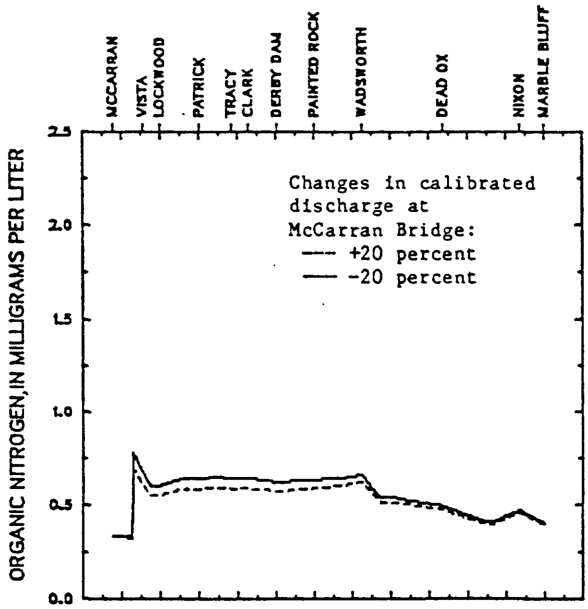
Figure 60 near here

Ammonia-nitrogen

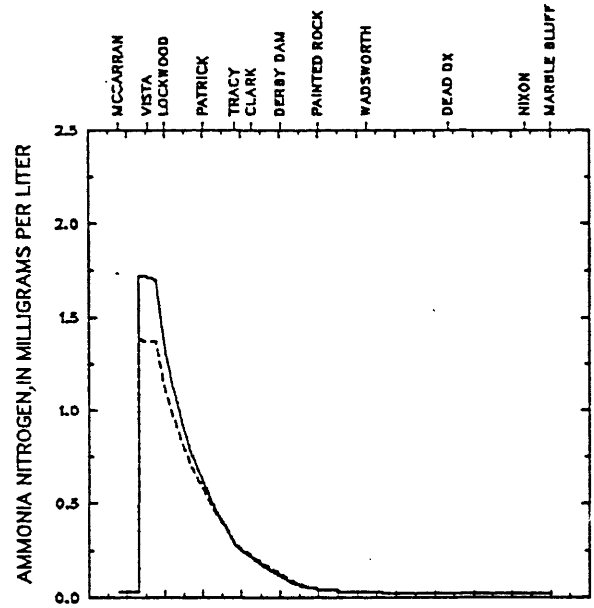
Ammonia-nitrogen concentrations (figure 60B) vary significantly with discharge in the Vista pool reach between the STP and Lockwood. The processes in effect (concentration/dilution effects, changing traveltimes) are the same as described for $CBOD_u$. Downstream convergence of the two profiles is even faster than for $CBOD_u$, phosphorus, and organic-nitrogen. The high reaction coefficients and higher initial concentrations of ammonia below the STP result in rapid assimilation of the increased instream ammonia concentrations for the lower streamflow in the first few miles of travel below the STP. Thus, simulated concentration profiles for the two differing flow regimes converge by the time Derby Dam is reached. Modeled concentrations of ammonia in return flows are lower than for $CBOD_u$ and organic-nitrogen, thus the concentration/dilution effects of changing river flows on the impacts of the nonpoint returns are less.

Nitrite-nitrogen

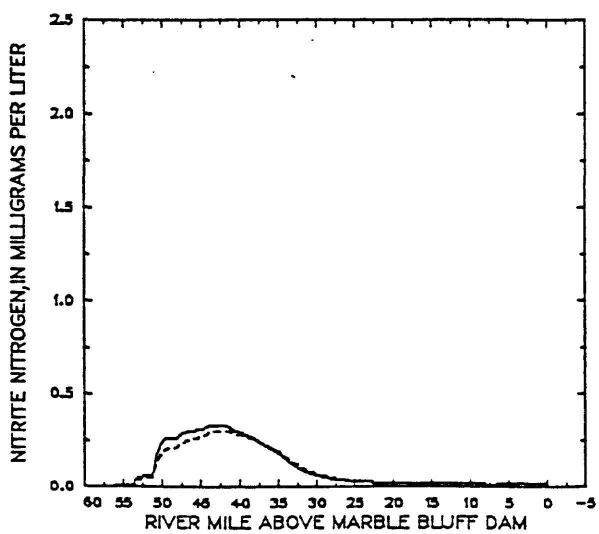
Nitrite concentrations in the river are relatively insensitive to changes in discharge (figure 60C). Although the rate coefficients for oxidation of ammonia to nitrite are relatively high, the coefficients for subsequent oxidation to nitrate are even higher, limiting the resultant instream nitrite concentrations. As with the other nonconservatives, the effect of decrease in streamflow is an increase in nitrite concentration, followed by convergence of the two profiles by Patrick for the August 1979 flows.



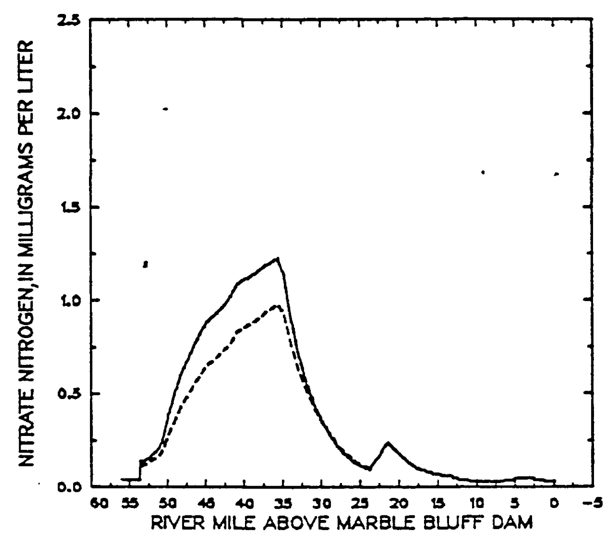
(A) The effects of changes in streamflow on concentrations of organic nitrogen diminish with downstream distance from the major inputs.



(B) An initial high sensitivity of ammonia concentrations to changes in streamflow decreases rapidly between Vista and Patrick.



(C) Concentrations of nitrite are not affected significantly by changes in streamflow.



(D) Nitrate concentrations are increasingly sensitive to changes in streamflow between Vista and Derby Dam; however, effects are insignificant below Derby Dam.

FIGURE 60.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in upstream Truckee River flow at McCarran Bridge: (A) Organic nitrogen, (B) ammonia nitrogen, (C) nitrite nitrogen, and (D) nitrate nitrogen.

Nitrate-nitrogen

Nitrate concentrations above Derby Dam are sensitive to changes in streamflow (figure 60D). As nitrate is the final product in the sequential oxidation of nitrogen, the maximum difference in nitrate concentrations between the two flow regimes is delayed until Derby Dam, by which time virtually all the initial increased ammonia for the lower flow has been oxidized to nitrate.

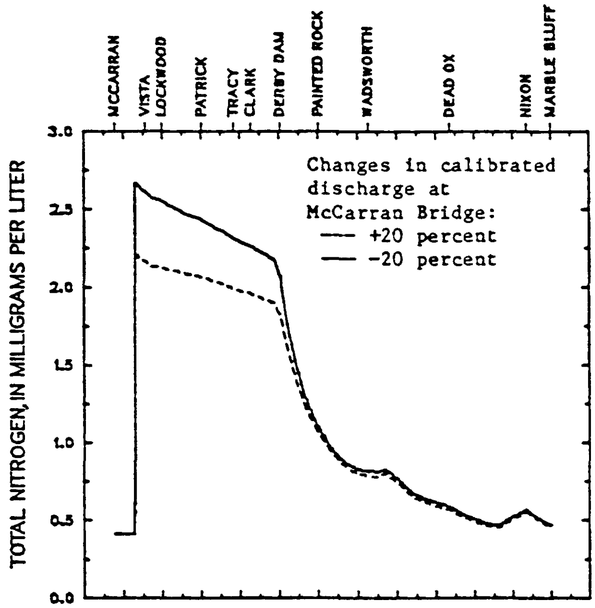
Total-nitrogen

Total-nitrogen profiles reflect the sum of the effects of streamflow on all forms of nitrogen (figure 61A). Total-nitrogen concentrations are uniformly higher for the lower river flows from the STP to Derby Dam, followed by rapid convergence of the profiles to a relatively small constant difference that persists throughout most of the rest of the river.

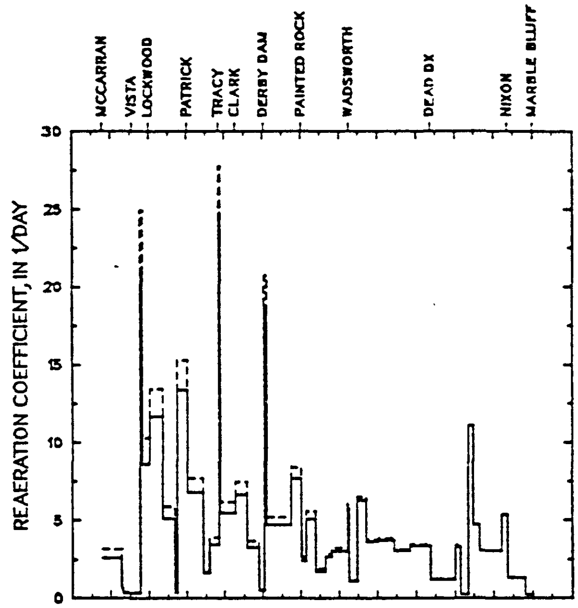
Figure 61 near here

Reaeration coefficents (K_2)

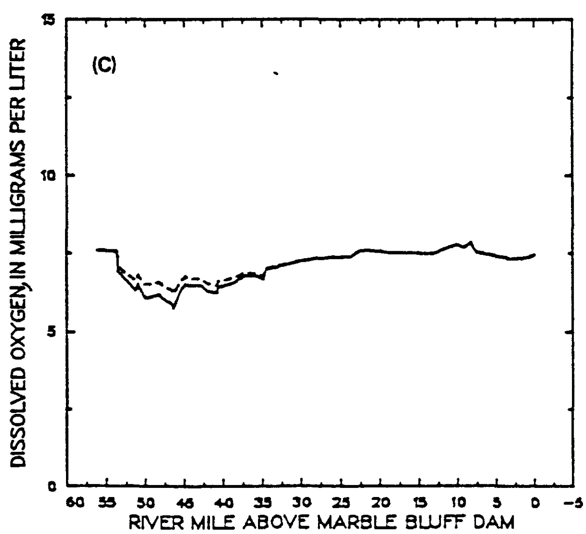
The calibrated version of the TRWQ model calculates K_2 for each of the 43 river segments as a function of stream velocity and slope (equation 32) and stream velocity is calculated as a function of discharge. Thus, changes in streamflow affect the calculated values for K_2 (figure 61B).

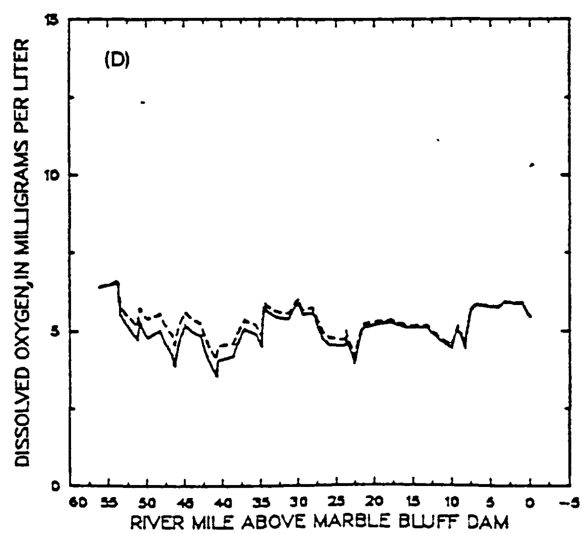


(A) Changes in streamflow result in relatively uniform effects on concentrations of total nitrogen between Steamboat Creek and Derby Dam and only minor effects below Derby Dam.



(B) Streamflow changes directly affect the values of the reaeration coefficient (K2) calculated by the ~~TRQMOD~~ model.
TRWQ





(C,D) Streamflow changes significantly affect mean (C) and minimum (D) daily dissolved-oxygen concentrations in the reach of oxygen deficits from Vista to Derby Dam.

FIGURE 61.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in upstream Truckee River flow at McCarran Bridge: (A) Total nitrogen, (B) reaeration coefficient, (C) average daily DO, and (D) minimum daily DO.

Dissolved oxygen

Changes in DO concentrations in the river above Derby Dam in response to changes in streamflow are shown in figure 61C. The relation between discharge and DO is the inverse of the effect on the other modeled constituents, with higher discharges resulting in higher DO concentrations. Increasing discharge dilutes concentrations of oxygen-demanding substances and increases river velocities and resultant reaeration rates. Lower flows result in higher concentrations of oxygen-demanding substances between Vista and Derby Dam, thus the resultant oxygen concentrations are decreased for the reduced streamflow conditions. Reduced streamflows above Derby Dam also result in lower values of K_2 and thus lower instream DO concentrations.

Model Sensitivity to Changes in Major Sources of Loadings

The sensitivity of simulated concentrations of selected variables to changes in the major inputs to the river are summarized in table 42. Since the STP was the greatest single source of loads to the river for the August 1979 data (table 21), changes in concentrations of the STP effluent had greater impacts for most constituents on simulated downstream quality than the same percentage change in the two tributaries or in the quality of the upstream river at McCarran Bridge. A more complete discussion of the relative impact of the Reno-Sparks effluent on downstream quality is given in following sections. Nonpoint loadings to the river from agricultural returns and, below Derby Dam, from ground water can also significantly affect river quality. Although individual sensitivity simulations were not run on the assumptions used to model these inputs, the impacts are obviously significant with respect to phosphorus above Derby Dam and, with the exception of dissolved oxygen, to most constituents in the river below Derby Dam (see preceding section on model calibration).

Model Sensitivity to Changes in Rate Coefficients

Sensitivity analyses of rate coefficients for a water-quality model provides an assessment of the relative importance of the several processes being modeled and identifies those coeffícents that have the greatest effect on individual output variables. Figures 62 to 70 show the results of sensitivity testing of selected rate coefficients.

$CBOD_u$ coefficients (K_C, K_{CR})

Although changes in the $CBOD_u$ coefficients had a significant impact on simulated concentrations of $CBOD_u$ throughout the river (figure 62A), the changes had little impact on resultant DO concentrations (figure 62B). Relatively low concentrations of $CBOD_u$ in the STP effluent compared to nitrogenous oxygen demands (ammonia) and the lower values of K_C compared to K_{NH3F} and K_{NO2F} result in carbonaceous oxygen demands having much less impact on DO in the river than nitrogenous demands.

Figure 62 near here

Orthophosphorus assimilation (K_{NCR1R})

Changes in the orthophosphorus assimilation coefficients have a significant effect on simulated orthophosphorus concentrations from Patrick to Marble Bluff Dam (figure 63). Plus and minus 20 percent changes in the coefficient resulted in changes from the calibrated concentrations of about plus or minus 0.04 mg/L through most of the reach.

Figure 63 near here

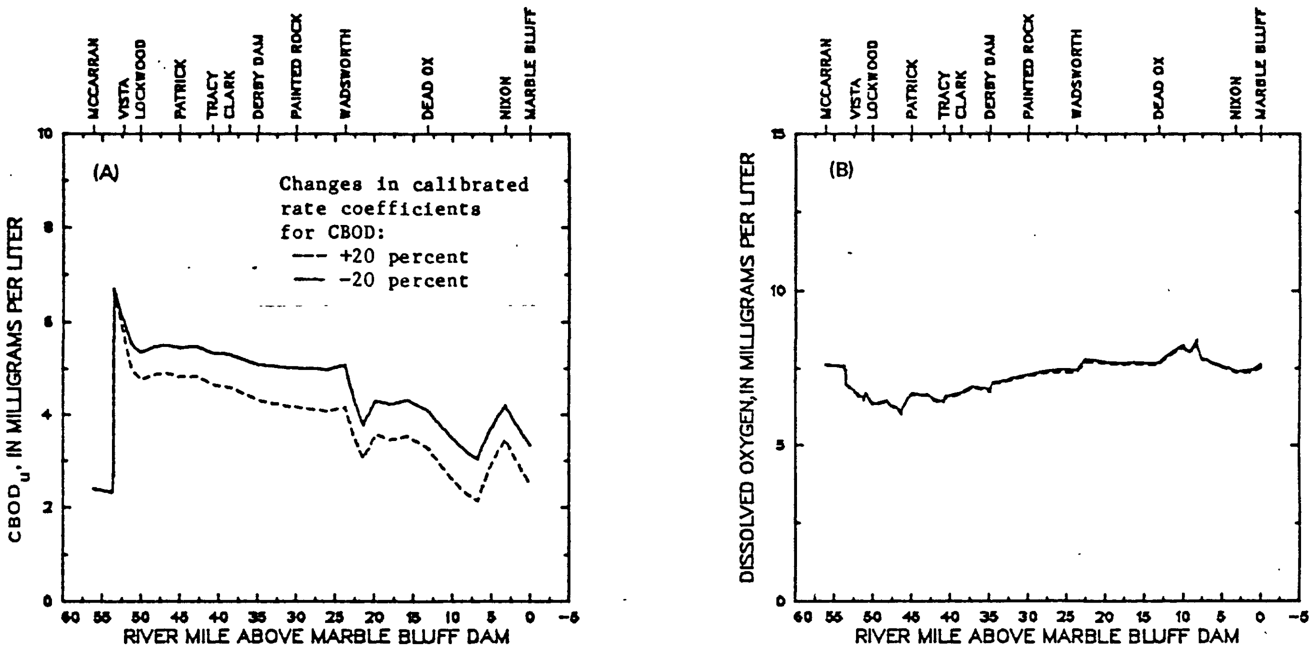


FIGURE 62.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in rate coefficients for CBOD: Changes in the rate coefficients for CBOD significantly affect CBODu concentrations (A) but have little impact on DO concentrations (B).

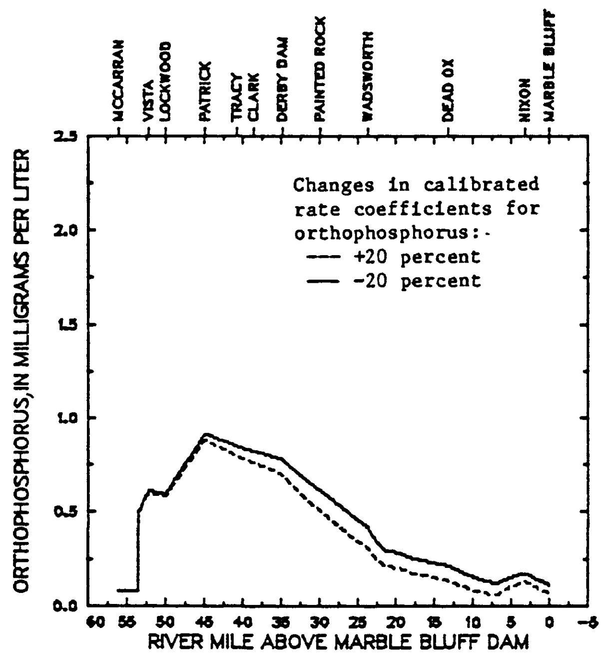


FIGURE 63.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in rate coefficients for orthophosphorus: Concentrations of orthophosphorus are significantly affected below the major point and nonpoint inputs.

Organic-nitrogen coefficients (K_{ONF}, K_{ONR})

Simulated concentrations of organic-nitrogen were sensitive to changes in the assimilation coefficent K_{ONR} (figure 64A), however the effects on the rest of the nitrogen cycle (figures 64B-C) and DO (figure 64D) are minimal due to the relatively low concentrations of organic-nitrogen in the river and the lower value of the forward reaction coefficient (K_{ONF}) relative to the other nitrogen reaction coefficients (table 24).

Figure 64 near here

Ammonia-nitrogen coefficients (K_{NH3F}, K_{NH3R})

Changes in the ammonia coefficents affect concentrations of ammonia, nitrite, and nitrate above Derby Dam (figures 65A-C). Instream DO concentrations above Derby Dam are somewhat sensitive to the changes in K_{NH3F}, the coefficient for oxidation to nitrite; the effects are most significant in the reach from Vista to Patrick where ammonia concentrations are high (figure 65D).

Figure 65 near here

Nitrite-nitrogen coefficients (K_{NO2F}, K_{NO2R})

Changes in the nitrite coefficients affect concentrations of nitrite-, nitrate-, and total-nitrogen (figures 66A-C). For the August 1979 data, higher values for K_{NO2F} lower the peak nitrite concentration, shift the location of the peak downstream (figure 66A), and significantly increase the peak nitrate concentrations near Derby Dam (figure 66B). Increased values for K_{NO2F} have minimal effect on DO concentrations (figure 66D), however, as most of the nitrogenous oxygen demand is exerted by the oxidation of ammonia (ammonia concentrations are significantly greater than nitrite throughout the reach of oxygen sag above Derby Dam). Decreasing the values for K_{NO2F} has opposite effects on the simulations.

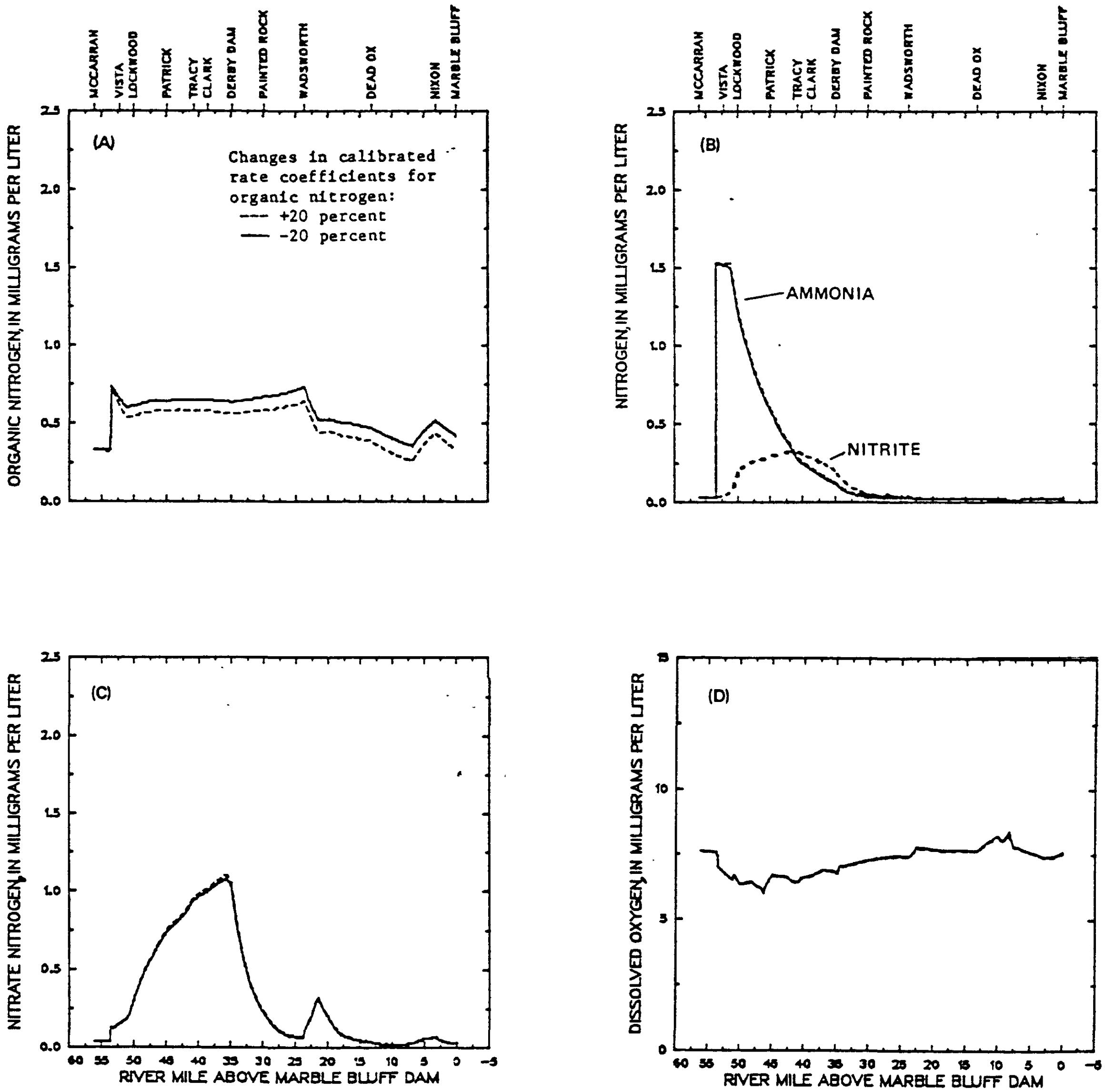


FIGURE 64.--Rate coefficients for organic nitrogen: Organic nitrogen concentrations (A) are significantly affected but there is little effect on (B) ammonia or nitrite, (C) nitrate, or (D) mean daily DO.

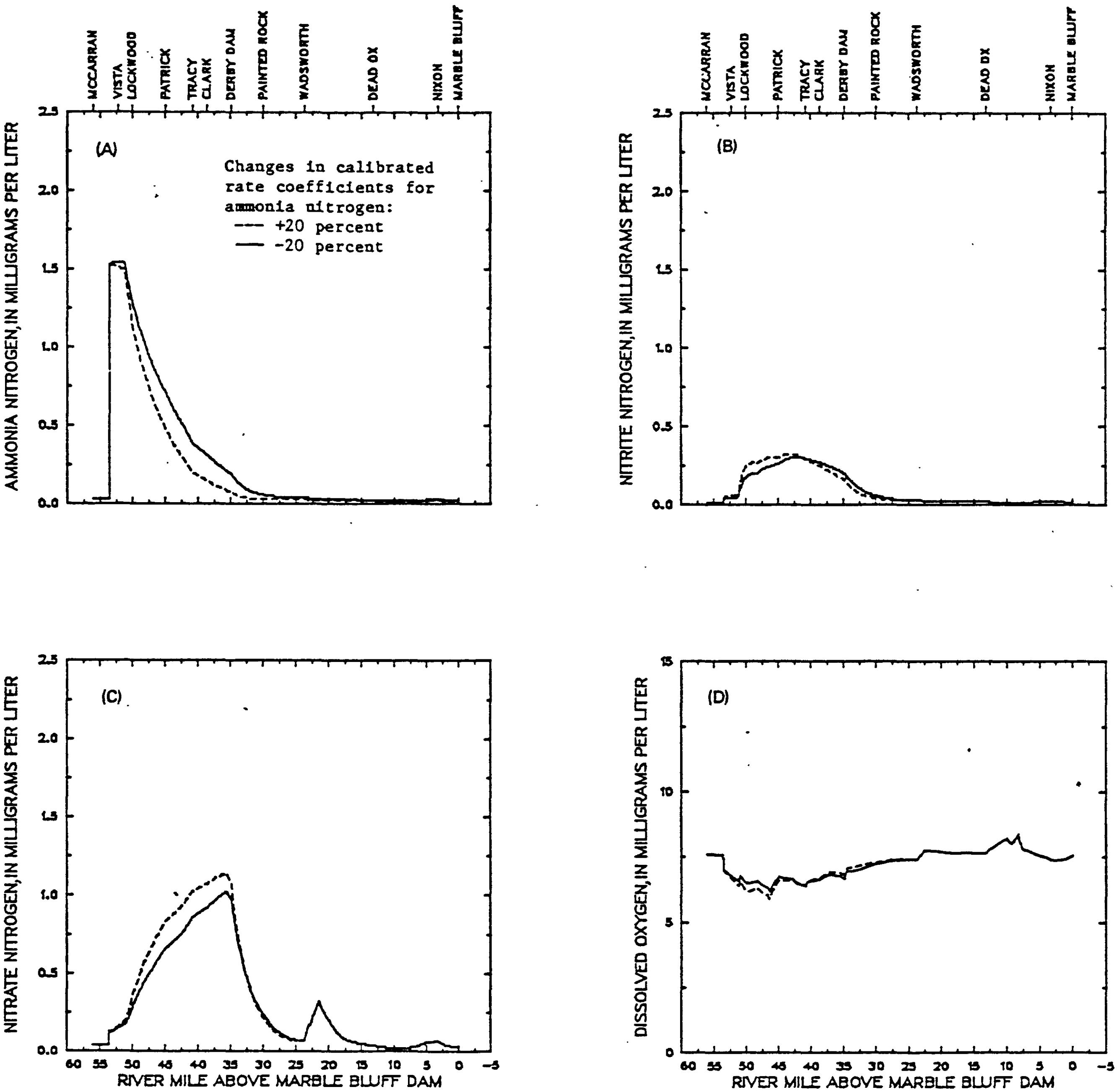


FIGURE 65.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in rate coefficients for ammonia nitrogen: Effects are significant on concentrations of ammonia (A), nitrate (C), and mean daily DO (D); nitrite concentration (B) are not significantly changed.

Figure 66 near here

Nitrate-nitrogen assimilation (K_{NO3R})

Changes in K_{NO3R} affect only simulated concentrations of nitrate and total-nitrogen (figure 67A, B). Effects are greatest in the reach affected by buildup of nitrate as the end product of nitrification of STP effluents (Patrick to Wadworth), although minor effects persist in the river below Wadsworth due to nonpoint sources of nitrate.

Figure 67 near here

Reaeration coefficients (K_2)

The computer program used for the TRWQ model allows either direct specification of values for K_2 or the calculation of K_2 as a function of channel hydraulics factors. In the model, K_2 is calculated for each modeled segment as a function of stream velocity and slope using coefficients developed from field gas-tracer tests in the Truckee River. To test the sensitivity of simulated DO concentrations to the values of K_2, the values calculated by the model for each river segment for the August 1979 data set (table 39) were varied by plus and minus 20 percent. Figure 69A shows the resultant ranges in values for K_2. Peak values occur at high-gradient reaches and the locations of diversion dams. Low values occur in slower, low gradient reaches such as the pool at Vista. Simulated mean and minimum DO concentrations are sensitive to changes in K_2 (figure 68B). Increasing the reaeration coefficient results in an increased rate of exchange of oxygen between the water and the atmosphere, driving the instream DO towards the equilibrium values (100 percent saturation) at a faster rate. The result is higher DO concentrations in the zone of DO sag above Derby Dam and lower DO concentrations in the supersaturated zone below Derby Dam. The greater the

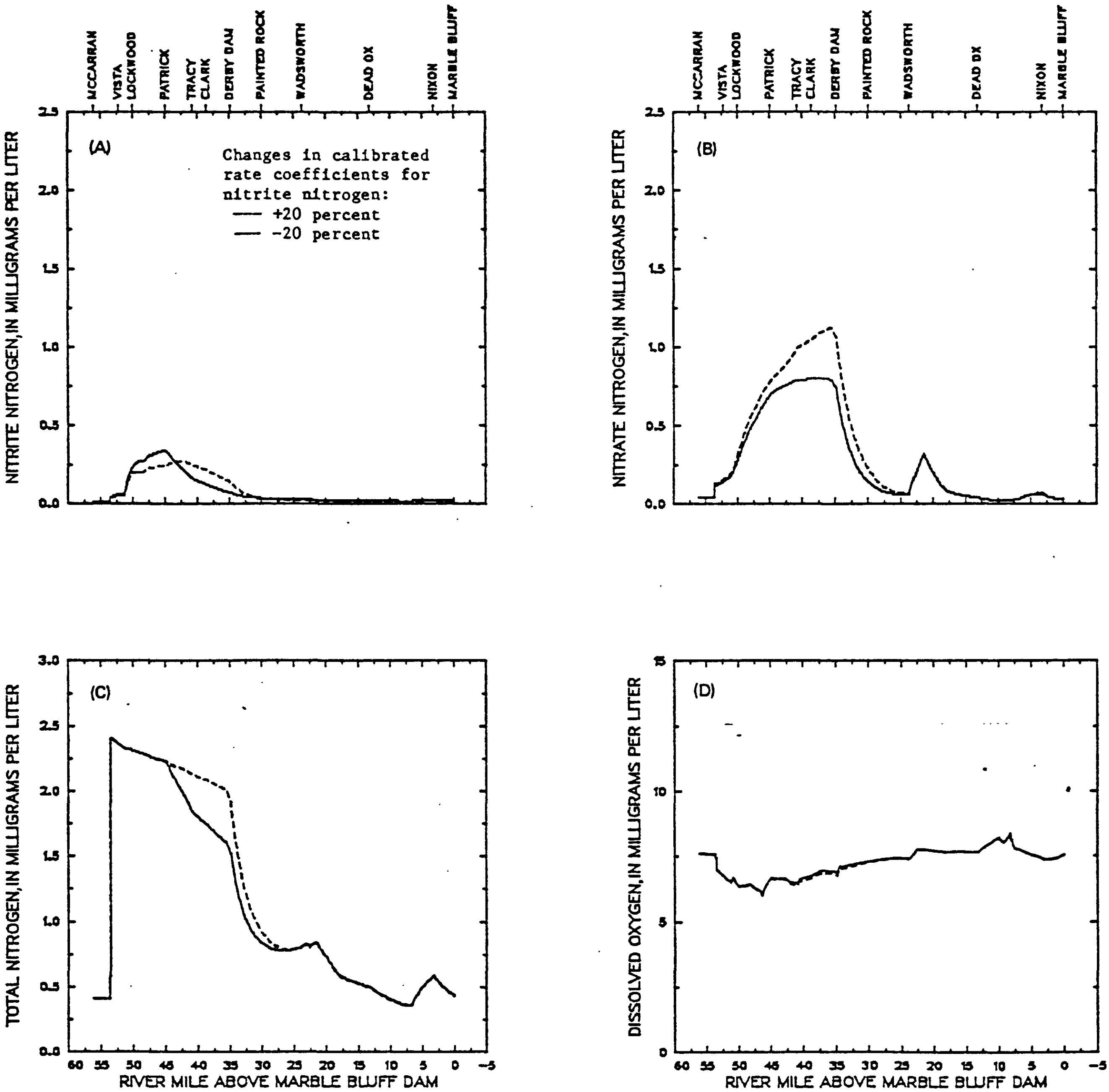


FIGURE 66.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in rate coefficients for nitrite nitrogen: Effects are significant on concentrations of nitrite (A), nitrate (B), and total nitrogen (C), but there is little effect on mean daily DO (D).

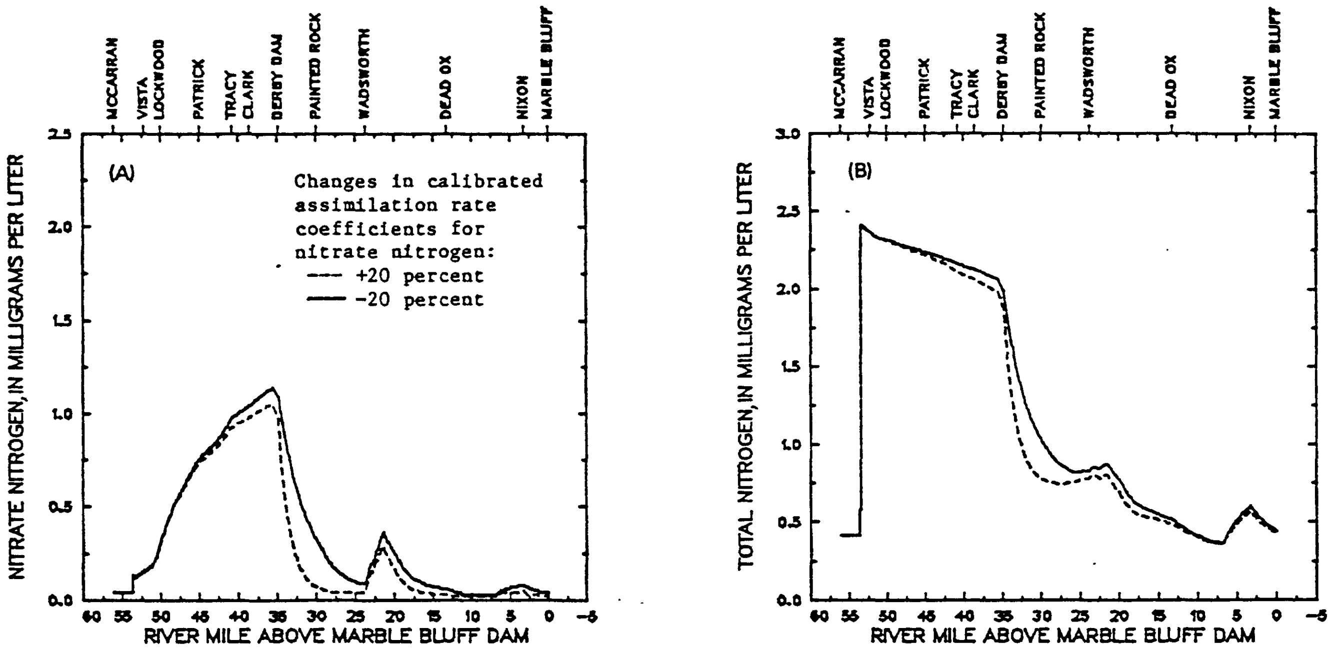


FIGURE 67.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in the assimilation rate coefficients for nitrate nitrogen: Effects on nitrate (A) and total nitrogen (B) are significant.

difference between instream and saturation DO concentrations, the greater the effect of K_2 on the predicted DO values. For the August 1979 data set, a plus and minus 20 percent change in K_2 resulted in differences of about 0.5 mg/L for simulated mean daily DO in the zone of maximum sag (Lockwood to Patrick). The sensitivity of predicted DO concentrations to reaeration coefficients demonstrates the value of modeling K_2 segment-by-segment as a response to the Truckee River environment rather than simply using published literature values developed for some other stream system.

Figure 68 near here

Net photosynthesis (P)

Calibrated rates for the net effect of photosynthetic production and respiratory demands for DO were derived by curve-fitting (table 41). DO concentrations are sensitive to P values, especially in the reach below Derby Dam where the oxygen regime is dominated by the effects of algae and aquatic plants (figure 69A). In this reach, changes in P had more effect on DO than any other rate coefficient (table 42).

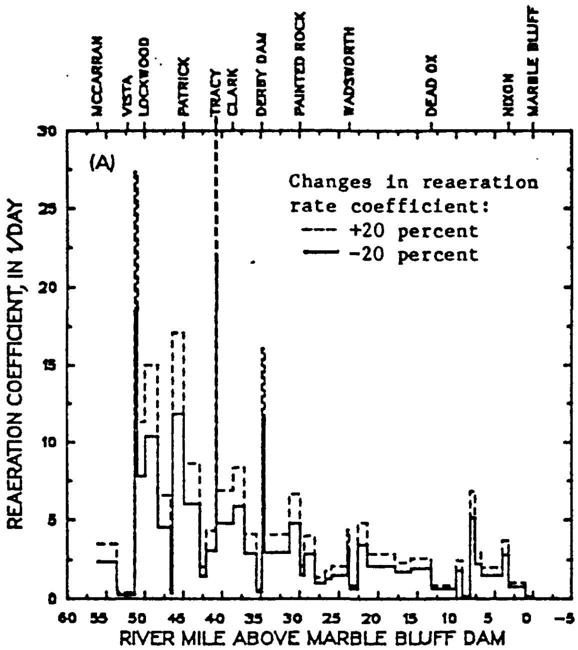
Figure 69 near here

Calibration factor for minimum daily DO (R)

Simulated minimum daily DO concentrations are very sensitve to the values of R used in the model (figure 70B), as might be expected since R values were calibrated by empirical curve-fitting to observed data (table 42).

Water temperature (T)

The effects of water temperature are included in the sensitivity analyses of rate coefficients as all the coefficients in the TRWQ model are corrected for temperature deviations from the standard reference temperatures of 20 °C (equation 23, tables 24, 39, 41). Average water temperatures for the 43 river



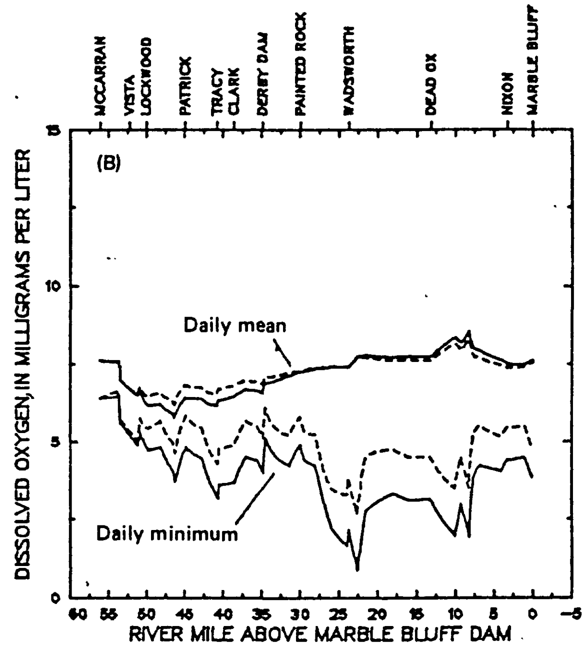


FIGURE 68.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in the reaeration coefficient: Changes in the reaeration coefficients (A) have significant impacts on mean and minimum daily DO concentrations (B and C).

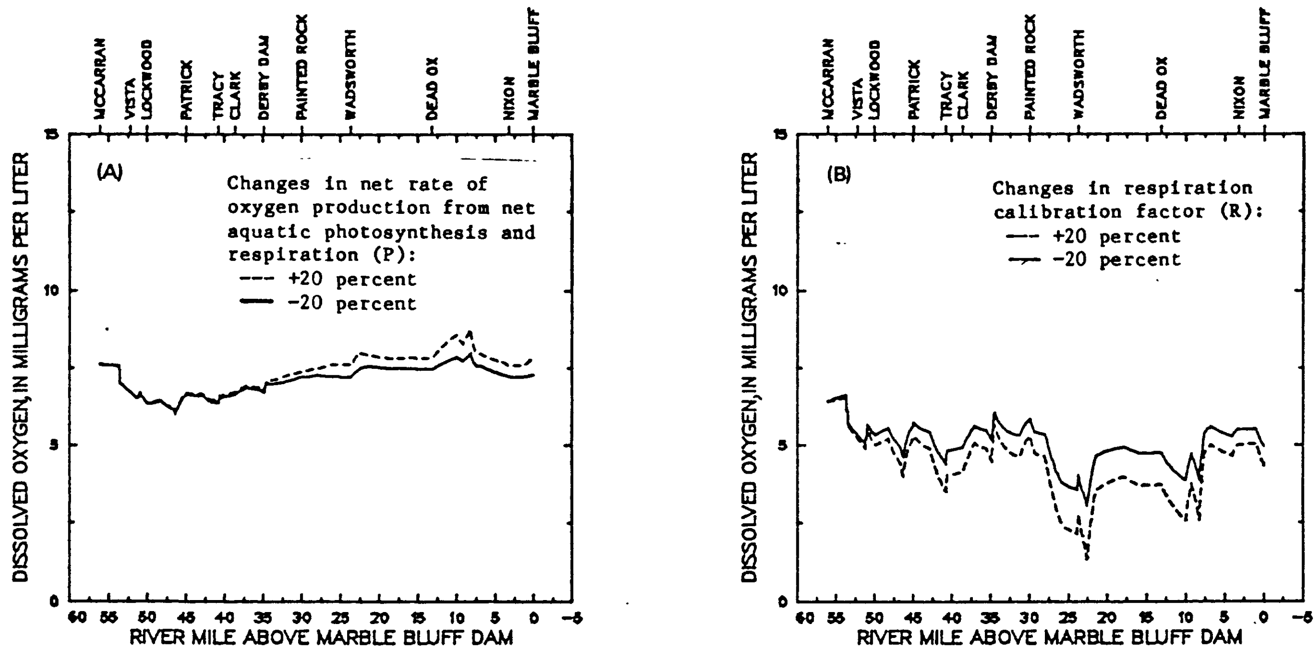


FIGURE 69.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in the net rate of oxygen production from aquatic photosynthesis and respiration: Mean daily DO concentrations are affected only below Derby Dam (A); minimum daily DO concentrations are affected throughout most of the river (B).

model segments for the August 1979 data set ranged from 20.5 to 23.0 °C; the temperatures used in the sensitivity analyses ranged from 16.4 to 27.6 °C (-4.1 to +4.7 from calibration temperatures). For all simulated variables except ammonia, the plus or minus 20 percent change in temperature had the greatest impact of all model parameters tested (table 42, figure 70) for ammonia, temperature effects were second only to changing the input ammonia loads at the STP. At first consideration, a total range in temperature of about 9 °C might seem extreme for sensitivity analysis. Temperatures in the Truckee River can be highly variable however, both in space and time. Just within the 3-day synoptic of August 8-10, 1979, observed instantaneous temperatures (2-hour intervals) ranged from 17 to 30 °C in the reach from McCarran Bridge to Marble Bluff Dam. For the August 13-14, 1980, synoptic, observed temperatures ranged from 13.5 to 27.5 °C.

Figure 70 near here

Summary of Controls on Individual Constituents

The results of the sensitivity analyses are summarized for selected predictor variables in table 42. For dissolved solids, changing the initial dissolved solids at McCarran Bridge and in North Truckee Drain had the greatest effect on the river above Derby Dam; changing initial river flows and dissolved solids at McCarran Bridge had the greatest effects below Derby Dam.

For $CBOD_u$ and the modeled nitrogen and phosphorus species, changing water temperatures (and thus reaction coefficients) had the greatest effects below Derby Dam. In the reach from Vista to Derby Dam, results were mixed: Input concentrations at the STP had the greatest effect on $CBOD_u$; water temperatures, followed by STP inputs had the greatest effects on organic-nitrogen and nitrate; STP inputs of ammonia, followed by the initial river

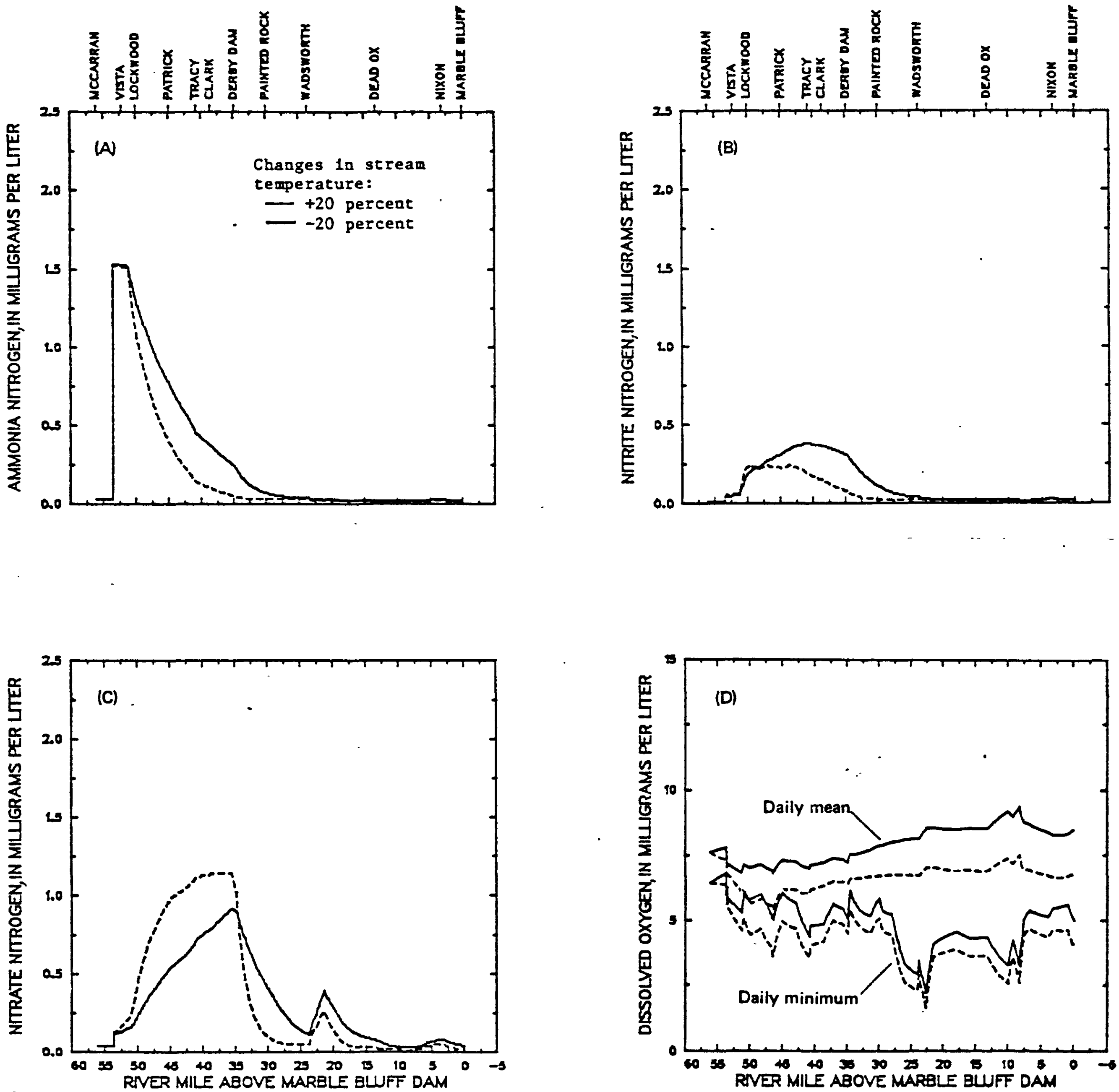


FIGURE 70.--Sensitivity of model simulations for the August 1979 data set to plus and minus 20 percent changes in stream temperature: Changed temperatures significantly affect concentrations of (A) ammonia nitrogen, (B) nitrite nitrogen, (C) nitrate nitrogen, and (D) DO concentrations.

flows at McCarran Bridge had the greatest effects on ammonia- and total-nitrogen; and temperature had the greatest effect on nitrite-nitrogen.

Table 42 near here

With respect to predicted mean daily concentrations of dissolved oxygen above Derby Dam, changing temperatures had the greatest effect, followed by changing the DO concentrations for the upstream river at McCarran Bridge and changing the ammonia loadings from the STP. Below Derby Dam, temperatures (effecting all reaction rates) had the greatest impact, followed by changing the estimates of net photosynthetic input of DO and changing the estimates for the reaeration coefficients.

For predicted minimum daily DO above Derby Dam, changing the reaeration rates had the greatest effects, followed by changing temperatures, respiration factors, and river flow at McCarran Bridge. Below Derby Dam, the order of significance changed, with respiration factors having more impact than temperatures.

Sensitivity of Water Quality to Effluent Discharges at the Reno-Sparks STP

Of principal concern to potential applications of the TRWQ model are the effects of various planning alternatives for expansion of the Reno-Sparks STP on the quality of the Truckee River and Truckee Canal. The water-quality impacts of selected alternatives for plant operation are discussed in the Model Applications section later in this report. As a gross sensitivity analysis of the maximum expected changes in quality from increased treatment at the STP, simulations with removal of STP loadings were made for the conditions observed in the August 1979 synoptic studies (lowest river flows) and June 1980 studies (highest flows).

TABLE 42.—Summary of model sensitivity testing

[Listed for six sites on the Truckee River are ranges in simulated values for selected constituents in response to changes of plus and minus 20 percent for the indicated input loadings or reaction rates. For each sensitivity test, only the parameter indicated in the first column of the table was changed; all other model parameters were set equal to those used for the August 1979 calibration. The effects of each tested parameter on a given indicator constituent are ranked by relative importance for two reaches of the river—Vista to Derby Dam, and Derby Dam to Marble Bluff Dam—with the parameter having the greatest effect ranked as "1." Parameters having no effect on the indicator constituent are ranked as "0." All simulated values below 100 are rounded to two significant figures.]

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF DISSOLVED SOLIDS (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
Inputs:								
River at McCarran Bridge:								
Discharge	146 - 161	148 - 165	149 - 166	156 - 186	222 - 340	273 - 471	3	1
Dissolved solids	143 - 162	145 - 165	147 - 166	159 - 180	280 - 296	376 - 390	1	2
North Truckee Drain:								
Dissolved solids	144 - 162	146 - 164	147 - 166	160 - 180	281 - 295	376 - 390	2	3
Steamboat Creek:								
Dissolved solids	147 - 158	150 - 161	151 - 162	164 -176	283 - 292	379 - 387	5	5
Reno-Sparks STP:								
Dissolved solids	146 - 159	149 - 162	150 - 163	163 - 177	283 - 293	378 - 388	4	4
RANGE IN SIMULATED CONCENTRATIONS OF $CBOD_u$ IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
River at McCarran Bridge:								
Discharge	5.5 - 6.3	4.9 - 5.4	4.5 - 4.9	4.4 - 4.8	3.7 - 3.6	3.0 - 3.0	5	4
$CBOD_u$	5.6 - 6.1	4.9 - 5.3	4.5 - 5.8	4.5 - 4.6	3.6 - 3.7	2.9 - 2.9	2	5
North Truckee Drain:								
$CBOD_u$	5.7 - 6.0	5.0 - 5.2	4.6 - 4.8	4.6 - 4.6	3.6 - 3.7	2.9 - 2.9	6	6
Reno-Sparks STP:								
$CBOD_u$	5.2 - 6.5	4.6 - 5.6	4.3 - 5.1	4.4 - 4.7	3.6 - 3.7	2.8 - 2.9	1	3
Rate Coefficients and River Environment:								
Temperature	5.6 - 6.0	4.8 - 5.4	4.2 - 5.1	4.1 - 5.0	3.2 - 4.1	2.4 - 3.3	4	1
K_{CBOD}	5.6 - 6.0	4.8 - 5.5	4.3 - 4.1	4.2 - 5.1	3.3 - 4.1	2.5 - 3.3	3	2

TABLE 42.--Summary of model sensitivity testing--Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF ORGANIC NITROGEN (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
River at McCarran Bridge:								
Discharge	.60 - .67	.58 - .64	.57 - .62	.62 - .66	.38 - .49	.38 - .40	3	3
Organic Nitrogen	.60 - .67	.58 - .63	.57 - .62	.67 - .70	.42 - .43	.37 - .37	4	5
North Truckee Drain:								
Organic Nitrogen	.61 - .66	.59 - .62	.58 - .61	.68 - .69	.42 - .43	.37 - .37	5	6
Steamboat Creek:								
Organic Nitrogen	.61 - .66	.59 - .62	.58 - .61	.68 - .69	.42 - .43	.37 - .37	5	6
Reno-Sparks STP:								
Organic Nitrogen	.58 - .69	.57 - .65	.56 - .63	.67 - .70	.41 - .43	.37 - .38	2	4
Rate Coefficients and River Environment:								
Temperature	.59 - .67	.54 - .66	.52 - .66	.59 - .76	.33 - .50	.28 - .46	1	1
K_{ORGN}	.61 - .66	.58 - .64	.56 - .63	.64 - .73	.38 - .47	.33 - .42	3	2

TABLE 42.--Summary of model sensitivity testing--Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF AMMONIA NITROGEN (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
INPUTS:								
River at McCarran Bridge:								
Discharge	1.4 - 1.7	.57 - .61	.13 - .11	.03 - .03	.02 - .02	.02 - .02	2	0
Organic Nitrogen	1.5 - 1.5	.58 - .58	.12 - .12	.03 - .03	.02 - .02	.02 - .02	0	0
Ammonia Nitrogen	1.5 - 1.5	.58 - .58	.12 - .12	.03 - .03	.02 - .02	.02 - .02	0	0
North Truckee Drain:								
Organic Nitrogen	1.5 - 1.5	.58 - .58	.12 - .12	.03 - .03	.02 - .02	.02 - .02	0	0
Ammonia Nitrogen	1.5 - 1.5	.58 - .58	.12 - .12	.03 - .03	.02 - .02	.02 - .02	0	0
Steamboat Creek:								
Organic Nitrogen	1.5 - 1.5	.58 - .58	.12 - .12	.03 - .03	.02 - .02	.02 - .02	0	0
Ammonia Nitrogen	1.5 - 1.5	.58 - .58	.12 - .12	.03 - .03	.02 - .02	.02 - .02	0	0
Reno-Sparks STP:								
Organic Nitrogen	1.5 - 1.5	.58 - .59	.12 - .12	.03 - .03	.02 - .02	.02 - .02	6	0
Ammonia Nitrogen	1.2 - 1.8	.48 - .69	.10 - .14	.03 - .03	.02 - .02	.02 - .02	1	0
Rate Coefficients and River Environment:								
Temperature	1.5 - 1.5	.39 - .37	.05 - .24	.03 - .03	.02 - .02	.02 - .02	4	0
K_{ORGN}	1.5 - 1.5	.57 - .59	.11 - .12	.03 - .03	.02 - .02	.02 - .02	5	0
K_{NH4}	1.5 - 1.5	.48 - .71	.08 - .19	.03 - .03	.02 - .02	.02 - .02	3	0

TABLE 42.--Summary of model sensitivity testing--Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF NITRITE NITROGEN (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
River at McCarran Bridge:								
Discharge	.05 - .06	.27 - .31	.19 - .18	.03 - .03	.01 - .02	.01 - .01	4	3
Organic Nitrogen	.05 - .05	.28 - .28	.18 - .18	.03 - .03	.02 - .02	.01 - .01	0	0
Ammonia Nitrogen	.05 - .05	.28 - .28	.18 - .18	.03 - .03	.02 - .02	.01 - .01	0	0
North Truckee Drain:								
Organic Nitrogen	.05 - .05	.28 - .28	.18 - .18	.03 - .03	.02 - .02	.01 - .01	0	0
Ammonia Nitrogen	.05 - .05	.28 - .28	.18 - .18	.03 - .03	.02 - .02	.01 - .01	0	0
Steamboat Creek:								
Organic Nitrogen	.05 - .05	.28 - .28	.18 - .18	.03 - .03	.02 - .02	.01 - .01	0	0
Ammonia Nitrogen	.05 - .05	.28 - .28	.18 - .18	.03 - .03	.02 - .02	.01 - .01	0	0
Reno-Sparks STP:								
Organic Nitrogen	.05 - .05	.28 - .29	.18 - .18	.03 - .03	.02 - .02	.01 - .01	0	0
Ammonia Nitrogen	.04 - .06	.23 - .33	.15 - .21	.03 - .03	.02 - .02	.01 - .01	2	0
Rate Coefficients and River Environment:								
Temperature	.06 - .05	.22 - .31	.08 - .31	.02 - .04	.01 - .02	.01 - .02	1	1
KORGN	.05 - .05	.28 - .29	.18 - .18	.03 - .03	.01 - .02	.02 - .02	5	3
KNH4	.04 - .06	.26 - .30	.20 - .16	.03 - .03	.02 - .02	.01 - .01	3	0
KNO2	.05 - .06	.24 - .34	.14 - .07	.02 - .03	.01 - .02	.01 - .02	2	2

TABLE 42.--Summary of model sensitivity testing--Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF NITRATE NITROGEN (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
River at McCarran Bridge:								
Discharge	.14 - .17	.65 - .88	.93- 1.2	.10 - .07	.06 - .03	.03 - .03	3	3
Organic Nitrogen	.15 - .15	.75 - .75	1.0 - 1.0	.07 - .07	.04 - .04	.03 - .03	0	0
Ammonia Nitrogen	.15 - .15	.75 - .75	1.0 - 1.0	.07 - .07	.04 - .04	.03 - .03	0	0
North Truckee Drain:								
Organic Nitrogen	.15 - .15	.75 - .75	1.0 - 1.0	.07 - .07	.04 - .04	.03 - .03	0	0
Ammonia Nitrogen	.15 - .15	.75 - .75	1.0 - 1.0	.07 - .07	.04 - .04	.03 - .03	0	0
Steamboat Creek:								
Organic Nitrogen	.15 - .15	.75 - .75	1.0 - 1.0	.07 - .07	.04 - .04	.03 - .03	0	.0
Ammonia Nitrogen	.15 - .15	.75 - .75	1.0 - 1.0	.07 - .07	.04 - .04	.03 - .03	0	0
Reno-Sparks STP:								
Organic Nitrogen	.15 - .15	.75 - .76	1.0 - 1.0	.07 - .07	.04 - .04	.03 - .03	7	0
Ammonia Nitrogen	.15 - .16	.64 - .87	.87- 1.2	.07 - .07	.04 - .04	.03 - .03	2	0
Rate Coefficients and River Environment:								
Temperature	.14 - .18	.54 - .98	.90- 1.0	.11 - .05	.07 - .02	.04 - .02	1	1
K_{ORGN}	.15 - .15	.75 - .76	1.0 - 1.0	.06 - .07	.04 - .04	.03 - .03	7	3
K_{NH4}	.15 - .16	.66 - .83	.97- 1.1	.07 - .07	.04 - .04	.03 - .03	5	0
K_{NO2}	.15 - .16	.70 - .79	.74- 1.1	.06 - .07	.04 - .04	.03 - .03	4	3
K_{NO3}	.15 - .15	.74 - .76	.98- 1.1	.04 - .09	.03 - .06	.02 - .04	6	2

TABLE 42.--Summary of model sensitivity testing--Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF TOTAL NITROGEN (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
River at McCarran Bridge:								
Discharge	2.2 - 2.6	2.1 - 2.4	1.8 - 2.1	.78 - .86	.57 - .45	.45 - .45	2	2
Organic Nitrogen	2.3 - 2.4	2.2 - 2.3	1.9 - 2.0	.80 - .82	.49 - .50	.43 - .43	5	6
Ammonia Nitrogen	2.4 - 2.4	2.2 - 2.2	1.9 - 1.9	.81 - .81	.50 - .50	.43 - .43	12	0
North Truckee Drain:								
Organic Nitrogen	2.3 - 2.4	2.2 - 2.2	1.9 - 1.9	.80 - .82	.49 - .50	.43 - .43	7	6
Ammonia Nitrogen	2.4 - 2.4	2.2 - 2.2	1.9 - 1.9	.81 - .81	.50 - .50	.43 - .43	0	0
Steamboat Creek:								
Organic Nitrogen	2.3 - 2.4	2.2 - 2.2	1.9 - 2.0	.80 - .82	.49 - .50	.43 - .43	6	6
Ammonia Nitrogen	2.3 - 2.4	2.2 - 2.2	1.9 - 1.9	.80 - .81	.49 - .50	.43 - .43	7	7
Reno-Sparks STP:								
Organic Nitrogen	2.3 - 2.4	2.2 - 2.3	1.9 - 2.0	.79 - .83	.49 - .51	.43 - .44	5	5
Ammonia Nitrogen	2.1 - 2.7	2.0 - 2.5	1.7 - 2.1	.81 - .81	.50 - .50	.43 - .43	1	0
Rate Coefficients and River Environment:								
Temperature	2.3 - 2.4	2.1 - 2.3	1.7 - 2.1	.69 - .95	.38 - .61	.32 - .54	3	1
K_{ORGN}	2.4 - 2.4	2.2 - 2.2	1.9 - 1.9	.78 - .85	.46 - .54	.39 - .48	0	3
K_{NH4}	2.4 - 2.4	2.2 - 2.2	1.9 - 2.0	.81 - .82	.49 - .50	.43 - .44	7	5
K_{NO2}	2.4 - 2.4	2.2 - 2.2	1.5 - 1.9	.81 - .81	.50 - .49	.43 - .43	4	6
K_{NO3}	2.4 - 2.4	2.2 - 2.2	1.9 - 2.0	.79 - .83	.48 - .51	.43 - .44	7	4

TABLE 42.--Summary of model sensitivity testing--Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF ORTHOPHOSPORUS (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
Inputs								
River at McCarran Bridge:								
Discharge	.55 - .67	.82 - .98	.68 - .80	.43 - .36	.27 - .13	.13 - .10	2	2
Orthophosphorus	.48 - .50	.86 - .88	.72 - .73	.38 - .38	.19 - .19	.11 - .11	5	0
North Truckee Drain:								
Orthophosphorus	.48 - .49	.87 - .88	.72 - .73	.38 - .38	.19 - .19	.11 - .11	6	0
Steamboat Creek:								
Orthophosphorus	.48 - .49	.87 - .88	.72 - .73	.38 - .38	.19 - .19	.11 - .11	6	0
Reno-Sparks STP:								
Orthophosphorus	.40 - .57	.80 - .94	.67 - .78	.36 - .40	.18 - .20	.10 - .11	1	3
Rate Coefficients and River Environment:								
Temperature	.60 - .61	.86 - .92	.65 - .80	.25 - .46	.10 - .25	.05 - .14	3	1
K_{PO4}, KP	.60 - .61	.88 - .91	.69 - .77	.31 - .42	.13 - .21	.07 - .11	4	2

TABLE 42.—Summary of model sensitivity testing—Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF DISSOLVED OXYGEN (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
River at McCarran Bridge:								
Discharge	6.6 - 6.8	6.5 - 6.8	6.7 - 6.8	7.4 - 7.4	7.5 - 7.8	7.4 - 7.6	5	4
$CBOD_u$	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.3 - 7.4	7.7 - 7.7	7.6 - 7.6	0	5
Dissolved oxygen	6.2 - 7.2	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.7	2	5
Organic Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	16	0
Ammonia Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	0	0
Nitrite Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	0	0
North Truckee Drain:								
$CBOD_u$	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	17	0
Dissolved oxygen	6.5 - 6.9	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	6	0
Organic Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	17	0
Ammonia Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	0	0
Nitrite Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	0	0
Steamboat Creek:								
$CBOD_u$	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	16	0
Dissolved oxygen	6.5 - 6.9	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	8	0
Organic Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	17	0
Ammonia Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 7.7	7.6 - 7.6	16	0
Nitrite Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	0	0
Reno-Sparks STP:								
$CBOD_u$	6.7 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	13	0
Dissolved oxygen	6.6 - 6.8	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	9	0
Organic Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	16	0
Ammonia Nitrogen	6.6 - 6.8	6.5 - 6.8	6.6 - 6.8	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	4	0
Nitrite Nitrogen	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	0	0
Rate Coefficients and River Environment:								
Temperature	6.4 - 7.0	6.0 - 7.4	6.3 - 7.3	6.7 - 8.2	7.0 - 8.5	6.8 - 8.5	1	1
K_2	6.7 - 6.7	6.4 - 6.8	6.5 - 6.8	7.4 - 7.4	7.8 - 7.6	7.7 - 7.5	3	3
K_{CBOD}	6.7 - 6.7	6.6 - 6.6	6.7 - 6.8	7.4 - 7.4	7.7 - 7.7	7.5 - 7.5	11	0
K_{ORGN}	6.7 - 6.7	6.6 - 6.6	6.7 - 6.7	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	15	0
K_{NH4}	6.6 - 6.8	6.6 - 6.7	6.8 - 6.6	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	7	0
K_{NO2}	6.6 - 6.7	6.6 - 6.6	6.7 - 6.8	7.4 - 7.4	7.7 - 7.7	7.6 - 7.6	10	0
P	6.7 - 6.7	6.6 - 6.6	6.7 - 6.8	7.2 - 7.6	7.5 - 7.9	7.3 - 7.9	12	2

TABLE 42.--Summary of model sensitivity testing--Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking	
							Vista-Derby Dam	Wadsworth Marble Bluff
RANGE IN SIMULATED CONCENTRATIONS OF MINIMUM DISSOLVED OXYGEN (MG/L) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
River at McCarran Bridge:								
Discharge	5.1 - 5.4	5.2 - 5.6	4.5 - 4.9	4.8 - 5.0	5.1 - 5.2	5.4 - 5.5	4	4
$CBOD_u$	5.2 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	15	0
Dissolved oxygen	4.8 - 5.7	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	5	0
Organic Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	17	0
Ammonia Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	17	0
Nitrite Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	18	0
North Truckee Drain:								
$CBOD_u$	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	17	0
Dissolved oxygen	5.1 - 5.4	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	9	0
Organic Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	18	0
Ammonia Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	0	0
Nitrite Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	0	0
Steamboat Creek:								
$CBOD_u$	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	16	0
Dissolved oxygen	5.2 - 5.4	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	11	0
Organic Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	18	0
Ammonia Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	17	0
Nitrite Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	0	0
Reno-Sparks STP:								
$CBOD_u$	5.2 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.2	3.9 - 3.9	4.4 - 4.4	13	7
Dissolved oxygen	5.1 - 5.4	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	10	0
Organic Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	16	0
Ammonia Nitrogen	5.2 - 5.3	5.3 - 5.6	4.6 - 4.8	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	6	0
Nitrite Nitrogen	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	17	0
River Environment:								
Temperature	5.0 - 5.5	5.0 - 6.0	4.5 - 5.0	2.9 - 3.4	3.6 - 4.3	4.1 - 5.1	2	3
K_2	5.2 - 5.3	4.8 - 5.8	4.0 - 5.1	2.2 - 3.8	3.1 - 4.5	3.8 - 4.8	1	1
K_{CBOD}	5.2 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.2	3.9 - 4.0	4.4 - 4.5	12	4
K_{ORGN}	5.3 - 5.3	5.4 - 5.4	4.7 - 4.7	3.1 - 3.2	3.9 - 4.0	4.4 - 4.4	14	5
K_{NH4}	5.2 - 5.3	5.4 - 5.5	4.8 - 4.6	3.1 - 3.1	3.9 - 3.9	4.4 - 4.4	8	0
K_{NO2}	5.6 - 5.7	5.4 - 5.4	4.5 - 4.3	3.0 - 3.0	3.9 - 3.9	4.4 - 4.4	7	6
R	5.2 - 5.3	5.2 - 5.6	4.3 - 5.0	2.5 - 3.8	3.4 - 4.5	4.1 - 4.8	3	2

TABLE 42.--Summary of model sensitivity testing--Continued

Changed model input or parameter	Vista Gage (RM 52.23)	Patrick Bridge (RM 44.92)	Derby Dam (RM 34.88)	Wadsworth Bridge (RM 23.69)	Dead Ox Wash (RM 13.18)	Marble Bluff (RM 0.00)	Ranking: Vista-Derby Dam	Ranking: Wadsworth Marble Bluff
RANGE IN SIMULATED REAERATION COEFFICIENT (K_2) IN RESPONSE TO PLUS OR MINUS 20 PERCENT CHANGES IN:								
River at McCarran Bridge:								
Discharge	.32 - .37	13 - 15	.49 - .55	5.7 - 6.0	3.4 - 3.4	.20 - .20	2	2
River Environment:								
Temperature	.31 - .38	12 - 16	.46 - .57	3.3 - 4.1	1.9 - 2.4	.12 - .15	1	1

For these simulations, the rate of effluent discharge was set to that observed in each synoptic, however, the quality of effluent was made equal to that observed in the upstream river at McCarran Bridge. The effect would be the same as a hypothetical automated "perfect" treatment process that would use a monitor in the river above the point of discharge to adjust the plant effluent to equal the quality measured by the upstream monitor. (Note that these simulations are not the same as removing the STP effluent from the river; for the August flows, removal of the effluent from the river results in the river going dry due to diversions below Derby Dam.) From comparison of these runs to the model runs with the calibration/verification data sets, the impact of the STP in comparison to the other point and nonpoint sources of loadings to the river may be inferred; the area between the two simulations represents the net effect of added loadings from the STP for the modeled conditions. Results of these four simulations are shown graphically for the Truckee River (profiles A and B) and Truckee Canal (profiles C and D) in figures 71 to 83 and discussed by individual constituent below.

Dissolved solids

Eliminating the observed loadings from the STP effluent resulted in uniform minor reductions in simulated concentrations of dissolved solids in the Truckee River (figure 71A, B). Effects of the STP loadings are minimal below Wadsworth in comparison to ground-water contributions of dissolved solids. Reductions in simulated dissolved solids in the river at Derby Dam resulted in uniform reductions in concentrations in the canal (figure 71C, D).

Figure 71 near here

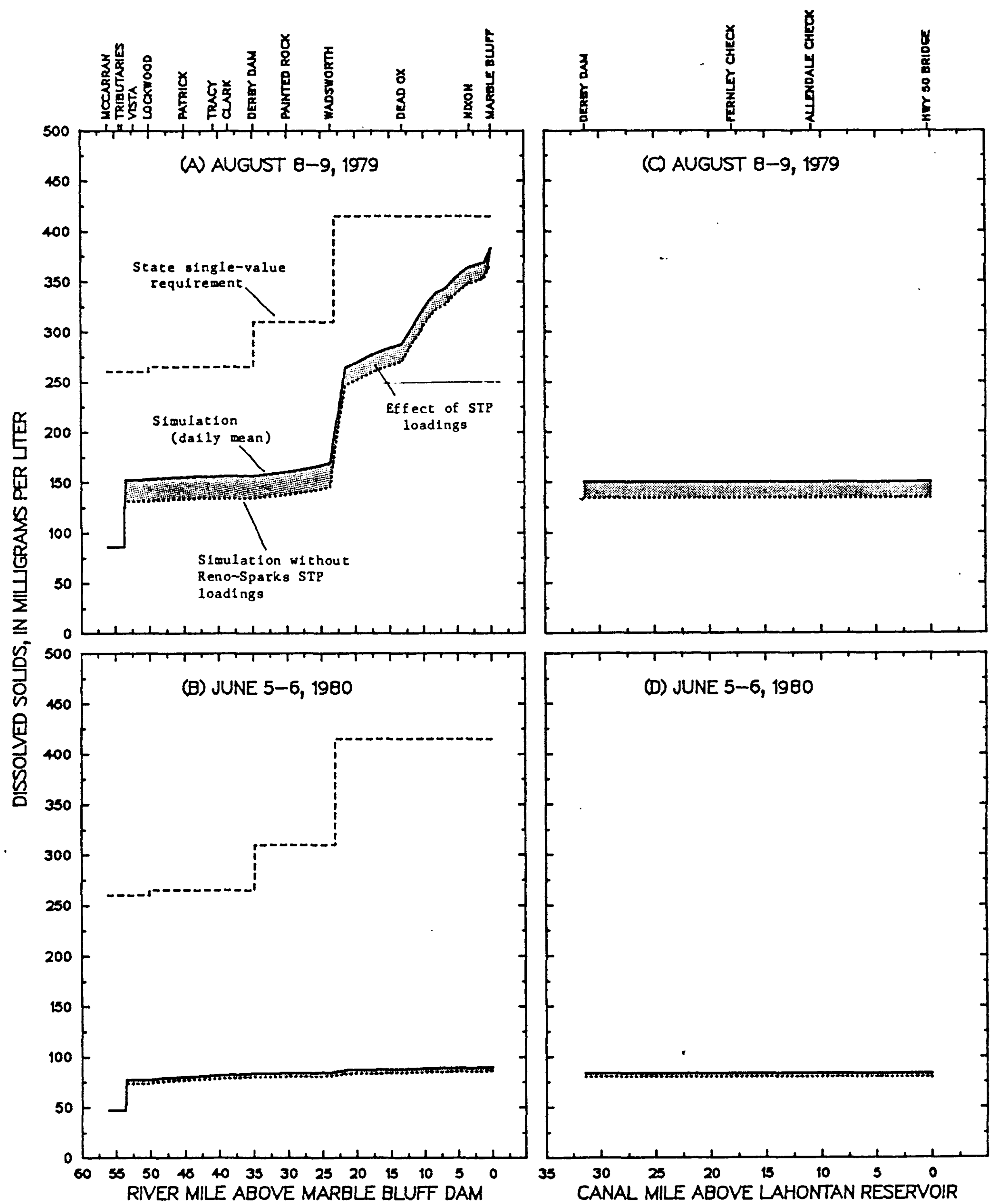


FIGURE 78.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected concentrations of dissolved solids in the Truckee River are slightly decreased with removal of loadings from the STP in varying amounts depending upon river flows. At low flows (A), the effects of the STP loadings are minimal compared to the loadings from ground-water inflows below Wadsworth.

$CBOD_u$

Simulations with and without the loadings from the STP show that the STP loadings had a significant impact on $CBOD_u$ concentrations in the river (figure 72A, B) and that the impact decreased with increased river flow from the August 1979 data set (B) to the June 1980 data set (C). The relative impact of the STP CBOD loadings decreased in a dowstream direction with assimilation of the effluent and increasing effects from local nonpoint returns below Derby Dam. In the Truckee Canal (figure 72C, D), the removal of the STP loadings is reflected in the difference between the initial concentrations at the head of the canal.

Figure 72 near here

Phosphorus

Simulations of ortho- and total phosphorus concentrations in the Truckee River are shown in figure 73. As with CBOD, the effects of STP loadings are variable with flow, are significant above Derby Dam, and diminish in significance at lower flows below Wadsworth. Note that the magnitude of modeled nonpoint sources of phosphorus is such that annual-average water-quality standard for orthophosphorus in the river is exceeded even without the loadings from the STP. Trends for the Truckee Canal are similar to CBOD, with the effect of the STP loadings dependent upon the river conditions at Derby Dam (figure 73C, D).

Figure 73 near here

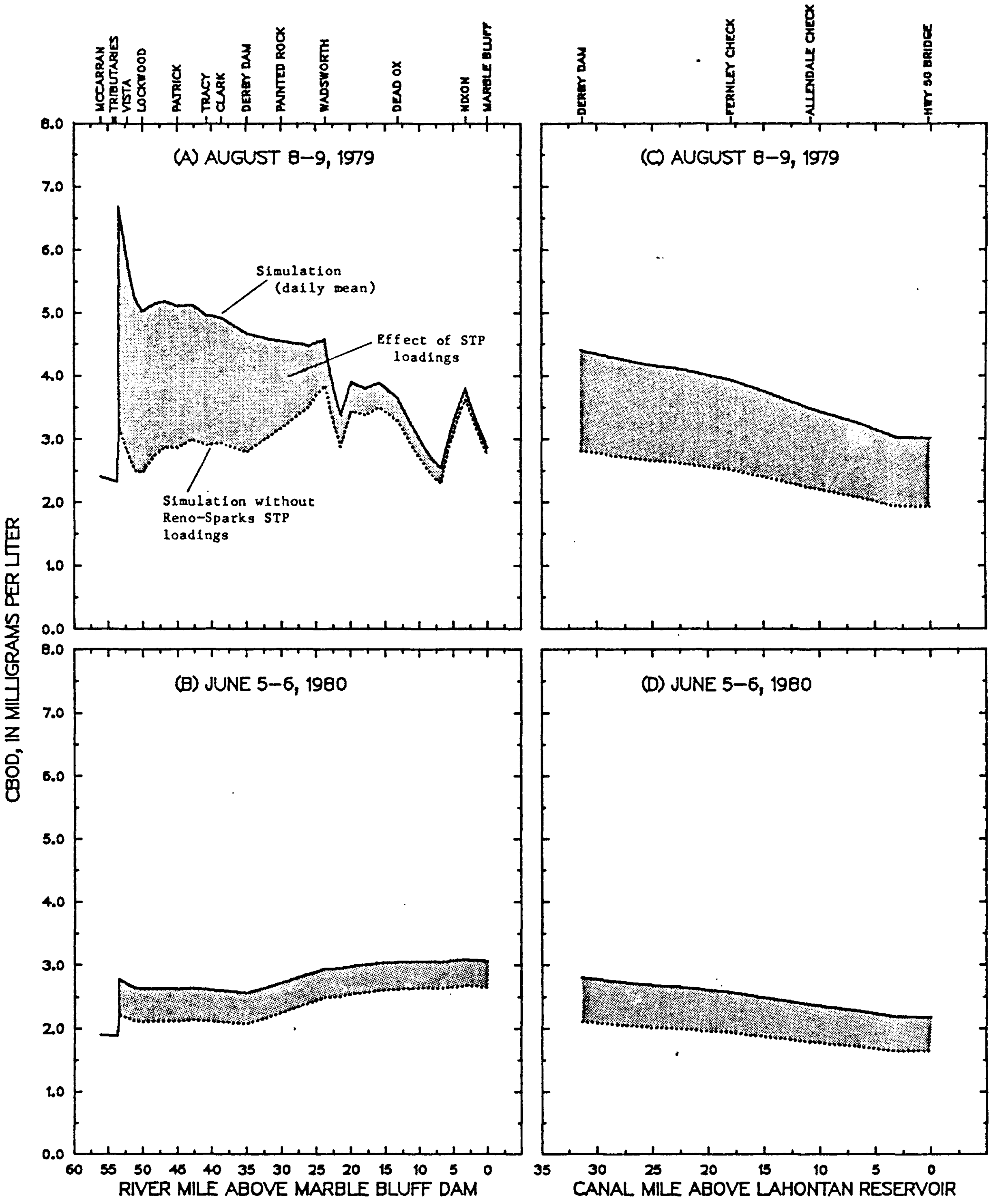


FIGURE 72.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected concentrations of CBOD in the Truckee River above Derby Dam and in the canal are significantly reduced at low to medium flows (A, C) with removal of loadings from the STP. Below Derby Dam, the effects of loadings from the STP decrease in comparison with nonpoint sources.

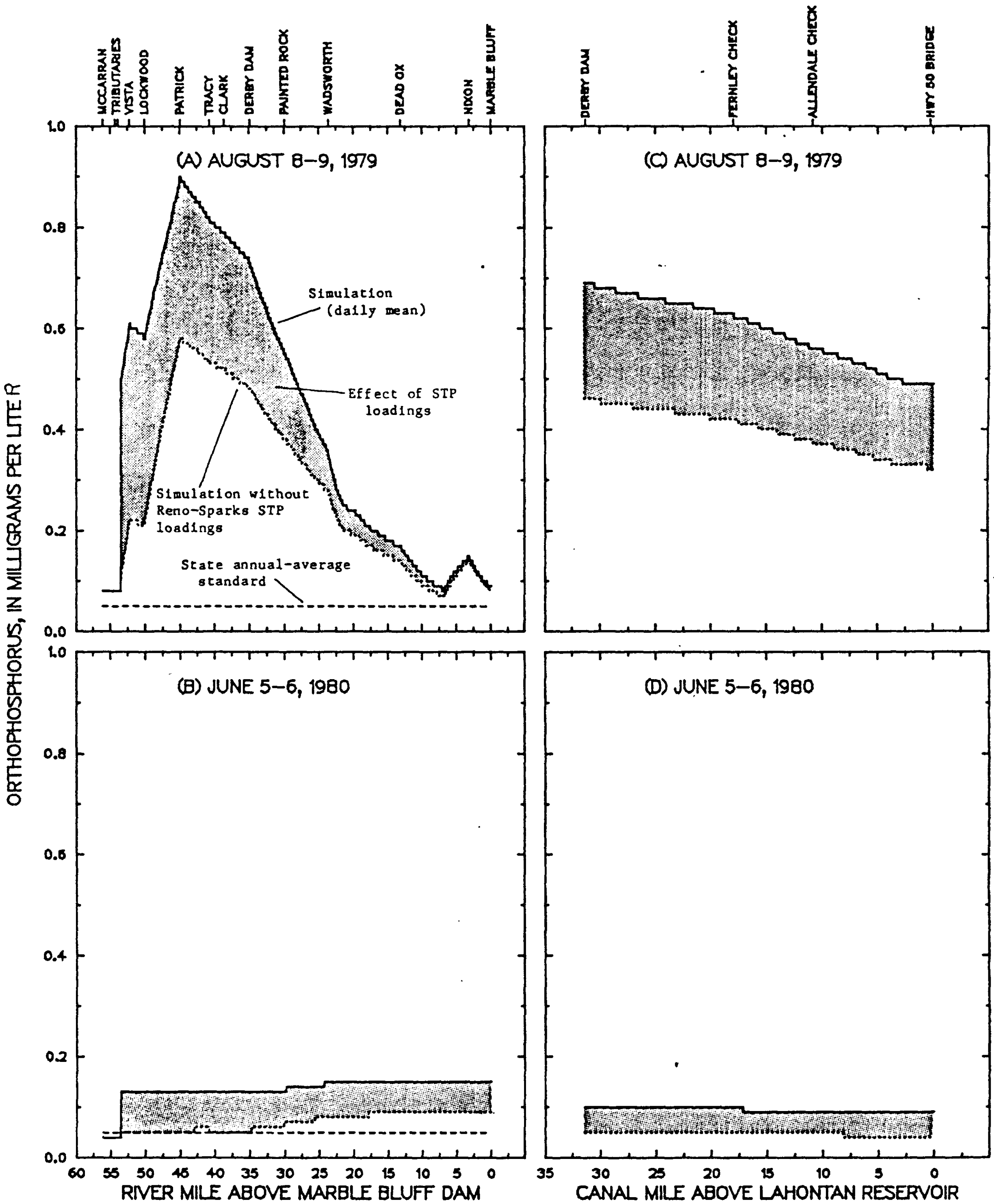


FIGURE 73.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected concentrations of orthophosphorus in the Truckee River above Wadsworth are significantly reduced with removal of loadings from the STP. At low flows below Wadsworth (A), effects of the STP are greatly reduced in comparison to nonpoint loadings. Concentrations in the canal are uniformly reduced with removal of STP loadings.

Simulated phosphorus concentrations above Wadsworth are largely controlled by the additions of "dummy" nonpoint loadings between Vista and Patrick for the the two August 1979 data. Simulations for orthophosphorus without the added loads are shown in figure 74 for the Truckee River and Canal. Under these assumptions, the projected orthophosphorus concentrations without the STP loadings remain at near background levels past Vista, and gradually increase in a downstream direction due to nonpoint loadings from agricultural returns. Projected orthophosphorus concentrations without the STP loadings still exceed the annual-average water-quality standard for much of the river due to the other nonpoint sources. Without the "dummy" loadings to the river, projected concentrations in the canal without STP loadings are greatly reduced over the observed conditions (figure 74C, D).

Figure 74 near here

Organic-nitrogen

Concentrations in the Truckee River follow a similar trend to CBOD, with effects of the STP increasing with decreasing river flows and decreasing with distance downstream (figure 75). In the canal, organic-nitrogen assimilation is minimal; thus, the effects of removing the STP loadings are directly related to reduced river concentrations at Derby Dam.

Figure 75 near here

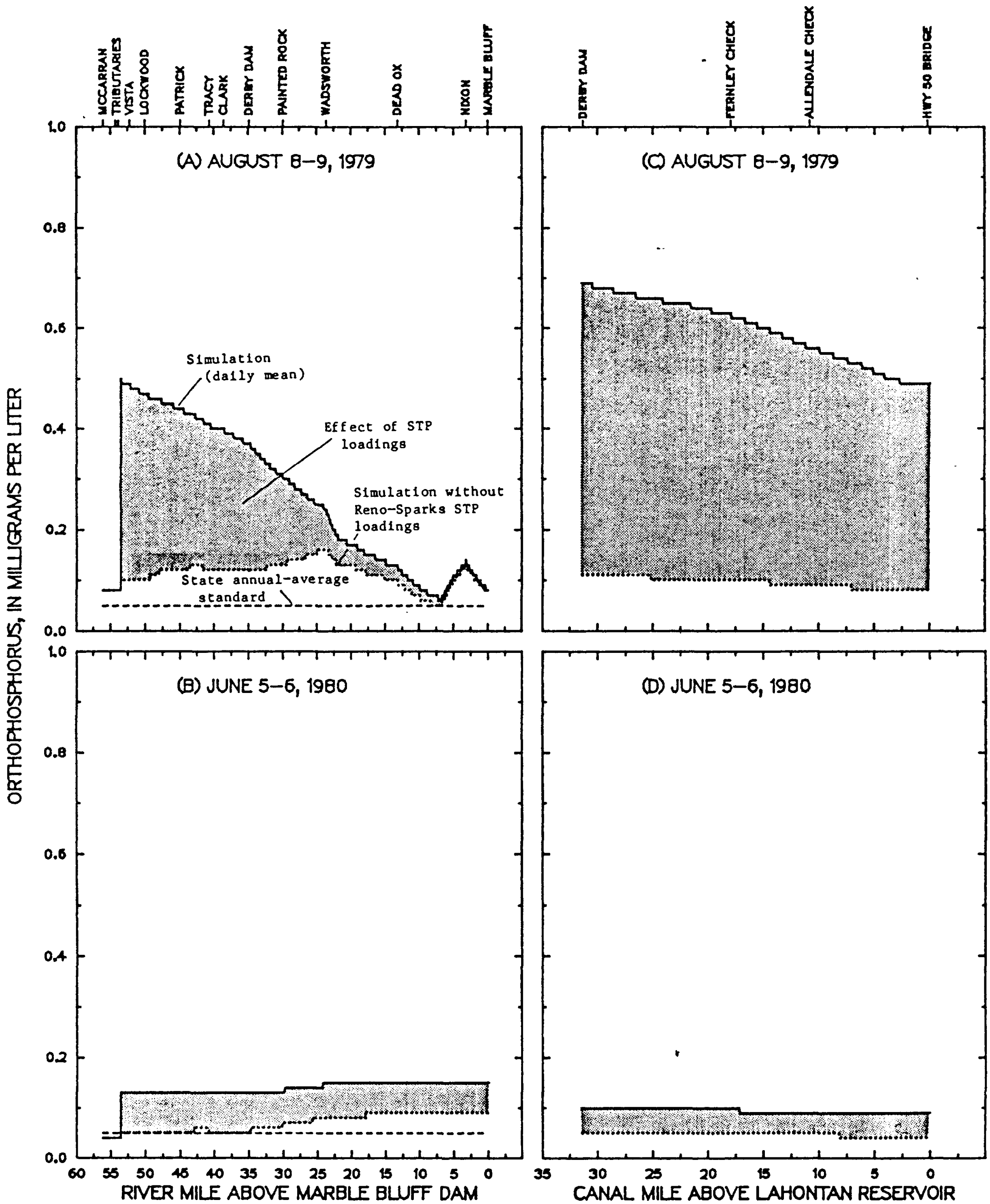


FIGURE 74.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP and simulations without calibrated "dummy" nonpoint phosphorus loadings between Vista and Patrick: At low river flows (A), projected concentrations of orthophosphorus in the Truckee River are reduced to near background levels at Vista with removal of loadings from the STP. Concentrations gradually increase in the downstream direction due to nonpoint agricultural returns, resulting in projected exceedance of water-quality standards even with the removal of the STP loadings.

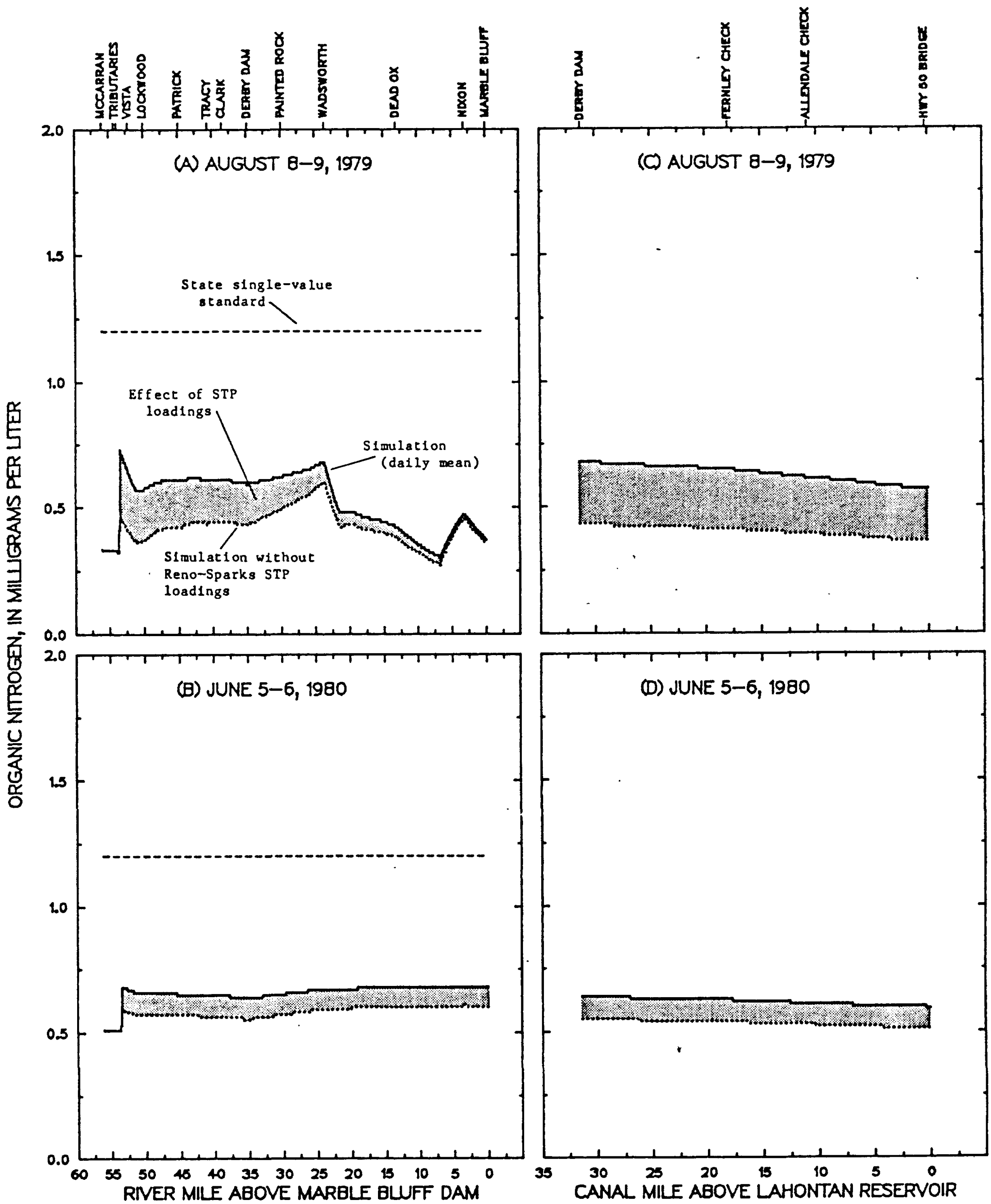


FIGURE 75.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected concentrations of organic nitrogen in the Truckee River at low flows are significantly reduced with removal of loadings from the STP (A).

Ammonia-nitrogen

Removal of the STP loadings results in significant reductions of concentrations in the river, especially at low flows above Derby Dam (figure 76A). High ammonia assimilation rates in the river result in no significant differences in ammonia concentrations for the two simulations below Wadsworth at low flows. Removal of the STP loadings also result in reduced concentrations in the canal (figure 76C, D). Projected mean-daily concentrations of un-ionized ammonia are greatly reduced in the river and canal (figure 77) with removal of the STP loadings.

Figures 76 and 77 near here

Nitrite-nitrogen

Reduced ammonia loadings for the simulations without the STP loadings result in greatly reduced concentrations of nitrite in the river above Wadsworth and the canal (figure 78), although projected concentrations at low flows still approach or exceed the water-quality standard of 0.04 mg/L in the river.

Figure 78 near here

Nitrate-nitrogen

Reduced ammonia loadings for the simulations without the STP loadings also result in greatly reduced nitrate concentrations in the river above Wadsworth (figure 79). Since observed nitrate concentrations for the August 1979 calibration data peaked near Derby Dam, the canal simulations without the STP loadings had significantly lower concentrations of nitrate (figure 79B).

Figure 79 near here

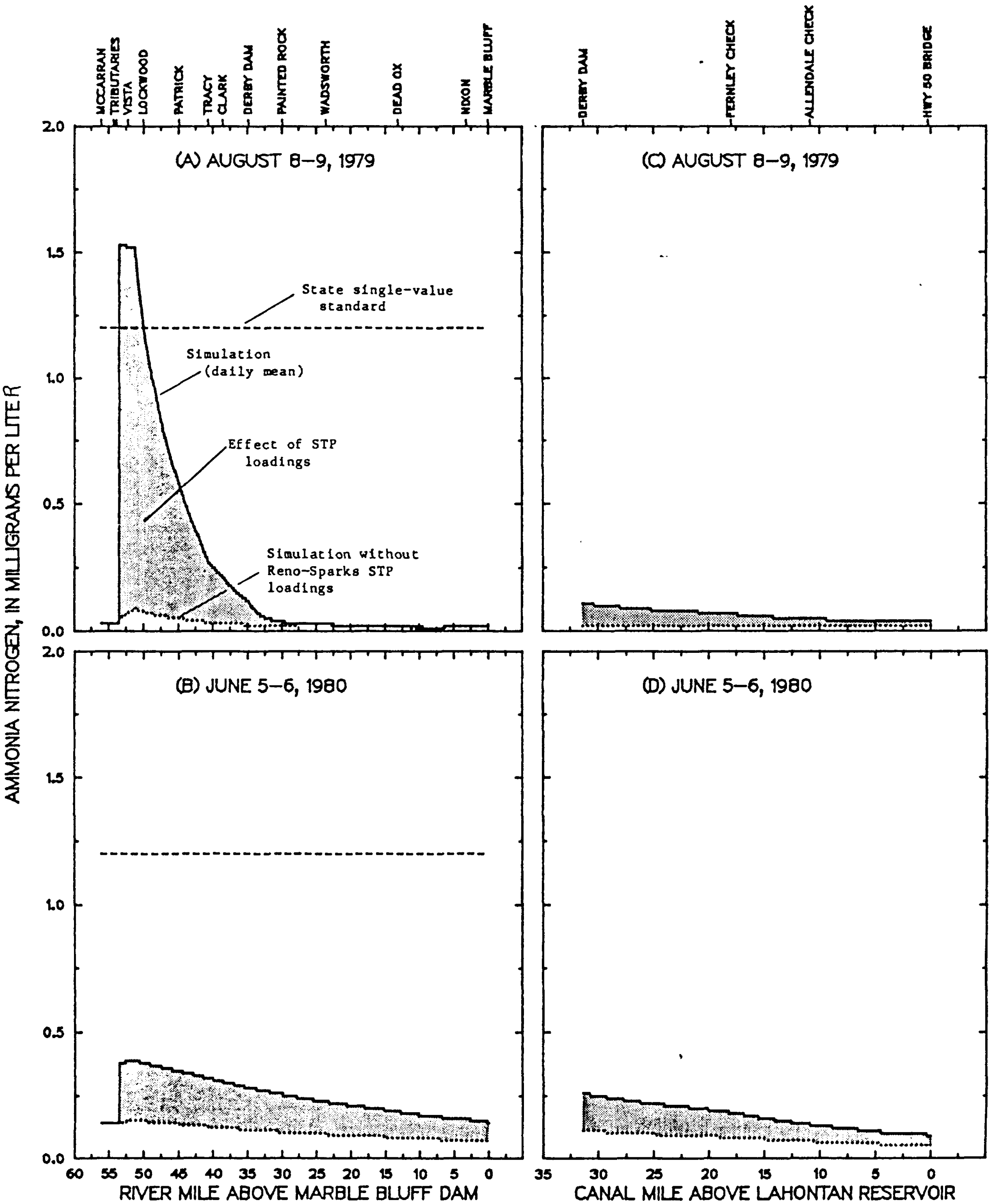


FIGURE 76.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected concentrations of ammonia nitrogen in the Truckee River and canal are reduced to near background levels with removal of loadings from the STP.

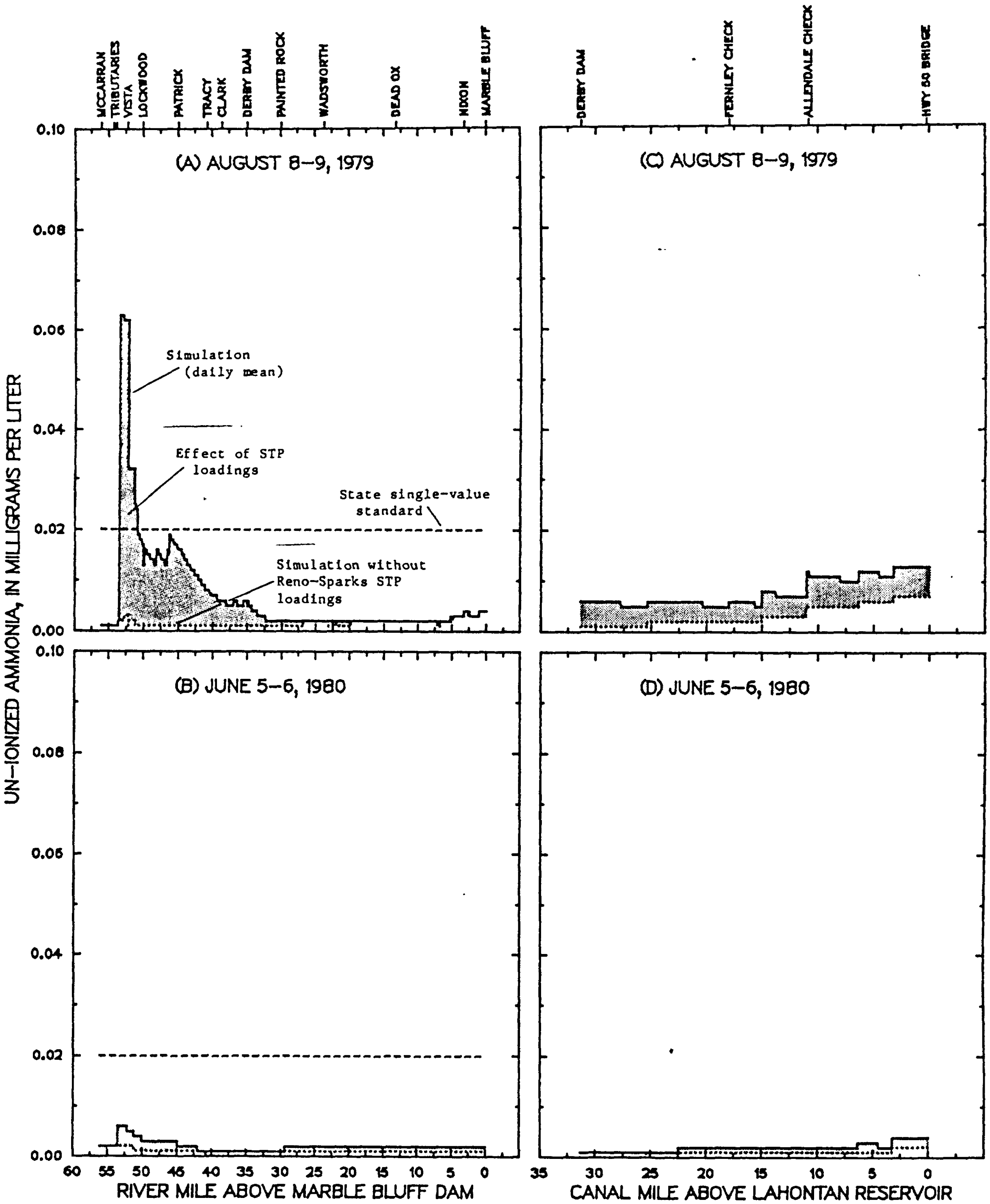


FIGURE 77.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected concentrations of un-ionized ammonia in the Truckee River and canal are reduced to near background levels with removal of the STP ammonia loadings.

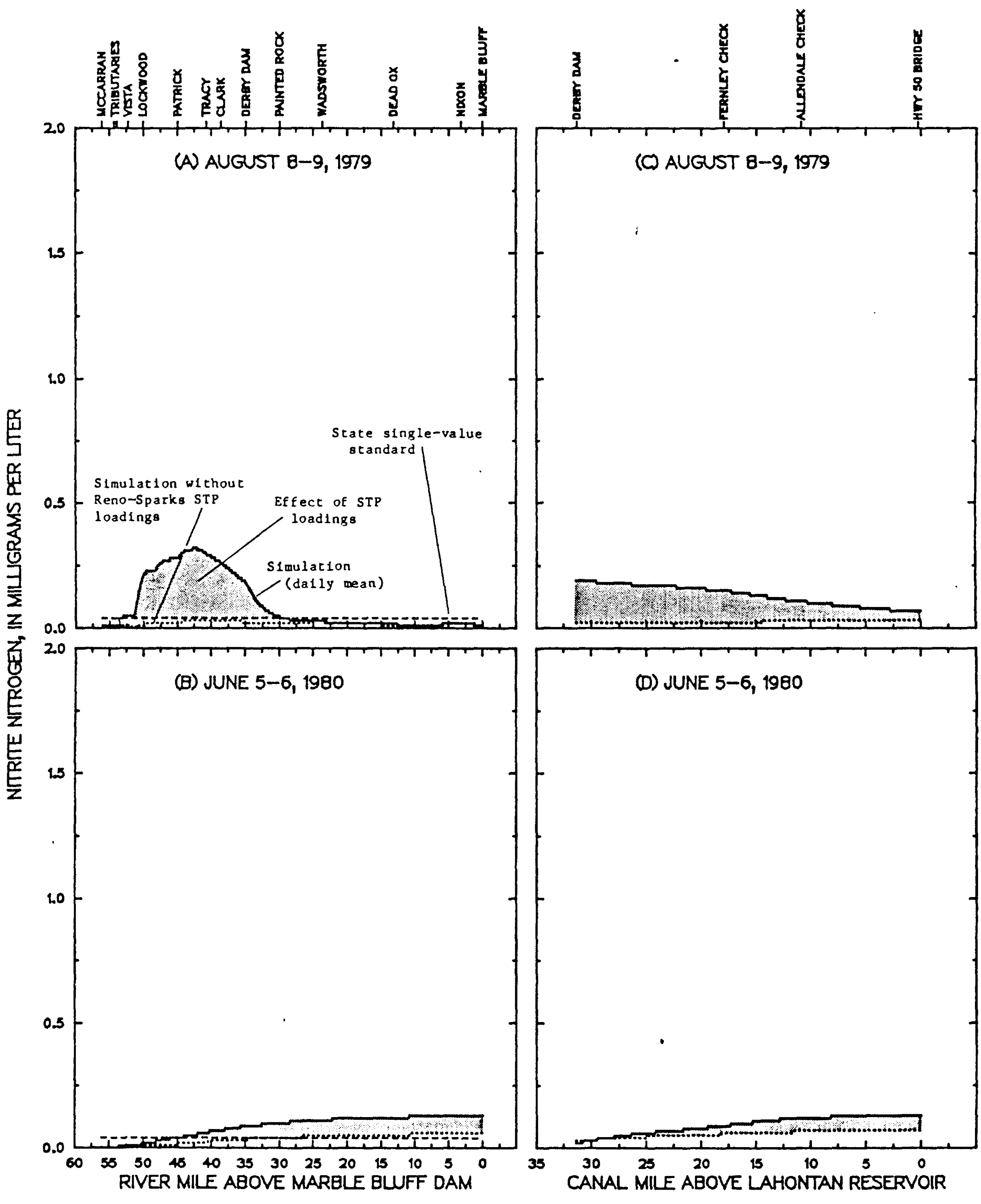


FIGURE 78.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected concentrations of nitrite nitrogen in the Truckee River and canal are reduced to very low levels with removal of nitrogen loadings from the STP.

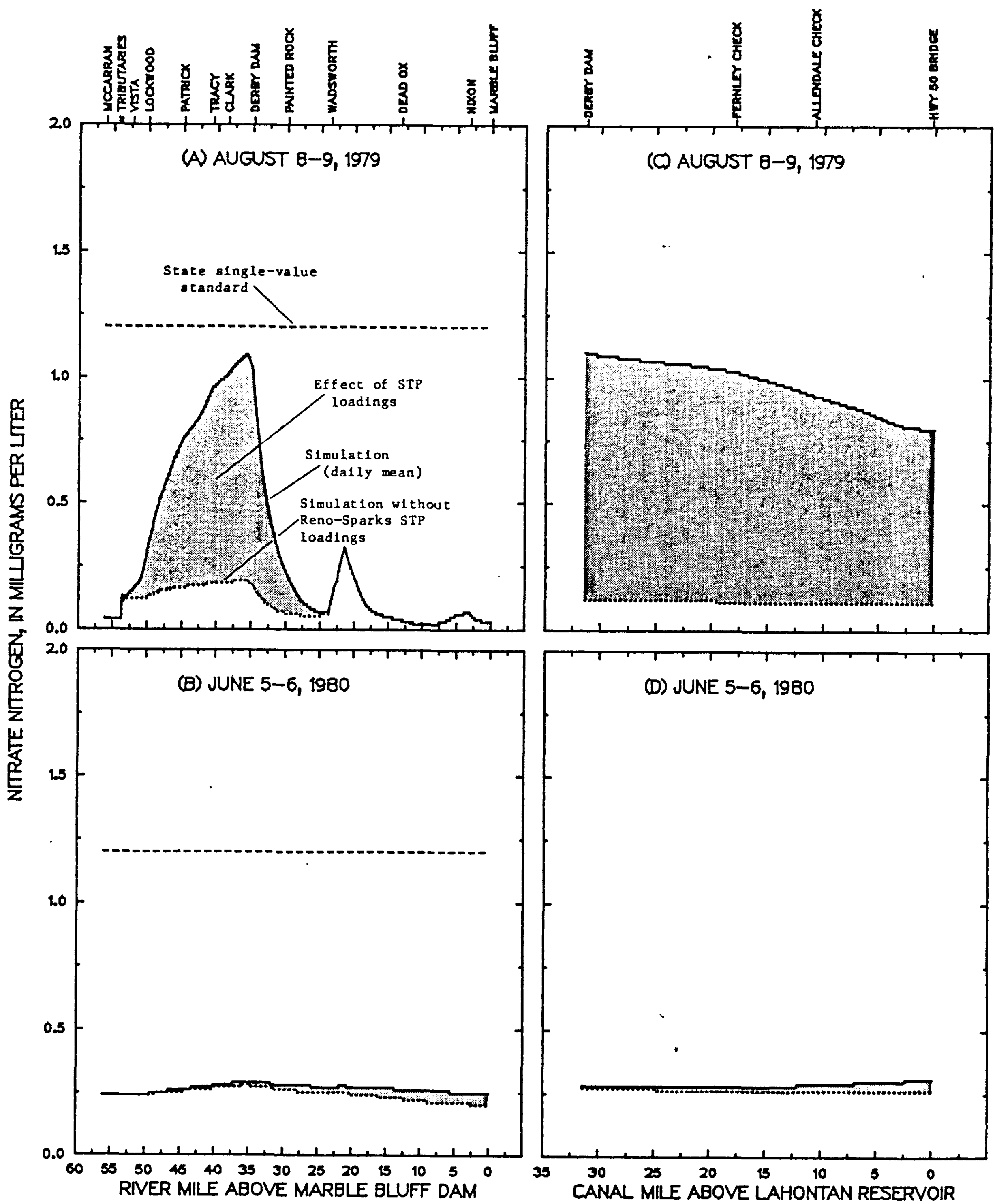


FIGURE 79.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected concentrations of nitrate nitrogen in the Truckee River above Wadsworth and in the canal are greatly reduced at low flows (A, C) with removal of nitrogen loadings from the STP. Below Wadsworth, nonpoint sources of nitrate predominate over upstream inputs.

Total-nitrogen

As expected from discussions of the individual nitrogen species above, concentrations of total-nitrogen in the river and the canal (figure 80) are greatly reduced for the simulations with the STP nitrogen loadings removed.

Figure 80 near here

Nitrogen/phosphorus ratio

For low river flows, removal of the nitrogen and phosphorus loadings from the STP result in shifts of the N/P ratios towards stronger indications of nitrogen limitation in both the river and the canal (figure 81) in comparison with the observed conditions in August 1979. For the June 1980 high flows the trends were reversed. For these data, removal of the STP loadings resulted in more reduction of orthophosphorus than ammonia, nitrite, and nitrate, thus the N/P ratios shifted towards stronger indications of phosphorus limitation. As with the individual nutrient species, the effects of removal of the STP loadings have greatly reduced effect on the N/P ratios below Derby Dam and Wadsworth.

Figure 81 near here

Dissolved oxygen

Projected effects of removal of the loadings of oxygen demands from the STP on mean-daily and minimum-daily DO concentrations are shown in figures 82 and 83 for the river and the canal. For the river, removal of the ammonia (and, to a lesser extent, CBOD) loadings from the STP results in significant improvement to the oxygen regime above Derby Dam for low flows (figures 82A and 83A), with virtual elimination of projected violations of water-quality standards for minimum DO in the reach. Below Derby Dam, the effects are minimal as oxygen deficits in the reach are due to the impact of nighttime

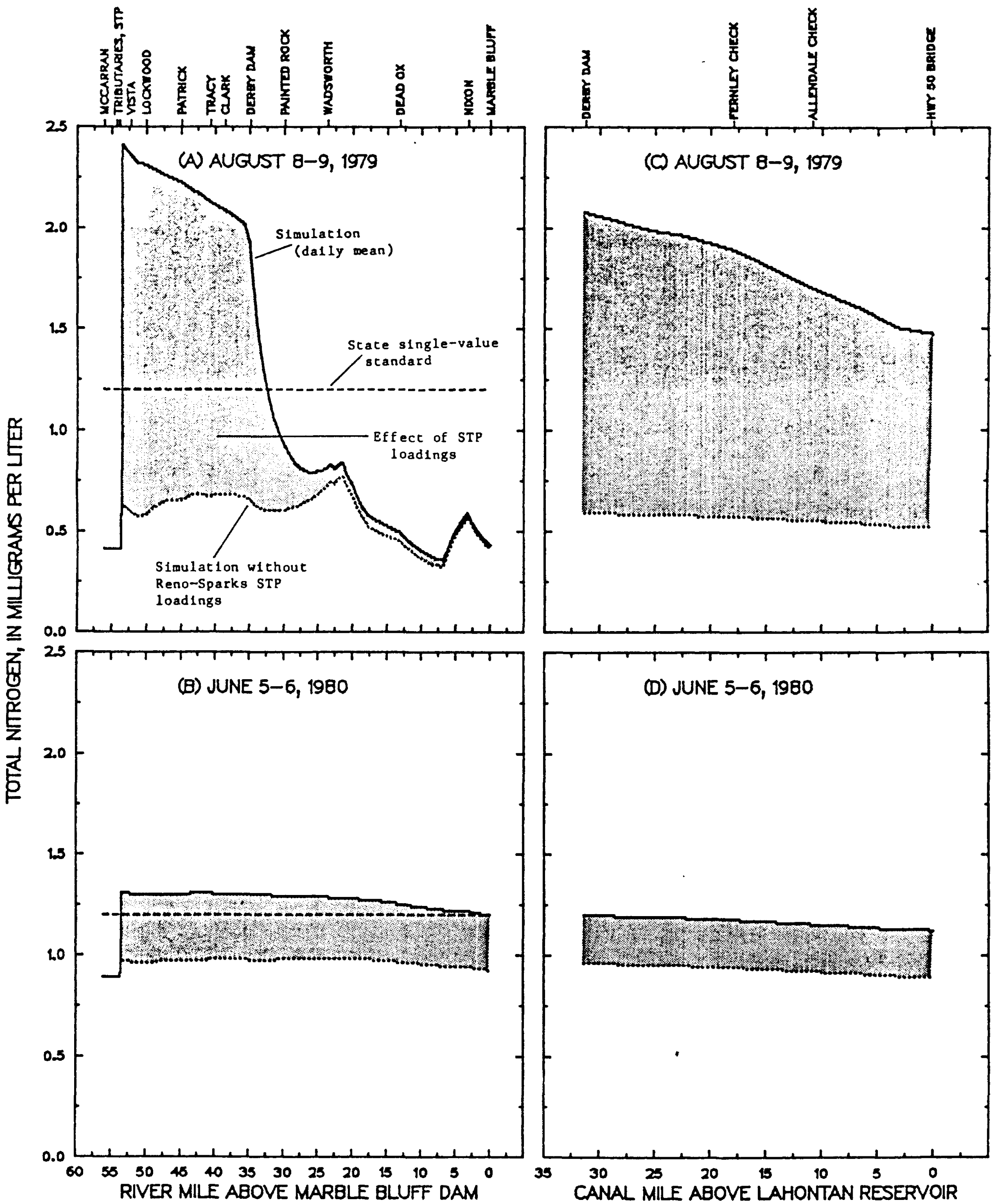


FIGURE 80.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP. Projected concentrations of total nitrogen in the Truckee River above Wadsworth and in the canal are greatly reduced with removal of nitrogen loadings from the STP. Removal of STP loadings has minimal effect below Wadsworth.

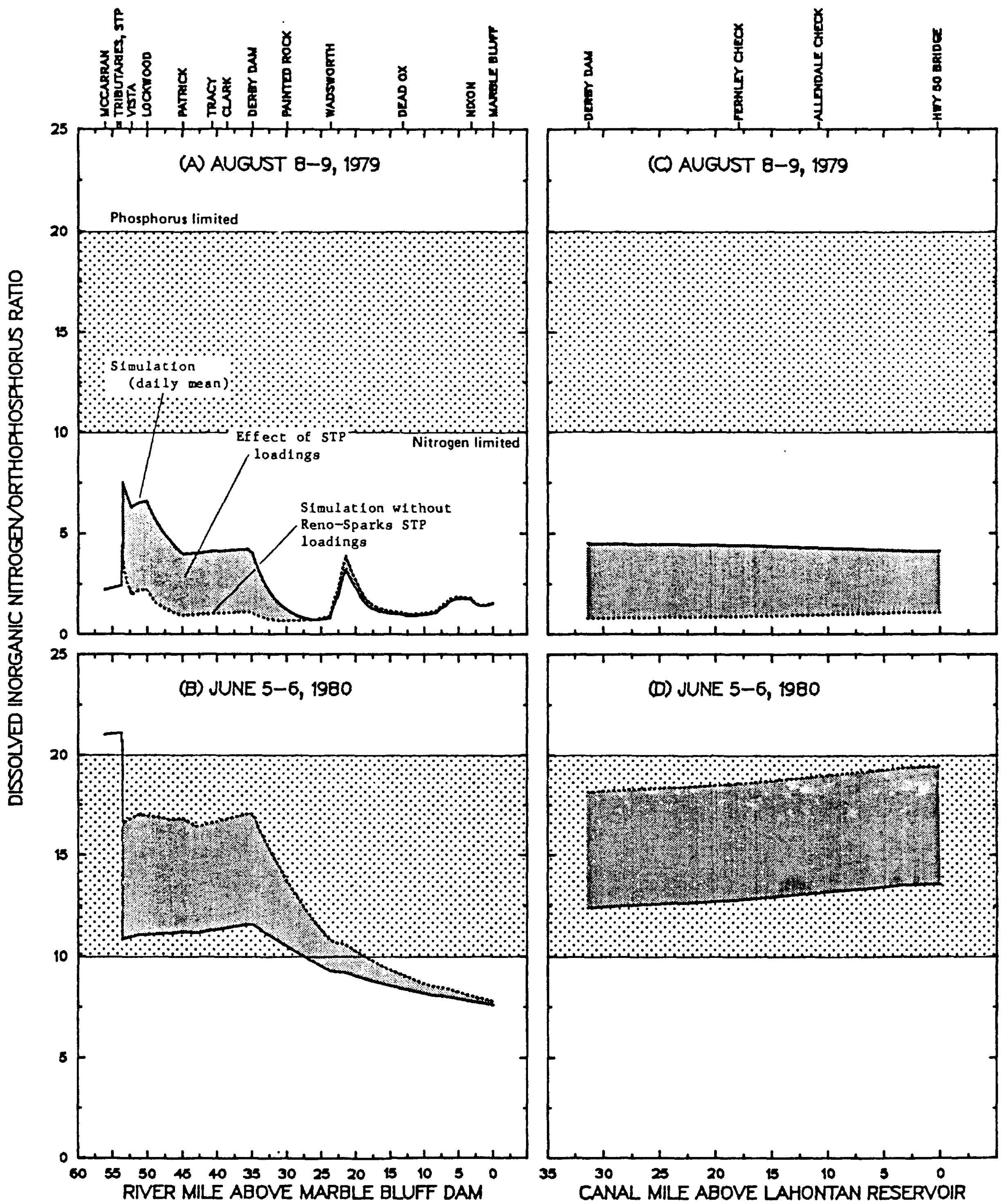


FIGURE 81.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: At low flows in the Truckee River (A), removal of nitrogen and phosphorus loadings from the STP shifts the N/P ratio in the river and the canal towards increased nitrogen limitation. At higher river flows (B, D), the ratio shifts towards phosphorus limitation.

respiration of aquatic plants, not the direct oxidation of ammonia or CBOD. In the canal, removal of STP loadings also results in an increase in projected oxygen levels (figure 83C, D). Unlike the lower river, even minimum-daily DO concentrations exceed saturation in the lower reaches of the canal (assuming that P and R rates in the canal would be unaffected by removal of the STP loadings). The much lower reaeration coefficients for the canal compared to the river (table 39, figures 53 and 54) result in "banking" of oxygen produced by algal photosynthesis during the daytime, resulting in a net downstream increase of oxygen throughout the length of the canal.

Figures 82 and 83 near here

Summary of the Principal Processes and Loadings Controlling Water Quality

Sensitivity analyses performed with the TRWQ model provide an assessment of the relative importance of individual processes controlling water quality in the river and canal, and the relative impact of principal sources of loadings of various constituents.

The sensitivity analyses for low-flow conditions as represented by the August 1979 data set pointed out the differences in factors controlling water quality in the Truckee River above and below Derby Dam. Above the Dam, concentrations of most constituents are affected principally by input loadings and assimilation rates. For dissolved solids, the principal sources of loadings were the river at McCarran Bridge, followed by North Truckee Drain, Steamboat Creek, and the STP. For nutrients, the STP was the major source of loadings, followed by the river and Steamboat Creek. For phosphorus, accretions from unknown sources between Lockwood and Derby Dam also were an

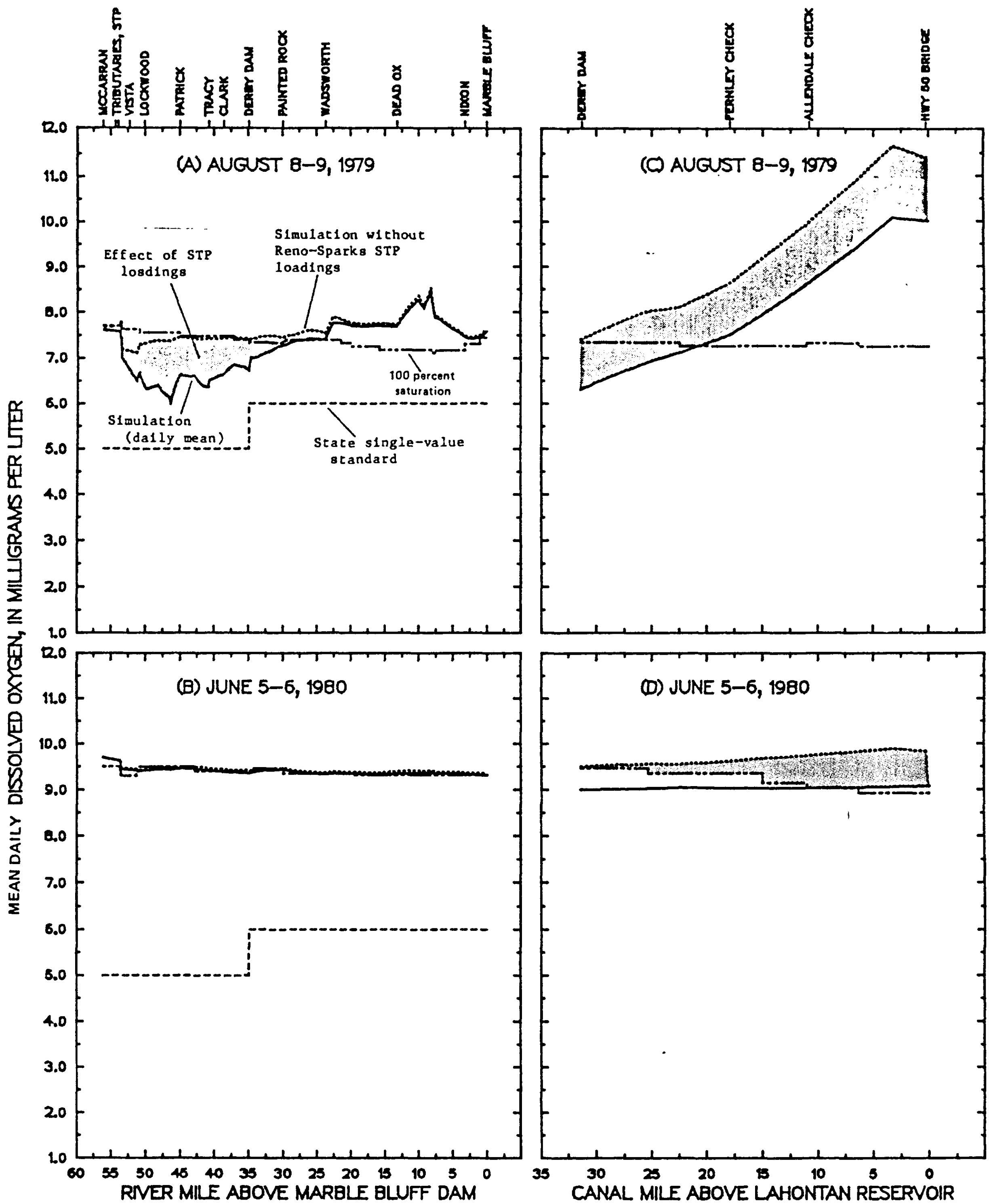


FIGURE 82.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: At low Truckee River flows, projected mean daily DO concentrations are significantly increased in the river above Derby Dam and in the canal with removal of loadings from the STP. Below Derby Dam, the effects are minimal.

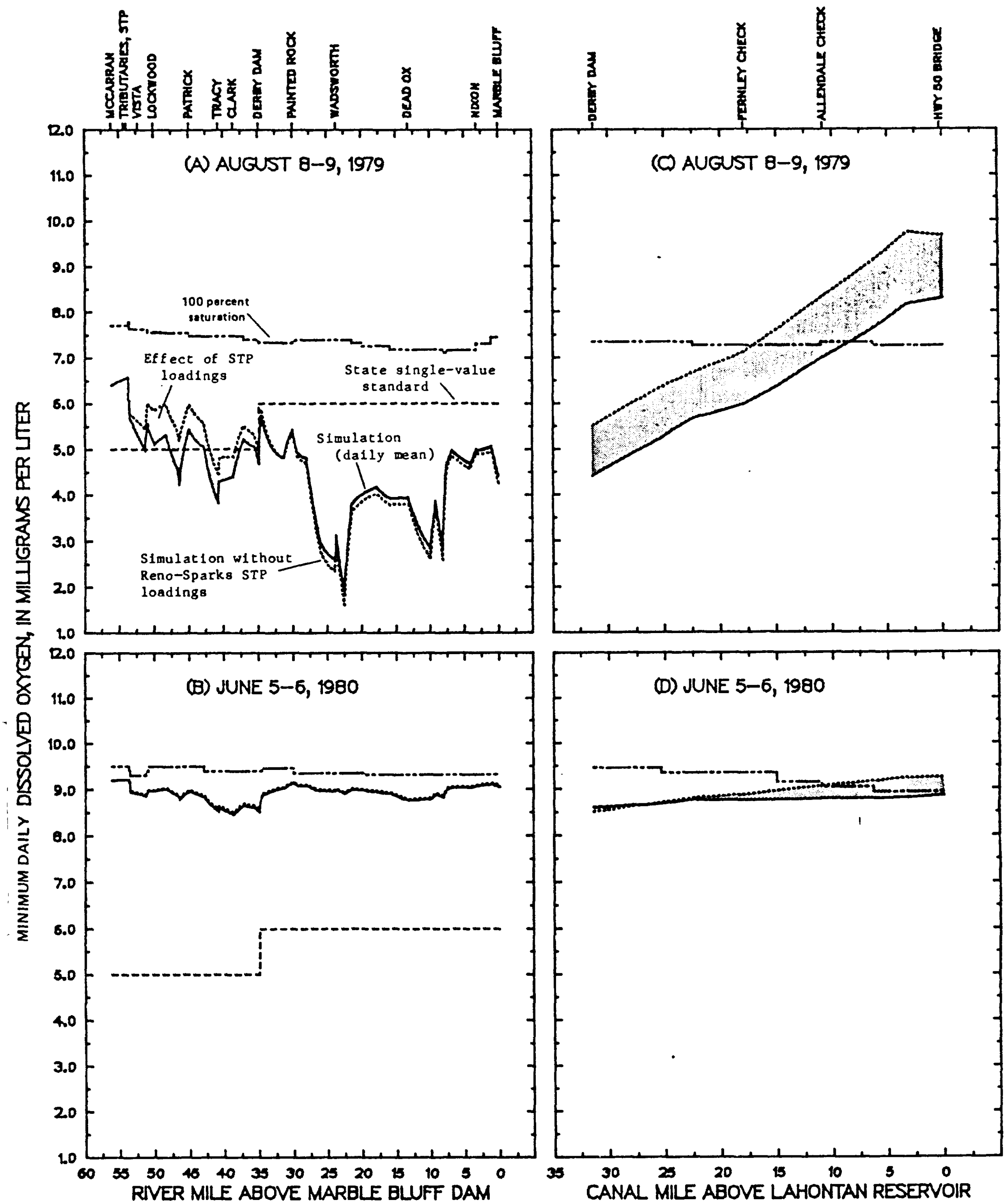


FIGURE 83.--Comparisons of simulations for the August 1979 and June 1980 data with and without loadings from the Reno-Sparks STP: Projected minimum daily DO concentrations in the Truckee River are increased at low flows (A, D) above Derby Dam with removal of nitrogen loadings from the STP. Below Derby Dam, the effects are minimal.

important source of loadings during the August studies. Ammonia from the STP was the most important single source affecting dissolved oxygen in the river above Derby Dam.

Nonpoint sources of loadings have increasing significance in comparison to upstream loadings from the STP and tributaries with respect to river quality below Derby Dam, and local nonpoint sources are the dominant loadings below Wadworth at low to medium flows.

The relative importance of processes controlling water quality in the river also changes above and below Derby Dam. Below Vista, loadings from the STP and the two tributaries result in significanty increased concentrations of $CBOD_u$ and nutrients. The degree of assimilation of these initial loadings between Vista and Derby Dam is dependent upon water temperatures and traveltimes, both of which are related to seasonal fluctuations in streamflows. Spring snowmelt periods result in high river flows and low water temperatures; loadings to the river are transported downstream with little change in quality.

During lower late-spring and summer flows, higher temperatures and increased traveltimes result in substantial assimilation of loads and greatly decreased concentrations of $CBOD_u$ and nutrients by Derby Dam. Lower, warmer flows also result in increased oxidation of CBOD, ammonia, and nitrite, creating moderately depressed oxygen concentrations; lowest observed mean-daily DO concentrations occurred between Lockwood and Tracy, and were almost entirely due to loadings from the STP. Superimposed on the DO sag from ammonia loadings were large diel swings in DO caused by photosynthesis and respiration of aquatic plants, predominately periphitic algae. These 24-hour fluctuations resulted in observed August minimum DO concentrations less than the Nevada single-value standard of 5.0 mg/L in the reach from Lockwood to Derby Dam.

The water quality in the reach between Vista and Derby Dam is thus dominated by upstream loadings from the STP, the tributaries, and the upstream river Assimilation of these loadings is controlled by the effect of river flows on traveltimes and dilution of loadings and the influence of water temperatures on assimilation rates and reaeration. In this environment, changes in loadings from the STP have a significant impact on water quality during all but high spring river flows.

During low to medium river flows, diversions of a substantial portion of the river into the Truckee Canal at Derby Dam result in reduced flows, longer traveltimes, and warmer temperatures in the river below the Dam. Most upstream loadings of nonconservative substances are reduced to levels sustained by nonpoint sources between Wadsworth and Marble Bluff Dam. Although greatly reduced in concentration from levels in the river above Derby, nutrient concentrations were sufficient to sustain prolific growths of algae, resulting in large diel swings in DO equal to or exceeding those upstream of the dam. The reduced ammonia and CBOD loadings coupled with increased photosynthetic DO production resulted in mean daily DO concentrations being raised above saturation levels in much of the reach. Nightime minimum concentrations during low to medium flows, however, were driven by algal respirations to as low or lower than minima in the reach of DO sag above the Dam.

In the reach below Derby Dam at low to medium flows, nutrient concentrations are dominated by local nonpoint agricultural and ground-water returns, the magnitude of streamflow, and temperatures. Oxygen concentrations are controlled by algal growths and temperature and flow effects on reaeration rates. In this environment, changes in upstream loadings such as the discharges at the STP have minimal direct impacts on the river quality.

Processes controlling water quality in the Truckee Canal are similar to those in effect in the river; however, transport in the canal is simplified by the absence of external loadings other than the river water received at Derby Dam. During much of the irrigation season, the canal may be thought of hydrologically as being more like a series of long, narrow lakes than a stream. Heads are maintained at a fairly constant elevation, somewhat irrespective of flow, at the six check dams along the canal to serve diversion gates, resulting in five major segments that resemble deep pools rather than the pool-and-rifle environment of the river.

Concentrations of conservative substances in the canal, such as dissolved solids, are directly related to the concentrations in the river at the point of diversion at Derby Dam. In the relatively deep, low-velocity waters of the canal, assimilation of nonconservative substances is more controlled by floating (phytoplanktonic) algae and bacteria and, in the shallower unlined sections, rooted aquatic plants than by attached periphytic algae, resulting in lower assimilation and oxidation rates for CBOD and nutrients than in the river. Oxygen concentrations in the canal are controlled by the relative low reaeration rates and relatively high net photosynthetic production during summer months.

Canal dynamics can be illustrated by the simulations of the effects of removing the STP effluent from the river. The resultant lower concentrations of substances diverted into the canal at Derby Dam result in lower canal concentrations of $CBOD_u$ and nutrients and concomitant lower assimilation rates. The decrease of loadings and oxidation rates results in increased concentration of dissolved oxygen, with simulated concentrations during spring and summer conditions exceeding saturation for much of the length of the canal.

SIMULATIONS

One of the objectives for develpment of the TRWQ model was to provide a tool to assess the impacts of various planning alternatives for sewage treatment on the quality of the Truckee River below Reno and the Truckee Canal. The following section documents an application of the model to simulate water quality for four levels of treatment at the Reno-Sparks STP under each of three assumed streamflow regimes.

Simulated Planning Alternatives for Sewage Treatment

The Reno-Sparks STP was constructed in 1967 with a design capacity of 20 Mgal/d, discharging secondary effluent to the Truckee River via Steamboat Creek. During the synoptic sampling studies in 1979 and 1980, the Reno-Sparks STP was operated as a secondary treatment facility with mean daily effluent discharges in the range of 16-23 Mgal/d (25-35 ft^3/s, table 21). Effluent was characterized by moderate concentrations of dissolved solids (about 300 mg/L), relatively high ammonia-nitrogen (about 14 mg/L, 70 to 80 percent of the total-nitrogen), moderate $CBOD_u$ (24 to 39 mg/L), and relatively high phosphorus (4 to 6 mg/L total P, about 80 percent as orthophosphorus). Oxygen concentrations in the effluent were maintained to 80-90 percent of saturation.

In 1975 planning began for expansion of the STP to accommodate a discharge of 40 Mgal/d (62 ft^3/s) to meet estimated needs in the service are of the Truckee Meadows for the year 2000. The planned facility was designated as the "Master Project." However, as planning proceeded, effluent flows were already approaching and occasionally exceeding, the 20 Mgal/d design capacity of the plant. An interim expansion, designated the "Early Start" project, was completed in 1981 to increase the capacity to 30 Mgal/d (46 ft^3/s) and lower phosphorus concentrations in the effluent to less than 1 mg/L.

A number of alternatives have been considered for Master Project facilities at the Reno-Sparks STP, ranging from land disposal of effluent near Wadsworth to piping treated effluent to the Truckee Canal (Kennedy/Jenks Engineers, 1980, U.S. Environmental Protection Agency, 1984). To demonstrate applications of the TRWQ model, four scenarios were set up for alternative operations of the STP:

Alternative	Discharge (Mgal/d)	Treatment
PAWT1	30	Early Start processes (1983 conditions).
PAWT2	40	Early Start processes with increased phosphorus removal.
AWT1	40	Master Project: Nitrification and effluent filters.
AWT2	40	Master Project: Nitrification and denitrification, effluent filters, breakpoint chlorination.

The foregoing scenarios were derived after consultation with engineers from the cities of Reno and Sparks and meetings with interested local, State, and Federal Agencies. Specifications of effluent quality for each alternative is given in table 43. Advanced-treatment alternatives PAWT1 and PAWT2 reflect 1983 operations with the Early Start plant at average 1983 discharges (PAWT1) and discharge at the design capacity (PAWT2). Alternative PAWT2 also considers a 33 percent reduction of phosphorus to 0.4 mg/L total P, 0.2 mg/L orthophosphorus. Alternatives AWT1 and AWT2 reflect two alternatives under consideration for increased nitrogen removal at the full design discharge of 40 Mgal/d: nitrification of most of the nitrogen to nitrate (AWT1), and subsequent denitrification for total-nitrogen reduction (AWT2). Both advanced-treatment alternatives also provide for effluent filters to reduce CBOD concentrations ($CBOD_u$ reduced from 34 to 15 mg/L).

Table 43 near here

River Flow Regimes Selected for the Simulations

For each alternative treatment, three river flow regimes were selected for modeling: (a) average June flows (spring runoff), (b) average August flows (summer low-flow conditions), and (c) $7Q_{10}$ flows (drought conditions). Representative river flows used for each condition are listed in table 44. For the June and August flow regimes, average monthly diversions (Federal Watermaster data) were used for the agricultural diversions to estimate flow balances for the modeled stream segments as previously described in the section on model calibrations. For the $7Q_{10}$ flow regime, the Truckee Canal diversion was adjusted to leave 30 ft^3/s flowing into the river below the dam

TABLE 43.--Flow and quality specifications for modeling effects of alternative STP operations: Reno-Sparks STP effluent.

(Data from cities of Reno and Sparks, except as noted.)

STP operational alternatives	Effluent discharge		Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	$CBOD_u$[a] (mg/L)	Dissolved solids (mg/L)	Nitrogen				Phosphorus		Remarks
	(ft^3/s)	(Mgal/d)					Organic (mg/L)	Ammonia (mg/L)	Nitrite[b] (mg/L)	Nitrate (mg/L)	Total (mg/L)	Ortho (mg/L)	
Alternative secondary operations													
PAWT1:													
June	46	30	20	[c]7.5	34	360	1.2	14	.2	.6	.6	.3	1983 treatment, expansion to 30 Mgal/d
August, $7Q_{10}$	46	30	23	[d]6.0	34	360	1.1	9.6	.2	1.2	.6	.3	
PAWT2:													
June	62	40	20	[c]7.5	34	360	1.2	14	.2	.6	.4	.2	1983 treatment with reduced phosphorus, expansion to 40 Mgal/d
August, $7Q_{10}$	62	40	23	[d]6.0	34	360	1.1	9.6	.2	1.2	.4	.2	
Tertiary operations													
AWT1:													
June	62	40	20	[c]7.5	14	360	.4	.5	.1	18	.4	.2	40 Mgal/d with nitrification and effluent filters
August, $7Q_{10}$	62	40	23	[d]6.0	14	360	.4	.5	.1	18	.4	.2	
AWT2:													
June	62	40	20	[c]7.5	14	420	.4	.5	.1	4	.4	.2	40 MGD with nitrification/denitrification, effluent filters, breakpoint chlorination
August, $7Q_{10}$	62	40	23	[d]6.0	14	420	.4	.5	.1	4	.4	.2	

[a] Assumes KC_R = ~~0.70~~ 0.07 at 20°C (base e).
[b] Assumes $NO_2 - N$ = 88% ($NO_2 + NO_3$), from USGS synoptics.
[c] Assumes 96 percent saturation at outfall (1983 data).
[d] Assumes 82 percent saturation at outfall (1983 data).

diversion and return flows were estimated from those used in calibration of the August 1979 data set. Water temperatures and dissolved oxygen concentrations for the STP effluent for June and August were estimated from average 1983 monthly data from the STP; August estimates were used for the $7Q_{10}$ flow conditions.

Table 44 near here

Tributary Inputs

Modeled inputs for the Truckee River at McCarran Bridge, North Truckee Drain, and Steamboat Creek used for each of the three flow regimes are given in table 45.

Table 45 near here

Results of Simulations

The combination of four treatment alternatives and three river flow regimes resulted in 12 simulation runs for the model. Results of these runs are summarized in table 46 and shown graphically in figures 84-99. In the figures, results of simulations for three of the synoptic data sets are also shown to provide a baseline of observed river conditions in 1979 and 1980 for comparison with the simulated alternatives. Simulations of the June 1980 data set are shown with the June modeling results, August 1980 simulations with the August results, and August 1979 simulations with the $7Q_{10}$ results.

Table 46 near here

TABLE 44.—Streamflow specifications for modeling effects of alternative STP operations: Truckee River and Canal

[Flows shown are balanced for representative diversions and returns. Where different, statistical flows at gages (10-year period October 1972 through September 1982) are shown in parentheses below modeled flows.]

Site	Main streamflows: June[a] (ft³/s)	Main streamflows: August[a] (ft³/s)	Low flow $7Q_{10}$[b,c] (ft³/s)
Tributaries			
North Truckee Drain	42[d]	37[d]	13[e]
Steamboat Creek	71[d]	55[d]	16[e]
Truckee River			
Gage near Sparks (McCarran Bridge)	858[f]	314[f]	36[e]
Gage near Vista	997	438	91
Gage at Tracy	999	411 (438)	78
At Derby Dam	1,001	413	79
Truckee Canal diversions	303	218	49
Gage below Derby Dam	698	195	30 (2)
Gage near Wadsworth	732	196	21 (6)
Gage near Nixon	768	200	28 (19)
At Marble Bluff Dam (Pyramid Lake inflow)	780	195	21
Truckee Canal			
Diversion at Derby Dam	303	218	49
Gage near Wadsworth	283	203 (218)	44 (.6)
Gage near Hazen	191	96	13 (1.0)
Highway 50 (Lahontan Reservoir inflow)	192	85	10

[a] Based on average monthly agricultural diversions, observed major canal diversions for June and August 1979.

[b] For sites below Derby Dam, assumed Derby release of 30 ft³/s by Federal Watermaster, applied observed 1979 diversions and returns.

[c] For canal, assumed 13 ft³/s at Hazen gage from analysis of 1977 low-flow data.

[d] Means for available Federal Watermaster data (July 1976-September 1982).

[e] Estimated from analysis of 1977 low-flow data.

[f] Estimated, less than 10-year record of gage.

TABLE 45.--Quality specifications for modeling effects of alternative STP operations: inputs for mainstem Truckee River and tributaries

(Estimates based on historical monitoring data and USGS synoptic studies, see table 44 for flows.)

Site	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	$CBOD_u$ (mg/L)	Dissolved solids (mg/L)	Nitrogen				Phosphorus	
					Organic (mg/L)	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Total (mg/L)	Ortho (mg/L)
Truckee River at McCarran bridge										
June	14	9.4	2.3	62	0.31	0.09	0.01	0.15	0.04	0.03
August	19	9.4	2.5	84	.30	.07	.02	.01	.05	.03
$7Q_{10}$	19	9.4	2.5	84	.30	.07	.02	.01	.05	.03
North Truckee Drain at Kleppe Lane										
June	15	8.8	4.4	264	.90	.06	.01	.28	.13	.11
August	19	7.5	3.9	262	.76	.03	.01	.28	.12	.10
$7Q_{10}$	19	7.5	3.9	262	.76	.03	.01	.28	.12	.10
Steamboat Creek at Kimlick Lane										
June	15	7.8	6.6	289	1.18	.07	.01	.11	.27	.18
August	20	6.7	6.4	263	1.24	.10	.01	.15	.20	.21
$7Q_{10}$	20	6.7	6.4	263	1.24	.10	.01	.15	.20	.21

TABLE 46.--Summary of water-quality simulations for planned alternative STP operations

Water-quality indicator and location	PAWT1			PAWT2			AWT1			AWT2		
	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$
Discharge (ft^3/s)												
River												
Sparks	858	314	36	858	314	36	858	314	36	858	314	36
Vista	1,017	452	111	1,033	468	127	1,033	468	127	1,033	468	127
Tracy	1,019	425	98	1,035	441	114	1,035	441	114	1,035	441	114
Derby	1,021	427	99	1,037	443	115	1,037	443	115	1,037	443	115
Painted Rock	738	218	54	754	234	70	754	234	70	754	234	70
Wadsworth	752	210	41	768	226	57	768	226	57	768	226	57
Dead Ox	780	213	47	796	229	63	796	229	63	796	229	63
Nixon Bridge	782	207	40	798	223	56	798	223	56	798	223	56
Marble Bluff	783	208	41	799	224	57	799	224	57	799	224	57
Canal												
Hwy 95-A (Fernley)	263	185	37	263	185	37	263	185	37	263	185	37
Hwy 50 near end	181	86	11	181	86	11	181	86	11	181	86	11
Dissolved solids (mg/L)												
River												
Sparks	62	84	84	62	84	84	62	84	84	62	84	84
Vista	100	148	245	104	156	260	104	156	260	107	164	289
Tracy	109	150	251	112	157	265	112	157	265	116	165	295
Derby	109	150	252	112	157	266	112	157	266	116	165	296
Painted Rock	109	152	257	113	159	270	113	159	270	117	167	300
Wadsworth	111	155	268	114	162	278	114	162	278	118	171	310
Dead Ox	118	177	340	122	182	331	122	182	331	125	190	358
Nixon Bridge	122	190	401	125	195	376	125	195	376	129	203	402
Marble Bluff	123	194	414	126	198	386	126	198	386	130	206	412
Canal												
Hwy 95-A (Fernley)	109	150	252	112	157	266	112	157	266	116	165	296
Hwy 50 near end	109	150	252	112	157	266	112	157	266	116	165	296
$CBOD_u$ (mg/L)												
River												
Sparks	2.3	2.4	2.3	2.3	2.4	2.3	2.3	2.4	2.3	2.3	2.4	2.3
Vista	3.9	5.5	12	4.3	6.4	14	3.2	4.0	6.7	3.2	4.0	6.7
Tracy	3.6	4.8	7.6	4.0	5.5	9.0	3.0	3.6	4.7	3.0	3.6	4.7
Derby	3.6	4.6	6.7	4.0	5.2	8.0	3.0	3.5	4.2	3.0	3.5	4.2
Painted Rock	3.7	4.7	6.1	4.1	5.2	7.2	3.2	3.6	4.2	3.2	3.6	4.2
Wadsworth	4.0	5.0	5.5	4.3	5.5	6.4	3.5	4.1	4.2	3.5	4.1	4.2
Dead Ox	4.1	4.9	5.4	4.4	5.3	5.8	3.6	4.2	4.5	3.6	4.2	4.5
Nixon Bridge	4.1	4.7	5.0	4.4	5.0	5.2	3.6	4.0	4.4	3.6	4.0	4.4
Marble Bluff	4.0	4.3	4.0	4.3	4.7	4.3	3.5	3.7	3.7	3.5	3.7	3.7
Canal												
Hwy 95-A (Fernley)	3.4	4.1	5.1	3.8	4.7	6.1	2.8	3.1	3.2	2.8	3.1	3.2
Hwy 50 near end	3.0	3.4	2.3	3.4	3.8	2.7	2.5	2.6	1.4	2.5	2.6	1.4

TABLE 46.--Summary of water-quality simulations for planned alternative STP operations--Continued

Water-quality indicator and location	PAWT1			PAWT2			AWT1			AWT2		
	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$
Organic Nitrogen (mg/L)												
River												
Sparks	0.31	0.29	0.28	0.31	0.29	0.28	0.31	0.29	0.28	0.31	0.29	0.28
Vista	.42	.48	.62	.43	.50	.66	.38	.42	.40	.38	.42	.40
Tracy	.41	.46	.55	.42	.48	.57	.38	.41	.40	.38	.41	.40
Derby	.41	.46	.51	.42	.47	.54	.38	.40	.38	.38	.40	.38
Painted Rock	.43	.49	.55	.44	.50	.56	.40	.44	.42	.40	.44	.42
Wadsworth	.48	.57	.62	.49	.57	.61	.45	.52	.50	.45	.52	.50
Dead Ox	.49	.53	.47	.50	.53	.49	.46	.49	.42	.46	.49	.42
Nixon Bridge	.50	.52	.54	.51	.53	.52	.47	.48	.48	.47	.48	.48
Marble Bluff	.50	.49	.45	.50	.50	.44	.47	.46	.41	.47	.46	.41
Canal												
Hwy 95-A (Fernley)	.40	.44	.45	.41	.45	.48	.37	.38	.34	.37	.38	.34
Hwy 50 near end	.39	.40	.31	.40	.41	.33	.36	.35	.23	.36	.35	.23
Ammonia Nitrogen (mg/L)												
River												
Sparks	.09	.07	.08	.09	.07	.08	.09	.07	.08	.09	.07	.08
Vista	.70	1.0	3.8	.90	1.3	4.5	.24	.41	1.2	.12	.15	.32
Tracy	.52	.34	.18	.66	.44	.27	.18	.15	.09	.09	.07	.04
Derby	.43	.19	.05	.56	.25	.07	.15	.09	.03	.08	.04	.02
Painted Rock	.37	.11	.03	.48	.15	.03	.14	.06	.02	.07	.03	.02
Wadsworth	.31	.06	.03	.40	.08	.03	.12	.04	.02	.07	.03	.02
Dead Ox	.23	.03	.02	.29	.04	.02	.09	.03	.02	.06	.02	.02
Nixon Bridge	.18	.03	.03	.23	.03	.03	.07	.02	.02	.05	.02	.02
Marble Bluff	.16	.02	.02	.20	.02	.02	.07	.02	.02	.04	.02	.02
Canal												
Hwy 95-A (Fernley)	.30	.09	.03	.39	.12	.03	.11	.05	.02	.06	.03	.02
Hwy 50 near end	.17	.03	.02	.22	.04	.02	.07	.02	.01	.04	.02	.01
Nitrite Nitrogen												
River												
Sparks	.01	.01	.02	.01	.01	.02	.01	.01	.02	.01	.01	.02
Vista	.02	.04	.15	.03	.05	.17	.02	.02	.05	.12	.01	.02
Tracy	.14	.28	.27	.18	.36	.39	.05	.12	.12	.09	.05	.04
Derby	.19	.24	.09	.24	.30	.14	.07	.10	.05	.08	.05	.02
Painted Rock	.20	.17	.03	.26	.22	.05	.08	.08	.02	.07	.04	.02
Wadsworth	.21	.10	.03	.27	.13	.03	.08	.06	.02	.07	.04	.02
Dead Ox	.21	.04	.02	.26	.05	.02	.08	.03	.02	.06	.02	.02
Nixon Bridge	.19	.03	.03	.24	.02	.02	.08	.02	.02	.05	.02	.02
Marble Bluff	.18	.02	.02	.23	.02	.02	.07	.02	.02	.04	.02	.02
Canal												
Hwy 95-A (Fernley)	.26	.20	.05	.33	.26	.03	.09	.09	.03	.05	.05	.02
Hwy 50 near end	.27	.10	.03	.35	.12	.02	.10	.05	.02	.06	.03	.02

TABLE 46.--Summary of water-quality simulations for planned alternative STP operations--Continued

Water-quality indicator and location	PAWT1			PAWT2			AWT1			AWT2		
	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$
Nitrate Nitrogen (mg/L)												
River												
Sparks	0.15	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00
Vista	.18	.19	.74	.18	.23	.84	1.2	2.4	8.5	.38	.58	2.0
Tracy	.26	.60	3.0	.27	.72	3.5	1.2	2.2	6.1	.42	.56	1.5
Derby	.28	.71	2.4	.31	.88	2.9	1.2	2.0	4.6	.41	.53	1.1
Painted Rock	.29	.54	.44	.32	.68	.75	1.0	1.2	1.1	.37	.35	.29
Wadsworth	.31	.35	.07	.32	.45	.12	.89	.64	.13	.33	.21	.07
Dead Ox	.31	.20	.05	.35	.25	.06	.72	.28	.06	.29	.13	.05
Nixon Bridge	.31	.10	.08	.36	.12	.07	.60	.12	.07	.25	.07	.07
Marble Bluff	.31	.06	.03	.36	.07	.03	.54	.06	.03	.23	.05	.03
Canal												
Hwy 95-A (Fernley)	.33	.76	1.8	.38	.94	2.2	1.1	1.8	3.3	.40	.49	.81
Hwy 50 near end	.42	.74	.68	.50	.92	.83	1.0	1.4	1.2	.38	.41	.33
Total Nitrogen (mg/L)												
River												
Sparks	.56	.38	.38	.56	.38	.38	.56	.38	.38	.56	.38	.38
Vista	1.3	1.8	5.4	1.5	2.1	6.2	1.8	3.2	10.	.90	1.2	2.7
Tracy	1.3	1.7	4.0	1.5	2.0	4.7	1.8	2.8	6.7	.92	1.1	2.0
Derby	1.3	1.6	3.0	1.5	1.9	3.7	1.8	2.6	5.0	.90	1.0	1.6
Painted Rock	1.3	1.3	1.0	1.5	1.6	1.4	1.6	1.8	1.5	.89	.87	.75
Wadsworth	1.3	1.1	.75	1.5	1.2	.78	1.5	1.3	.68	.89	.80	.62
Dead Ox	1.2	.81	.56	1.4	.88	.59	1.4	.82	.51	.86	.67	.51
Nixon Bridge	1.2	.67	.68	1.3	.71	.64	1.2	.65	.59	.82	.60	.59
Marble Bluff	1.1	.59	.52	1.3	.61	.52	1.2	.56	.47	.79	.54	.47
Canal												
Hwy 95-A (Fernley)	1.3	1.5	2.3	1.5	.94	2.8	1.1	2.3	3.7	.88	.95	1.2
Hwy 50 near end	1.2	1.3	1.0	1.5	.92	1.2	1.0	1.8	1.4	.84	.81	.60
Un-ionized Ammonia (mg/L)												
River												
Sparks	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Vista	.01	.04	.10	.01	.05	.12	.00	.01	.01	.00	.01	.01
Tracy	.00	.01	.01	.00	.01	.01	.00	.00	.00	.00	.00	.00
Derby	.00	.02	.00	.00	.02	.00	.00	.01	.00	.00	.00	.00
Painted Rock	.00	.02	.00	.00	.02	.00	.00	.01	.00	.00	.00	.00
Wadsworth	.00	.01	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00
Dead Ox	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Nixon Bridge	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Marble Bluff	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Canal												
Hwy 95-A (Fernley)	.00	.01	.00	.01	.01	.00	.00	.00	.00	.00	.00	.00
Hwy 50 near end	.01	.01	.00	.01	.01	.01	.00	.01	.00	.00	.01	.00

TABLE 46.--Summary of water-quality simulations for planned alternative STP operations--Continued

Water-quality indicator and location	PAWT1			PAWT2			AWT1			AWT2		
	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$
Orthophosphorus (mg/L)												
River												
Sparks	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Vista	.06	.08	.17	.05	.08	.14	.05	.08	.14	.05	.08	.14
Tracy	.11	.20	.54	.11	.19	.47	.11	.19	.47	.11	.19	.47
Derby	.11	.19	.45	.11	.18	.40	.11	.18	.40	.11	.18	.40
Painted Rock	.12	.19	.37	.12	.18	.35	.12	.18	.35	.12	.18	.35
Wadsworth	.14	.21	.29	.14	.20	.28	.14	.20	.28	.14	.20	.28
Dead Ox	.15	.19	.17	.14	.18	.19	.14	.18	.19	.14	.18	.19
Nixon Bridge	.15	.17	.17	.15	.17	.17	.15	.17	.17	.15	.17	.17
Marble Bluff	.15	.15	.11	.14	.15	.12	.14	.15	.12	.14	.15	.12
Canal												
Hwy 95-A (Fernley)	.11	.17	.36	.11	.16	.32	.11	.16	.32	.11	.16	.32
Hwy 50 near end	.10	.14	.17	.10	.13	.15	.10	.13	.15	.10	.13	.15
Total phosphorus (mg/L)												
River												
Sparks	.04	.05	.05	.04	.05	.05	.04	.05	.05	.04	.05	.05
Vista	.08	.12	.29	.08	.12	.24	.08	.12	.24	.08	.12	.24
Tracy	.13	.24	.63	.13	.23	.55	.13	.23	.55	.13	.23	.55
Derby	.13	.23	.52	.13	.21	.47	.13	.21	.47	.13	.21	.47
Painted Rock	.14	.23	.43	.15	.22	.40	.15	.22	.40	.15	.22	.40
Wadsworth	.16	.26	.34	.17	.25	.33	.17	.25	.33	.17	.25	.33
Dead Ox	.17	.22	.20	.18	.22	.22	.18	.22	.22	.18	.22	.22
Nixon Bridge	.18	.20	.20	.18	.20	.20	.18	.20	.20	.18	.20	.20
Marble Bluff	.17	.18	.13	.18	.17	.14	.18	.17	.14	.18	.17	.14
Canal												
Hwy 95-A (Fernley)	.12	.21	.41	.12	.19	.37	.12	.19	.37	.12	.19	.37
Hwy 50 near end	.12	.17	.20	.12	.16	.18	.12	.16	.18	.12	.16	.18
Inorganic N/P ratio (moles/mole)												
River												
Sparks	19	7	8	19	7	8	19	7	8	19	7	8
Vista	36	34	63	46	46	90	61	81	160	21	21	37
Tracy	18	14	14	23	18	19	29	28	29	11	8	7
Derby	18	14	12	23	18	17	29	27	26	11	8	6
Painted Rock	16	9	3	20	13	5	23	17	7	9	5	2
Wadsworth	13	5	1	16	7	1	18	8	1	7	3	1
Dead Ox	11	3	1	14	4	1	14	4	1	6	2	1
Nixon Bridge	10	2	2	13	2	2	11	2	2	5	2	2
Marble Bluff	10	2	1	12	2	1	11	2	1	5	1	1
Canal												
Hwy 95-A (Fernley)	19	14	12	23	18	16	28	26	23	11	8	6
Hwy 50 near end	19	14	10	24	18	13	27	25	17	11	8	5

TABLE 46.--Summary of water-quality simulations for planned alternative STP operations--Continued

Water-quality indicator and location	PAWT1			PAWT2			AWT1			AWT2		
	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$
Daily Mean Dissolved Oxygen (mg/L)												
River												
Sparks	9.4	8.9	7.9	9.4	8.9	7.9	9.4	8.9	7.9	9.4	8.9	7.9
Vista	9.2	7.9	5.4	9.1	7.8	5.2	9.1	7.9	6.4	9.1	8.0	6.6
Tracy	9.3	7.0	5.6	9.1	6.8	5.1	9.4	7.4	6.8	9.5	7.5	7.2
Derby	9.2	7.0	6.4	9.0	6.8	6.0	9.4	7.4	7.1	9.5	7.6	7.3
Painted Rock	9.4	7.5	7.3	9.2	7.4	7.2	9.4	7.6	7.4	9.4	7.6	7.4
Wadsworth	9.3	7.3	7.3	9.2	7.3	7.2	9.4	7.4	7.4	9.4	7.4	7.4
Dead Ox	9.3	7.6	7.4	9.2	7.6	7.4	9.4	7.6	7.4	9.4	7.6	7.4
Nixon Bridge	9.3	7.7	7.2	9.2	7.6	7.2	9.4	7.7	7.2	9.4	7.7	7.2
Marble Bluff	9.3	7.6	7.3	9.2	7.6	7.3	9.4	7.7	7.4	9.4	7.7	7.4
Canal												
Hwy 95-A (Fernley)	8.5	7.8	8.8	8.2	7.5	8.2	9.0	8.4	9.9	9.2	8.6	10
Hwy 50 near end	8.2	9.6	17	7.7	9.1	16	8.9	10	19	9.1	11	19
Daily Mean Percent Saturation (percent)												
River												
Sparks	99	108	100	99	108	100	99	111	100	99	111	100
Vista	97	102	72	96	101	68	97	103	84	97	103	87
Tracy	99	92	75	97	89	68	100	97	92	101	99	97
Derby	97	92	86	95	90	81	100	97	96	100	99	98
Painted Rock	99	99	99	98	98	98	100	100	100	100	100	101
Wadsworth	100	99	98	98	98	98	100	100	100	100	100	100
Dead Ox	100	100	104	98	100	103	101	100	104	101	101	104
Nixon Bridge	100	101	100	99	101	100	101	101	101	101	101	101
Marble Bluff	100	100	99	99	100	98	101	101	100	101	101	100
Canal												
Hwy 95-A (Fernley)	98	106	121	94	102	112	103	115	136	105	118	138
Hwy 50 near end	96	132	232	91	126	218	105	143	257	108	147	260

TABLE 46.--Summary of water-quality simulations for planned alternative STP operations--Continued

Water-quality indicator and location	PAWT1			PAWT2			AWT1			AWT2		
	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$
Daily Minimum Dissolved Oxygen (mg/L)												
River												
Sparks	9.2	6.8	6.4	9.2	6.8	6.4	9.2	6.8	6.4	9.2	6.8	6.4
Vista	8.7	6.3	3.6	8.6	6.2	.5	8.7	6.3	4.6	8.7	6.4	4.9
Tracy	7.9	5.3	1.9	8.2	5.1	1.7	8.1	5.7	3.4	8.3	5.8	3.8
Derby	7.8	5.5	3.0	7.8	5.3	2.9	8.0	5.9	4.0	8.3	6.0	4.2
Painted Rock	8.8	6.9	5.8	8.7	6.9	6.0	8.8	7.0	6.1	9.0	7.0	6.1
Wadsworth	8.7	6.5	4.1	8.6	6.5	4.8	8.8	6.6	5.0	9.0	6.6	5.0
Dead Ox	8.4	6.6	4.7	8.1	6.6	5.2	8.5	6.7	5.3	8.6	6.6	5.3
Nixon Bridge	8.8	7.1	5.5	8.7	7.1	5.9	8.9	7.1	5.9	9.0	7.1	5.9
Marble Bluff	8.8	6.7	4.8	8.4	6.7	5.3	8.9	6.8	5.4	9.0	6.7	5.4
Canal												
Hwy 95-A (Fernley)	7.3	5.2	2.8	7.1	4.9	2.3	7.8	5.8	4.0	8.1	5.9	4.2
Hwy 50 near end	6.7	4.6	1.0	6.4	4.2	.2	7.5	5.4	3.0	7.9	5.6	3.1
Daily Minimum Percent Saturation (percent)												
River												
Sparks	105	86	81	105	86	81	105	86	81	105	86	81
Vista	91	81	47	92	80	46	93	82	61	93	83	65
Tracy	84	70	25	87	68	23	86	76	46	89	77	51
Derby	82	72	41	82	70	40	84	77	54	88	79	56
Painted Rock	93	91	79	92	91	81	94	92	84	95	93	84
Wadsworth	93	87	55	92	87	65	94	89	67	95	89	67
Dead Ox	90	86	66	87	87	72	91	88	73	93	87	73
Nixon Bridge	95	93	76	94	93	82	96	94	83	97	93	83
Marble Bluff	95	88	65	91	88	71	96	89	73	97	89	73
Canal												
Hwy 95-A (Fernley)	83	71	38	82	67	32	89	80	55	93	81	58
Hwy 50 near end	80	64	14	76	58	3	89	75	41	94	78	43

Streamflows

Modeled riverflows for the three flow regimes ranged from 98 to 1,037 ft^3/s in the river between Vista and Derby Dam, from 36 to 799 ft^3/s between Derby Dam and Marble Bluff Dam, and from 11 to 263 ft^3/s in the Truckee Canal (table 22, figure 84). In comparison, the observed June 1980 flows were about 1,000 ft^3/s greater than the simulated average June flows. The observed August 1980 flows were about 150 ft^3/s greater than the simulated average August flows throughout most of the river. The observed August 1979 flows in the river were also about 150 ft^3/s greater than the simulated $7Q_{10}$ flows above Derby Dam, however, below the dam the simulated low flows were slightly below those observed in August 1979. Modeled $7Q_{10}$ flows in the Canal were about the same as observed in the August 1979 data set for the upper end, and about a third of the observed flows in the lower end.

Figure 84 near here

In comparing simulations between flow regimes, the effects of flow on concentration should be noted; increased flows tend to reduce concentrations in the river due to dilution, and, at the same time for nonconservatives, reduce the assimilation effects (resulting in higher concentrations) due to shorter traveltimes. In addition to these effects of differing flows for the three flow regimes, the lower water temperatures for the June simulations will reduce the effective oxidation and assimilation rates, resulting in less assimilation compared to the warmer temperatures for the August and $7Q_{10}$ simulations.

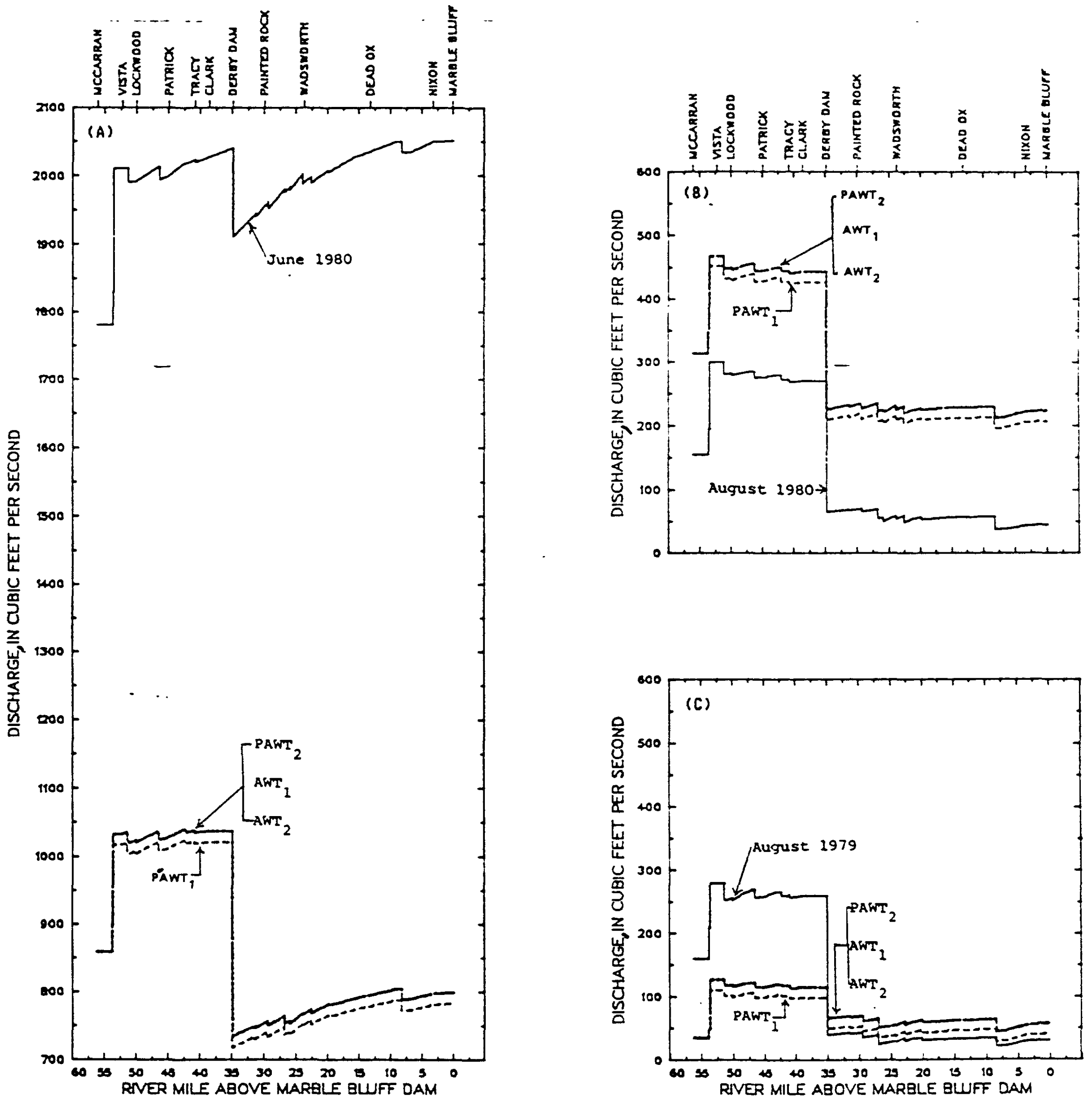


FIGURE 84.--Simulations of streamflow for alternative operations at the Reno Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Flows in the Truckee River vary markedly for the three flow regimes modeled.

Traveltimes

Simulated traveltimes in the river for the modeled alternatives are shown in figure 85. Notable is the relatively greater effect of changes in discharge on resultant traveltimes for low flows in comparison to the higher flows. The about 1,000-ft^3/s difference in discharge between the observed June 1980 flow regime and the simulated average June conditions result in about a 12-hour difference in traveltime between McCarran Bridge and Marble Bluff Dam, whereas a difference of about 140 ft^3/s between the observed August 1980 and simulated average August flows results in a traveltime difference of about 4 days for the same reach.

Figure 85 near here

Dissolved Solids

Estimated concentrations of dissolved solids in the STP effluent are the same for alternatives PAWT1, PAWT2, and AWT1 (360 mg/L) and increase for the denitrification alternative (AWT2) (420 mg/L; Bill Vann, City of Reno, written communication, 1984). With the differing effluent discharges taken into account, the results of simulations for PAWT2 and AWT1 on dissolved solids in the river are identical and intermediate between PAWT1 and AWT2 (figure 86). For the $7Q_{10}$ low-flow simulations, alternatives PAWT2 and AWT1 at 40 Mgal/d effluent discharge slightly exceed single-value Nevada water-quality standards for dissolved solids in the reach from Steamboat Creek to Derby Dam. The increased dissolved solids in the proposed denitrification alternative (AWT2) result in standards being significantly exceeded above Derby Dam for the $7Q_{10}$ flows.

Figure 86 near here

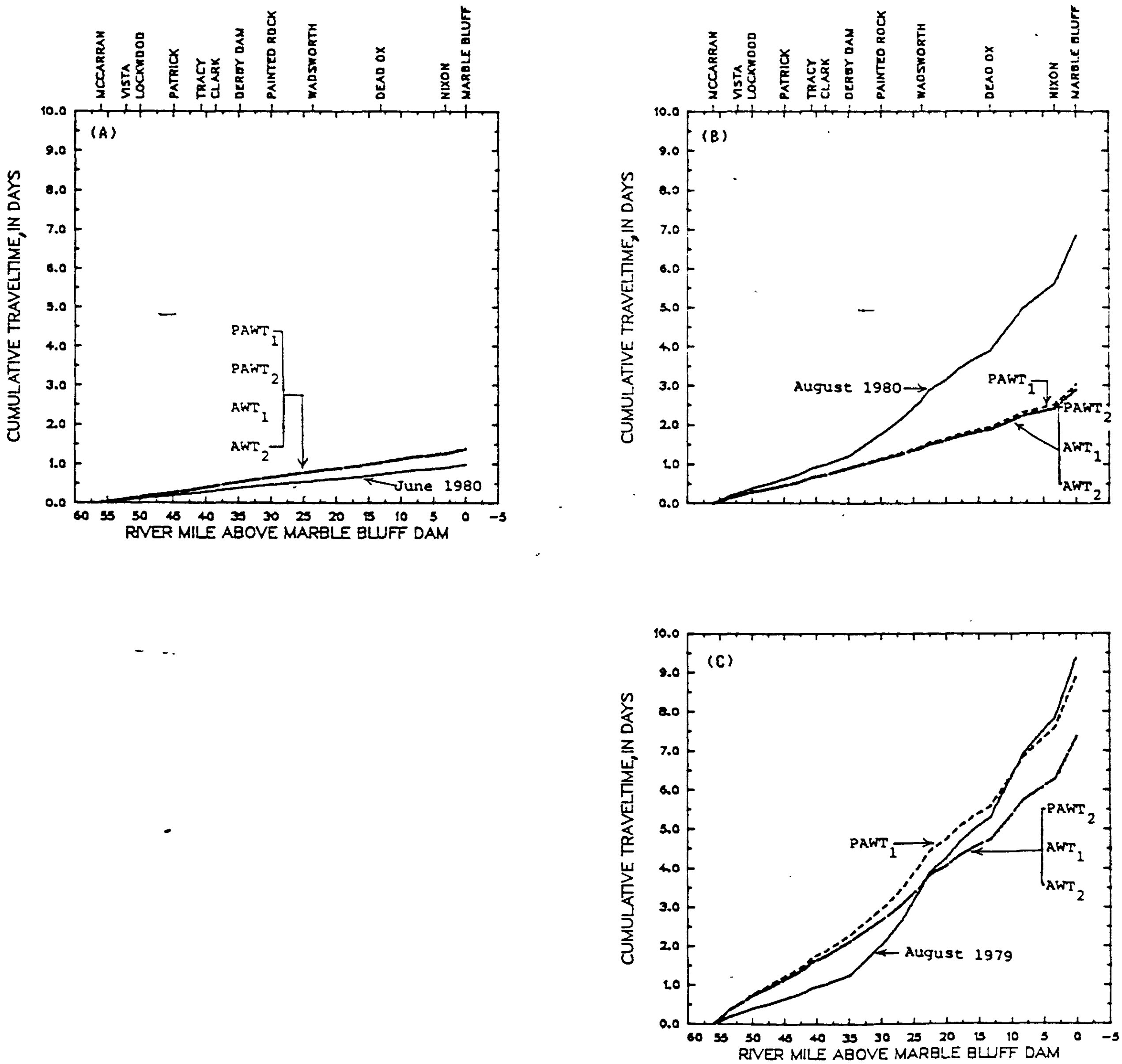


FIGURE 85.--Simulations of traveltime for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Traveltimes in the Truckee River vary consideraby for the three flow regimes modeled. Lower observed flows in the river below Derby Dam in August 1980 result significantly longer traveltime to Marble Bluff Dam in comparison to the four modeled alternatives.

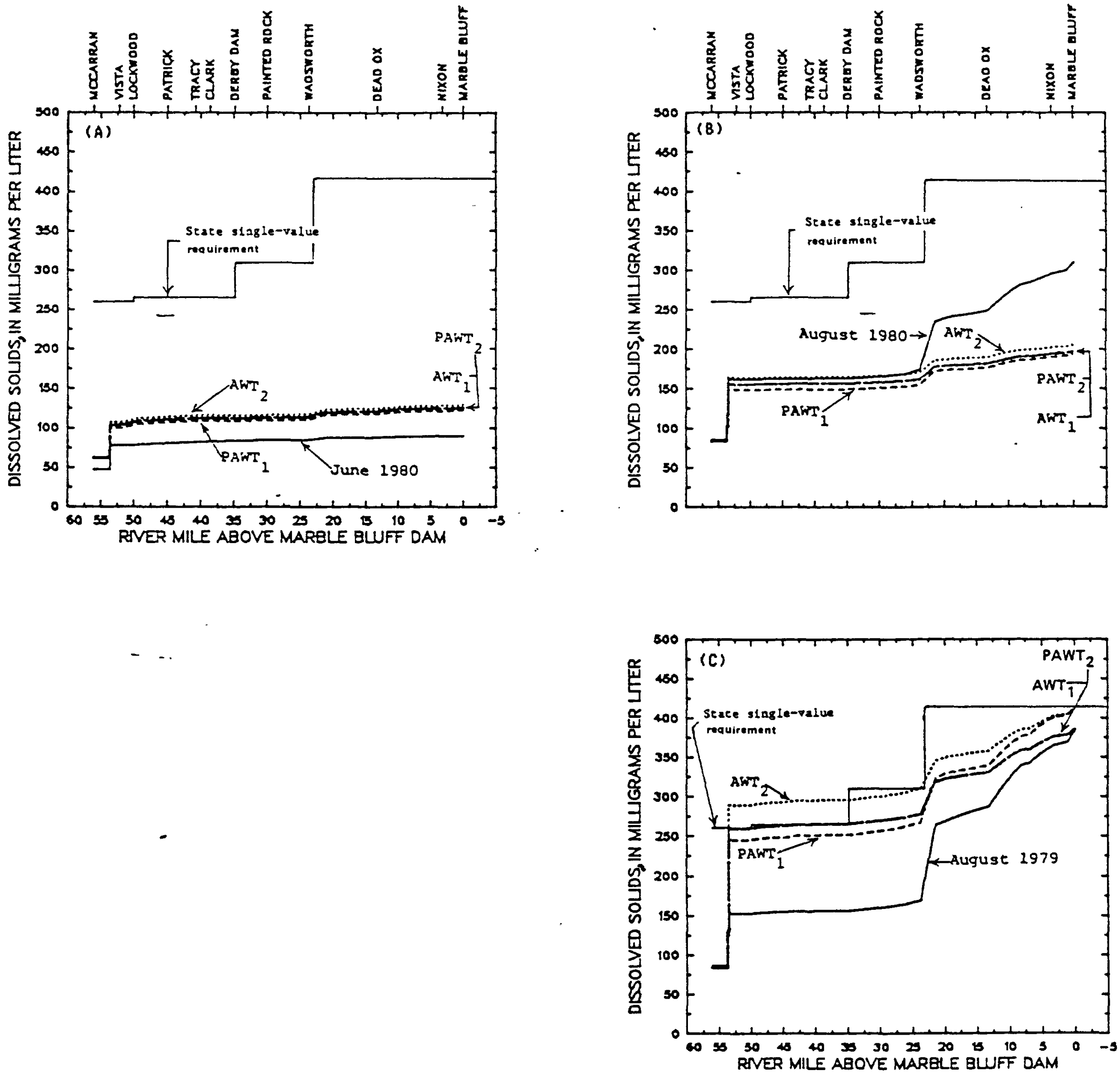


FIGURE 86.--Simulations of dissolved solids for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: The denitrification option (AWT2) is projected to significantly increase concentrations in the Truckee River at low flows (C).

$CBOD_u$

Proposed 60 percent reductions of $CBOD_u$ in STP effluent for the two advanced treatment operations at 40 Mgal/d result in a 47 percent reduction in river concentrations of $CBOD_u$ at Derby Dam for the $7Q_{10}$ simulations and a 25 percent reduction for the June simulations in comparison to the PAWT2 simulations at 40 Mgal/d effluent discharge. The reduction in $CBOD_u$ for the advanced treatment operations is significant above Wadsworth for the $7Q_{10}$ flows (figure 87C). However, as pointed out in the section on sensitivity testing, variations in concentrations of $CBOD_u$ in the river have little effect on DO compared to other factors in the Truckee River or the Truckee Canal.

Figure 87 near here

Phosphorus

Tabulated results for simulations of ortho- and total phosphorus (table 46) include the "dummy" nonpoint loadings to the river in the reach from Lockwood to Patrick as explained in the section on model calibration. Under these assumptions, the Nevada annual-average water-quality standard for orthophosphorus of 0.05 mg/L is exceeded below Steamboat Creek for all alternatives and flow regimes (figures 88 and 89). Standards for orthophosphorus also are exceeded for all simulations with no assumptions made as to added nonpoint loadings (figure 90). Reductions in river concentrations of phosphorus for the reduced loadings from the STP under the post-1981 Early Start operations are significant for the August and $7Q_{10}$ flow regimes; however, additional reductions in phosphorus concentrations in the STP effluent for the PAWT2 and AWT alternatives have little impact on river concentrations for any of the simulations. The effects on phosphorus concentrations in the canal are similar; a 33 percent reduction in total

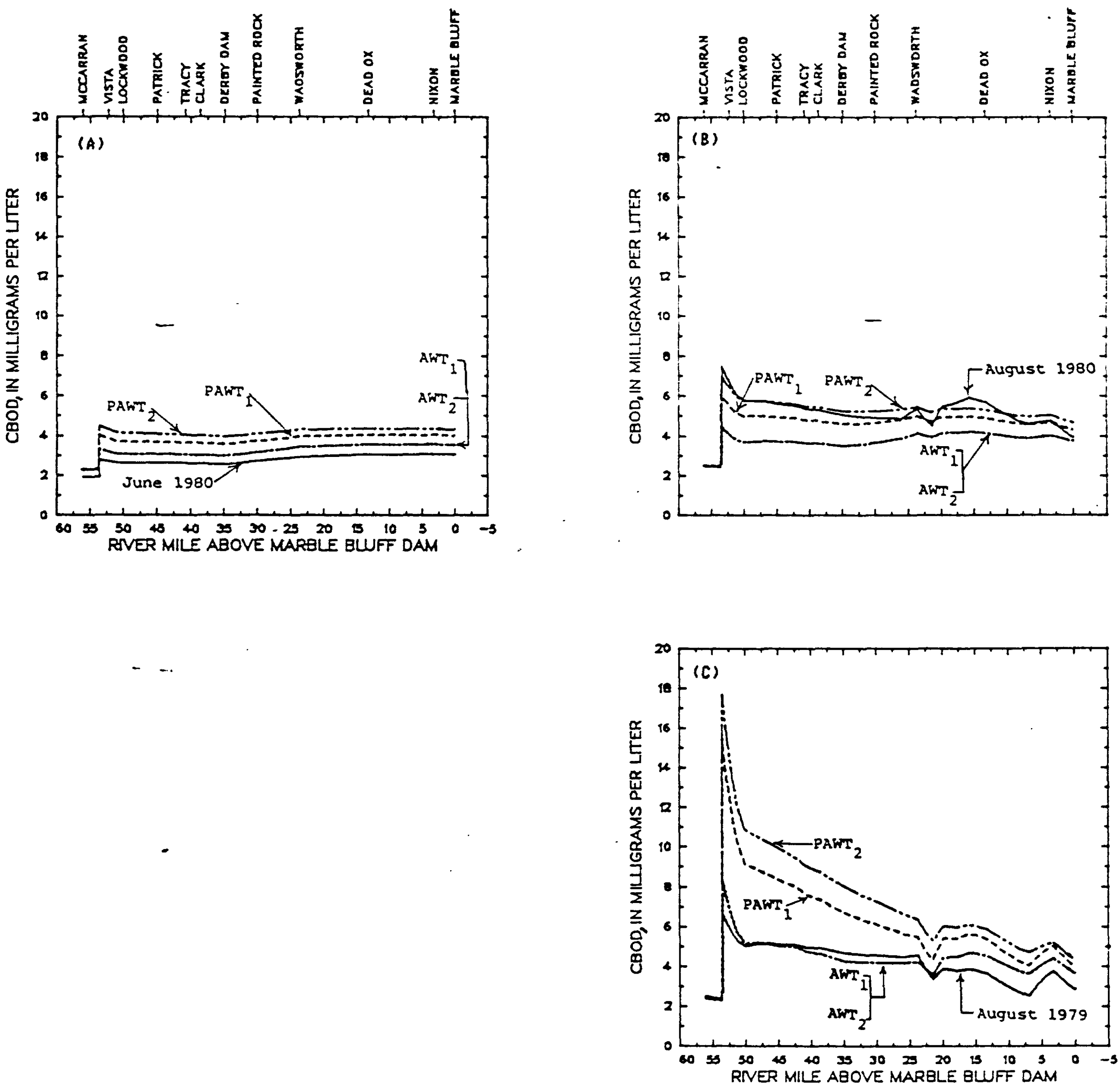


FIGURE 87.--Simulations of CBOD for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Reduction in CBODu loadings from the STP for the two advanced-treatment alternatives would significantly reduce river concentrations at low flows (B, C).

phosphorus in the STP effluent (0.6 to 0.4 mg/L) results in only a 10 percent reduction (0.20 to 0.18 mg/L) in projected concentrations in the canal at Highway 50 above Lahontan Reservoir for the worst-case $7Q_{10}$ flow conditions (table 46).

Figures 88-90 near here

Organic-Nitrogen

The advanced treatment alternatives include a 60 to 70 percent reduction in organic-nitrogen in the STP effluent due to the nitrification of organic-nitrogen to nitrate in the proposed STP processes. At an effluent discharge of 40 Mgal/d, this would result in 30, 15, and 10 percent reductions in instream concentrations of organic-nitrogen at Derby Dam for the $7Q_{10}$, August, and June flow conditions. As with $CBOD_u$, however, sensitivity testing of the model indicates that these reductions in organic-nitrogen would have little effect on concentrations of DO in the river (figure 91) or the canal.

91

Figure [redacted] near here

Ammonia-Nitrogen

Increased effluent discharge rates for the current-treatment alternatives PAWT1 and PAWT2 result in increased river concentrations of ammonia-nitrogen as compared to the observed 1979 and 1980 conditions (figure 92). The nitrogen-control alternatives AWT1 and AWT2 result in significant reductions in ammonia concentrations over observed conditions above Derby Dam; below Derby Dam the effects are minimal. Even with denitrification (AWT2), ammonia concentrations from Steamboat Creek to Lockwood are projected to exceed the water-quality standard of 1.2 mg/L for total-nitrogen at extreme low flows. Increased instream concentrations of ammonia result in higher nitrogenous oxygen demands and lower concentrations for both mean daily and minimum daily

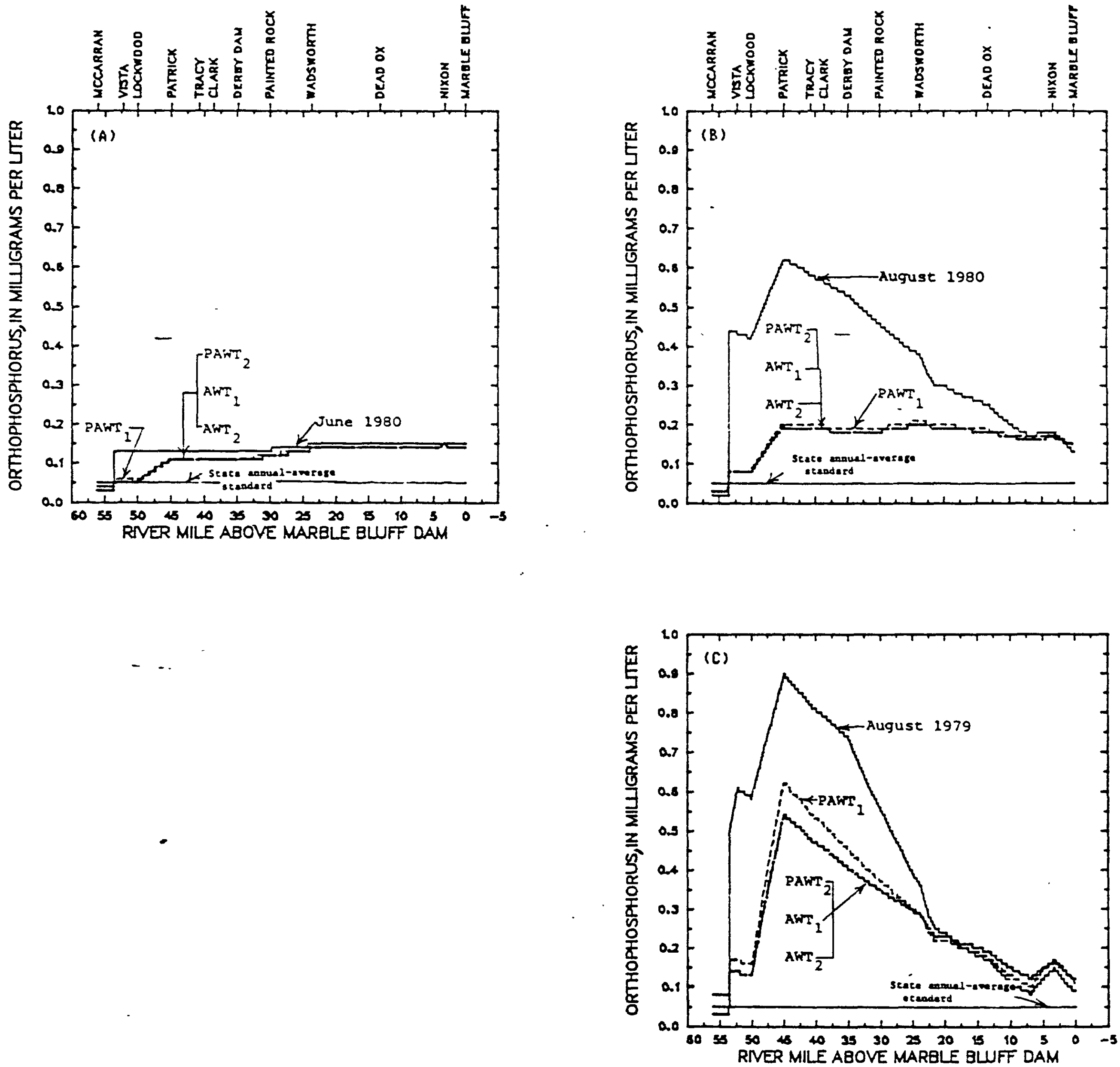


FIGURE 88.--Simulations of orthophosphorus for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$(C) regimes of river flow: Concentrations would be substantially reduced for the four alternatives over observed conditions in 1979 and 1980; however, nonpoint sources of phosphorus are projected to exceed Nevada water-quality standards even with increased removal of phosphorus in the STP effluent.

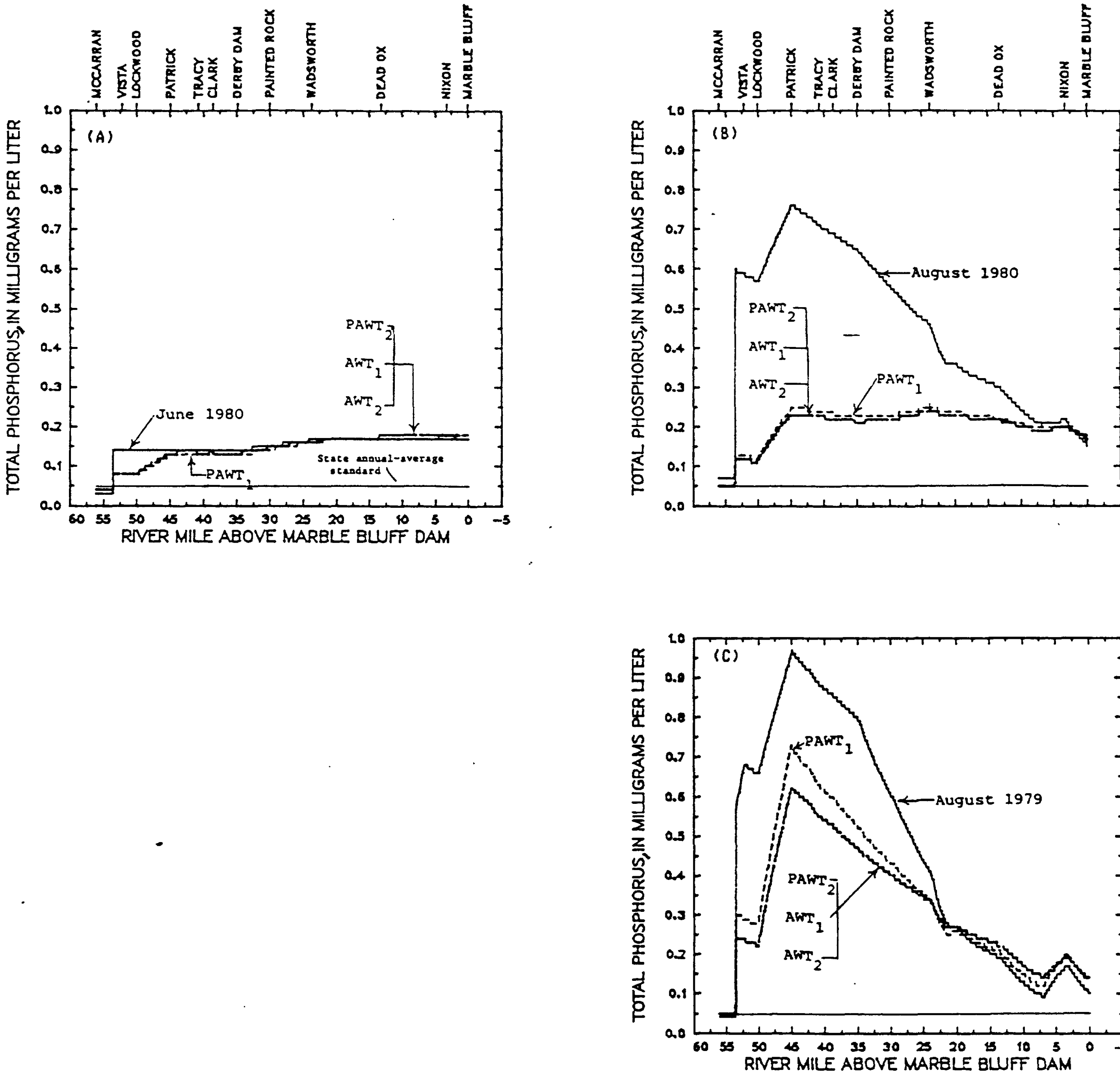


FIGURE 89.--Simulations of total phosphorus for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Concentrations would be substantially reduced for the four alternatives over observed conditions in 1979 and 1980.

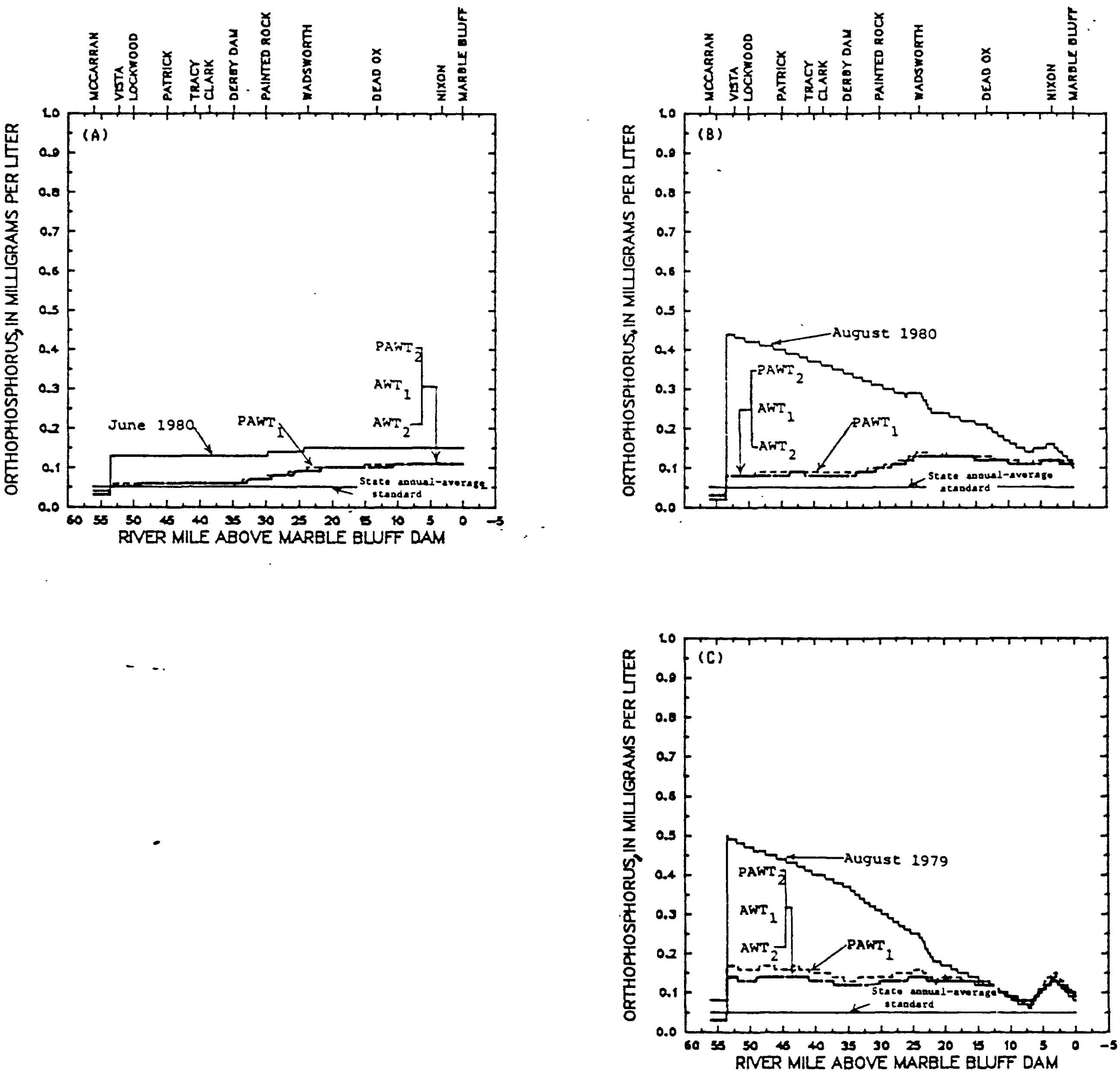


FIGURE 90.--Simulations of orthophosphorus for alternative operations at the Reno-Sparks STP for average June (A), August (B), and 7Q10 (C) regimes of river flow: Concentrations are projected to exceed water-quality standards even with removal of modeled "dummy" nonpoint sources of phosphorus between Vista and Patrick.

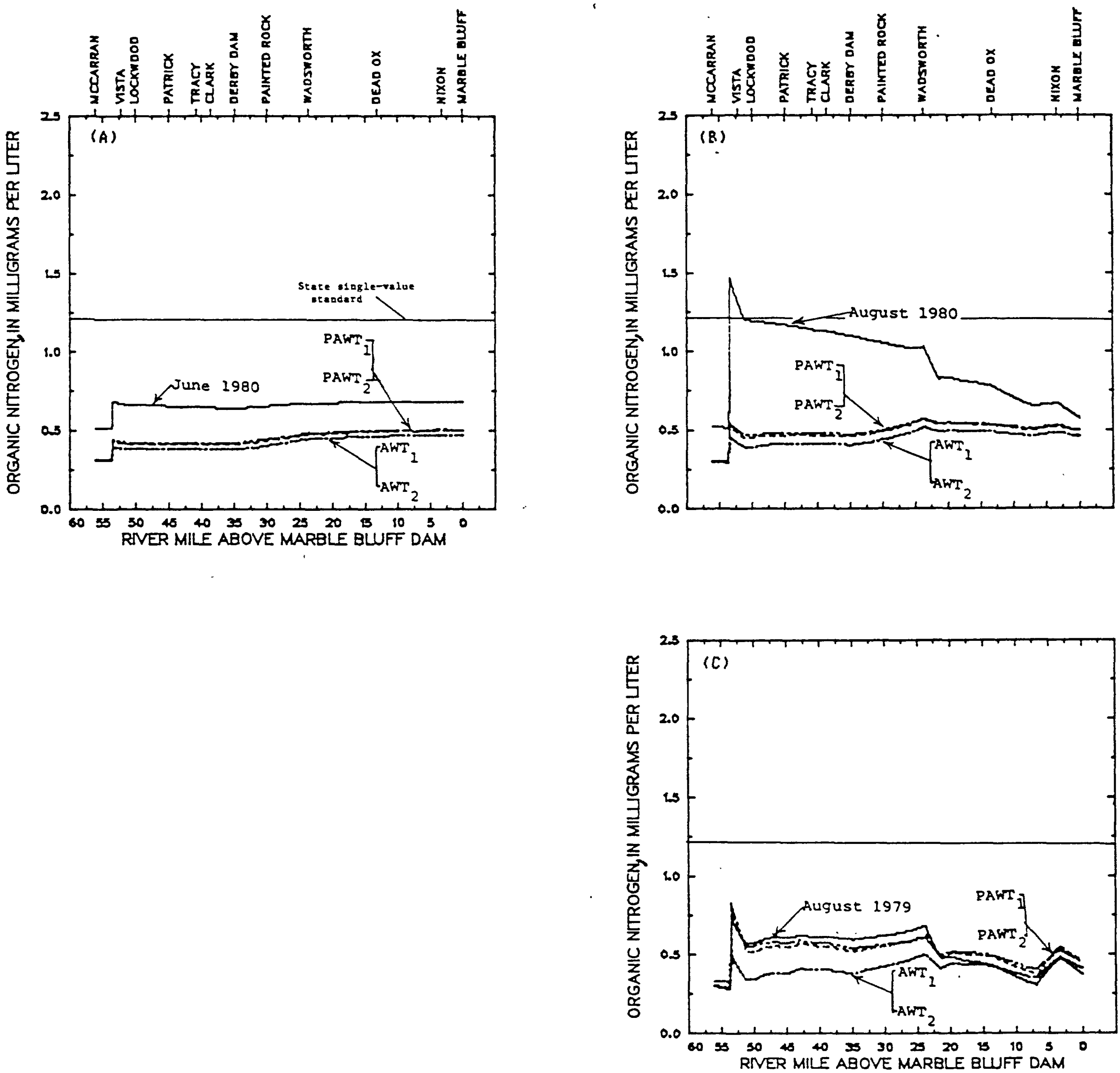


FIGURE 91.--Simulations of organic nitrogen for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$(C) regimes of river flow: With the proposed alternatives, concentrations are projected to be significantly reduced over conditions observed in 1979 and 1980. Advanced treatment alternatives (AWT1, 2) provide significant reductions in concentrations only at low flows (C).

dissolved oxygen (figures 98 and 99). Conversely, the greatly lowered concentrations of ammonia in the effluent for the advanced-treatment alternatives results in higher instream oxygen concentrations. For the June flow regimes (relatively high flows, short traveltimes, reduced assimilation compared to the August and $7Q_{10}$ flows), simulations for the advanced-treatment alternatives made a significant impact on concentrations of ammonia in the lower canal, with reductions compared to the PAWT2 concentrations of 68 percent for nitrification (AWT1) and 82 percent for denitrification (AWT2).

Figure 92 near here

Un-ionized Ammonia

Ammonia concentrations are of concern due to potential toxicity to fish of un-ionized ammonia. Simulated mean daily concentrations of un-ionized ammonia are below the Nevada single-value standard of 0.02 mg/L for the June simulations. For the August conditions, reductions in effluent ammonia loadings for the AWT alternatives result in standards being met throughout the river. During the $7Q_{10}$ flows, however, standards are exceeded between Steamboat Creek and Lockwood even for the nitrification alternative (AWT1). As shown in the synoptic monitoring data, diel swings in pH and temperature at low flows are likey to result in instantaneous un-ionized ammonia concentrations exceeding 0.02 mg/L even when total ammonia concentrations are near background (figure 93).

Figure 93 near here

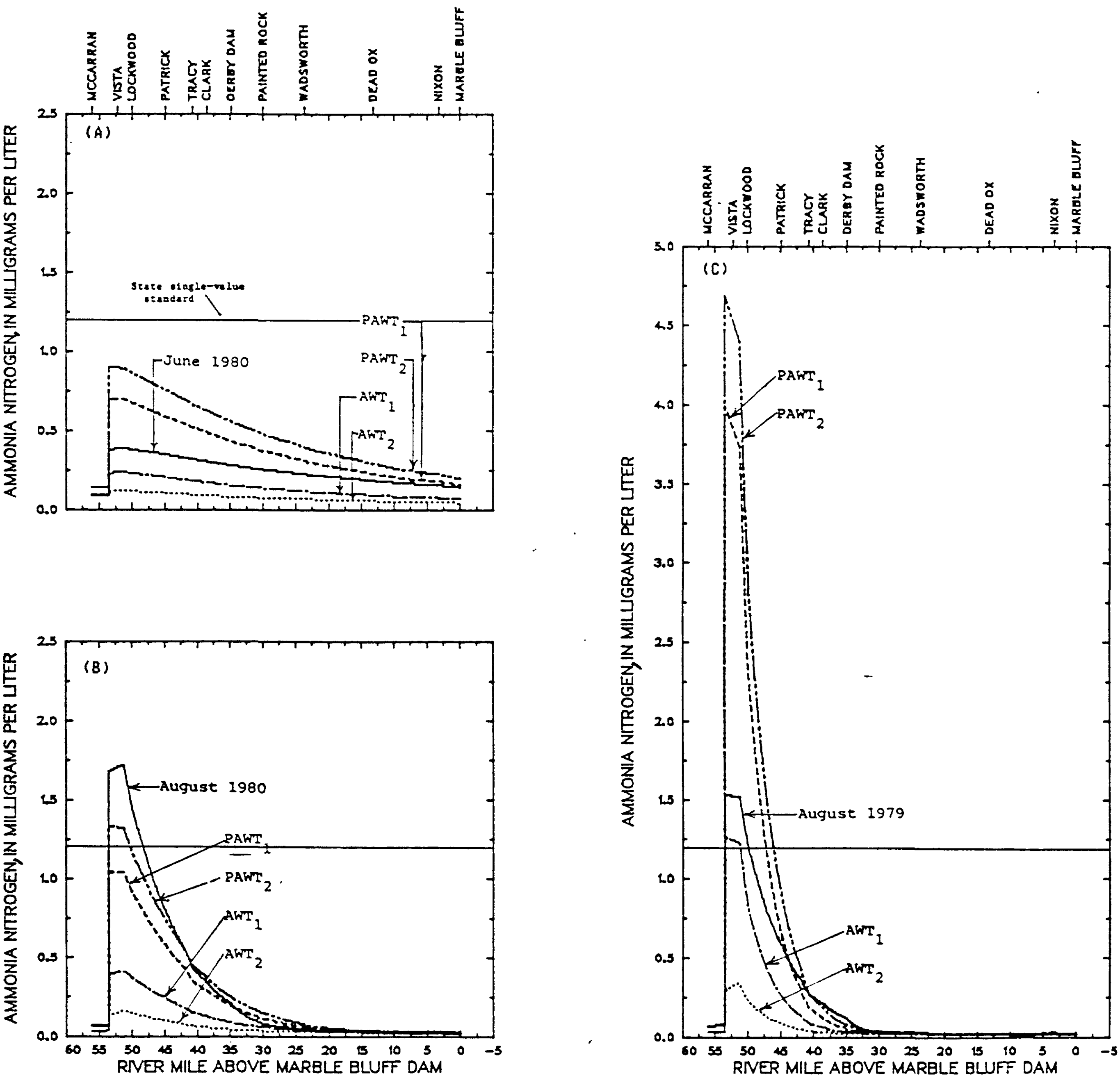


FIGURE 92.--Simulations of ammonia nitrogen for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Advanced-treatment alternatives (AWT1, 2) result in significant reductions in concentrations above Derby Dam for all three flow regimes.

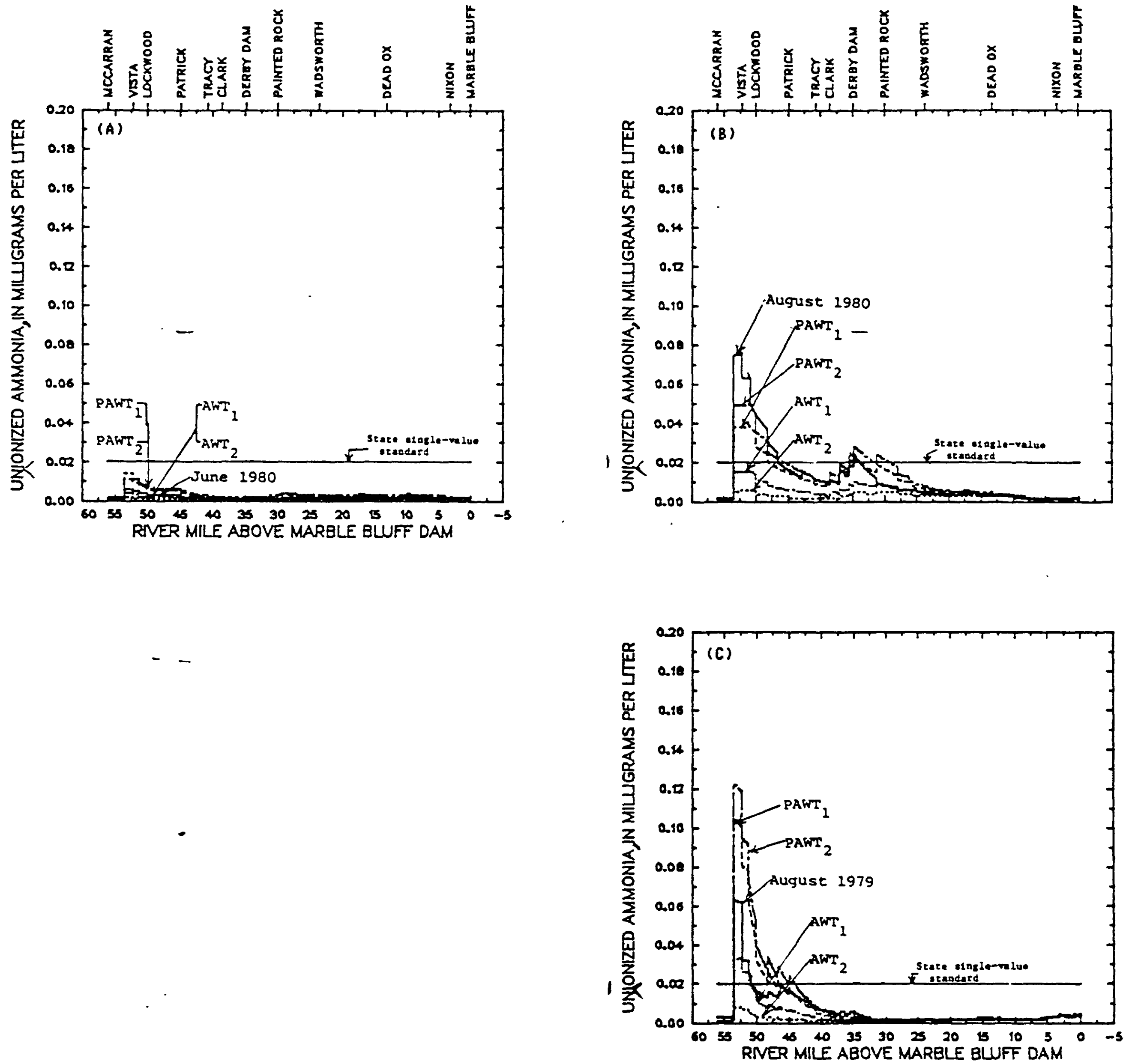


FIGURE 93.--Simulations of un-ionized ammonia for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Concentrations in the river are significantly reduced for the two advanced-treatment alternatives (AWT1, 2).

Nitrite-Nitrogen

The trends in concentrations of nitrite-nitrogen for the four alternatives are similar to those for ammonia; the proposed reductions in ammonia in the STP effluent for alternatives AWT1 and AWT2 result in greatly reduced instream concentrations of nitrite-nitrogen (figure 94). Sensitivity analysis indicates, however, that the changes in nitrite concentrations will have less impact on dissolved oxygen than the changes in ammonia concentration. Nevada single-value water-quality standards for nitrite (based on toxicity concerns for aquatic life) are 0.04 mg/L for the entire reach of the river, and are exceeded above Derby Dam for all simulations.

Figure 94 near here

Nitrate-Nitrogen

The nitrification alternative (AWT1) results in most of the nitrogen load from the STP going into the river as nitrate and has a significant impact on simulated instream nitrate concentrations (figure 95). Simulated nitrate concentrations between Steamboat Creek and Derby Dam exceed the 1.2 mg/L single-value water-quality standard (total nitrogen) for the August and $7Q_{10}$ flow regimes for the nitrification alternative. The standard is also exceeded during the $7Q_{10}$ low flows from Lockwood to Derby Dam at the 30 and 40 Mgal/d effluent discharges for secondary operations (PAWT1 and PAWT2) due to instream nitrification of the effluent ammonia. The effects of the various alternatives have decreasing impacts on simulated instream concentrations of nitrate-nitrogen below Derby Dam, and virtually no effect below Wadsworth. In the canal, the highest projected nitrate concentrations are for the August flow regime; the nitrification alternative (AWT1) resulted in a 52 percent

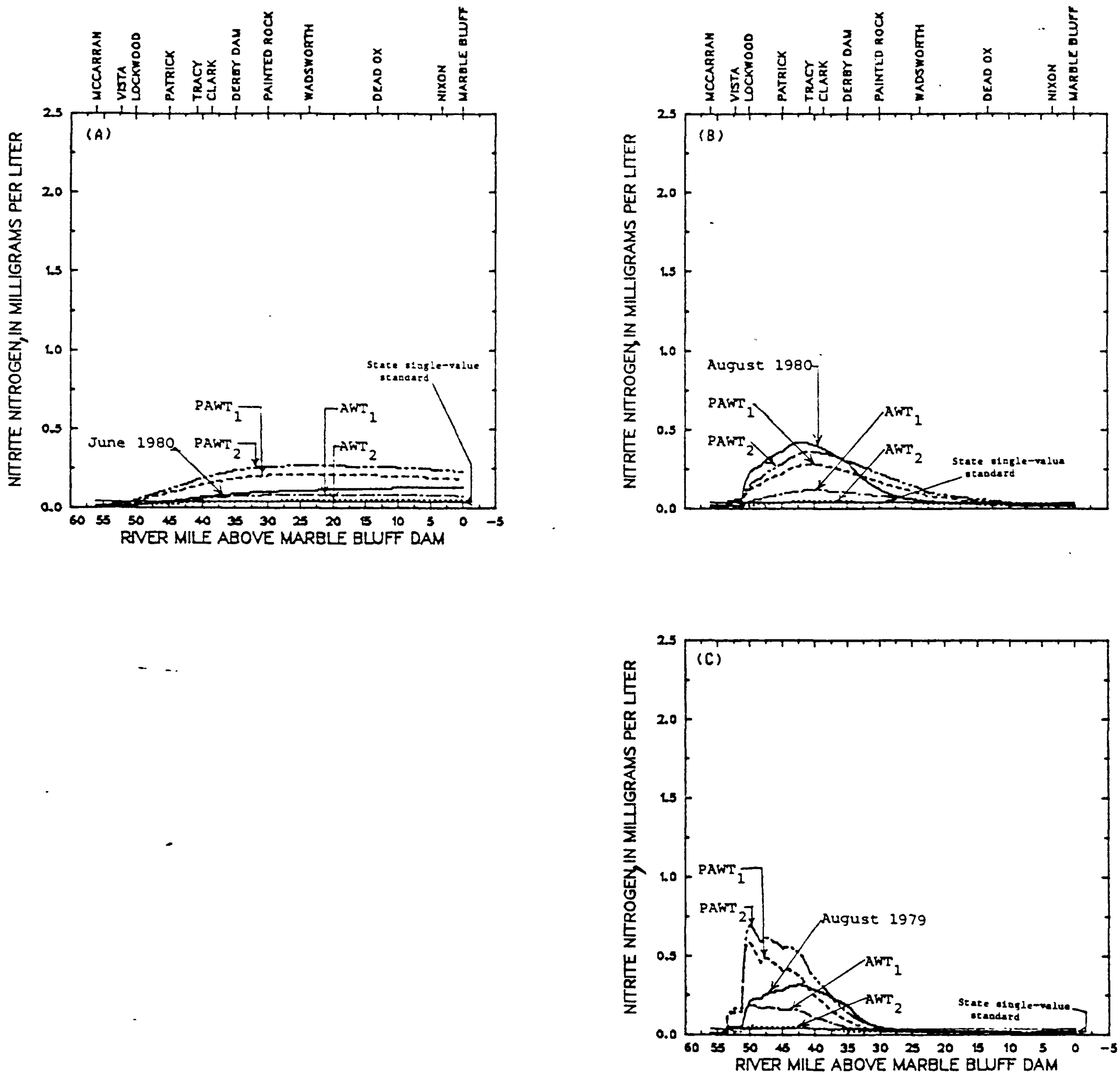


FIGURE 94.--Simulations of nitrite nitrogen for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Concentrations in the river are significantly reduced for the two advanced-treatment alternatives (AWT1, 2); however, exceedance of the water-quality standard is projected to continue even with denitrification of the STP effluent.

increase in nitrate at Highway 50 over secondary treatment at 40 Mgal/d (PAWT2). Denitrification (AWT2) resulted in a 55 percent decrease in nitrate compared to PAWT1.

Figure 95 near here

Total-Nitrogen

Simulated total-nitrogen concentrations for most alternatives exceed the single-value Nevada water-quality standard of 1.2 mg/L (figure 96). Total-nitrogen concentrations for the denitrification alternative are less than the standard for the June and August flow regimes, however, the standard is exceeded at $7Q_{10}$ flows above Derby Dam.

Figure 96 near here

Nitrogen/Phosphorus Ratio

For all alternatives except denitrification, simulated N/P ratios from Steamboat Creek to Derby Dam exceed 20, indicating potential phosphorus limitation for algal stimulation (figure 97). The tendency towards phosphorus limitation increases in the progression of alternatives from observed 1979-80 conditions to nitrification of the STP effluent (AWT1), and also increases with decreasing streamflows. The increased effluent discharge and decreased loading of phosphorus for the AWT2 simulation in comparison with the observed conditions results in higher N/P ratios, with phosphorus limitation indicated for the AWT2 simulation at $7Q_{10}$ flows in the reach from Steamboat Creek to Lockwood. For June streamflow conditions, the N/P ratios below Derby Dam for all alternatives except AWT2 are in the range of 10 to 20, indicating that neither nitrogen or phosphorus is limiting. The simulation for AWT2 at June

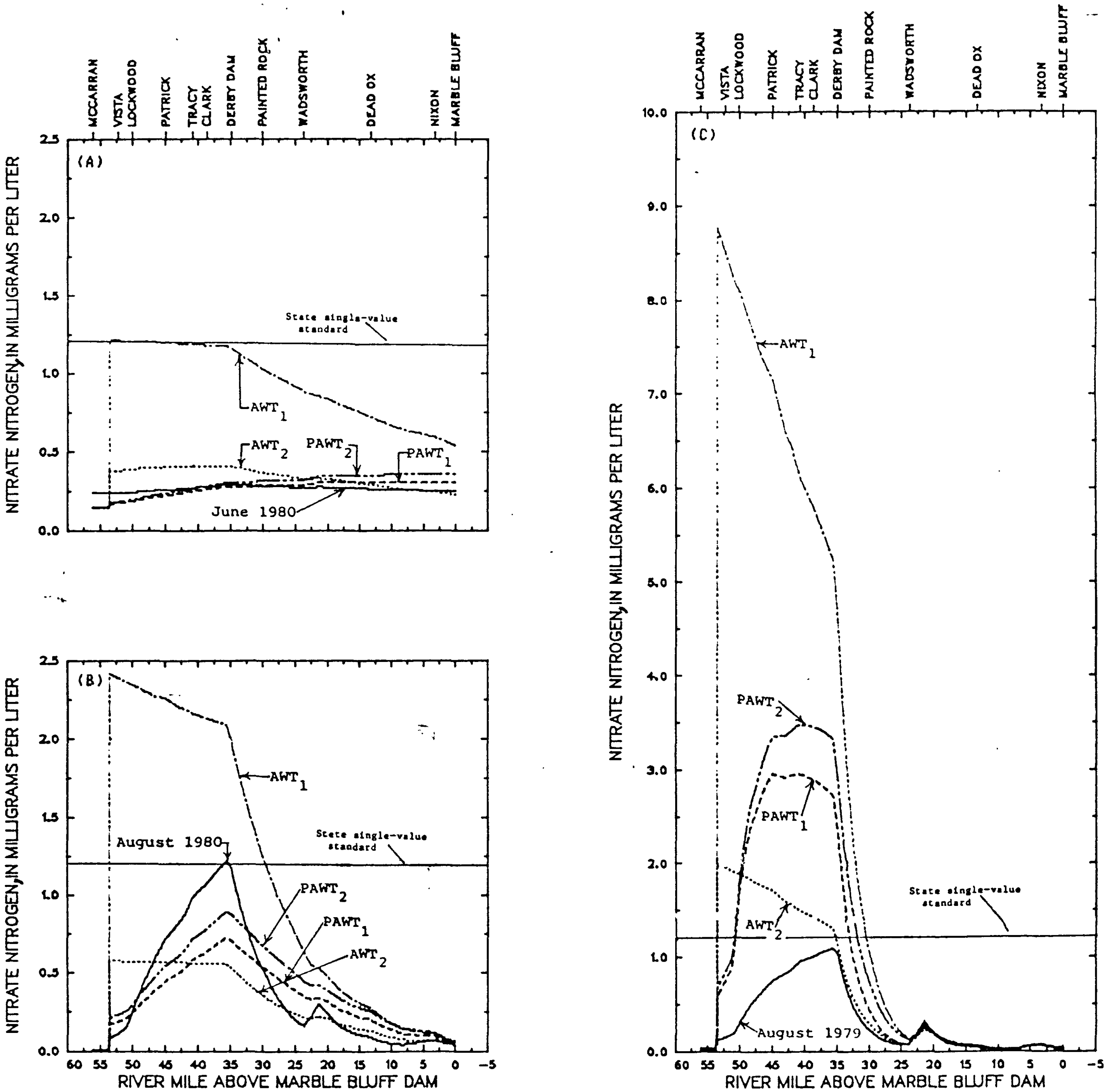


FIGURE 95.--Simulations of nitrate nitrogen for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$(C) regimes of river flow: Nitrification of STP effluent (AWT1) is projected to significantly increase concentrations in the river, resulting in projected exceedance of water-quality standard at all three modeled flow regimes.

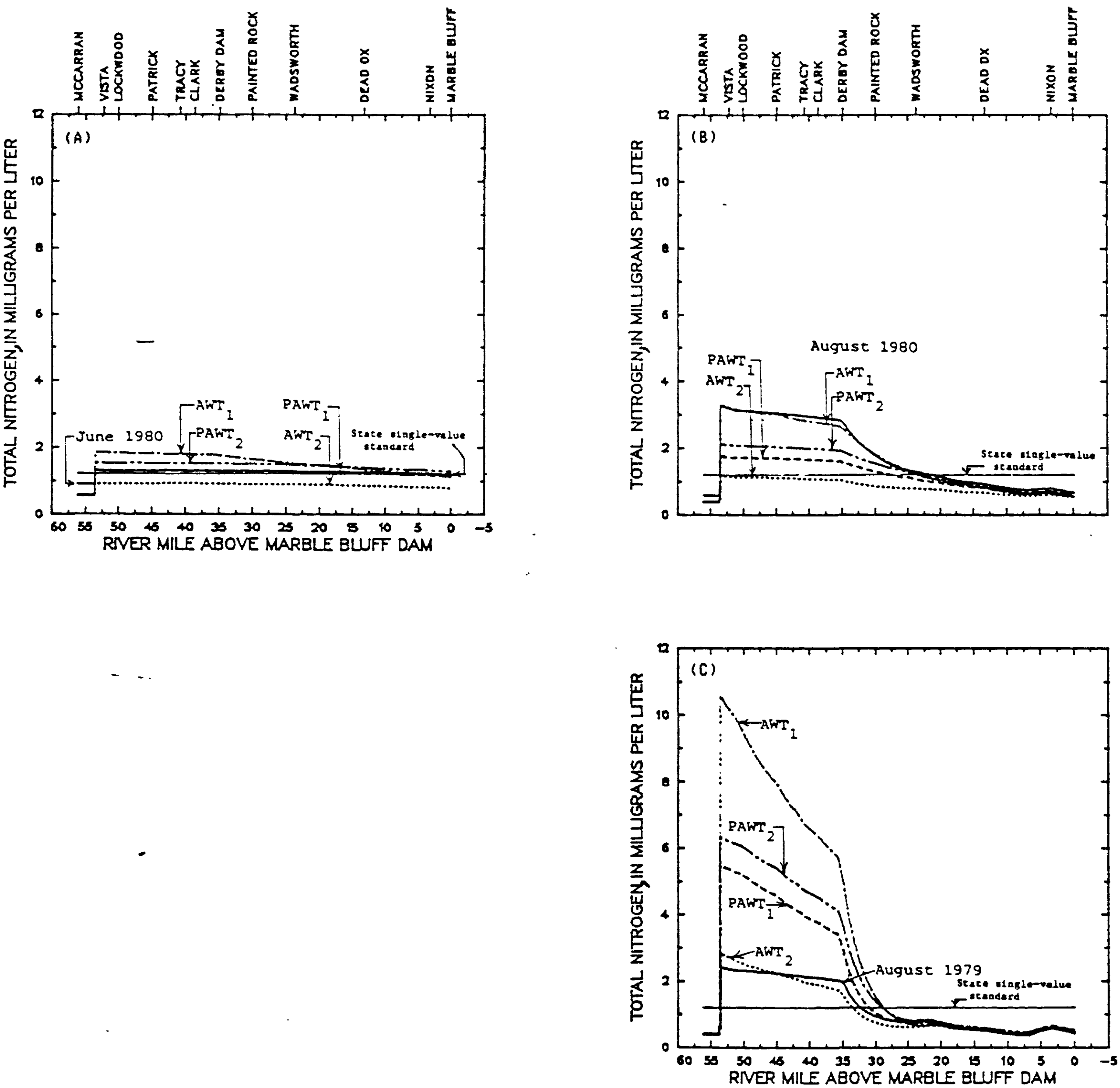


FIGURE 96.--Simulations of total nitrogen for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Concentrations, although greatly reduced for the denitrification alternative (AWT2), are projected to exceed water-quality standards for all three flow modeled flow regimes.

flows indicates that nitrogen is limiting below Derby Dam. For lower flows, nitrogen becomes potentially limiting for all alternatives between Derby Dam and Wadsworth.

Figure 97 near here

Mean Daily Dissolved Oxygen

Simulated mean daily concentrations of DO meet the Nevada single-value standards of 5.0 to 6.0 mg/L for all alternatives except PAWT1 and PAWT2 at the $7Q_{10}$ flows, where the increased ammonia loadings from secondary treatment at STP discharges of 30 and 40 Mgal/d result in increased oxygen deficits between Vista and Derby Dam (figure 98). For the denitrification alternative (AWT2), simulated DO concentrations are within 80 to 90 percent of saturation for all modeled flow conditions.

Figure 98 near here

Mininum Daily Dissolved Oxygen

Simulated concentrations are less than the 5.0 mg/L standard in the vicinity of Tracy for the secondary treatment alternatives PAWT1 and PAWT2 for August flow conditions and in several reaches of the river for all alternatives for $7Q_{10}$ flows (figure 99). Simulated concentrations for the secondary alternatives PAWT1 and PAWT2 drop to zero in the reach between Patrick and Clark, however, the uncertainties in rates of aquatic photosynthesis and respiration for conditions so far removed from calibration make the precision of estimates of minimum concentrations for these simulations questionable.

Figure 99 near here

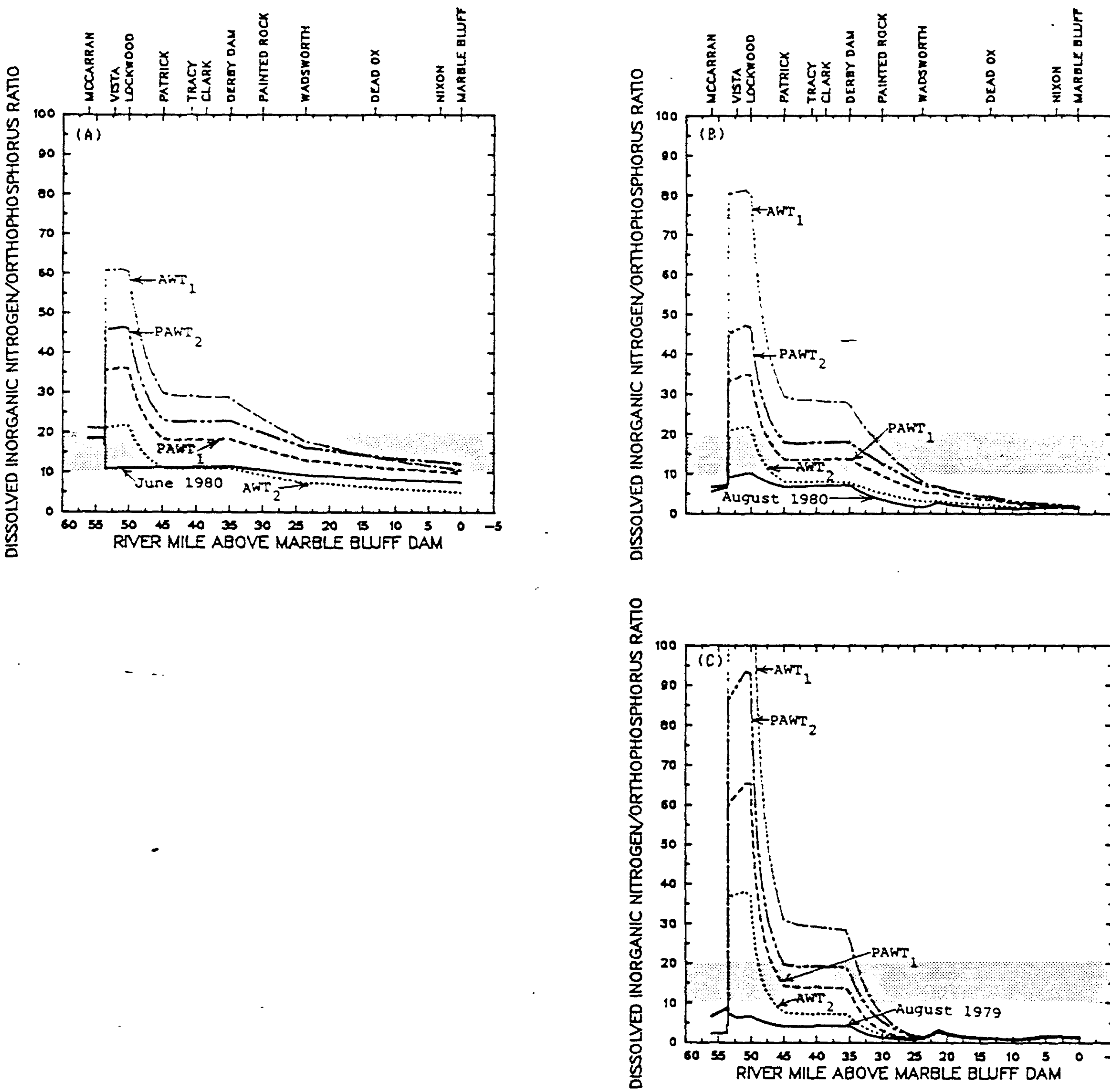


FIGURE 97. --Simulations of nitrogen/phosphorus ratio for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Increased concentrations of inorganic nitrogen are projected to shift the N/P ratio towards stronger indications of phosphorus limitation above Derby Dam for all but the denitrification alternative (AWT2).

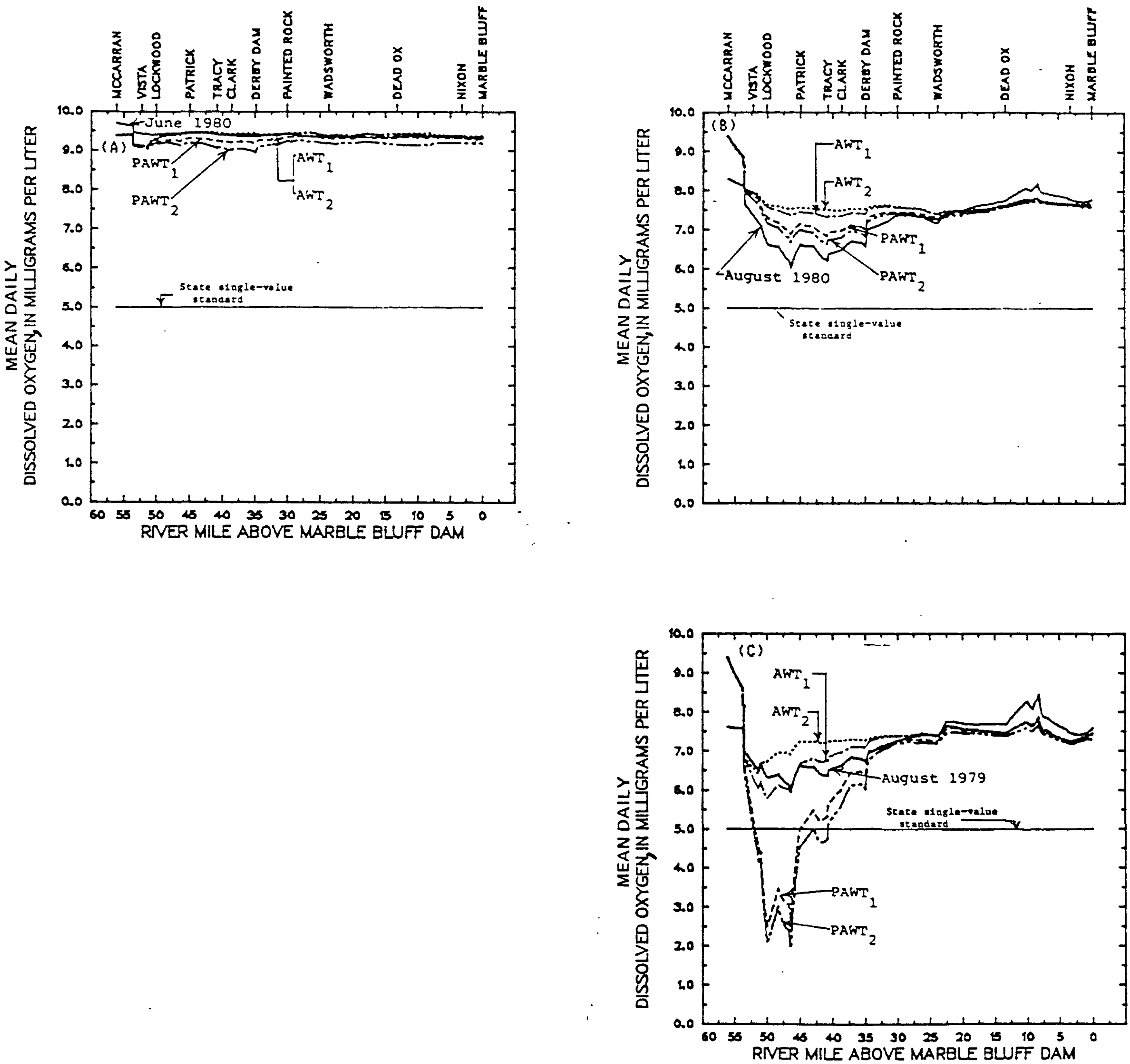


FIGURE 98.--Simulations of daily mean dissolved oxygen for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: Increased loadings of the STP for alternatives PAWT1 and PAWT2 are projected to decrease concentrations for August flows above Derby Dam. Both advanced-treatment alternatives would result in a substantial improvement in oxygen concentrations between Vista and Derby Dam.

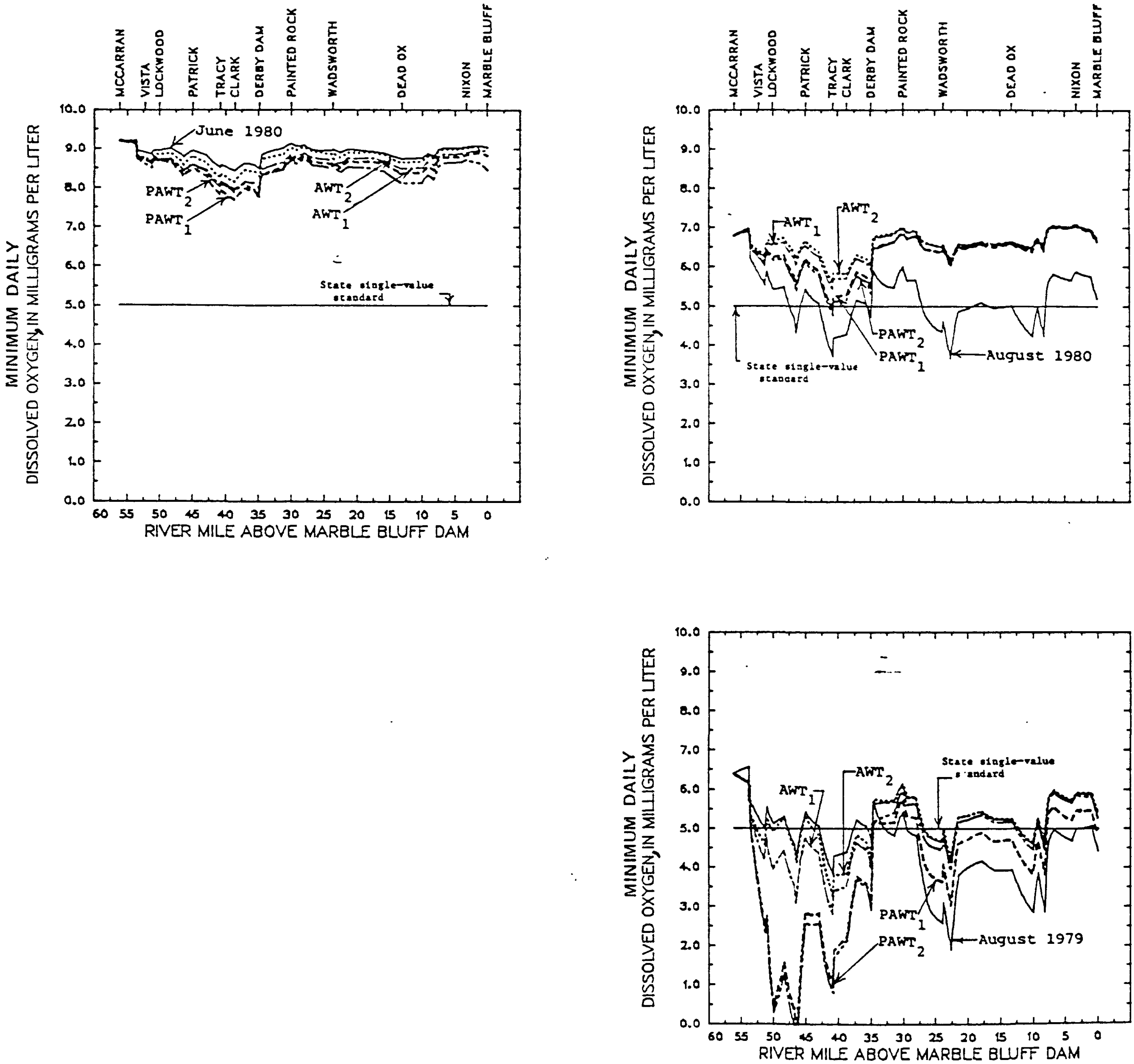


FIGURE 99.--Simulations of daily minimum dissolved oxygen for alternative operations at the Reno-Sparks STP for average June (A), August (B), and $7Q_{10}$ (C) regimes of river flow: In comparison to observed 1979-80 conditions, concentrations would decrease for alternatives PAWT1 and PAWT2, and increase for the advanced-treatment alternatives. Exceedance of water-quality standards are projected to continue even with denitrification of effluent (AWT2), however, if the algal populations in the river are not substantially reduced.

Summary of Simulations

Simulations of water-quality responses to four alternatives for future operation of the Reno-Sparks STP demonstrate the utility of the TRWQ model. The simulations demonstrate the effects of increasing stresses on river quality from increasing effluent discharge under secondary treatment to 30 and 40 Mgal/d. The simulations project violations, under one or more of the modeled flow regimes, of water-quality standards for dissolved solids, orthophosphorus, un-ionized ammonia, nitrite-, nitrate-, total-nitrogen, and dissolved oxygen. Advanced treatment with nitrification of effluent to reduce ammonia loadings made significant improvements with respect to projected concentrations of ammonia, nitrite, and dissolved oxygen in the river, but resulted in significantly higher projected nitrate concentrations. Denitrification resulted in elimination of projected violations of standards attributable to the STP for nitrogen and dissolved oxygen, but increased the projected violations of standards for dissolved solids. Reductions in $CBOD_u$ and organic-nitrogen for advanced treatment with effluent filtration had little significant impact on modeled constituents. Reductions in phosphorus concentrations beyond the planned secondary treatment had little impact on the projected phosphorus profiles for the river.

In addition to projecting water-quality conditions along the river and canal, the TRWQ model can be used to predict loadings to the receiving bodies of Pyramid Lake and Lahontan Reservoir. Projected loadings for the four simulations are listed in table 47. For advanced treatment with denitrification in comparison with secondary treatment, loadings of dissolved solids to Pyramid Lake are projected to increase by 4 to 8 percent and loadings to Lahontan Reservoir by up to 14 percent at low flows. For the same scenarios, total-nitrogen loadings to Pyramid Lake would be reduced by up to 39 percent (June flows) and loadings to Lahontan Reservoir by 40 to 50 percent. With respect to river loadings to Pyramid Lake, advanced treatment results in the greatest reduction of nutrient loadings during high spring flows when assimilation processes are minimized (short traveltimes, low instream concentrations, low water temperatures) and the least reduction during summer low flows when river assimilation is high.

Table 47 near here

TABLE 47.—Summary of projected loadings to Pyramid Lake and Lahontan Reservoir for planned alternative STP operations

[Projected loadings are shown for inflow of the Truckee River into Pyramid lake estimated from flows and concentrations at Marble Bluff Dam, 2 to 4 miles above the lake, depending upon lake stage, and for inflows of the Truckee Canal into Lahontan Reservoir at the terminal weir, .06 to .08 mile above the reservoir.]

Constituent and location	PAWT1			PAWT2			AWT1			AWT2		
	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$	June	August	$7Q_{10}$
Discharge (ft^3/s)												
Marble Bluff Dam	783	208	41	799	224	57	799	224	57	799	224	57
Terminal Weir	180	85	10	180	85	10	180	85	10	180	85	10
Dissolved Solids (lb/day)												
Marble Bluff Dam	520,000	220,000	92,000	540,000	240,000	120,000	540,000	240,000	120,000	560,000	250,000	130,000
Terminal Weir	110,000	69,000	14,000	110,000	72,000	14,000	110,000	72,000	14,000	110,000	76,000	16,000
$CBOD_u$ (lb/day)												
Marble Bluff Dam	17,000	4,800	880	19,000	5,600	1,300	15,000	4,500	1,100	15,000	4,500	1,100
Terminal Weir	3,000	1,500	120	3,300	1,700	147	2,500	1,200	77	2,500	1,200	77
Organic Nitrogen (lb/day)												
Marble Bluff Dam	2,100	550	99	2,200	600	140	2,000	550	120	2,000	550	120
Terminal Weir	380	180	17	380	190	18	350	160	13	350	160	13
Ammonia Nitrogen (lb/day)												
Marble Bluff Dam	660	25	4	860	27	6	290	25	5	190	25	5
Terminal Weir	160	16	1	210	18	1	65	11	1	41	10	1
Nitrite Nitrogen (lb/day)												
Marble Bluff Dam	770	22	4	990	26	5	320	22	5	200	21	5
Terminal Weir	260	45	1	340	56	1	97	24	1	55	16	1
Nitrate Nitrogen (lb/day)												
Marble Bluff Dam	1,300	64	8	1,500	81	11	2,300	73	10	990	55	10
Terminal Weir	410	340	37	490	420	44	1,000	650	61	370	190	18
Total Nitrogen (lb/day)												
Marble Bluff Dam	4,800	660	120	5,600	730	160	5,000	670	150	3,400	650	150
Terminal Weir	1,200	580	56	1,400	680	64	1,500	840	76	820	370	32
Orthophosphorus (without assumed nonpoint loadings between Lockwood and Patrick, lb/day)												
Marble Bluff Dam	460	120	22	460	126	29	460	130	29	460	130	29
Terminal Weir	52	31	3	52	27	2	52	27	2	52	27	2
Orthophosphorus (with assumed nonpoint loadings between Lockwood and Patrick, lb/day)												
Marble Bluff Dam	620	170	25	620	180	36	620	180	36	620	180	36
Terminal Weir	95	65	9	95	61	8	95	61	8	95	61	8
Total Phosphorus (with assumed nonpoint loadings between Lockwood and Patrick, lb/day)												
Marble Bluff Dam	730	200	29	760	210	42	760	210	42	760	210	42
Terminal Weir	110	78	10	110	71	9	113	71	9	113	71	9

SUMMARY AND CONCLUSIONS

The Truckee River is a unique water resource in the Great Basin, flowing about 116 miles from the pristine mountain waters of Lake Tahoe in the Sierra Nevada of California to the brackish waters of Pyramid Lake, lying some 2,400 feet lower in the desert of Nevada. At the foot of the Sierra about midlength along the river is the semi-arid Truckee Meadows, a valley in which river water is diverted for agriculture and municipal supplies in the rapidly urbanizing Reno-Sparks area, and in which secondary-treated effluent is discharged to the river. At Derby Dam, about 21 miles below Reno and 35 miles above Pyramid Lake, water from the Truckee River is diverted into the Truckee Canal for use in the Newlands Irrigation Project in the Carson Desert at the lower end of the adjacent Carson River basin. Small agricultural diversions also exist along much of the Truckee River below Reno, reducing river flows during low-flow periods and contributing nonpoint loadings to the river.

Intensive studies by the Truckee-Carson River Quality Assessment in 1979 and 1980 provided data for the construction, calibration, and validation of a one-dimensional water-quality transport model for 56 miles of the Truckee River between Reno and Pyramid Lake and for the 31-mile length of the Truckee Canal.

Field dye-tracer traveltime data were used to develop exponential relations used in the model to calculate velocity and cross-sectional area as a function of stream and canal discharge. Channel surveys provided data on stream slope used in reaeration computations and stream profiles used in segmentation of the river and canal into hydrologically uniform segments for modeling.

Gas-injection reaeration studies provided field data to test alternative equations for the prediction of the stream reaeration coefficient (K_2). The Tsivoglou equation (Tsivoglou and Neal, 1976) was selected as the best predictor of K_2 for the Truckee River.

Four intensive 24- to 36-hour synoptic surveys were performed in June and August of 1979 and 1980 to describe the quality of the river and canal and to provide detailed data sets for model calibration and validation (La Camera and others, 1985). Concentrations of DO in the river and canal were found to exhibit significant daily cycles due to photosynthesis and respiration of aquatic plants, principally periphytic algae. Daytime maxima were as high as 13 mg/L (190 percent of saturation) in the river and 14 mg/L (210 percent of saturation) in the canal. Nighttime minima in the river went as low as 3.4 mg/L (45 percent) in reaches of high algal productivity in the river. DO concentrations generally met State standards (instantaneous concentrations 5.0 mg/L or higher) except during nighttime minima in the daily cycle. A sag in mean daily DO concentrations of as much as 2.0 mg/L occured in a 19-mile reach below the inflow of the Reno-Sparks sewage effluent by way of Steamboat Creek. Principal cause of the DO sag was nitrification of ammonia (as much as 16 mg/L) in the sewage effluent. Below Derby Dam, mean DO concentrations generally were at, or exceeded, saturation values due to the high photosynthetic production of oxygen. During the 1979-80 synoptic studies, State standards also were violated for concentrations of un-ionized ammonia, nitrite- and total-nitrogen, and ortho- and total phosphorus. The STP was the major single source of loading for all of these constituents.

A steady-state one-dimensional water-quality transport model was constructed and applied to the river below Reno and to the canal. Modeled constituents included dissolved solids, $CBOD_u$, DO (daily mean and minima), ortho- and total phosphorus, and the nitrogen cycle (organic-, ammonia-, nitrite-, and nitrate-nitrogen). The river was subdivided into 43 segments for modeling on the basis of locations of agricultural diversions and returns, analysis of ground-water returns, and changes in slope and other channel characteristics. For each river segment, inputs could include water diversions, tributary or point-source inflows, and separate linearly distributed nonpoint inflows for surface agricultural returns and ground-water inflows. The canal was divided into nine segments on the basis of location of head-control structures and diversions.

Model applications require specification of the magnitude of diversions, and the magnitude and quality of agricultural returns and ground-water return flows to the river. The quality of surface agricultural returns to the river was estimated from supplemental samples collected during the field studies and from a statistical analysis of 3 years of detailed sampling of irrigation headwater and tailwater in similar areas in the Carson River basin A data base containing the results of over 1,000 water-quality analyses of water from wells and springs along the Truckee River was compiled to estimate the quality of ground-water inflows to the river. Procedures were developed and documented to estimate the magnitude of surface irrigation returns and ground-water inflows to the river from an analysis of measured gains and losses between gaging stations and diversion estimates from the Federal Watermaster. For the canal, the model considers seepage losses estimated for unlined reaches and agricultural diversions estimated from records of the Truckee Carson Irrigation District.

The model uses first-order equations to describe stream assimilation of nonconservatives ($CBOD_u$, nitrogen, and phosphorus) and sequential transformations of nitrogen from organic-nitrogen to nitrate. The DO regime is modeled by considering first-order reactions describing oxidation of CBOD, ammonia-, and nitrite-nitrogen. Provisions are included in the computer program for accounting of oxygen input from algal photosynthesis and uptake by algal respiration and benthic oxygen demands. In applying the model to the river and canal, the net effects of photosynthesis were considered by calibration of one factor for the net effect of photosynthesis and respiration on measured mean DO, and another factor for measured DO minimas.

Although the computer program provides for separate coefficients for algal uptake and benthic exchange of phosphorus, data limitations led to model calibration assuming simple first-order assimilation. In three of the four 1979-80 data sets and other historical data sets for the river, both ortho- and total-phosphorus concentrations were observed to increase in a 5-mile reach of the river between Lockwood and Patrick. No sources of phosphorus (either point or non-point) sufficient to account for the observed increases were found during the field studies, and the magnitude of the apparent increases (140 to 720 lb/day of P) were greater than reasonably attributable to benthic releases. Phosphorus assimilation rates were calibrated for the river below Patrick and "dummy" nonpoint sources of P were assigned to the Lockwood to Patrick reach and quantified by curve-fitting the predictions to the observed data.

One set of model coefficients was found to apply to both the June and August data sets. Calibrated ranges in model coefficients (1/day, base e at 20 degrees Celsius) for the river are: CBOD decay, 0.14 to 1.7, CBOD oxidation, 0.14 to 0.20; organic-nitrogen decay, 0.10 to 1.7 organic-nitrogen hydrolysis, 0.10 to 0.80; ammonia-nitrogen decay and oxidation, 0.40 to 2.4, nitrite-nitrogen decay and oxidation, 1.0 to 10; nitrate-nitrogen decay, 0.30 to 2.0; net photosynthesis and respiration of DO, 1 to 2 mg/L/day; and calculated reaeration, 0.12 to 120.

Calibration and application of the model provided assessment as to the relative importance of processes and sources of loading that affect water quality in the river and canal. Between Reno and Derby Dam, river quality is influenced predominately by discharges from the two principal tributaries draining urban and agricultural lands in the Truckee Meadows and from the Reno-Sparks sewage plant. At typical summer low flows, river assimilation results in substantial reduction of concentrations of nutrients and oxygen-demanding substances attributable to the upstream sources and the sewage effluent, with effects of nonpoint agricultural returns and ground-water inflows predominating over those of upstream sources in the lower river below Derby Dam.

Sensitivity analyses of the model for the calibrated August 1979 conditions showed differences in the significance of factors controlling water quality above and below Derby Dam. Above the dam, concentrations of most modeled constituents are affected principally by input loadings (from the upstream river, North Truckee Drain, Steamboat Creek, and sewage effluent) and assimilation rates. Assimilation of these loadings is controlled by the effect of river flows on traveltimes and dilution of inputs, and by the influence of water temperatures on assimilation rates and reaeration. In this environment, changes in loadings of major sources such as the sewage effluent have a significant impact on water quality during all but high spring flows.

Below the dam, nonpoint sources of loadings have increasing significance in comparison to residual effects of the upstream major inputs. Diversions into the Truckee Canal at low to medium flows result in increased traveltimes and warmer temperatures in the depleted river below the dam. At these flows, upstream loadings are reduced by river assimilation to concentrations that may significantly be affected by local nonpoint loadings from irrigation returns and ground-water inflows. Although greatly reduced by assimilation between Vista and Derby Dam, nitrogen and phosphorus concentrations below the Dam are sufficient to sustain prolific growths of algae, resulting in large diel cycles in DO concentrations, with nighttime concentrations falling below minimum standards. Nutrient concentrations below the dam are dominated by local nonpoint returns, the magnitude of streamflow, and the effects of water temperatures on assimilation rates.

The calibrated model was applied to alternatives for sewage treament ranging from continued secondary treatment to tertiary treatment with denitrification of the effluent. Simulations at projected effluent discharges for the year 2000 were performed for average June, August, and $7Q_{10}$ low flows) river flows. For the $7Q_{10}$ low-flow conditions, simulations projected that water-quality standards for dissolved solids, nitrite, nitrate, phosphorus, and minimum daily dissolved oxygen would be violated in one or more reaches of the river for all modeled alternatives at the proposed sewage discharge for the year 2000 (40 Mgal/d). However, except for dissolved solids, projected violations of standards for the denitrification alternative were attributable mainly to sources other than the sewage discharge. The model applications indicated that increasing effluent discharge at the Reno-Sparks STP from 30 to 40 Mgal/day would result in variable increases in loadings of constituents to Pyramid Lake and Lahontan Reservoir, depending on flow regime and season. In comparison to secondary treatment, nitrification of STP effluent would reduce total-nitrogen loadings to Pyramid Lake by 7 to 11 percent and increase total-nitrogen loadings to Lahontan Reservoir by 7 to 24 percent for the simulated flow regimes. Denitrification is projected to significantly reduce nitrogen loadings to both Pyramid Lake and Lahontan Reservoir at most river flows; however, simulations show little effect on nitrogen loadings to Pyramid Lake for $7Q_{10}$ low flows.

The TRWQ model has been shown to perform well for the assumptions used in its calibration and to provide a useful tool for analysis of the cause-and-effect relationships between input loadings, streamflow, and resultant water quality in the Truckee River and Canal. Basic limitations of the model should be noted, however, as caveats to future applications:

(1) The model is based on steady-state assumptions as to flow and quality; thus, applications to conditions of varying streamflow due to snowmelt, floods, or periods of changing river regulation are inappropriate. With the exception of the estimated DO minima, model projections are daily mean values that do not take into account changes in quality with time. Thus it may be inappropriate to use monitoring data based on single samples for model inputs.

(2) Application of the model to environmental conditions beyond those represented by data sets used for calibration and validation is not advised without further validation. Model development was based on Truckee River flows in the range from about 140 to 1,900 ft^3/s (Sparks gage). At significantly higher or lower flows, channel hydraulics and aquatic habitats may be sufficiently altered as to change calibration. Coefficients describing assimilation and transformation of non-conservatives were based on data collected during stable June and August seasonal environments. Aquatic ecosystems during other seasons, such as winter periods, or during periods of environmental instabilty following floods or other significant periods of environmental change, may result in substantially different coefficients.

(3) Substantial changes in the nature of the STP effluent also could require recalibration of the model. Major increases or decreases in nutrients could alter the species composition of the aquatic community downstream from the STP sufficiently as to require recalibration of model coefficients for nutrient assimiliation, photosynthesis, and respiration.

REFERENCES CITED

Andrews, A. K, Ellison, R. A., Hamilton, D. B., and Roelle, J. E., 1981, Application of the adaptive environmental assessment methodology to the Truckee-Carson River-Quality Assessment: U.S. Fish and Wildlife Service, Western Energy and Land Use Team Report W/AEAG-81/W11, 64 p.

Bansal, M. K., 1976, Nitrification in natural streams: Water Pollution Control Federation Journal, v. 48, n. 10, p. 2380-2393.

Bauer, D. P., Jennings, M. D., and Miller, J. E., 1979, One-dimensional, steady-state, stream-quality model: U.S. Geological Survey Water-Resources Investigations Report 79-45, 215 p.

Bauer, D. P., Steele, T. D., and Anderson, R. D., 1978, Analysis of waste-load assimilative capacity of the Yampa River, Steamboat Springs to Hayden, Routt County, Colorado: U.S. Geological Survey Water-Resources Investigations Report 77-119, 69 p.

Blodgett, J. C., Oltmann, R. N., and Paeschel, K. R., 1984, Estimation of streamflow at selected sites on the Carson and Truckee Rivers in California and Nevada, 1944-80: U.S. Geological Survey Water-Resources Investigations Report 84-4058, 223 p.

Born, S. M., 1970, Deltaic sedimentation at Pyramid Lake, Nevada: Wisconsin University, unpublished Ph. D. thesis, 234 p.

-----1972, Lake Quaternary history, deltaic sedimentation, and mudlump formation at Pyramid Lake, Nevada: Center for Water Resources, Desert Research Institute, 97 p.

Born, S. M., and Ritter, D. F., 1970, Modern terrace development near Pyramid Lake, Nevada, and its geologic implications: Geological Society of America Bulletin 81, p. 1233-1242.

Bowie, G. L., Mills, W. B., Porcella, D. B., Campbell, C. L., Pagenkopf, J. R., Rupp, G. L., Johnson, K. M., Chan, P. W., and Gherini, S A., 1985, Rates, constants, and kinetics formulations in surface water quality modeling: U.S. Environmental Protection Agency Report EPA/600/3-85/040, 455 p.

Bratberg, David, 1980, Hydrogeology of Dodge Flat and its relation to flow and quality changes in the Truckee River: University of Nevada, Reno, unpublished M.S. thesis, 76 p.

Brown, W. M. III, Nowlin, J. O., Smith, L. H., and Flint, M. R., 1986, River-quality assessment of the Truckee and Carson river system, California and Nevada--Hydrologic characteristics: U.S Geological Survey Open-File Report 84-576, 201 p.

Bryce, R. W., 1981, Phosphorus transfer between the liquid and solid phase in Lahontan Reservoir, Nevada: University of Nevada, Reno, unpublished M.S. thesis, 122 p.

Cain, Doug, Baldridge, Duaina, and Edelmann, Patrick, 1980, Waste-assimilation capacity of the Arkansas River in Pueblo County, Colorado, as it relates to water-quality guidelines and stream classification: U.S. Geological Survey Water-Resources Investigations Report 80-82, 104 p.

Callendar, Edward, and Hammond, D. E., 1982, Nutrient exchange across the sediment-water interface in the Potomac River Estuary Estuarine, Coastal and Shelf Science, v. 15, pp. 395-413.

Campana, M. E., 1979, Feasibility study of a ground-water supply for Pyramid Lake Indian Hatchery: University of Nevada, Reno, unpublished report.

Capaccio, R. S., 1971, The rate of release of phosphorus from natural benthal deposits: Northeastern University, Boston, M.S. Thesis.

CH2M-Hill, Inc., 1980, Truckee River irrigation and drainage study for Pyramid Lake Indian Reservation, Wadsworth, Nevada--Phase I: Stewart, Nev., Bureau of Indian Affairs, 50 p.

Churchill, M. A , Elmore, H. L., and Buckingham, R. A., 1962, The prediction of stream reaeration rates: Journal of Environmental Engineering Division, American Society of Civil Engineers, v. 88, no. SA-4, p. 1-46.

Cooper, J. J., Howell-Cooper, S., and Peacock, M., 1984, Peripython growth in the Truckee River, Nevada 1980-1982: Seasonal variations and nutrient biostimulation: University of Nevada, Desert Research Institute, Bioresources Center Publication 5029, 66 p.

Crawford, C. G., Wilber, W. G., and Peters, J. G., 1979, A one-dimensional steady-state, dissolved-oxygen model and waste-load assimilation study for South Fork Wildcat Creek, Clinton County, Indiana: U.S. Geological Survey Open-File Report 79-1074, 66 p.

-----1980, A one-dimensional steady-state, dissolved-oxygen model and waste-load assimilation study for the Wabash River, Huntington County, Indiana: U.S. Geological Survey Open-File Report 80-75, 55 p.

Crippen, J. R., and Pavelka, B. R., 1970, The Lake Tahoe basin, California-Nevada: U.S. Geological Survey Water-Supply Paper 1972, 56 p.

Curran, Harold, 1982, Fearful Crossing--the central Overland Trail through Nevada: Reno, Great Basin Press, 212 p.

Dahl, A. J., 1978, An economic evaluation of water policy alternatives in Washoe County, Nevada: Nevada Division of Water Planning Technical Memorandum 4, Water-Supply Report 1, 58 p.

-----1980, An update on water in the Truckee Meadows *in* Nevada review of business and economics, Fall 1980: University of Nevada, Reno, Bureau of Business and Economic Research, p. 12-20.

Dobbins, W. E., 1965, Closure to "BOD and oxygen relationships in streams": Journal of Sanitary Engineering Division, American Society of Civil Engineers, v. 91, no SA-5, p. 49-55.

Elmore, H. L., and West, W. F., 1961, Effects of water temperature on stream reaeration: Journal of Sanitary Engineering Division, American Society of Civil Engineers, v. 87, no. SA-6, p. 59-71.

Fillos, J., and Molof, A. H., 1972, Effects of benthal deposits on oxygen and nutrient economy of flowing waters: Water Pollution Control Federation Journal, v. 44, p. 644.

Fillos, J., and Swanson, W. R., 1975, The release rate of nutrients from river and lake sediments: Water Pollution Control Federation Journal, v. 47, no. 5, p. 1032-1042.

Glancy, P. A., Van Denburgh, A. S., and Born, S. M., 1972, Runoff, erosion, and solutes in the lower Truckee River, Nevada, during 1969: Nevada Division Water Resources, Information Report 18, 16 p.

Goddard, K. E., 1980, Calibration and potential uses of a digital water-quality model for the Arkansas River in Pueblo County, Colorado: U.S Geological Survey Water-Resources Investigations Report 80-38, 87 p.

Greeson, P. E., Ehlke, T. A., Irwin, G. A., Lium, B. W., and Slack, K. V., 1977, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigations Book 5, Chapter A4, 332 p.

Grimm, N. B., Fisher, S. G., and Minckley, W. L., 1983, Nitrogen and phosphorus dynamics in hot desert streams of Southwestern U.S.A.: Hydrobiologia, v. 83, p. 303-312.

Gruen Gruen and Associates, 1979, Master project facilities plan, expansion of Reno-Sparks joint water pollution control plant, Appendix A--The regional economy, future population growth and housing: U.S. Environmental Protection Agency Draft Environmental Impact Statement EPA-9-CA-C-32-0114, Appendices A-D, p. A1-A117.

Guitjens, J. C., Mahannah, C. N., and Miller, W. W., 1976, Quality monitoring of irrigation water and return flows, 1974 irrigation season: University of Nevada, Reno, Agricultural Experiment Station Report 114, 81 p.

Guitjens, J. C., Miller, W. W., Joung, H. M., and Mahannah, C. N., 1978, Quality monitoring of irrigation water and surface return flows in the Carson Valley, Nevada--1975 irrigation season: University of Nevada, Reno, Agricultural Experiment Station Report 119, 140 p.

Guitjens, J. C., Miller, W. W., Joung, H. M., Tuteur, L. F., and Mahannah, C. N., 1979, Quality monitoring of flows from irrigation water and surface runoff in Carson Valley, Nevada--1976 irrigation season: University of Nevada, Reno, Agricultural Experiment Station Report 131, 129 p.

Harris, E. E., 1970, Reconnaissance bathymetry of Pyramid Lake, Washoe County, Nevada: U.S. Geological Survey Hydrologic Atlas 379, 1 sheet.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water, 2nd ed.: U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Hoffman, R. J. 1982, Intragravel pipe for measuring the quality of water in salmonid spawning gravel (abs.): Joint Technical Conference, American Fisheries Society and The Wildlife Society, Reno, Nev., January 22.

-----1986, A horizontal intragravel pipe for sampling water quality in salmonid spawning gravel: North American Journal of Fisheries Management, v. 6, p. 445-448.

Hoffman, R. J., and Scoppettone, G. G., 1984, Effect of water quality on survival of Lahontan Cutthroat trout eggs in the Truckee River, West-Central Nevada and Eastern California: U.S. Geological Survey Open-File Report 84-437, 35 p.

Holdren, G. C., Jr., 1977, Factors affecting phosphorus release rates from lake sediments: University of Wisconsin, Madison, Ph. D. thesis.

Houghton, J. G., Sakamoto, C. M., and Gifford, R. D., 1975, Nevada's weather and climate: Nevada Bureau of Mines and Geology Special Publication 2, 78 p.

Hubbard, E. F., Kilpatrick, F. A., Martens, L. A., and Wilson, J. F., Jr., 1982, Measurement of time of travel and dispersion in streams by dye tracing: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A9, 44 p.

Isaacs, W. P., and Gaudy, A. F., 1968, Atmospheric oxygenation in a simulated stream: Journal of Sanitary Engineering Division, American Society of Civil Engineers, v. 94, no. SA-2, p. 319-344.

Jones and Stokes Associates, Inc., 1980, Master project facilities plan, expansion of Reno-Sparks joint water pollution control plant, Appendix E--Surface water hydrology: U S. Environmental Protection Agency Draft Environmental Impact Statement EPA-9-CA-C-32-0114, Appendices E-G, p. E1-E37.

Jones and Stokes Associates and Stanford Environmental Law Society, 1980, Master project facilities plan, Expansion of Reno-Sparks joint water pollution control plant, Appendix C--Institutional constraints affecting water rights in the Truckee River Basin: U.S. Environmental Protection Agency Draft Environmental Impact Statement EPA-9-CA-C-32-0114, Appendices A-D, p. C1-C122.

Kaiser Engineers, 1973, Water-Quality survey of the Truckee River-v. 1: Oakland, Calif., Kaiser Engineers.

Kennedy/Jenks Engineers, 1980, Draft master project facilities plan, expansion of Reno-Sparks joint water pollution control plant, cities of Reno and Sparks, Nevada: San Francisco, Calif., Kennedy/Jenks Engineers, 190 p., plus appendices.

Knack, M. C., and Stewart, O. C., 1984, As long as the river shall run--An ethnohistory of the Pyramid Lake Indian Reservation: Berkeley, University of California Press, 432 p.

La Camera, R. L., Hoffman, R. J., Nowlin, J. O., Smith, L. H., and Lima, S. M., 1985, Data on surface-water quality and quantity, Truckee River System, California and Nevada, 1979-81: U.S. Geological Survey Open-File Report 84-238, 189 p.

Langbein, W. B., and Durum, W. H., 1967, The aeration capacity of streams: U.S. Geological Survey Circular 542, 6 p.

Lider, E. L., Baily, C. J., and Koch, D. L., 1980, Algal growth potentials in the Truckee River, Lahontan Reservoir, and Pyramid Lake, Nevada: University of Nevada, Desert Research Institute Publication 50017, 47 p.

Mawson, S. J., Gibbons, H. L., Jr., Funk, W. H., and Hartz, K. E., 1983, Phosphorus flux rates in lake sediments: Journal Water Pollution Control Federation, v. 55, no. 8, p. 1105-1110.

McCutcheon, S. C., 1983a, Evaluation of selected one-dimensional stream water-quality models with field data: U.S. Geological Survey Open-File Report 82-851, 181 p.

-----1983b, Evaluation of stream water-quality models: Journal of Environmental Engineering Division, American Society of Civil Engineers, v. 188, n. 3, p. 190-193.

Miller, W. W., Guitjens, J. C., and Mahannah, C. N., 1977, Quality of irrigation water and surface return flows from selected agricultural lands in Nevada during the 1974 irrigation season: Journal of Environmental Quality, no. 6, p. 193-200.

Miller, J. E., and Jennings, M. E., 1978, Modeling nitrogen and oxygen in the Chattahoochee River, Georgia: American Society of Civil Engineers Convention, Chicago, 1978, preprint 3373, 17 p.

National Council of the Paper Industry for Air and Stream Improvement (NCASI), 1980, A review of the mathematical water quality model QUAL-II and guidance for its use: New York, NCASI Stream Improvement Technical Bulletin 338, 37 p. plus appendices.

Nevada Environmental Commission, 1984, Standards of water quality, Truckee River: Nevada Revised Statutes 445-143-152.

Nevada State Study Team, 1973, Alternative multiobjective plans emphasizing water resource use in Area II--Carson-Truckee Basins Planning Region: Nevada Division of Water Resources, 67 p. plus appendices.

Newbold, J. D., Elwood, J. W., O'Neil, R. V., and Van Winkel W., 1981, Measuring nutrient spiralling in streams: Canadian Journal of Fisheries and Aquatic Science, no. 38, p. 860-863.

Nowlin, J. O., Brown, W. M., III, Smith, L. H., and Hoffman, R. J., 1980, Planning and design of studies for river-quality assessment in the Truckee and Carson river basins, California and Nevada: U.S. Geological Survey Open-File Report 80-435, 75 p.

O'Connell, R. L., Geckler, J. R., Clark, R. M., Cohen, J. B., and Hirth, C. R., 1962, Report of survey of the Truckee River: U.S Public Health Service Report, 47 p.

O'Connor, D. J., 1967, The temporal and spatial distribution of dissolved oxygen in streams: Water Resources Research, v. 1, n. 3, pp. 65-69.

O'Connor, D. J., and Di Toro, D. M., 1970, Photosynthesis and oxygen balance in streams: Journal of the Sanitary Engineering Division, American Society of Civil Engineers v. 96, n. SA2, p. 547-571.

O'Connor, D. J., and Dobbins, W. E., 1958, Mechanisms of reaeration in natural streams: Transactions, American Society of Civil Engineers, v. 123, p. 641-684.

Odum, H. T., 1956, Primary production in flowing waters: Limnology and Oceanography, v. 1, no. 2, p. 102-117.

-----1957, Primary production in eleven Florida springs and a marine turtle-grass community: Limnology and Oceanography, v. 2, p. 85-97.

Pacific Environmental Laboratory, 1979, Effects of the Reno-Sparks joint water-pollution control plant on water quality of the Truckee River--prepared for cities of Reno and Sparks, Nevada, 1979, Appendix: San Francisco, Pacific Environmental Laboratory, 489 p.

Padden, T. J., and Gloyna, E. F., 1971, Simulation of stream processes in a model river: University of Texas, Austin, Report EHE-70-23, CRWR-72, 130 p.

Parkhurst, J. D., and Pomeroy, R. D., 1972, Oxygen absorption in streams: Journal of Sanitary Engineering Division, American Society of Civil Engineers, v. 98, no. SA-1, p. 101-124.

Pomeroy, L. R., Smith, E. E., and Grant, C. M., 1965, The exchange of phosphates between estuarine water and sediments: Limnology and Oceanography, v. 10, p. 167-172.

Pyramid Lake Indian Tribal Council, 1982, Pyramid Lake 208 Program studies: Pyramid Lake Indian Tribal Council report.

Rathbun, R. E., 1977, Reaeration coefficients of streams--state-of-the-art: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 103, no. HY4, p. 409-424.

-----1979, Estimating the gas and dye quantities for modified tracer technique measurements of stream reaeration coefficients: U.S. Geological Survey Water-Resources Investigations Report 79-27, 42 p.

Rathbun, R. E., and Grant, R. S., 1978, Comparison of the radioactive and modified techniques for measurement of stream reaeration coefficients: U.S. Geological Survey Water-Resources Investigations Report 78-68, 57 p.

Rathbun, R. E., Schultz, D. J., and Stephens, D. W., 1975, Preliminary experiments with a modified tracer technique for measurement of stream reaeration coefficients: U.S. Geological Survey Open-File Report 75-256, 36 p.

Rathbun, R. E., Shultz, D. J., Stephens, D. W., and Tai, D. Y., 1977, Experimental modeling of the oxygen absorption characteristics of streams and rivers: International Association for Hydraulic Research, 17th Congress, v. 1, p. 483-490.

Redfield, A. C., 1958, The biological control of chemical factors in the environment: American Scientist, v. 46, p. 205-221.

Rhee, G. Y., 1978, The effects of N:P atomic ratios and nitrate limitation on algal growth, cell composition, and nitrate uptake: Limnology and Oceanography, v. 23, p. 10-25.

Richard-Haggard, K., 1983, External and internal phosphorus loading studies, v. III, *in* The Lahontan water quality project: University of Nevada, Desert Research Institute, 142 p.

Riggs, H. C., 1968a, Frequency curves: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chapter A2, 15 p.

-----1968b, Low-flow investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 4, Chapter B1, 18 p.

Roesner, L. A., Giguere, P. A., and Evenson, D. E., 1977a, User's Computer program documentation for the stream quality model Manual for the stream quality model QUAL II: Water Resource QUAL II: Walnut Creek, Calif., Water Resource Engineers, Inc.

-----1977b, User's manual for the stream quality model QUAL II: Water Resource QUAL II: Walnut Creek, Calif., Water Resource Engineers, Inc.

Ryther, J. H., and Dunstan, W. M., 1971, Nitrogen, phosphorus and eutrophication in the coastal marine environment: Science, v. 171, p. 1008-1013.

Searcy, J. K., 1959, Flow-duration curves--U.S. Geological Survey Manual of Hydrology Part 2.--Low-flow techniques: U.S. Geological Survey Water-Supply Paper 1542-A, 33 p.

Shelton, S. P., Burdick, J. C., and Drewry, W. A., 1978, Water quality modeling in a low flow stream: Journal of the Water Pollution Control Federation, p. 2289-2306.

Shindala, Adnan, 1972, Mathematical modeling for water-quality management in streams and estuaries: Mississippi State University Department of Civil Engineering, 62 p.

Sinclair, W. C., and Loeltz, O. J., 1963, Ground-water conditions in the Fernley-Wadsworth area, Churchill, Lyon, Storey, and Washoe Counties, Nevada: U.S. Geological Survey Water-Supply Paper 1619AA, p. AA1-AA22.

Smith, L. H., 1980, Approximate relationships between river inflows and the lake level and dissolved-solids concentration of Pyramid Lake, Washoe County, Nevada: U.S. Geological Survey Open-File Report 82-80, 5 p.

Sonzogni, W. C., Chapara, S. C., Armstrong, D. E., and Logan, T. J., 1982, Bioavailability of phosphorus inputs to lakes: Journal of Environmental Quality, v. 11, no. 4, p. 555-562.

Stamer, J. K., Bennett, J. P., and McKenzie, S. W., 1983, Determination of ultimate carbonaceous BOD and the specific rate constant (kl): U.S. Geological Survey Open-File Report 82-645, 21 p.

Stamer, J. K., McKenzie, S. W., Cherry, R. N., Scott, C. T., and Stamer, S. L., 1979, Methods of ultimate carbonaceous BOD determination: Water Pollution Control Federation Journal, v. 51, no. 5, p. 918-925.

Stephens, D. W., and Jennings, M. E., 1976, Determination of primary productivity and community metabolism in streams and lakes using diel oxygen measurements: U.S. Geological Survey Computer Contribution: NTIS report PB-256-645, 88 p.

Stratton, Frank, 1966, Nitrification effects on oxygen resources in streams: Stanford University, Ph. D. thesis.

Streeter, H. W., and Phelps, E. B., 1925, A study of the pollution and natural purification of the Ohio River: U.S. Public Health Service, Public Health Bulletin 146, 75 p.

Stumm, Werner, and Morgan, J. J., 1970, Aquatic chemistry--An introduction emphasizing chemical equilibria in natural waters: New York, Wiley-Interscience, 583 p.

Terry, J. E., Morris, E. E., and Bryant, C. T., 1983, Water-quality assessment of White River between Lake Sequoyah and Beaver Reservoir, Washington County, Arkansas: U.S. Geological Survey Water-Resources Investigations Report 82-4036, 84 p.

Terry, J. E., Morris, E. E., Petersen, J. C., and Darling, M. E., 1984, Water-quality assessment of the Illinois River Basin, Arkansas: U.S. Geological Survey Water-Resources Investigations Report 83-4092, 262 p.

Thackston, E. L., and Krenkel, P. A., 1969, Reaeration prediction in natural streams: Journal of Sanitary Engineering Division, American Society of Civil Engineers, v. 95, no. SA-1, p. 65-94.

Thomann, R. V., 1974, Systems analysis and water quality management: New York, McGraw-Hill.

-----1982, Verification of water quality models: Journal of Environmental Engineering, American Society of Civil Engineers, v. 108, no. EE5, p. 923-940.

Thomann, R. V., O'Connor, D. J., and Di Toro, D. M., 1971, The effect of nitrification on the dissolved oxygen of streams and estuaries: Technical Report, Manhattan College, Environmental Engineering and Science Program, 55 p.

Thurston, R. V., Russo, R. C., and Emerson, K., 1974, Aqueous ammonia equilibrium calibrations: Montana State University, Fisheries Bioassay Laboratory Technical Report 74-1, 18 p. plus appendix.

Townley, J. M., 1977, Turn this water into gold--The story of the Newlands project: Nevada Historical Society, 160 p.

Tsivoglou, E. C., and Neal, L. A., 1976, Tracer measurement of reaeration, Part III, Predicting the reaeration capacity of inland streams: Water Pollution Control Federation Journal, v. 48, no. 12, p. 2699-2689.

Tsivoglou, E. C., and Wallace, J. R., 1972, Characterization of stream reaeration capacity: U.S. Environmental Protection Agency Ecological Research Series EPA-R3-72-012, 317 p.

Tuffey, T. J., Hunter, J. V., and Matulewich, V. A., 1974, Zones of nitrification: Water Resources Bulletin, v. 10, no. 3, p. 555-563.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: U.S. Environmental Protection Agency, EPA-440/9-76-023, 256 p.

-----1984, Final environmental impact statement, Master Project facilities plan, expansion of Reno/Sparks joint water pollution control plant: U.S. Environmental Protection Agency, EPA-9-CA-C-32-0114.

U.S. Geological Survey, 1972, Water resources data for Nevada, 1971: U S. Geological Survey Water-Data Report NV-71-1, 239 p.

Van Denburgh, A. S., Lamke, R. D., and Hughes, J. L., 1973, A brief water-resources appraisal of the Truckee River basin, western Nevada: Nevada Division of Water Resources, Reconnaissance Report 57, 122 p.

Van Denburgh, A. S., and Arteaga, F. E., 1985, Revised water budget for the Fernley area, west-central Nevada, 1979: U.S. Geological Survey Open-File Report 84-712, 17 p.

Velz, C. J., 1970, Applied stream sanitation: New York, John Wiley, 619 p.

Vollenweider, R. A., 1968, Scientific fundamentals of the eutrophication of lakes and flowing waters with particular reference to nitrogen and phosphorus as a factor in eutrophication: Paris, Organization for Economic Cooperation and Development, Technical Report DAS/CIS/68, 192 p.

Vollenweider, R. A. (ed), 1974, A manual on methods for measuring primary production in aquatic environments: Oxford, Blackwell Scientific Publications, International Biological Programme Handbook No. 12, p. 95.

Walters Engineering, 1979, Water-rights inventory for potential land application sites for the Reno-Sparks sewage effluent. Reno, Nev., Walter Engineering, 18 p. plus appendices.

Webster, J. R., 1975, Analysis of potassium and calcium dynamics in stream ecosystems on three southern Appalachian watersheds of contrasting vegetation: University of Georgia, Athens, Ph. D. thesis.

Wheeler, S. B., 1967, The Desert Lake: Caldwell, Idaho, Caxton Printers, 133 p.

Williams, G. P., 1978, Hydraulic geometry of river cross sections--Theory of minimum varience: U.S. Geological Survey Water-Supply Paper 1029, 47 p.

Willingham, W. T., 1976, Ammonia toxicity: U.S. Environmental Protection Agency Region VIII, EPA-908/3-76-001, 20 p.

Willis, Robert, Anderson, D. R., and Dracup, J. A., 1976, Transient water quality modeling in streams: Water Resources Bulletin, v. 12, no 1, p. 157-173.

Wilson, J. F., Jr., 1968, Fluorometric procedures for dye tracing: U.S. Geological Survey Techniques of Water-Resources Investigations Book 3, Chapter A12, 31 p.

Yake, W. E., and James, R. K., 1983, Setting effluent ammonia limits to meet in-stream toxicity criteria: Water Pollution Control Federation Journal, v. 55, no. 3, p. 303-309.

Zison, S. W., Haven, K. F., and Mills, W. B., 1978, Rates, constants, and kinetics formulations in surface water quality modeling: Athens, Ga., Environmental Research Laboratory Report, EPA-600/3-78-105, NTIS PB-290-938, 317 p.

METRIC CONVERSION TABLE

Multiply inch-pound unit	by	to obtain metric unit
	Length	
foot (ft)	0.3048	meter (m)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4047	square meter (m^2)
acre	0.4047	hectare
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	0.001233	cubic kilometers (km^3)
	Velocity	
foot per second (ft/s)	0.3048	meter per second (m/s)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
pound per day (lb/day)	0.4556	kilograms per day
	Mass	
pound, avoirdupois (lb)	28.35	gram (g)
tons	0.9072	metric tons (t)
	Specific Conductance	
micromhos per centimeter at 25 °C (micromhos)	1.000	microsiemens per centimeter at 25 °C (microsiemens; μS)

For temperature, degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [(1.8)(°C)] + 32.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), which is derived from a general adjustment of the first-order leveling networks of both the United States and Canada.

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APPENDIX A.--REDUCTION OF SYNOPTIC DATA

INTRODUCTION

Four intensive synoptic studies were conducted in June and August of 1979 and 1980 to obtain water-quality data for model calibration and validation. During these studies, the Truckee River and Canal, North Truckee Drain, Steamboat Creek, and the Reno-Sparks STP outfall were sampled at 2- to 4-hour intervals over 24- to 36-hour periods. These comprehensive field studies resulted in the collection of over 1,000 water samples and over 20,000 individual measurements of water-quality characteristics. Raw data and details of methods used in sampling and analysis during the synoptics are presented by La Camera and others (1985). The purpose of this appendix is to summarize the synoptic data as used in model calibration and verification and to document methods used in data reduction to produce the summary data set.

SAMPLING SITES

Types of data collected in the four synoptics are listed in table A1. During the 1979 studies, McCarran bridge (the start of the modeled reach) was selected as the upstream sampling station. In 1980, two additional upstream sites were added at Verdi and the Mayberry bridge near Reno to provide baseline data on the quality of the River above the Reno-Sparks metropolitan area. A third new river site, Painted Rock bridge, was added to provide data on rates of nitrification and phosphorus uptake in the river between Derby Dam and Wadsworth, and a new canal site, Allendale Check, was added to provide further definition of changes in water quality in the canal between Fernley and Lahontan Reservoir.

Table A1 near here

TABLE A1.—Summary of selected water-quality data used for model calibration and verification

[Headnotes]

Data from intensive water-quality surveys over 24- to 36-hour periods conducted in June and August, 1979 and 1980, to describe water-quality variations in the Truckee River during spring snow-melt and low-flow late summer conditions. Full data published in La Camera and others (1985). Site location data given in table 15 in this report. Data summarized below are mean values for individual samples collected during the indicated sampling period. For sampling and analytical methodology see La Camera and others (1985). Number of samples indicates approximate number of samples averaged for major types of data. Number of samples for any given parameter may be less than indicated due to missing data. Discharge data based on analysis of hourly values at gaging stations or, at non-gaged sites, on instantaneous measurements during the sampling period. Data flagged with "E" are estimates. Discharge estimates based on flow routing between gages or measuring sites and from estimations of intervening diversions and return flows. Estimated dissolved solids based on regression relationships with measured specific conductance (see text). Nutrient data for June 1979 are based on non-filtered samples. Remaining nutrient data are based on filtered samples, and values for organic nitrogen, total phosphorus, and orthophosphorus are estimates derived from regression relationships between data from filtered and non-filtered samples (see text). Nutrient data for June 1979 are based on non-filtered samples. All BOD data are derived from 20-day time-series analyses.

TABLE A1.--Summary of selected water-quality data used for model calibration and verification

JUNE 1979: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature (°C)	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance (µS at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
Site 3.--Truckee River at McCarran Bridge											
6/6 0545-		Mean	375	15.4	650	8.5	100	8.4	90	61	--
6/7 2010	13	Range	335- 385	11.5- 18.5	647- 653	7.4- 9.4	92- 107	--	85- 102	58- 69	--
Site 4.--North Truckee Drain at Kleppe Lane											
6/6 0545-		Mean	40	17.8	650	8.8	108	8.5	337	235	--
6/7 2050	16	Range	35- 40	13.5- 22.0	650- 650	5.0- 12.2	60- 152	--	303- 385	211- 268	--
Site 5.--Steamboat Creek at Kimlick Lane											
6/6 0655-		Mean	50	19.1	650	7.8	99	--	367	255	--
6/7 2050	15	Range	40- 60	14.0- 23.5	647- 652	4.6- 10.3	58- 136	--	335- 413	233- 287	--
Site 6.--Reno-Sparks STP outfall											
6/6 0750-		Mean	25	22.0	650	7.1	94	9.6	524	299	--
6/7 2110	12	Range	0.0- 35	22.0- 22.5	647- 653	5.0- 7.6	66- 101	--	482- 583	275- 333	--
Site 7.--Truckee River at Vista gage											
6/6 0640-		Mean	490	16.8	650	8.3	100	--	159	106	--
6/7 2130	16	Range	420 560	13.0- 20.0	650- 650	7.2- 9.4	81- 115	--	140- 173	95- 114	--
Site 8.--Truckee River at Lockwood Bridge											
6/6 0715-		Mean	470E	17.3	650	8.1	99	8.0	160	107	--
6/7 2215	18	Range	405E 545E	14.5- 19.5	650- 650	7.0- 9.4	88- 113	7.8- 8.3	144- 174	97- 114	--

TABLE A1.—Summary of selected water-quality data used f[illegible]el calibration and verification—Continued

JUNE 1979: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized ammonia (NH_3)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
			Site 3.—Truckee River at McCarran Bridge							
6/6 0545-		Mean	.33	.03	.02	.01	.38	.002	.02	.03
6/7 2010	9	Range	.25-.45	.01-.05	.01-.02	.00-.03	.29-.49	.000-.000	.01-.05	.02-.04
			Site 4.—North Truckee Drain at Kleppe Lane							
6/6 0545-		Mean	.87	.05	.02	.29	1.2	.005	.10	.14
6/7 2050	9	Range	.66-1.2	.04-.06	.02-.04	.23-.39	1.0-1.7	—	.08-.12	.12-.20
			Site 5.—Steamboat Creek at Kimlick Lane							
6/6 0655-		Mean	1.2	.06	.05	.06	1.3	—	.22	.27
6/7 2050	9	Range	.93-1.5	.03-.10	.02-.06	.03-.10	1.1-1.8	—	.19-.25	.24-.30
			Site 6.—Reno-Sparks STP outfall							
6/6 0750-		Mean	.40	13	2.1	.24	15	8.4	4.9	5.8
6/7 2110	10	Range	.00-1.0	10-16	1.1-3.1	.00-.80	13-19	—	3.6-6.1	4.0-7.8
			Site 7.—Truckee River at Vista gage							
6/6 0640-		Mean	.38	.65	.19	.03	1.2	—	.31	.38
6/7 2130	11	Range	.00-.52	.52-.90	.06-.28	.00-.20	.45-1.6		.04-.56	.06-.53
			Site 8.—Truckee River at Lockwood Bridge							
6/6 0715-		Mean	.44	.56	.15	.10	1.3	.018	.30	.36
6/7 2215	12	Range	.00-.72	.11-.84	.04-.27	.02-.38	.42-1.6	.009-.055	.08-.55	.08-.56

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

JUNE 1979: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 3.--Truckee River at McCarran Bridge											
6/6 0545-		Mean	—	—	—	—		2.7	.13	.1	—
6/7 2010	0	Range	—	—	—	—	12	1.9- 3.8	.07- .17	.0- .6	—
Site 4.--North Truckee Drain at Kleppe Lane											
6/6 0545-		Mean	—	—	—	—		4.2	.11	.9	—
6/7 2050	0	Range	—	—	—	—	9	3.5- 5.0	.09- .14	.0- .14	—
Site 5.--Steamboat Creek at Kimlick Lane											
6/6 0655-		Mean	—	—	—	—		7.6	.11	1.6	—
6/7 2050	0	Range	—	—	—	—	10	5.5- 11.0	.06- .15	.0- 3.9	—
Site 6.--Reno-Sparks STP outfall											
6/6 0750-		Mean	—	—	—	—		24.3	.05	59	—
6/7 2110	0	Range	—	—	—	—	8	13.0- 37.0	.03- .07	41- 75	—
Site 7.--Truckee River at Vista gage											
6/6 0640-		Mean	—	—	—	—		2.4	.13	6.4	—
6/7 2130	0	Range	—	—	—	—	10	1.7- 3.1	.08 .22	1.1- 9.3	—
Site 8.--Truckee River at Lockwood Bridge											
6/6 0715-		Mean	—	—	—	—		3.7	.12	5.1	—
6/7 2215	0	Range	—	—	—	—	10	2.8- 4.8	.07- .18	.3- 9.0	—

TABLE A1.—Summary of selected water-quality data used for model calibration and verification—Continued

JUNE 1979: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance (µS at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
					Site 9.—Truckee River at Patrick Bridge						
6/6 0545-		Mean	460E	17.2	650	8.1	98	7.8	163	108	—
6/7 2030	16	Range	405E 520E	15.0 20.5	650- 650	7.0- 9.2	81- 112	7.2- 8.5	148- 184	100- 120	—
					Site 10.—Truckee River at Tracy gage						
6/6 0520-		Mean	470	18.1	653	8.2	100	8.2	168	111	—
6/7 2100	18	Range	410- 520	16.0- 20.5	650- 655	6.3- 9.7	78- 118	7.6 8.7	149- 183	100- 120	—
					Site 11.—Truckee River at Derby Dam						
6/6 0645-		Mean	480E	19.5	652	8.2	103	8.2	169	112	—
6/7 2015	16	Range	420E 530E	16.5- 22.5	650- 655	6.8- 9.6	80- 123	7.7- 8.5	159- 186	106- 121	—
					Site 12.—Truckee Canal at Highway 95-A						
6/6 0635-		Mean	360E	18.3	653	7.1	89	7.7	174	114	—
6/8 1700	25	Range	340E- 380E	17.0- 20.0	650- 655	5.7- 8.0	78- 98	7.7- 7.7	158- 185	105- 121	—

TABLE A1.—Summary of selected water-quality data used [illegible]del calibration and verification—Continued

JUNE 1979; MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized ammonia (NH_3)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
			Site 9.—Truckee River at Patrick Bridge							
6/6 0545-		Mean	.46	.28	.11	.37	1.2	.006	.35	.40
6/7 2030	12	Range	.28-.70	.03-.57	.02-.21	.10-1.1	.87-1.8	.002-.025	.11-.62	.12-.58
			Site 10.—Truckee River at Tracy gage							
6/6 0520-		Mean	.45	.25	.13	.41	1.2	.013	.32	.42
6/7 2100	10	Range	.15-.94	.03-.54	.02-.25	.20-.90	.93-1.7	.011-.038	.15-.44	.32-.52
			Site 11.—Truckee River at Derby Dam							
6/6 0645-		Mean	.57	.21	.18	.49	1.5	.012	.33	.40
6/7 2015	13	Range	.37-.97	.01-.34	.02-.27	.34-.82	1.2-1.8	.004-.042	.17-.41	.21-.51
			Site 12.—Truckee Canal at Highway 95-A							
6/6 0635-		Mean	.55	.09	.14	.49	1.3	.002	.31	.38
6/8 1700	10	Range	.43-.77	.01-.20	.02-.25	.32-.87	.97-1.7	--	.26-.40	.31-.50
			Site 14.—Truckee Canal at Highway 50							
6/7 0650-		Mean	.55	.04	.13	.58	1.3	.002	.30	.35
6/8 2023	8	Range	.43-.61	.02-.05	.06-.18	.42-.70	1.0-1.5	.001-.004	.24-.38	.30-.43

TABLE A1.--Summary of selected water-quality d[illegible]d for model calibration and verification--Continued

JUNE 1979: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 9.--Truckee River at Patrick Bridge											
6/6 0545-		Mean	--	--	--	--		3.8	.14	4.2	--
6/7 2030	0	Range	--	--	--	--	11	2.2- 4.7	.10- .19	2.6- 6.8	--
Site 10.--Truckee River at Tracy gage											
6/6 0520-		Mean	--	--	--	--		3.9	.11	4.5	--
6/7 2100	0	Range	--	--	--	--	11	3.2- 4.7	.07- .15	1.7- 9.3	--
Site 11.--Truckee River at Derby Dam											
6/6 0645-		Mean	--	--	--	--		3.8	.12	3.2	--
6/7 2015	0	Range	--	--	--	--	10	3.1- 5.2	.08- .17	1.4- 6.2	--
Site 12.--Truckee Canal at Highway 95-A											
6/6 0635-		Mean	--	--	--	--		3.4	.11	2.5	--
6/8 1700	0	Range	--	--	--	--	15	2.6- 4.3	.05- .16	.0- 6.4	--
Site 14.--Truckee Canal at Highway 50											
6/7 0650-		Mean	--	--	--	--		4.1	.15	1.7	--
6/8 2023	0	Range	--	--	--	--	10	3.2- 5.4	.09- .20	.0- 3.2	--

TABLE A1.--Summary of selected water-quality [illegible] used for model calibration and verification--Continued

JUNE 1979: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance (µS at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
Site 14.--Truckee Canal at Highway 50											
6/7 0650-		Mean	290E	18.8	655	7.8	96	8.1	166	110	—
6/8 2023	16	Range	300E- 280E	17.0- 20.5	655- 655	7.2- 8.1	87- 104	8.0- 8.3	157- 176	105 116	—
Site 15.—Truckee River at gage below Derby Dam											
6/6 0800-		Mean	90	19.2	660	8.1	101	7.9	169	112	—
6/7 2045	15	Range	65- 110	15.0- 22.5	660- 660	7.1- 9.0	86- 113	7.9- 7.9	152- 182	102- 119	—
Site 17.—Truckee River at Wadsworth Bridge											
6/6 0530-		Mean	75	20.0	663	—	—	9.4	174	114	—
6/7 1915	17	Range	60- 95	15.0- 24.0	660- 665	—	—	7.6- 10.4	152- 190	102- 124	—
Site 18.—Truckee River at Dead Ox Wash											
6/6 0700		Mean	90E	19.3	664	—	—	9.2	288	179	—
6/7 2015	18	Range	75E 110E	12.5- 23.0	660- 665	—	--	8.9- 9.6	265- 311	166- 192	—
Site 19.—Truckee River at Nixon Bridge											
6/7 0540-		Mean	75E	18.9	666	8.4	102	—	401	244	—
6/8 2010	16	Range	50E- 85E-	13.5- 24.0	665- 670	7.4- 9.0	82- 116	—	378- 443	231- 268	—
Site 20.—Truckee River at Marble Bluff Dam											
6/7 0640-		Mean	76E	17.9	666	7.5	91	—	400	243	—
6/8 2010	12	Range	50E- 85E	15.0- 20.0	665- 670	6.3- 9.0	75- 108	—	369- 420	225- 254	—

TABLE A1.--Summary of selected water-quality data used fo[illegible] calibration and verification--Continued

JUNE 1979: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized ammonia (NH_3)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
Site 15.--Truckee River at gage below Derby Dam										
6/6 0800-		Mean	.56	.16	.13	.53	1.4	.005	.33	.38
6/7 2045	10	Range	.40- .74	.01- .23	.02- .25	.35- .72	1.3- 1.6	—	.24- .41	.29- .47
Site 17.—Truckee River at Wadsworth Bridge										
6/6 0530-		Mean	.56	.05	.08	.05	.73	.025	.25	.32
6/7 1915	13	Range	.37- .78	.01- .12	.04- .14	.00- .22	.48- 1.0	.001- .059	.14- .29	.19- .37
Site 18.—Truckee River at Dead Ox Wash										
6/6 0700		Mean	.56	.04	.01	.01	.62	.015	.16	.23
6/7 2015	13	Range	.42- .72	.01- .08	.01- .02	.00- .02	.47- .78	.003 .050	.14- .19	.18- .29
Site 19.—Truckee River at Nixon Bridge										
6/7 0540-		Mean	.53	.03	.02	.00	.59	—	.15	.19
6/8 2010	9	Range	.37- .72	.01- .06	.01- .02	.00- .01	.43- .74	—	.14- .17	.16- .20
Site 20.—Truckee River at Marble Bluff Dam										
6/7 0640-		Mean	.57	.11	.02	.00	.70	—	.18	.22
6/8 2010	10	Range	.46- .73	.06- .16	.01- .02	.00- .02	.59- .89	—	.16- .20	.20- .25

TABLE A1.—Summary of selected water-quality d[illegible]ed for model calibration and verification—Continued

JUNE 1979: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll *a*(ug/L)	Phytoplankton: Chlorophyll *b*(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 15.—Truckee River at gage below Derby Dam											
6/6 0800-		Mean	—	—	—	—		3.5	.12	3.6	—
6/7 2045	0	Range	—	—	—	—	10	2.9- 5.0	.10- .18	.0- 6.8	—
Site 17.—Truckee River at Wadsworth Bridge											
6/6 0530-		Mean	—	—	—	—		5.1	.11	.7	—
6/7 1915	0	Range	—	—	—	—	9	4.8- 5.9	.08- .20	.0- 2.6	—
Site 18.—Truckee River at Dead Ox Wash											
6/6 0700-		Mean	—	—	—	—		6.7	.13	.7	—
6/7 2015	0	Range	—	—	—	—	10	4.7- 9.6	.05- .22	.0- 3.0	—
Site 19.—Truckee River at Nixon Bridge											
6/7 0540-		Mean	—	—	—	—		5.0	.16	.6	—
6/8 2010	0	Range	—	—	—	—	9	4.0- 6.8	.10- .21	.0- 3.5	—
Site 20.—Truckee River at Marble Bluff Dam											
6/7 0640-		Mean	—	—	—	—		5.2	.17	.2	—
6/8 2010	0	Range	—	—	—	—	8	4.4- 6.2	.13- .22	.0- 2.3	—

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

AUGUST 1979: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature (°C)	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance (µS at 25 °C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
Site 3.--Truckee River at McCarran Bridge											
8/8 0800-		Mean	160	20.3	653	7.6	98	8.3	127	86	--
8/9 0800	13	Range	150- 175	17- 23.5	651- 654	6.4- 9.2	84- 123	7.5- 9.1	116- 143	79- 97	--
Site 4.--North Truckee Drain at Kleppe Lane											
8/8 0900-		Mean	50	19.9	652	7.0	90	8.1	359	250	--
8/9 0640	12	Range	49- 52	17- 22.5	650- 653	4.4- 11.0	56- 147	7.6- 8.9	328- 396	228- 276	--
Site 5.--Steamboat Creek at Kimlick Lane											
8/8 0815-		Mean	40	22.2	652	5.8	78	8.0	279	194	--
8/9 0600	11	Range	31- 42	18.5- 25.5	651- 654	4.0- 8.2	49- 115	7.7- 8.3	263- 294	183- 205	--
Site 6.--Reno-Sparks STP outfall											
8/8 0900-		Mean	30	24.8	652	6.6	92	7.8	509	291	--
8/9 0640	11	Range	23- 34	24.0- 26.0	651- 654	6.3- 6.8	90- 94	7.7- 8.0	490- 530	280- 303	--
Site 7.--Truckee River at Vista gage											
8/8 0825-		Mean	275	21.0	653	6.6	86.0	7.9	244	154	--
8/9 0755	13	Range	260- 290	18.5- 24.5	651- 654	5.4- 8.2	67.0- 114.0	7.4- 8.4	222- 253	142- 159	--
Site 8.--Truckee River at Lockwood Bridge											
8/8 0900-		Mean	255E-	21.4	653	6.0	79	7.5	249	157	--
8/9 0830	13	Range	240E- 270E	19.0- 24.0	651- 655	4.5- 7.8	58- 104	7.1- 8.0	230- 261	146- 164	--

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

AUGUST 1979: MAJOR NUTRIENTS

...mpling ...riod	No. of samples	Statistic	Nitrogen (mg/L as N)						Phosphorus (mg/L as P)	
			Organic	Ammonia (NH_3)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized Ammonia (NH_4)	Ortho- (PO_4)	Total
Site 9.--Truckee River at Patrick Bridge										
/8 0830-		Mean	.70	.58	.28	.77	2.3	.020	.91	.94
/9 0555	10	Range	.46- .90	.33- .94	.21- .33	.68- .82	1.7- 3.0	.007 .075	.44- 1.4	.50- 1.4
Site 10.--Truckee River at Clark bridge										
/8 0930-		Mean	.64	.21	.26	1.1	2.2	.007	.74	.85
/9 0740	9	Range	.45- 1.1	.10- .32	.16- .33	.92- 1.4	1.6- 3.2	.001 .036	.47- 1.1	.60- 1.2
Site 11.--Truckee River at Derby Dam										
/8 2235-		Mean	.68	.11	.19	1.1	2.1	.006	.69	.78
/10 0800	9	Range	.48- .92	.01- .28	.14- .27	.95- 1.2	1.6- 2.7	.001- .013	.52- .98	.58- 1.1
Site 12.--Truckee Canal at Highway 95-A										
/9 1000-		Mean	.70	.06	.14	1.1	2.0	.006	.75	.82
/10 0815	10	Range	.52- 1.1	.01- .12	.05- .19	.64- 1.3	1.2- 2.7	.001 .007	.38- .99	.53- 1.0
Site 14.--Truckee Canal at Highway 50										
/9 2035		Mean	.86	.01	.12	.76	1.8	.003	.67	.79
8/10 2020	7	Range	.51- 1.4	.01- .01	.05- .23	.68- .91	1.2- 2.6	.003 .005	.53- .82	.62- .95

TABLE A1.--Summary of selected water-qual[illegible] used for model calibration and verification—Continued

AUGUST 1979: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance (µS at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
Site 9.--Truckee River at Patrick Bridge											
8/8 0830-		Mean	260E	21.7	655	6.6	88	7.9	243	154	—
8/9 0555	10	Range	230E 280E	20- 24	653- 656	4.5- 9.0	57- 125	7.5- 8.6	229- 258	146- 162	—
Site 10.--Truckee River at Clark bridge											
8/8 0930-		Mean	260E	22.1	655	6.3	84	7.9	251	158	—
8/9 0740	10	Range	230E- 270E	20.0- 24.0	654- 656	3.8- 9.1	48- 123	7.5- 8.4	241- 268	153- 168	—
Site 11.--Truckee River at Derby Dam											
8/8 2235-		Mean	260E	22.8	656	6.3	86	8.1	237	150	—
8/10 0800	16	Range	225E- 280E	21.0- 25.0	650- 658	4.4- 10.2	58- 144	7.7- 8.8	223- 248	142- 157	—
Site 12.--Truckee Canal at Highway 95-A											
8/9 1000-		Mean	180E	23.6	657	7.5	101	8.3	245	155	—
8/10 0815	12	Range	165E- 195E	23.0- 24.5	655- 662	5.9- 9.0	80- 120	8.1- 8.4	231- 258	147- 162	—
Site 14.--Truckee Canal at Highway 50											
8/9 2035-		Mean	60E	23.8	658	10.1	139	9.0	246	155	—
8/10 2020	12	Range	50E- 85E	21.0- 28.0	656- 660	7.5- 14.1	100- 206	8.8- 9.3	234- 261	149- 164	—

TABLE A1.--Summary of selected water-quality data used f[illegible]l calibration and verification--Continued

AUGUST 1979: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll *a*(ug/L)	Phytoplankton: Chlorophyll *b*(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand, Carbonaceous: No. of Samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 9.--Truckee River at Patrick Bridge											
8/8 0830-		Mean	—	1.07	.13	—		5.5	.13	—	—
8/9 0555	10	Range	—	.53- 2.12	.02- .21	—	5	4.4- 6.2	.12- .15	—	—
Site 10.--Truckee River at Clark bridge											
8/8 0930-		Mean	48.0	1.43	.30	—	6	5.3	.16	—	—
8/9 0740	10	Range	43.0- 53.0	.21- 4.07	.02- .84	—		3.9- 7.1	.14- .17	—	—
Site 11.--Truckee River at Derby Dam											
8/8 2235-		Mean	48.5	1.36	.21	1033		4.4	.11	3.3	—
8/10 0800	8	Range	40.0- 57.0	.65- 2.06	.05- .30	712- 1175	7	3.8- 5.4	.07- .18	.6- 7.2	—
Site 12.--Truckee Canal at Highway 95-A											
8/9 1000-		Mean	20.0	1.86	.24	155		4.4	.11	—	—
8/10 0815	9	Range	20.0- 20.0	.53- 3.99	.04- .52	144- 162	6	4.0- 4.9	.09- .15	—	—
Site 14.--Truckee Canal at Highway 50											
8/9 2035-		Mean	29.5	17.7	2.67	12,053		6.1	.12	—	—
8/10 2020	7	Range	23.0- 36.0	9.98- 38.9	1.55- 5.69	7900 17,453	5	4.6- 7.3	.09- .15	—	—

TABLE A1.--Summary of selected water-quality [illegible] used for model calibration and verification--Continued

AUGUST 1979: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance (µS at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
					Site 15.--Truckee River at gage below Derby Dam						
8/8 2055-		Mean	40.0	23.2	656	6.6	89	8.1	238	151	—
8/10 0830	17	Range	40.0- 40.0	21.0- 25.0	655- 658	5.5- 8.2	73- 114	7.7- 8.7	225- 246	144- 155	—
					Site 17.--Truckee River at Wadsworth Bridge						
8/9 0900-		Mean	31.0	23.0	660	6.9	94	8.4	260	163	—
8/10 0900	12	Range	25.0- 45.0	21.0- 26.0	657- 662	3.4- 11.8	45- 166	7.8- 9.3	249- 278	157- 174	—
					Site 18.--Truckee River at Dead Ox Wash						
8/9 0945-		Mean	35E	24.5	661	7.2	100	8.5	455	274	—
8/10 0800	12	Range	30E- 40E	20.0- 29.0	660- 662	4.6- 10.4	58- 153	8.1- 8.9	431- 477	261- 287	—
					Site 19.--Truckee River at Nixon Bridge						
8/9 1005-		Mean	30E	24.9	663	7.7	107	8.5	607	361	—
8/10 0820	12	Range	25E- 35E	21.0- 30.0	662- 664	5.2- 10.4	68- 158	8.0- 8.9	564- 649	336- 385	— —
					Site 20.--Truckee River at Marble Bluff Dam						
8/9 1030-		Mean	31E	22.8	664	8.2	109	9.0	634	376	—
8/10 1000	12	Range	25E- 35E	21.5- 24.5	663- 665	6.6- 10.2	87- 140	8.8- 9.2	577- 664	344- 393	— —

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

AUGUST 1979: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_3)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized Ammonia (NH_4)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
			Site 15.--Truckee River at gage below Derby Dam							
8/8 2055-		Mean	.58	.12	.17	1.1	2.0	.007	.72	.78
8/10 0830	9	Range	.42- .75	.06- .23	.13- .23	.97- 1.2	1.6- 2.4	.002 .013	.51- 1.1	.56- 1.1
			Site 17.--Truckee River at Wadsworth Bridge							
8/9 0900-		Mean	.52	.02	.01	.02	.57	.002	.38	.48
8/10 0900	9	Range	.36- .70	.01- .04	.01- .01	.00- .08	.38 .83	.000- .019	.35- .44	.45- .50
			Site 18.--Truckee River at Dead Ox Wash							
8/9 0945-		Mean	.40	.02	.01	.00	.43	.003	.23	.25
8/10 0800	6	Range	.27- .54	.01- .07	.01- .01	.00- .00	.29- .62	.001- .007	.22- .24	.22- .29
			Site 19.--Truckee River at Nixon Bridge							
8/9 1005-		Mean	.66	.01	.01	.01	.69	.002	.14	.15
8/10 0820	6	Range	.38- .99	.01- .01	.01- .01	.00- .03	.40- 1.0	.001- .004	.11- .20	.12- .19
			Site 20.--Truckee River at Marble Bluff Dam							
8/9 1030-		Mean	.62	.02	.01	.00	.65	.007	.23	.28
8/10 1000	6	Range	.54- .74	.01- .03	.01- .01	.00- .00	.56- .78	.002 .012	.20- .25	.24- .29

TABLE A1.—Summary of selected water-quality data used f[illegible] [illegible]del calibration and verification—Continued

AUGUST 1979: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand, Carbonaceous: No. of Samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
			Site 15.—Truckee River at gage below Derby Dam								
8/8 2055-		Mean	46.0	1.02	.20	—		3.8	.12	—	—
8/10 0830	10	Range	44.0- 48.0	.26- 2.03	.02- .33	—	8	2.9- 4.5	.08- .14	—	—
			Site 17.—Truckee River at Wadsworth Bridge								
8/9 0900-		Mean	42.0	1.30	.32	—		4.1	.11	—	—
8/10 0900	7	Range	42.0- 42.0	.45- 4.20	.04- 1.23	—	5	2.9- 5.4	.06- .16	—	—
			Site 18.—Truckee River at Dead Ox Wash								
8/9 0945-		Mean	—	1.46	.20	—		3.7	.13	—	—
8/10 0800	6	Range	—	.53- 2.31	.10 .30	—	4	3.1- 4.3	.04- .17	—	—
			Site 19.—Truckee River at Nixon Bridge								
8/9 1005-		Mean	6.35	2.22	.36	—		3.6	.15	—	—
8/10 0820	6	Range	3.10- 9.60	1.50- 2.76	.20- .53	—	6	2.8- 4.3	.08- .21	—	—
			Site 20.—Truckee River at Marble Bluff Dam								
8/9 1030-		Mean	3.35	6.45	.37	4819		5.9	.18	—	—
8/10 1000	6	Range	2.80- 3.90	4.20- 9.71	.28- .49	3351- 7262	5	3.6- 8.1	.10- .23	—	—

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

JUNE 1980: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen Concentration (mg/L)	Dissolved oxygen Saturation (percent)	pH (units)	Specific conductance ([illegible] at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
Site 1.--Truckee River at Verdi											
6/5 0930-		Mean	1590E	9.6	637	9.5	98	7.5	64	43	8.2
6/6 1305	13	Range	--	8.5- 11.0	636- 638	9.3- 9.9	100- 104	7.2- 7.9	61- 66	41- 45	5.0- 11
Site 2.--Truckee River at Mayberry Bridge											
6/5 1050-		Mean	1910E	9.9	643	9.6	100	7.6	66	45	8.3
6/6 1205	12	Range	--	9.0- 11.5	642- 644	9.2- 9.9	98- 103	7.3- 7.9	62- 69	42- 47	5.0- 11
Site 3.--Truckee River at McCarran Bridge											
6/5 1000-		Mean	1780	10.3	648	9.7	101	7.9	70	47	12
6/6 1315	12	Range	1740- 1950	8.0- 12.5	647- 649	9.2- 10.4	93- 107	7.6- 8.2	64- 72	43- 49	8.0- 16
Site 4.--North Truckee Drain at Kleppe Lane											
6/5 1020-		Mean	50	12.3	647	8.8	98	8.2	381	265	45
6/6 1135	11	Range	45- 50	9.5- 17.0	645- 650	7.2- 10.3	77- 120	7.8- 8.4	344- 406	239- 283	30- 61
Site 5.--Steamboat Creek at Kimlick Lane											
6/5 1145-		Mean	145	13.1	648	7.9	88	8.0	485	337	45
6/6 1300	11	Range	125- 165	10.0- 17.0	647- 649	6.7- 8.8	71- 105	7.8- 8.3	445- 527	310- 367	35- 53

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

JUNE 1980: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized Ammonia (NH_3)	Phosphorus (mg/L as P) Ortho (PO_4)	Total
			Site 1.--Truckee River at Verdi							
6/5 0930-		Mean	.50	.09	.00	.07	.66	.001	.02	.02
6/6 1305	7	Range	.32- .88	.04- .17	.00- .01	.03- .10	.39- 1.2	.000- .001	.01- .03	.01- .03
			Site 2.--Truckee River at Mayberry Bridge							
6/5 1050-		Mean	.48	.09	.00	.08	.65	.001	.02	.01
6/6 1205	7	Range	.32- .78	.06- .10	.00- .01	.03- .14	.41- .78	.000- .001	.01- .03	.00- .02
			Site 3.--Truckee River at McCarran Bridge							
6/5 1000-		Mean	.51	.14	.00	.24	.89	.002	.04	.03
6/6 1315	6	Range	.24- .69	.12- .17	.00- .01	.11- .36	.47- 1.2	.001 .003	.01- .08	.01- .07
			Site 4.--North Truckee Drain at Kleppe Lane							
6/5 1020-		Mean	1.2	.12	.01	.44	1.8	.004	.09	.11
6/6 1135	7	Range	.80- 1.7	.00- .23	.00- .01	.26- .62	1.1- 2.5	.000- .017	.05- .12	.08- .15
			Site 5.--Steamboat Creek at Kimlick Lane							
6/5 1145-		Mean	1.4	.15	.01	.19	1.8	.003	.18	.20
6/6 1300	6	Range	1.2- 1.6	.08- .26	.00- .02	.13- .25	1.4- 2.2	.002 .007	.16- .20	.15- .22

TABLE A1.--Summary of selected water-quality data used for[illegible] calibration and verification--Continued

JUNE 1980: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 1.--Truckee River at Verdi											
6/5 0930-		Mean	.80	.81	.19	521		1.7	.12	.2	--
6/6 1305	2	Range	--	.64- .98	.13- .25	407- 635	7	.90- 2.3	.09- .15	.0- 1.2	--
Site 2.--Truckee River at Mayberry Bridge											
6/5 1050-		Mean	.70	--	--	516		1.9	.08	.1	--
6/6 1205	1	Range	.60- .80	--	--	492- 539	7	1.6- 2.2	.06- .12	.0- .6	--
Site 3.--Truckee River at McCarran Bridge											
6/5 1000-		Mean	.50	1.43	.27	413		1.9	.09	.4	--
6/6 1315	1	Range	--	--	--	--	7	1.4- 2.9	.07- .13	.0- 1.2	-- --
Site 4.--North Truckee Drain at Kleppe Lane											
6/5 1020-		Mean	13.0	1.29	.12	1760		4.6	.09	1.3	--
6/6 1135	2	Range	--	.85- 1.74	.11- .14	1450- 2070	7	3.7- 5.1	.07- .11	.8- 2.1	-- --
Site 5.--Steamboat Creek at Kimlick Lane											
6/5 1145-		Mean	5.00	1.69	.11	1420		5.7	.09	1.8	--
6/6 1300	3	Range	4.40- 5.60	.95 2.20	.08- .16	1250- 1590	6	4.6 6.6	.07 .11	1.0- 2.7	-- --

TABLE A1.--Summary of selected water-quality data used fo[illegible]l calibration and verification--Continued

JUNE 1980: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance (µS at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
					Site 6.--Reno-Sparks STP outfall						
6/5 1130-		Mean	45	18.6	648	8.6	107	7.7	498	284	13
6/6 1020	11	Range	45- 45	17.0- 20.0	647- 649	8.3- 9.0	102- 112	7.5- 7.9	472- 527	270- 301	10- 20
					Site 7.--Truckee River at Vista gage						
6/5 1125-		Mean	2010	10.9	647	9.5	101	7.9	115	81	13
6/6 1215	12	Range	1960- 2130	9.0- 12.5	646- 649	8.9- 9.8	95- 108	7.5- 8.2	106- 123	76- 85	10- 19
					Site 8.--Truckee River at Lockwood Bridge						
6/5 1010-		Mean	1990E	10.7	649	9.3	97	7.6	112	79	15
6/6 1200	13	Range	1940E- 2060E	9.0- 12.0	647- 653	8.6- 9.8	92- 103	7.5- 7.8	102- 121	74- 84	12- 21
					Site 9.--Truckee River at Patrick Bridge						
6/5 1050-		Mean	1990E	10.7	650	9.2	96	7.6	112	79	17
6/6 1300	13	Range	1940E 2060E	10.0- 11.5	648- 654	8.7- 9.7	93- 103	7.5- 7.7	105- 119	75- 83	10- 23
					Site 10.--Truckee River at Tracy gage						
6/5 1000-		Mean	2015	10.8	651	9.1	96	7.2	121	84	14
6/6 1210	14	Range	1940- 2060	9.5- 12.0	650- 655	8.7- 9.9	91- 106	7.0- 7.3	117- 125	82- 87	12- 15

Al.--Summary of selected water-quality data used for model [illegible]tion and verification--Continued

JUNE 1980: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N)						Phosphorus (mg/L as P)	
			Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized Ammonia (NH_3)	Ortho- (PO_4)	Total
Site 6.--Reno-Sparks STP outfall										
6/5 1130-		Mean	6E	14	.28	.23	22	.25	4.5	5.7
6/6 1020	5	Range	—	12- 16	.19- .42	.03- .51	17- 26	.24 .35	3.6- 6.0	3.7- 8.3
Site 7.--Truckee River at Vista gage										
6/5 1125		Mean	.40	.31	.01	.24	.97	.005	.12	.10
6/6 1215	4	Range	.18- .78	.22- .42	.00- .02	.10- .33	.50- 1.6	.001 .009	.09- .15	.07- .12
Site 8.--Truckee River at Lockwood gage										
6/5 1010		Mean	.42	.33	.01	.20	.96	.003	.13	.12
6/6 1200	7	Range	.36- .44	.26- .39	.01- .01	.13- .26	.76- 1.1	.002 .004	.11- .14	.09- .16
Site 9.--Truckee River at Patrick Bridge										
6/5 1050-		Mean	.60	.26	.01	.21	1.1	.002	.11	.11
6/6 1300	6	Range	.40- .75	.15- .36	.01- .02	.10- .45	.67- 1.6	.001 .003	.08- .14	.07- .13
Site 10.--Truckee River at Tracy gage										
6/5 1000-		Mean	.63	.26	.02	.23	1.1	.001	.12	.11
6/6 1210	6	Range	.08- .88	.14- .32	.01- .02	.11- .47	.34- 1.7	.000- .001	.04- .15	.08- .13

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

JUNE 1980: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: Carbonaceous: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 6.--Reno-Sparks STP outfall											
6/5 1130-		Mean	123	--	--	--		34.9	.08	53	--
6/6 1020	1	Range	--	--	--	--	6	30.5 43.4	.06 .10	32- 67	-- --
Site 7.--Truckee River at Vista gage											
6/5 1125-		Mean	9.9	.57	.10	471		2.5	.10	--	--
6/6 1215	2	Range	7.80- 12.0	--	--	458- 483		2.0- 2.7	.07- .13	--	--
Site 8.--Truckee River at Lockwood Bridge											
6/5 1010-		Mean	9.15	1.28	.20	476		2.4	.11	1.7	--
6/6 1200	1	Range	9.10- 9.20	--	--	355- 596	6	2.0- 3.0	.08- .15	.9- 2.5	-- --
Site 9.--Truckee River at Patrick Bridge											
6/5 1050-		Mean	--	--	--	512	7	2.6	.10	--	--
6/6 1300	0	Range	--	--	--	--		2.4- 3.1	.06- .18	--	--
Site 10.--Truckee River at Tracy gage											
6/5 1000-		Mean	--	--	--	539		3.0	.12	--	--
6/6 1210	2	Range	--	--	--	412- 665	7	2.2- 5.0	.08- .14	--	--

TABLE A1.--Summary of selected water-quality data used [illegible] model calibration and verification--Continued

JUNE 1980: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance [illegible] at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
Site 11.--Truckee River at Derby Dam											
6/5 1100-		Mean	2040E	10.9	652	9.0	95	7.2	121	84	19
6/6 1300	12	Range	1990E 2110E	10.0- 13.0	650- 655	8.6- 9.4	89- 103	6.8- 7.4	115- 126	81- 87	15- 22
Site 12.--Truckee Canal at Highway 95-A											
6/5 1000-		Mean	115E	11.6	655	8.5	90	7.8	129	89	16
6/6 1200	13	Range	110E- 115E	10.0- 12.5	653- 656	8.2- 8.8	88- 95	7.7- 7.9	121- 142	84- 96	10- 20
Site 13.--Truckee Canal at Allendale Check											
6/5 1005-		Mean	100E	12.8	653	9.0	99	7.7	128	88	16
6/6 1005	11	Range	90E- 105E	11.5- 14.0	652- 654	8.8- 9.1	94- 103	7.6- 7.8	124- 134	86- 92	14- 17
Site 14.--Truckee Canal at Highway 50											
6/5 1125-		Mean	90E	13.7	653	9.7	110	8.3	130	89	15
6/6 1200	10	Range	80E 95E	12.0- 15.0	652- 655	9.2- 10.2	99- 119	8.1- 8.5	125- 137	87- 93	14- 17
Site 15.--Truckee River at gage below Derby Dam											
6/5 1130-		Mean	1910	10.9	652	9.2	98	7.2	124	86	—
6/6 1300	13	Range	1860- 1950	9.5- 13.0	650- 655	9.0- 9.7	93- 107	7.1- 7.4	117- 131	82- 90	--

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

JUNE 1980: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized Ammonia (NH_3)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
			Site 11.--Truckee River at Derby Dam							
6/5 1100-		Mean	.64	.26	.02	.28	1.2	.001	.10	.11
6/6 1300	6	Range	.46- .90	.22- .34	.01- .03	.12- .60	.81- 1.9	--	.06- .14	.08- .12
			Site 12.--Truckee Canal at Highway 95-A							
6/5 1000-		Mean	.60	.19	.02	.24	1.0	.002	.11	.10
6/6 1200	5	Range	.32- .78	.12- .26	.02- .03	.16- .32	.62- 1.4	.002 .003	.09- .12	.09- .13
			Site 13.--Truckee Canal at Allendale Check							
6/5 1005-		Mean	.54	.19	.02	.30	1.1	.002	.12	.10
6/6 1005	4	Range	.33- .90	.13- .25	.01- .03	.20- .38	.67- 1.6	.001 .002	.10- .13	.09- .11
			Site 14.--Truckee Canal at Highway 50							
6/5 1125		Mean	.51	.08	.02	.31	.92	.004	.12	.11
6/6 1200	5	Range	.39- .62	.04- .12	.01- .03	.26- .35	.70- 1.1	.001 .008	.11- .16	.09- .15
			Site 15.--Truckee River at gage below Derby Dam							
6/5 1130-		Mean	--	--	--	--	--	--	--	--
6/6 1300	0	Range	--	--	--	--	--	--	--	--

TABLE A1.--Summary of selected water-quality data used for calibration and verification--Continued

JUNE 1980: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 11.--Truckee River at Derby Dam											
6/5 1100-		Mean	10.5	.80	.12	502		2.8	.11	1.2	--
6/6 1300	2	Range	10.0- 11.0	.11- 1.50	.08- .17	478- 526	7	2.4- 3.6	.09- .13	.4- 2.4	--
Site 12.--Truckee Canal at Highway 95-A											
6/5 1000-		Mean	12.5	.79	.10	363		2.8	.09	--	--
6/6 1200	2	Range	12.0- 13.0	--	--	348- 377	7	2.1- 3.9	.06- .12	--	--
Site 13.--Truckee Canal at Allendale Check											
6/5 1005-		Mean	--	--	--	582		2.1	.10	--	--
6/6 1005	1	Range	--	--	--	582- 582	6	1.8- 2.7	.08- .12	--	--
Site 14.--Truckee Canal at Highway 50											
6/5 1125-		Mean	10.5	1.11	.12	1224		2.3	.12	.46	--
6/6 1200	2	Range	10.0- 11.0	.51- 1.71	.09- .15	1006- 1441	6	2.1- 2.6	.10- .15	.0- 1.0	--
Site 15.--Truckee River at gage below Derby Dam											
6/5 1130-		Mean	--	--	--	--		--	--	--	--
6/6 1300	0	Range	--	--	--	--	0	--	--	--	--

TABLE A1.--Summary of selected water-quality data used [illegible] model calibration and verification--Continued

JUNE 1980: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance ([illegible] at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
Site 16.--Truckee River at Painted Rock Bridge											
6/5 1055-		Mean	1940E	11.2	654	9.2	98	7.6	128	88	27
6/6 1235	9	Range	1870E- 1960E	10.0- 12.5	652- 657	8.9- 9.5	93- 102	7.3- 8.0	122- 134	85- 92	15- 39
Site 17.--Truckee River at Wadsworth Bridge											
6/5 1000-		Mean	1990	11.7	656	9.3	98	7.6	127	88	31
6/6 1200	11	Range	1940- 2060	10.5- 13.0	654- 659	9.2- 9.6	95- 101	7.3- 7.7	111- 148	79- 100	22- 41
Site 18.--Truckee River at Dead Ox Wash											
6/5 1205-		Mean	2040E	11.8	659	9.1	97	7.8	129	89	29
6/6 1200	11	Range	1980E- 2090E	9.5- 14.0	658- 666	8.9- 9.4	92- 103	7.4- 8.0	118- 139	83- 95	21- 36
Site 19.--Truckee River at Nixon Bridge											
6/5 1000-		Mean	2050E	11.8	660	9.3	99	7.8	141	96	36
6/6 1150	14	Range	1990E- 2150E	10.0- 14.0	659- 661	8.9- 9.7	95- 102	7.7- 7.9	135- 145	92- 98	27- 52
Site 20.--Truckee River at Marble Bluff Dam											
6/5 1050-		Mean	2060E	11.9	660	9.1	97	7.7	144	97	32
6/6 1230	14	Range	1990E- 2100E	9.0- 15.0	659- 662	8.6- 9.4	91- 102	7.6- 7.8	137- 149	93- 100	27- 48

Table A1.--Summary of selected water-quality data used for model calibration and verification--Continued

JUNE 1980: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized Ammonia (NH_3)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
			Site 16.--Truckee River at Painted Rock Bridge							
6/5 1055-		Mean	.48	.20	.02	.30	1.0	.002	.13	.12
6/6 1235	7	Range	.36- .63	.13- .23	.01- .03	.18- .48	.68- 1.4	.001- .002	.12- .15	.10- .14
			Site 17.--Truckee River at Wadsworth Bridge							
6/5 1000-		Mean	.62	.20	.03	.27	1.1	.002	.13	.13
6/6 1200	6	Range	.34- .96	.13- .26	.01- .04	.18- .43	.66- 1.7	.001- .003	.09- .21	.09- .21
			Site 18.--Truckee River at Dead Ox Wash							
6/5 1205-		Mean	.40	.13	.02	.30	.85	.002	.12	.11
6/6 1200	6	Range	.20- .60	.10- .18	.01- .03	.20- .52	.51- 1.3	.001- .003	.09- .15	.09- .13
			Site 19.--Truckee River at Nixon Bridge							
6/5 1000-		Mean	.45	.08	.02	.25	.80	.001	.11	.11
6/6 1150	6	Range	.30- .72	.04- .13	.02- .03	.16- .31	.52- 1.2	.000- .002	.06- .15	.09- .15
			Site 20.--Truckee River at Marble Bluff Dam							
6/5 1050-		Mean	.32	.21	.03	.43	.99	.002	.12	.11
6/6 1230	5	Range	.24- .51	.10- .29	.02- .03	.24- .87	.60- 1.7	.001 .003	.09- .15	.09- .14

TABLE A1.--Summary of selected water-quality data used f[illegible]el calibration and verification--Continued

JUNE 1980: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand, Carbonaceous: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 16.--Truckee River at Painted Rock Bridge											
6/5 1055-		Mean	18.5	1.02	.15	449		2.7	.11	1.1	--
6/6 1235	2	Range	17.0- 20.0	.58- 1.50	.09- .18	382- 516	6	2.1 3.2	.08- .15	.7- 1.6	--
Site 17.--Truckee River at Wadsworth Bridge											
6/5 1000-		Mean	10.85	1.13	.20	564		2.5	.12	1.1	--
6/6 1200	3	Range	9.70- 12.0	.93- 1.47	.15- .25	462- 666	6	2.1- 2.8	.09- .16	.6- 1.8	--
Site 18.--Truckee River at Dead Ox Wash											
6/5 1205-		Mean	--	--	--	387		2.7	.12	--	--
6/6 1200	2	Range	--	--	--	348- 426	7	2.0- 3.8	.09- .13	--	--
Site 19.--Truckee River at Nixon Bridge											
6/5 1000-	1	Mean	10.5	1.23	.20	401		2.9	.10	.5	--
6/6 1150		Range	10.0- 11.0	1.23 1.23	.20- .20	360- 442	7	2.1- 3.6	.06- .12	.0- 1.3	--
Site 20.--Truckee River at Marble Bluff Dam											
6/5 1050-		Mean	15.0	.73	.09	321		2.6	.08	.3	--
6/6 1230	2	Range	11.0- 19.0	.69- .77	.09- .09	311- 331	7	2.2- 3.0	.06- .10	.0- .5	--

TABLE A1.--Summary of selected water-quality data used f[illegible]el calibration and verification--Continued

AUGUST 1980: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen Concentration (mg/L)	Dissolved oxygen Saturation (percent)	pH (units)	Specific conductance ([illegible] at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
					Site 1.--Truckee River at Verdi						
8/13 1005-		Mean	410E	16.1	635	8.4	102	8.1	101	68	2.9
8/14 1120	14	Range	--	12.5- 20.5	634- 636	7.8- 9.2	93- 114	7.8- 8.6	101- 103	68- 70	1.5- 4.7
					Site 2.--Truckee River at Mayberry Bridge						
8/13 1105-		Mean	340E	17.2	640	8.7	107	8.5	109	74	3.4
8/14 1200	13	Range	--	15.0- 19.5	640- 642	7.6- 9.8	95- 123	7.8- 9.2	105- 119	71- 81	1.7- 5.4
					Site 3.--Truckee River at McCarran Bridge						
8/13 1000-		Mean	155	17.9	646	8.3	102	8.3	126	85	4.0
8/14 1145	14	Range	145- 165	14.5- 21.5	645- 648	6.8- 9.7	82- 126	7.6- 8.9	124- 130	84- 88	2.3- 6.3
					Site 4.--North Truckee Drain at Kleppe Lane						
8/13 1100-		Mean	40	17.5	646	8.0	99	8.0	348	242	28
8/14 1215	14	Range	33- 41	13.5- 22.0	645- 648	5.6- 10.8	66- 143	7.5- 8.6	299- 384	208- 267	16 36
					Site 5.--Steamboat Creek at Kimlick Lane						
8/13 1200-		Mean	70	19.6	646	6.9	89	8.1	290	202	28
8/14 1200	14	Range	64- 79	15.0- 24.0	646- 648	5.0- 9.0	59- 126	7.6- 8.6	277- 302	193- 210	26- 30

TABLE A1.—Summary of selected water-quality data used for m[illegible]calibration and verification—Continued

AUGUST 1980; MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized ammonia (NH_3)	Phosphorus (mg/L as P) Ortho— (PO_4)	Total
			Site 1.—Truckee River at Verdi							
8/13 1005–		Mean	.64	.03	.01	.00	.68	.001	.01	.04
8/14 1120	7	Range	.44– .96	.01– .07	.00– .02	.00– .00	.45– 1.0	.001– .003	.00– .01	.02– .07
			Site 2.—Truckee River at Mayberry Bridge							
8/13 1105–		Mean	.58	.02	.01	.00	.61	.002	.01	.06
8/14 1200	5	Range	.52– .69	.00– .04	.00– .02	.00– .00	.52– .75	.000– .015	.00– .04	.03– .09
			Site 3.—Truckee River at McCarran Bridge							
8/13 1000–		Mean	.52	.03	.02	.00	.57	.002	.02	.07
8/14 1145	6	Range	.34– .69	.01– .06	.01– .02	.00– .00	.36– .77	.000– .007	.01– .04	.04– .11
			Site 4.—North Truckee Drain at Kleppe Lane							
8/13 1100–		Mean	1.0	.04	.02	.44	1.5	.001	.04	.11
8/14 1215	7	Range	.51– 1.4	.01– .07	.01– .04	.35– .51	.88– 2.0	.000– .006	.00– .06	.09– .15
			Site 5.—Steamboat Creek at Kimlick Lane							
8/13 1200–		Mean	1.8	.06	.02	.07	1.5	.003	.09	.16
8/14 1200	6	Range	1.3– 2.9	.03– .09	.01– .03	.04– .09	1.4– 3.1	.001– .014	.05– .13	.14– .21

TABLE A1.--Summary of selected water-quality data used for [illegible]el calibration and verification--Continued

AUGUST 1980: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll *a*(ug/L)	Phytoplankton: Chlorophyll *b*(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 1.--Truckee River at Verdi											
8/13 1005-		Mean	2.30	.18	.18	207		1.7	.14	.1	—
8/14 1120	2	Range	—	.17- .19	—	168- 301	7	1.6- 2.1	.13- .15	.0- .7	—
Site 2.--Truckee River at Mayberry Bridge											
8/13 1105-		Mean	2.25	.20	—	210		2.4	.14	.1	—
8/14 1200	2	Range	2.10- 2.40	.15- .25	—	184- 245	7	1.8- 2.9	.12- .17	.0- .9	— —
Site 3.--Truckee River at McCarran Bridge											
8/13 1000-		Mean	1.50	.18	—	393		2.5	.15	.4	—
8/14 1145	2	Range	1.40- 1.60	—	—	302- 478	7	1.9- 3.0	.12- .19	.0 1.0	— —
Site 4.--North Truckee Drain at Kleppe Lane											
8/13 1100-		Mean	12.50	.94	.16	1654		4.0	.11	1.2	—
8/14 1215	2	Range	12.0- 13.0	.87- 1.01	.12- .20	1375- 1847	7	3.7- 4.4	.10- .11	.3 2.0	— —
Site 5.--Steamboat Creek at Kimlick Lane											
8/13 1200-		Mean	3.80	1.75	.40	1749		5.8	.13	2.0	—
8/14 1200	2	Range	3.10- 4.50	.89- 2.60	.32- .49	1160- 2056	7	4.9- 6.3	.11- .18	1.5- 2.7	— —

TABLE A1.—Summary of selected water-quality data used [illegible] model calibration and verification—Continued

AUGUST 1980: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen Concentration (mg/L)	Dissolved oxygen Saturation (percent)	pH (units)	Specific conductance (µS at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
					Site 6.—Reno-Sparks STP outfall						
8/13 1030-		Mean	35	23.3	646	7.6	104	7.7	572	327	10
8/14 1130	14	Range	19- 40	22.0- 25.0	645- 648	7.2- 8.5	99- 118	7.6- 7.8	525- 621	300- 355	7.8 14
					Site 7.—Truckee River at Vista gage						
8/13 0945		Mean	300	19.5	646	7.2	91	8.1	240	152	6.6
8/14 1200	13	Range	290- 320	16.0- 23.0	645- 648	6.0- 8.5	74- 115	7.8- 8.5	215- 253	138- 159	4.9- 8.7
					Site 8.—Truckee River at Lockwood Bridge						
8/13 1100-		Mean	285E	20.0	647	6.9	88	7.9	246	155	7.9
8/14 1245	13	Range	275E- 310E	17.5- 22.5	647- 649	5.6- 8.0	68- 107	7.8- 8.1	234- 254	149- 160	5.3- 11
					Site 9.—Truckee River at Patrick Bridge						
8/13 1000-		Mean	280E	20.6	649	7.1	93	7.9	251	158	7.1
8/14 1200	15	Range	280E- 285E	18.0- 24.0	648- 651	5.4- 9.2	68- 128	7.4- 8.5	240- 268	152- 168	6.8- 7.4
					Site 10.—Truckee River at Clark bridge						
8/13 1100-		Mean	275E	20.9	649	7.5	98	8.0	253	159	4.6
8/14 1230	14	Range	270E- 280E	17.5- 24.5	647- 651	5.2- 9.9	64- 138	7.3- 8.6	239- 265	151- 166	3.0- 7.3

TABLE A1.--Summary of selected water-quality data used for mod[illegible]ibration and verification--Continued

AUGUST 1980: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized ammonia (NH_3)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
			Site 6.--Reno-Sparks STP outfall							
8/13 1030-		Mean	6E	14E	.15	.00	20E	.34E	3.5	4.4
8/14 1130	7	Range	1E- 7E	10E- 19E	.10 - .20	.00- .02	—	—	1.2 5.9	2.5- 6.7
			Site 7.--Truckee River at Vista gage							
8/13 0945-		Mean	1.7	1.1	.06	.11	3.0	.051	.46	.51
8/14 1200	7	Range	—	—	.04- .08	.07- .14	—	.008- .099	.20- .76	.30- .79
			Site 8.--Truckee River at Lockwood Bridge							
8/13 1100-		Mean	1.4	.76	.10	.26	2.5	.023	.42	.48
8/14 1245	8	Range	—	—	.03- .14	.21- .31	—	.003- .032	.14- .77	.20- .8'
			Site 9.--Truckee River at Patrick Bridge							
8/13 1000-		Mean	1.1	.54	.24	.63	2.5	.017	.65	.65
8/14 1200	7	Range	—	—	.10- .31	.26- .82	—	.003- .076	.35- .99	.38- 1.0
			Site 10.--Truckee River at Clark bridge							
8/13 1100-		Mean	1.1	.35	.29	.86	2.6	.014	.64	.68
8/14 1230	7	Range	.98- 1.4	.19- .49	.21- .34	.45- 1.10	1.8- 3.3	.002- .065	.37- .94	.40- .97

TABLE A1.—Summary of selected water-quality data used fo. model calibration and verification—Continued

AUGUST 1980: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll *a*(ug/L)	Phytoplankton: Chlorophyll *b*(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 6.—Reno-Sparks STP outfall											
8/13 1030–		Mean	11.0	.28	.05	—		39.3	.07	69	—
8/14 1130	2	Range	—	.23– .34	—	—	7	31.0– 46.5	.05– .08	56– 76	— —
Site 7.—Truckee River at Vista gage											
8/13 0945–		Mean	48.5	.36	.21	1043		6.2	.13	—	—
8/14 1200	1	Range	42.0– 55.0	—	—	692– 1204	7	5.4– 7.3	.10– .16	—	—
Site 8.—Truckee River at Lockwood Bridge											
8/13 1100–		Mean	55.0–	.52	.20	1167		5.6	.13	8.8	—
8/14 1245	2	Range	52.0– 58.0	—	—	951– 1337	7	4.9– 6.7	.12– .15	5.6– 12.3	—
Site 9.—Truckee River at Patrick Bridge											
8/13 1000–		Mean	47.5	1.00	.30	1443		5.7	.14	—	—
8/14 1200	2	Range	39.0– 56.0	.64– 1.35	.27– .34	1098– 1806	7	4.5– 6.5	.12– .16	—	—
Site 10.—Truckee River at Clark bridge											
8/13 1100–		Mean	32.0	.75	.42	1962		5.1	.13	—	—
8/14 1230	2	Range	25.0– 39.0	.24– 1.27	—	1671– 2640	7	4.4– 6.3	.06– .16	—	—

TABLE A1.--Summary of selected water-quality data used for [illegible] calibration and verification--Continued

AUGUST 1980: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen: Concentration (mg/L)	Dissolved oxygen: Saturation (percent)	pH (units)	Specific conductance (µS at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
Site 11.--Truckee River at Derby Dam											
8/13 1000-		Mean	270E	20.6	650	6.7	87	8.5	260	163	--
8/14 1145	13	Range	265E- 285E	18.5- 23.0	650- 650	5.5- 9.0	69- 122	8.3- 8.8	256 272	161- 170	--
Site 12.--Truckee Canal at Highway 95-A											
8/13 1130-		Mean	150E	21.6	650	6.8	92	7.4	245	155	6.4
8/14 1330	12	Range	145E- 165E	20.0- 23.0	650 650	6.4- 7.0	85- 114	7.2- 7.5	238- 251	151- 158	4.6- 9.6
Site 13.--Truckee Canal at Allendale Check											
8/13 1130-		Mean	70E	22.2	652	8.8	118	8.2	234	149	7.0
8/14 1230	14	Range	50E- 90E	21.0- 24.0	652- 654	7.8- 9.8	103- 132	7.8- 8.6	225- 242	144- 153	4.9- 8.5
Site 14.--Truckee Canal at Highway 50											
8/13 1015-		Mean	E20	21.5	652	10.2	137	8.6	217	139	4.4
8/14 1130	13	Range	E15- E25	8.5- 26.0	652- 654	7.8- 14.2	98- 206	8.1- 9.2	210- 226	135- 144	3.2- 5.1
Site 15.--Truckee River at gage below Derby Dam											
8/13 1010-		Mean	65	--	650	7.0	--	--	--	--	--
8/14 1145	13	Range	60- 70	--	650- 650	5.7- 8.0	--	--	--	--	--

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

AUGUST 1980: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized ammonia (NH_3)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
			Site 11.--Truckee River at Derby Dam							
8/13 1000-		Mean	1.4	.25	.30	1.1	3.0	.029	.66	.72
8/14 1145	7	Range	.90- 2.0	.12- .34	.24- .39	.96- 1.2	2.2- 3.9	.010- .076	.40- .99	.47- 1.0
			Site 12.--Truckee Canal at Highway 95-A							
8/13 1130-		Mean	1.0	.11	.23	1.2	2.5	.001	.56	.60
8/14 1330	7	Range	.69- 1.5	.04- .15	.15- .31	.93- 1.3	1.8- 3.3	.000- .002	.30- .86	.35- .87
			Site 13.--Truckee Canal at Allendale Check							
8/13 1130-		Mean	.99	.03	.19	1.2	2.4	.002	.45	.52
8/14 1230	6	Range	.74- 1.5	.00- .07	.05- .26	1.1- 1.3	1.9- 3.1	.000- .005	.36- .58	.43- .62
			Site 14.--Truckee Canal at Highway 50							
8/13 1015-		Mean	.88	.03	.09	.78	1.8	.004	.30	.35
8/14 1130	7	Range	.57- 1.1	.00- .06	.04- .13	.44- 1.1	1.0- 2.4	.000- .019	.20- .37	.26- .43
			Site 15.--Truckee River at gage below Derby Dam							
8/13 1010-		Mean	--	--	--	--	--	--	--	--
8/14 1145	0	Range	--	--	--	--	--	--	--	--

TABLE A1.—Summary of selected water-quality data used for model calibration and verification—Continued

AUGUST 1980: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 11.—Truckee River at Derby Dam											
8/13 1000–		Mean	43.0	.84	.27	2632		5.4	.14	2.6	—
8/14 1145	2	Range	—	.68– 1.00	.17– .36	2114– 3332	7	4.6– 6.7	.11– .18	1.5– 4.4	—
Site 12.—Truckee Canal at Highway 95-A											
8/13 1130–		Mean	38.0	.67	.29	2987		4.3	.11	—	—
8/14 1330	2	Range	33.0– 43.0	.35– .99	.20– .38	2449– 3615	7	3.5– 5.4	.10– .14	—	—
Site 13.—Truckee Canal at Allendale Check											
8/13 1130–		Mean	31.5	2.07	.87	8950		4.8	.14	—	—
8/14 1230	2	Range	29.0– 34.0	.79– 3.35	.36– 1.38	6401– 11,317	6	4.1– 5.6	.14– .16	—	—
Site 14.—Truckee Canal at Highway 50											
8/13 1015–		Mean	20.5	1.49	.47	3948		3.9	.16	1.0	—
8/14 1130	2	Range	16.0– 25.0	.16– 2.83	—	2338– 5391	7	3.5– 4.4	.14– .19	.4 1.6	—
Site 15.—Truckee River at gage below Derby Dam											
8/13 1010–		Mean	—	—	—	—		—	—	—	—
8/14 1145	0	Range	—	—	—	—	0	—	—	—	—

TABLE A1.--Summary of selected water-quality data used for model calibration and verification--Continued

AUGUST 1980: PHYSICAL AND CHEMICAL DATA

Sampling period	No. of samples	Statistic	Discharge (ft^3/s)	Water temperature	Barometric pressure (mm Hg)	Dissolved oxygen Concentration (mg/L)	Dissolved oxygen Saturation (percent)	pH (units)	Specific conductance (µmho at 25°C)	Dissolved solids (ROE at 180°C)	Turbidity (NTU)
					Site 16.—Truckee River at Painted Rock Bridge						
8/13 1115-		Mean	70E	21.7	651	8.4	113	8.7	263	165	6.4
8/14 1230	11	Range	70E- 70E	18.0- 25.0	650- 653	6.3- 9.9	81- 138	8.2- 9.1	252- 270	159- 169	5.6- 7.0
					Site 17.—Truckee River at Wadsworth Bridge						
8/13 1015-		Mean	55	21.8	651	8.6	115	8.5	264	166	5.0
8/14 1230	14	Range	50- 60	18.0- 26.0	650- 655	5.0- 13.1	64- 188	8.0- 8.8	254- 274	160- 171	3.4- 7.5
					Site 18.—Truckee River at Dead Ox Wash						
8/13 1000-		Mean	55E	21.5	659	7.6	101	8.7	384	234	5.8
8/14 1200	14	Range	50E- 60E	18.0- 26.0	655- 660	4.8- 11.2	59- 158	8.0 9.3	353- 406	216- 247	3.5 7.9
					Site 19.—Truckee River at Nixon Bridge						
8/13 1035-		Mean	44E	21.5	660	7.5	99	8.2	517	310	5.3
8/14 1200	14	Range	40E 50E	18.0- 26.5	660- 660	5.9- 9.2	73- 130	7.8- 8.5	477- 532	287- 318	3.2- 7.5
					Site 20.—Truckee River at Marble Bluff Dam						
8/13 1000-		Mean	45E	20.6	660	7.4	92	8.4	533	319	5.9
8/14 1130	12	Range	40E- 55E	19.5- 22.5	658- 662	5.2- 10.4	66- 132	8.1- 8.6	511- 557	306- 332	4.5- 8.4

TABLE A1.—Summary of selected water-quality data used for model calibration and verification—Continued

AUGUST 1980: MAJOR NUTRIENTS

Sampling period	No. of samples	Statistic	Nitrogen (mg/L as N) Organic	Ammonia (NH_4)	Nitrite (NO_2)	Nitrate (NO_3)	Total	Un-ionized ammonia (NH_3)	Phosphorus (mg/L as P) Ortho- (PO_4)	Total
			Site 16.—Truckee River at Painted Rock Bridge							
8/13 1115-		Mean	1.8	.07	.15	.92	2.9	.013	.55	.60
8/14 1230	6	Range	1.2- 2.4	.04- .10	.08- .24	.64- 1.2	1.9- 3.9	.005- .042	.34- .77	.45- .80
			Site 17.—Truckee River at Wadsworth Bridge							
8/13 1015-		Mean	.99	.04	.07	.38	1.5	.005	.33	.40
8/14 1230	7	Range	.68- 1.6	.02- .06	.02- .09	.29- .52	1.0- 2.2	.001- .007	.24- .46	.29- .50
			Site 18.—Truckee River at Dead Ox Wash							
8/13 1000-		Mean	.80	.04	.01	.00	.85	.007	.22	.28
8/14 1200	7	Range	.64- 1.0	.00- .07	.01- .02	.00- .00	.65- 1.1	.000- .028	.15- .28	.24- .31
			Site 19.—Truckee River at Nixon Bridge							
8/13 1035-		Mean	1.1	.04	.01	.00	1.2	.003	.21	.24
8/14 1200	7	Range	.84- 1.4	.01- .07	.00- .02	.00- .00	.85- 1.5	.000- .007	.13- .25	.16- .29
			Site 20.—Truckee River at Marble Bluff Dam							
8/13 1000-		Mean	1.0	.05	.00	.00	1.0	.005	.21	.26
8/14 1130	7	Range	.54- 1.3	.02- .10	.00- .01	.00- .00	.56- 1.4	.002- .005	.13- .24	.20- .30

TABLE A1.—Summary of selected water-quality data used for model calibration and verification—Continued

AUGUST 1980: BIOLOGICAL DATA

Sampling period	No. of samples	Statistic	Phytoplankton: Algal growth potential (mg/L)	Phytoplankton: Chlorophyll a(ug/L)	Phytoplankton: Chlorophyll b(ug/L)	Phytoplankton: Cell count (cells/ml)	Biochemical oxygen demand: No. of samples	Carbonaceous: Ultimate (mg/L)	Carbonaceous: Decay rate (1/day at 20°C)	Nitrogenous: Ultimate (mg/L)	Nitrogenous: Decay rate (1/day at 20°C)
Site 16.—Truckee River at Painted Rock Bridge											
8/13 1115-		Mean	33.0	1.03	.40	2707		4.8	.14	2.3	—
8/14 1230	2	Range	29.0- 37.0	.64- 1.41	.34- .46	1745- 3191	6	4.1- 5.4	.14- .17	1.1- 4.3	—
Site 17.—Truckee River at Wadsworth Bridge											
8/13 1015-		Mean	16.0	2.73	1.32	3233		5.5	.14	1.3	—
8/14 1230	2	Range	12.0- 20.0	1.35- 4.11	.77- 1.87	2019- 4236	7	3.8- 7.0	.13 .15	.9 2.6	—
Site 18.—Truckee River at Dead Ox Wash											
8/13 1000-		Mean	2.30	1.11	.34	3558		5.8	.14	—	—
8/14 1200	2	Range	2.00- 2.60	.98- 1.24	.33- .34	3154- 4035	7	4.8- 6.7	.13- .16	—	—
Site 19.—Truckee River at Nixon Bridge											
8/13 1035-		Mean	1.45	.61	.25	4228		4.1	.12	1.0	—
8/14 1200	2	Range	1.00- 1.90	.35- .87	.20- .31	3522- 4733	7	3.6- 4.5	.09- .17	.7 1.4	—
Site 20.—Truckee River at Marble Bluff Dam											
8/13 1000-		Mean	4.15	1.13	.22	4386		3.4	.14	.7	—
8/14 1130	2	Range	1.50- 6.80	.66- 1.60	.19- .26	3877- 5426	7	2.8- 3.7	.12- .19	.4- 1.3	—

SUMMARY OF METHODS FOR DATA COLLECTION AND ANALYSIS

Samples were collected at most sites from bridges or cableways at the visual center of flow. At Derby Dam, samples were collected at the center of the gate structure at the head of the Truckee Canal. Cross sectional measurements of dye concentrations during traveltime studies and a reconnaissance survey in May 1980 of temperature, dissolved oxygen, and specific conductance indicated that grab samples near the centroid of flow were sufficiently representative of the total flow for dissolved water-quality characteristics. At Marble Bluff Dam, samples were collected off the upstream side of the north wingwall of the dam. Van Dorn or standard sewage samplers were used to collect samples at mid-depth without surface aeration.

Measurement of water temperature, specific conductance, pH, and dissolved oxygen were performed on site at the time of sample collection. Barometric pressure readings were also take in the field for calculation of dissolved oxygen saturation. Measurements of turbidity and BOD determinations were performed in a field laboratory by project personnel. Other physical and chemical analyses were performed at the U.S. Geological Survey Central Water-Quality Laboratory in Arvada, Colo. Samples sent to the Central laboratory were stored in the dark on ice and shipped on ice within 12 hours of sampling. Nutrient samples were preserved with mercuric chloride. Chlorophyl *a*, AGP, and seston analyses were also performed by the Geological Survey Central Laboratory in Atlanta, Ga. Algal speciation and total cell counts were performed by Susswasser Laboratory in Paso Robles, Calif. BOD determinations consisted of 20-day time series measurements on inhibited samples (nitrapyrin inhibitor) using methods of Stamer and others (1979, 1983). Data reduction was performed using an interactive graphics program that gave direct values for $CBOD_u$, CBOD decay rate, and, for uninhibited samples, the total BOD, nitrogenous BOD, and nitrogenous decay rate (W. E. Webb, U.S. Geological Survey, written communication, 1980).

DATA REDUCTION FOR MODELING

A summary of the synoptic data most pertinent to the water-quality model is presented in table A1. Included are the dates and times sampled at each site, an approximate number of samples taken for major types of data, and the means and ranges of values observed for each characteristic or constituent sampled.

Discharges shown in the table are based on an intensive analysis of gaging station records for the sampling periods and on supplemental field measurements made during the synoptic studies. For ungaged or unmeasured sites, discharges were estimated by balancing measured flow at upstream and downstream sites with diversions estimated from the records of the Federal Watermaster and estimates of return flows (see section titled "Streamflow Balance" in the main text).

Data shown for dissolved solids concentrations are estimated based on regression analysis of the relationship between concentrations of dissolved solids and specific conductance on paired samples. Regressions were performed for all data, and data grouped by reaches of the river, canal, and individual tributaries. The final relationships selected are listed in table A2 and illustrated in figures A1 to A4.

Table A2 and Figure A1 near here

In the June 1979 synoptic, all analyses for the nitrogen and phophorus nutrients were performed on well-mixed unfiltered samples. For the August 1979 and June and August 1980 synoptics, most samples for nutrients were filtered in the field through 0.45-micron membrane filters. For about 30 percent of the filtered samples, additional unfiltered samples were taken to provide data on the relationships between the concentrations of nitrogen and

TABLE A2.--Regression equations used to estimate concentrations of dissolved solids from specific conductance

[Paired analyses of dissolved solids and specific electrical conductance were obtained from USGS files for the 1979 and 1980 water years. Data were fit by least-squares regression to the equation TDS = A x COND + B, where TDS is the concentration of dissolved solids (residue on evaporation at 180 °C, in mg/L), COND is the specific conductance, (micromhos per cm at 25 °C), and A and B are regression coefficients. Also given in the table are the number of data pairs used in the analysis, the correlation coefficient for the regressions (r^2) and the standard error of estimate for the estimated dissolved solids.]

Site or reach	Observed TDS (mg/L) Mean	Observed TDS (mg/L) Range	Number of points	Regression coefficients (A)	Regression coefficients (B)	Correlation coefficient (r^2)	Standard error of estimate (mg/L)
Upper Truckee River (outlet of Lake Tahoe to McCarran bridge in Reno)	64	44-92	42	0.667	0[a]	0.99	7.4
North Truckee Drain (Kleppe Lane) and Steamboat Creek (Kimlick Lane)	254	184-431	15	.696	0[a]	.94	17
Reno-Sparks STP effluent	289	242-416	9	.571	0[a]	.99	30
Truckee River (Vista and below) and Truckee Canal	174	64-564	105	.569	15.5	.99	11

[a] Regression equation with a zero intercept gave the best r^2 and was used for this site.

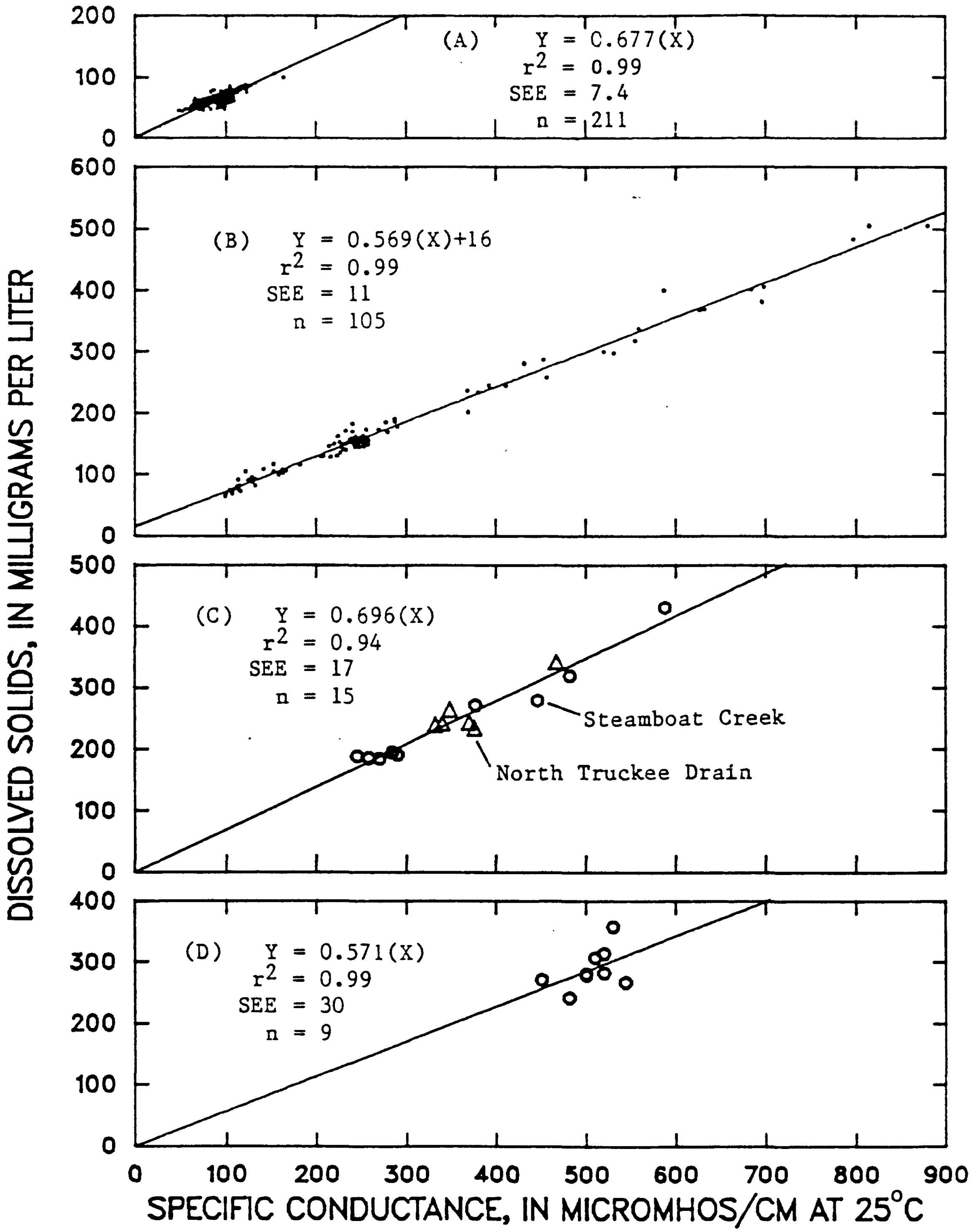

FIGURE A1.--Concentrations of dissolved solids van be estimated from measurements of specific conductance: (A) Truckee River, Lake Tahoe to McCarran Bridge; (B) Truckee River, Vista to Marble Bluff Dam; (C) North Truckee Drain and Steamboat Creek; and (D) Reno-Sparks STP effluent. (Regression parameters: r^2, regression coefficient; SEE, standard error of estimate; n, number of samples used in regression.)

phosphorus in solution (filtered samples) to total concentrations (unfiltered samples). Regression analyses were performed on the paired samples to estimate the percentage of nutrients carried in solution as summarized in table A3. These relationships were used to estimate total concentrations for modeling shown in table A3 for organic-nitrogen, orthophosphorus, and total phosphorus. For ammonia, nitrite, and nitrate forms, all nitrogen was assumed to be in the dissolved state. Un-ionized ammonia concentrations were calculated from the water temperature, pH, and ammonia concentrations using equations of Thurston and others (1974).

Table A3 near here

Analysis of Kjeldahl (ammonia + organic) and ammonia-nitrogen at the Reno-Sparks STP presented problems during the two August studies. For August 1979, the average dissolved organic-nitrogen at the STP was 2.5 mg/L, which resulted in an estimated total organic-nitrogen of 7.4 mg/L. Using 7.4 mg/L as the organic-nitrogen concentration in the model resulted in gross overestimation of observed downstream organic-nitrogen concentrations. Both total and dissolved-nitrogen data were available for one sample at the STP on August 7 prior to the synoptic. For this single sample, the dissolved organic-nitrogen was 2 mg/L and the total was 3 mg/L. Based on this one sample, the total organic-nitrogen for the synoptic was estimated at 3 mg/L, which resulted in acceptable model calibration. For the August 1980 synoptic, errors in sample dilution in the laboratory resulted in no direct values for ammonia-nitrogen. Based on six analyses from the STP laboratory for the period July 30 to August 20 for total organic-nitrogen (average 0.8, range 0.6 to 1.4), an average concentration of 1 mg/L was estimated for the study.

TABLE A3.--Regression equations used to estimate total concentrations of nitrogen and phosphorous nutrients from dissolved concentrations

[Paired values for dissolved (filtered samples) and total (unfiltered samples) concentrations of Kjeldahl and organic nitrogen and ortho- and total phosphorous were obtained from USGS files for the 1979 and 1980 water years. Data were fit by least-squares regression to the equation T = A x D, where T is the total concentration, D is the dissolved concentration, and A is the regression coefficient. Also given in the table are the number of data pairs used in the analysis, the correlation coefficient for the regressions, and the standard error of estimate for the total concentrations.]

Constituent and site or reach	Observed TDS (mg/L)		Number of points	Regression coefficient	Correlation coefficient	Standard error of estimate
	Mean	Range		(A)	(r^2)	(mg/L)
Total Kjeldahl nitrogen (organic + ammonia)[1]						
Reno-Sparks effluent	16	19-23	7	1.3	0.78	2.4
Total organic nitrogen						
Truckee River and Canal	0.83	.22-1.0	26	1.5	.88	.15
North Truckee Drain and Steamboat Creek	.77	.41-2.6	24	1.5	.92	.23
Total orthophosphorous						
Truckee River and Canal	.21	.00-1.0	70	1.0	.98	.04
North Truckee Drain and Steamboat Creek	.12	.06-.19	24	1.0	.96	.03
Reno-Sparks effluent	4.7	3.9-5.5	3	1.1	.99	.44
Total phosphorous						
Truckee River and Canal	.23	.01-1.4	72	1.1	.97	.05
North Truckee Drain and Steamboat Creek	.87	.07-.20	23	1.1	.94	.04
Reno-Sparks effluent	4.6	3.0-7.4	8	1.2	.98	.74

[1] Insufficient data were available for organic nitrogen. For data in table A2, total Kjeldahl nitrogen was estimated from the dissolved Kjeldahl, then total organic nitrogen estimated as (total Kjeldahl) - (dissolved ammonia).

Ammonia-nitrogen concentrations were then estimated by subtracting 1.0 from the USGS Kjeldahl nitrogen values. Similar problems existed for ammonia data at the Vista, Lockwood, and Patrick sampling sites for August 1980. The ammonia and organic-nitrogen concentrations at these sites are based on single values rather than a daily average.

Although not used in the water-quality model, summaries of analyses for AGP (bottle test), phytoplankton chlorophyll *a* and *b*, and phytoplankton cell counts are included as indicies of the trophic state of the river during the synoptics. Additional data on species composition of phytoplankton are available in the full data report.

SUMMARY

The four synoptic studies summarized in table A1 provide independent and comprehensive data sets for modeling water quality in the Truckee River and Canal. The mean values and ranges listed in the table were used as observed data for model calibration and validation. Full data are available in a preceding report (La Camera and others, 1985).

APPENDIX B.--REPRESENTATION OF IRRIGATION RETURN FLOWS

INTRODUCTION

The quality of surface return waters from simple flood irrigation such as practiced along the Truckee River is a function of several processes. First, the quality of return flows depends upon the quality of applied waters. The applied quality may be modified by losses of substances due to chemical precipitation, sedimentation, plant uptake, soil absorption or cation exchange, or by biological or photoactive processes. Irrigation can add substances by soil erosion, soil desorption or cation exchange, addition of natural or chemical fertilizers, or accumulation of animal wastes. For any given water constiutent, the net effect of irrigation on the quality of return waters will be a complex function of the quality of the applied water, soil slope, soil type, climate, land- and water-management practices, and previous irrigation history.

Options for Representation in the Model

The TRWQ model provides two methods for inputing the quality of surface return flows for each modeled stream segment: (1) specification of the average concentration of each constituent, or (2) specification of the concentration of each constituent as a linear function of the concentration in the upstream diversion supplying water to the stream segment generating the returns. For a given stream segment, either method can be applied to each modeled constituent.

TRUCKEE RIVER FIELD INVESTIGATIONS

During the field work for this study, samples were collected at five pairs of sites to provide data on the effect of irrigation along the Truckee River on water quality. The results of this investigation are summarized in table B1. The first four data sets in the table are based on discrete samples of (a) headwaters in irrigation systems or applications to individual fields and (b) the returns to the river or tailwaters in the fields. The fifth data set provides a comparison of the average quality of Truckee River water diverted into the Gregory-Monte/Herman ditch system with the average quality of the Herman ditch point return to the Truckee River at Wadsworth. These data allow evaluations to be made both of the average quality of return flows to the river and of relative enrichment or depletion of individual constituent (as expressed by the ratio of tailwater [return] concentrations to the headwater [diverted] concentrations).

The quality of irrigation returns along the Truckee River was found to be highly variable, both with respect to time and location. For turbidity, organic- and ammonia-nitrogen, and CBOD, the observed variability over 26 hours at the Herman ditch return was greater than the variability between the other four returns. For most constituents, the observed range in concentration in return flows for the five data sets was greater than the mean value. The phosphorus concentrations and CBOD decay rate showed the least variablity between sites. In terms of relative enrichment or depletion of substances due to irrigation, specific conductance, dissolved solids, organic- and ammonia-nitrogen, total phosphorus, and $CBOD_u$ concentrations generally were higher in return flows than in applied waters.

Table B1 near here.

TABLE B1.--Summary of selected water-quality data for agricultural return flows to the Truckee River

Irrigation system and sampling sites	River mile of return	Date (mo., day, year) Time (24 hrs)	Physical and chemical data: Water temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µS)	Dissolved solids (mg/L)	Turbidity (NTU)	Major nutrients: Total-nitrogen (mg/L as N): Organic	Ammonia	NO_2	NO_3	Total	Dissolved nitrogen (mg/L as N): Organic	Ammonia	NO_2	NO_3	Total	Phosphorus (mg/L as P): Total: Ortho	Total	Dissolved: Ortho	Total	Biological data: $CBOD_u$ (mg/L)	$CBOD_5$ (mg/L)	CBOD k_1 (day)
1. Largomarsino-Murphy ditch																								
a. At Lockwood road		6/12/80 1030	—	—	142	—	—	1.3	0.39	0.06	0.07	1.8	0.49	0.34	0.01	0.07	0.91	.21	.22	.21	.16	4.3	—	.21
b. Road near Mustang: accumulated returns from mixed crops	47.4	6/12/80 1240	16.0	9.2	145	102	—	1.1	.25	.01	.00	1.4	.54	.00	.00	.00	.54	.20	.22	.18	.14	—	—	—
Tailwater/headwater ratio			—	—	1.0	—	—	.85	.64	.17	.00	.78	1.1	.00	.00	.00	.59	.95	1.0	.86	.88	—	—	—
2. Largomarsino-Murphy ditch																								
a. Diversion to small onion field above Lockwood Bridge		9/3/80 1000	17.5	7.6	248	150	5.6	.98	.42	.10	1.2	2.7	.66	.44	.11	.67	1.9	.71	.78	.72	.72	7.5	3.2	.11
b. Tailwaters of field	50.1	9/3/80 1115	24.0	11.7	214	141	4.7	1.3	.01	.06	.12	1.5	.59	.01	.06	.12	.78	.66	.77	.66	.68	10.7	5.6	.15
Tailwater/headwater ratio			1.4	1.5	.86	.94	.84	1.3	.02	.60	.10	.56	.89	.02	.54	.18	.41	.93	.99	.92	.94	1.4	1.8	1.4
3. McCarran ditch																								
a. Diversion to native pasture at McCarran ranch		9/3/80 1315	19.5	7.7	245	155	10	.93	.67	.21	4.1	5.9	.85	.55	.21	.65	2.3	.72	.79	.72	.72	6.4	2.9	.12
b. Tailwaters at pasture	44.4	9/3/80 1415	30.0	7.4	240	156	4.4	1.3	.05	.01	2.5	3.9	.98	.02	.01	.00	1.0	.56	.65	.56	.58	9.2	4.4	.13
Tailwater/headwater ratio			1.5	.96	.98	1.0	.44	1.4	.08	.05	.61	.66	1.2	.04	.05	.00	.44	.78	.82	.78	.81	1.4	1.5	1.1
4. Herman ditch																								
a. Diversion to alfalfa field near Wadsworth		9/4/80 1330	20.0	9.2	261	173	6.1	.89	.03	.08	3.9	4.9	.57	.03	.08	.76	1.4	.40	.43	.37	.39	4.2	1.4	.08
b. Tailwaters of alfalfa field	23.7	9/4/80 1430	22.5	4.0	279	181	8.3	1.4	.12	.11	1.2	2.8	1.1	.10	.11	.99	2.3	.47	.53	.46	.48	10.7	6.1	.17
Tailwater/headwater ratio			1.1	.44	1.1	1.0	1.4	1.6	4.0	1.4	.31	.57	1.9	3.3	1.38	1.3	1.6	1.2	1.2	1.2	1.2	2.6	4.4	2.1
5. Gregory Monte Herman ditch system																								
a. Truckee River above Gregory Monte diversion (Painted Rock bridge)		8/12-13/80 [a]																						
Mean			21.7	8.4	263	—	6.4	2.0	.12	.12	.98	3.2	1.2	.07	.15	.92	2.3	.50	.50	.50	.55	4.8	2.4	.14
Range			18.0-25.0	6.3-9.9	252-270	—	5.6-7.0	—	—	—	—	—	.78-1.6	.04-.01	.08-.24	.64-1.2	—	—	—	.31-.70	.41-.73	4.1-5.4	2.1-3.1	.14-.17
b. Herman ditch point return above Wadsworth bridge	23.7	8/12-13/80 [b]																						
Mean			19.6	6.4	303	190	5.2	1.4	.11	.06	.46	2.1	1.0	.08	.10	.41	1.6	.48	.57	.44	.50	10.5	5.5	.15
Range			16.0-27.5	4.4-8.7	278-320	—	3.7-8.6	1.1-1.8	—	.04-.08	.16-.75	2.0-2.1	.64-1.7	.03-.12	.06-.16	.14-.68	1.1-2.6	.42-.53	.55-.59	.30-.58	.40-.62	5.4-15.4	2.3-8.8	.11-.17
Tailwater/headwater ratio of means			.90	.76	1.2	—	.81	.70	.92	.50	.47	.66	.83	1.1	.67	.45	.70	.98	1.1	.88	91	2.2	2.3	1.1
6. Average concentration of return flows																								
Mean by site			22.4	7.7	236	154	5.6	1.3	.11	.05	.86	2.3	.84	.04	.06	.30	1.2	.47	.55	[illegible]	[illegible]	[illegible]	5.4	[illegible]
Range			16.0-30.0	4.0-11.7	145-320	102-190	3.7-8.6	1.1-1.8	.01-.25	.01-.11	.00-.25	1.4-3.9	.54-1.7	.00-.12	.00-.16	.00-.99	.54-2.6	.20-.66	.22-.77	[illegible]-.66	[illegible]-.68	5.4-15.4	2.3-8.8	[illegible]-.17
Average depletion or enrichment ratio			1.2	.91	1.0	.98	.87	1.2	1.1	.54	.30	.65	1.2	.91	.53	.39	.75	.97	1.0	.94	.95	1.9	2.0	1.4

[a] Sampled between [illegible] on 8/12/80 and 1235 on 8/14/80: 14 physical and chemical samples; 1 total nutrient sample and 8 dissolved nutrient samples.

[b] Sampled between 1045 on 8/12/80 and 1245 on 8/14/80: 14 physical and chemical samples; 3 total nutrient and 8 dissolved nutrient samples.

Qualitative assessments as the the effects of irrigation on the quality of return flows may be made from the data in table B1, but there are insufficient data for a choice between the two methods of modeling irrigation returns to the river. Thus a search of literature on the agricultural impacts on water quality was made, with the objective of finding a more detailed data set with high potential for transfer of results to the Truckee River basin. The final choice was a 3-year study conducted by the University of Nevada in Carson Valley, a large agricultural area in the Carson River basin.

CARSON VALLEY IRRIGATION STUDY

The Carson Valley study was the most intensive investigation in Nevada on the effects of irrigation on the quality of surface return flows. This project monitored four agricultural sites for 3 years spanning the 1974 to 1976 irrigation seasons (Guitjens and others, 1976, 1978, 1979). The four sites included three ranches in the valley using surface irrigation from Carson River diversions. Irrigation applications included native pasture, grass/alfalfa mixed pastures, and alfalfa. Most fields were cut for hay during the irrigation season and used for livestock grazing during the rest of the year. On one ranch, dairy wastes were periodically intermingled with irrigation waters. During active irrigations, headwaters and tailwaters at all study sites were monitored at approximately 12-hour intervals for flow and a variety of water-quality parameters. Constituents pertinent to the Truckee River model are BOD_5 (5-day uninhibited biochemical oxygen demand) DO, electrical conductivity, total-nitrogen, nitrate-nitrogen, total phosphorus, and orthophosphorus.

The Carson Valley study found both concentrations and loads of monitored constituents to be highly variable from irrigation to irrigation on the same ranch and between ranches. Differences between applied loads via headwater ditches and measured loads in tailwaters showed the net effect of irrigation to be a consistent reduction in loads of TDS (total dissolved solids, as estimated by electrical conductivity), and total and nitrate-nitrogen, a consistent increase in loads of BOD_5, and, depending upon ranch and irrigation, both increases and decreases in loads of total and orthophosphate phosphorus. Reductions in loads of TDS and nitrogen were due to the loss of water between headwaters and tailwaters. Actual concentrations of TDS, total phosphorus, total-nitrogen, and BOD_5 generally were found to increase from headwater to tailwater on the plots studied. However, based on analyses of loads, only BOD_5 and phosphorus were concluded to be major agricultural pollutants contributed by irrigation surface returns (Miller and others, 1977).

Statistical Testing for Model Representations

In order to expand on the conclusions of the Carson Valley study, the 3 years of monitoring data were compiled into a data set containing 1,020 individual analyses of irrigation head and tailwaters. These data were analyzed to test two basic approaches to model the quality of irrigation returns: (A) the quality of return waters can be most accurately described by average values, or (B) the quality of return waters can be described as a linear function of the quality of applied waters. Comparison of the standard deviation of the mean to the standard error of the linear function was chosen as the selection criterion between methods. For the second hypothesis, two variations were tested by linear regression:

$$TC(i) = m(HC(i)) \qquad (41)$$

$$TC(i) = m(HC(i-L)), \qquad (42)$$

where TC = tailwater concentration of a given constituent,

HC = headwater concentration,

i = time interval over which headwater and tailwater concentrations are averaged, and

L = lag time between sampling the head and tailwaters to test potential effects of traveltime across the fields.

Data were available at about 12-hour intervals for the head and tailwaters of each field during periods of active irrigation. Time intervals of 12 and 24 hours were tested for averaging data for each application. To test potential effects of traveltime across the fields, lag times equal to the averaging period were tested by pairing tailwater data with the average headwater data for the previous 12 or 24 hours.

Results

A summary of the results of this analysis is presented in table B2, along with comparable data from the more limited irrigation sampling from this study along the Truckee River. The table lists mean daily concentrations for surface returns (tailwaters), and the ratio between tailwater concentrations and headwater concentrations as determined by regression analysis. Statistics are shown for averaging periods and lags of 12 and 24 hours.

Table B2 near here.

TABLE B2.--Comparison of methods for estimation of the quality of agricultural surface-return flows

Constituent and statistic	Data averaged over 12 hours: No lag	Data averaged over 12 hours: 12-hour lag	Data averaged over 24-hours: No lag	Data averaged over 24-hours: 24-hour lag	Pooled Truckee River data[a] (table B1)
Water discharge (ft^3/s)					
(A) Tailwater means	4.0		4.1		--
Number of samples	324		218		--
Standard deviation	4.1		3.8		--
Range of values	.0-29		.0-23		--
(B) Tailwater/headwater ratio	.40	.39	.41	.41	--
Number of paired samples	263	298	195	181	--
Correlation coefficient (r^2)	.71	.64	.77	.68	--
Standard error of estimate	3.3	3.5	2.8	3.1	--
Turbidity (mg/L)					
(A) Tailwater means	11		12		5.6
Number of samples	341		225		--
Standard deviation	16		17		--
Range of values	.4-160		.9-160		3.7-8.6
(B) Tailwater/headwater ratio	.11	.06	.11	.03	.87
Number of paired samples	201	313	201	189	--
Correlation coefficient (r^2)	.40	.28	.40	.06	--
Standard error of estimate	16	17	16	15	--
Water temperature (deg C)					
(A) Tailwater means	16.8		16.8		22.4
Number of samples	356		241		--
Standard deviation	5.7		3.8		--
Range of values	1.0-32.5		4.5-25.5		16.0-30.0
(B) Tailwater/headwater ratio	1.0	.96	1.0	.97	1.2
Number of paired samples	290	327	212	198	--
Correlation coefficient (r^2)	.97	.85	.95	.93	--
Standard error of estimate	3.7	6.8	3.8	4.4	--
Electrical conductance (μS/cm)					
(A) Tailwater means	252		248		236
Number of samples	362		240		--
Standard deviation	104		100		--
Range of values	.6-635		54-52		145-320
(B) Tailwater/headwater ratio	1.2	1.2	1.2	1.2	1.0
Number of paired samples	293	331	215	200	--
Correlation coefficient (r^2)	.96	.96	.96	.95	--
Standard error of estimate	57	54	54	60	--
$CBOD_5$ (mg/L)					
(A) Tailwater means	12		12		5.4
Number of samples	352		232		--
Standard deviation	9.5		9.0		--
Range of values	1.1-53		1.1-45		2.3-8.8
(B) Tailwater/headwater ratio	1.0	1.3	1.1	1.0	2.0
Number of paired samples	285	323	208	195	--
Correlation coefficient (r^2)	.22	.28	.25	.26	--
Standard error of estimate	14	13	13	13	--

TABLE B2.--Comparison of methods for estimation of the quality of agricultural surface-return flows--Continued

Constituent and statistic	Data averaged over 12 hours: No lag	Data averaged over 12 hours: 12-hour lag	Data averaged over 24-hours: No lag	Data averaged over 24-hours: 24-hour lag	Pooled Truckee River data (table B1)
Dissolved oxygen (mg/L)					
(A) Tailwater means	3.6		3.7		7.7
Number of samples	352		232		--
Standard deviation	1.9		1.8		--
Range of values	.0-9.3		.2-9		4.0-12.0
(B) Tailwater/headwater ratio	.65	.64	.68	.71	.91
Number of paired samples	285	323	208	195	--
Correlation coefficient (r^2)	.80	.82	.88	.89	--
Standard error of estimate	1.8	1.78	1.4	1.3	--
Nitrate-nitrogen (mg/L)[1]					
(A) Tailwater means	.39		.40		.30
Number of samples	362		240		--
Standard deviation	.32		.32		--
Range of values	.00-1.9		.00-1.9		.00-.99
(B) Tailwater/headwater ratio	1.1	1.1	1.2	1.1	.39
Number of paired samples	293	331	215	200	--
Correlation coefficient (r^2)	.46	.46	.48	.49	--
Standard error of estimate	.38	.37	.38	.35	--
Total-nitrogen (mg/L)					
(A) Tailwater means	1.3		1.3		2.3
Number of samples	236		158		--
Standard deviation	.78		.80		--
Range of values	.12-3.0		.17-5.8		1.4-3.9
(B) Tailwater/headwater ratio	.90	1.0	.79	.72	.65
Number of paired samples	188	223	141	133	--
Correlation coefficient (r^2)	.37	.48	.33	.37	--
Standard error of estimate	1.2	1.1	1.3	1.2	--
Orthophosphorus (mg/L)[1]					
(A) Tailwater means	.49		.50		.47
Number of samples	362		240		--
Standard deviation	.35		.37		--
Range of values	.10-3.0		.10-3.0		.18-.66
(B) Tailwater/headwater ratio	1.5	1.6	1.7	1.6	.94
Number of paired samples	293	331	215	200	--
Correlation coefficient (r^2)	.51	.50	.52	.57	--
Standard error of estimate	.42	.42	.43	.36	--
Phosphorus (mg/L)[1]					
(A) Tailwater means	.83		.87		.55
Number of samples	236		158		--
Standard deviation	.64		.69		--
Range of values	.10-4.4		.10-4.4		.22-.77
(B) Tailwater/headwater ratio	1.6	1.5	1.6	1.4	1.0
Number of paired samples	188	223	141	133	--
Correlation coefficient (r^2)	.54	.52	.52	.49	--
Standard error of estimate	.76	.74	.81	.74	--

[1] Values for Carson Valley data are based on unfiltered samples; values for Truckee River data are from filtered samples.

For each constituent, a comparison of the standard deviation of the mean value to the standard error of estimate for the regression analysis gives an indication of the relative precision of the two methods for predicting the quality of surface return flows. For example, figure B1 shows a comparison for specific conductance (24-hour averages). The mean conductance of tailwaters for 240 samples was 252 microsiemens, with a standard deviation of 100 microsiemens. The relationship between tailwater and headwater conductivities had a regression coefficient (r^2) of 0.96, indicating an excellent correlation between the two variables; the predicted tailwater/headwater ratio was 1.2. The standard error of estimate for the mean tailwater conductivity predicted by the regression relationship is 54 microsiemens, about half the standard error of the mean. The statistics indicate that the conductance of tailwaters can be represented more accurately by the relationship with conductance of applied headwaters than by a simple mean value.

Figure B1 near here.

In contrast, figure B2 shows a comparison between phosphorus concentrations in tailwaters and headwaters. The mean phosphorus concentration in tailwaters for 141 observations was 0.87 mg/L, with a standard deviation of 0.69 mg/L. The relationship between tailwater and headwater nitrate concentrations had a regression coefficient of 0.52, indicating a weak relationship between tailwater and headwater concentrations. The lack of good correlation also is indicated by the wide scatter in the plot. The tailwater/headwater ratio indicated by the regression relationship is 1.4. The standard error of the prediction is 0.81 mg/L, greater than the

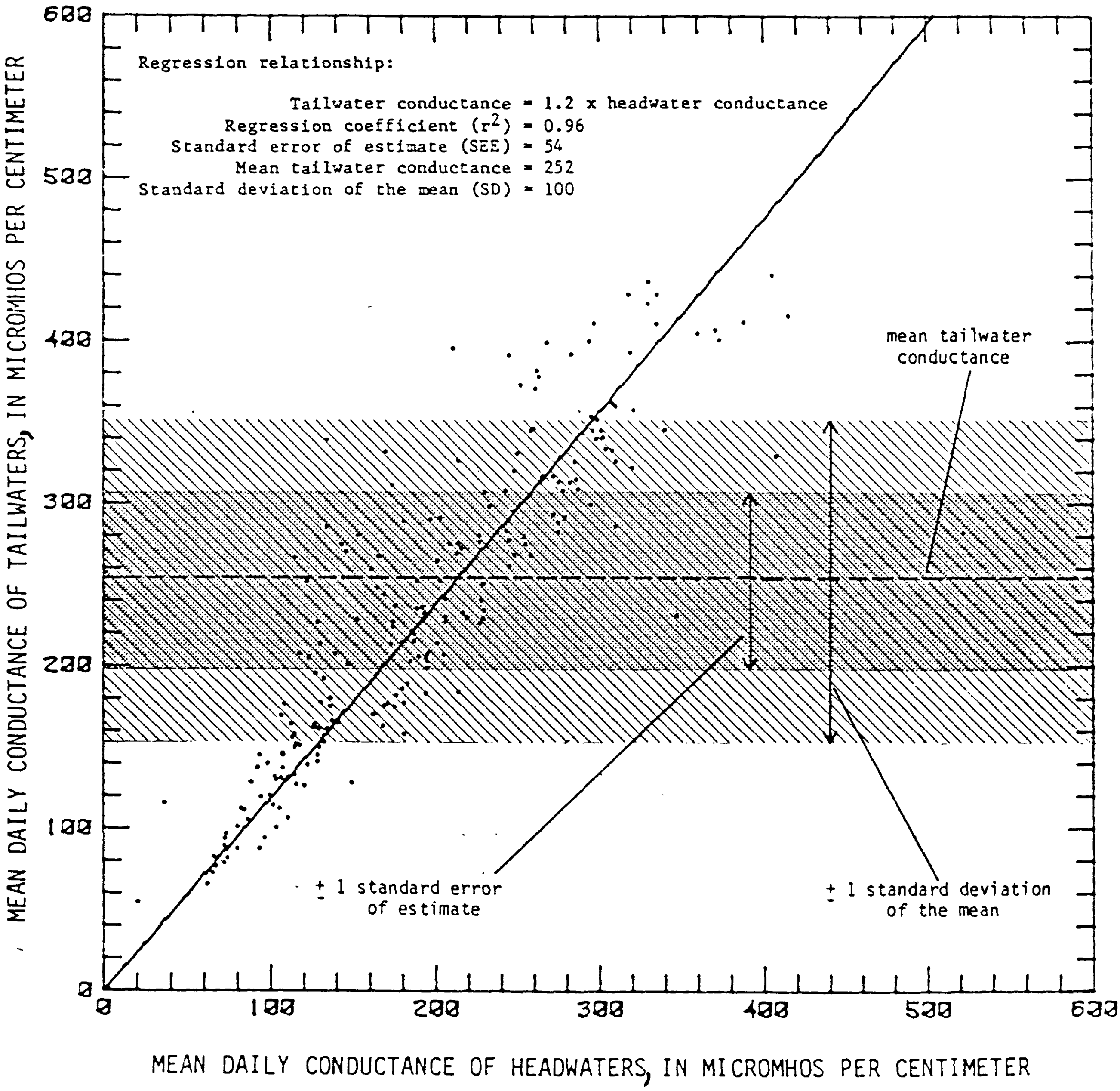

FIGURE B1.--The tailwater/headwater ratio is a better predictor of tailwater conductivity than the mean value.

standard deviation of the mean value. For phosphorus, the statistics indicate that the mean value is a more accurate estimator of phosphorus in tailwaters than the relationship between concentration in tailwaters and applied headwaters.

Figure B2 near here.

For discharge, temperature, dissolved oxygen, and conductivity, the standard deviation of the mean is higher than the standard error of the regression estimate, indicating that these concentrations can be better predicted as a function of the quality of the applied water than by an average value. The regression relationships between tailwater and headwater values for these parameters also had relatively high correlation coefficients, with r^2 of 0.7 or better.

For turbidity, BOD_5, and the nitrogen and phosphorus concentrations, the mean value describes the quality of the irrigation tailwaters as well or better than the statistical relationship with applied headwaters. The correlation coeficients for the regression relationships for these parameters were low, with r^2 of 0.5 or less. Averaging over 12 hours produced the better results for temperature, conductance, nitrogen, and phosphorus; 24-hour averages were better for discharge, turbidity, dissolved oxygen, and BOD_5. Lagging the headwater data by 12 or 24 hours did not significantly improve any of the regression relationships.

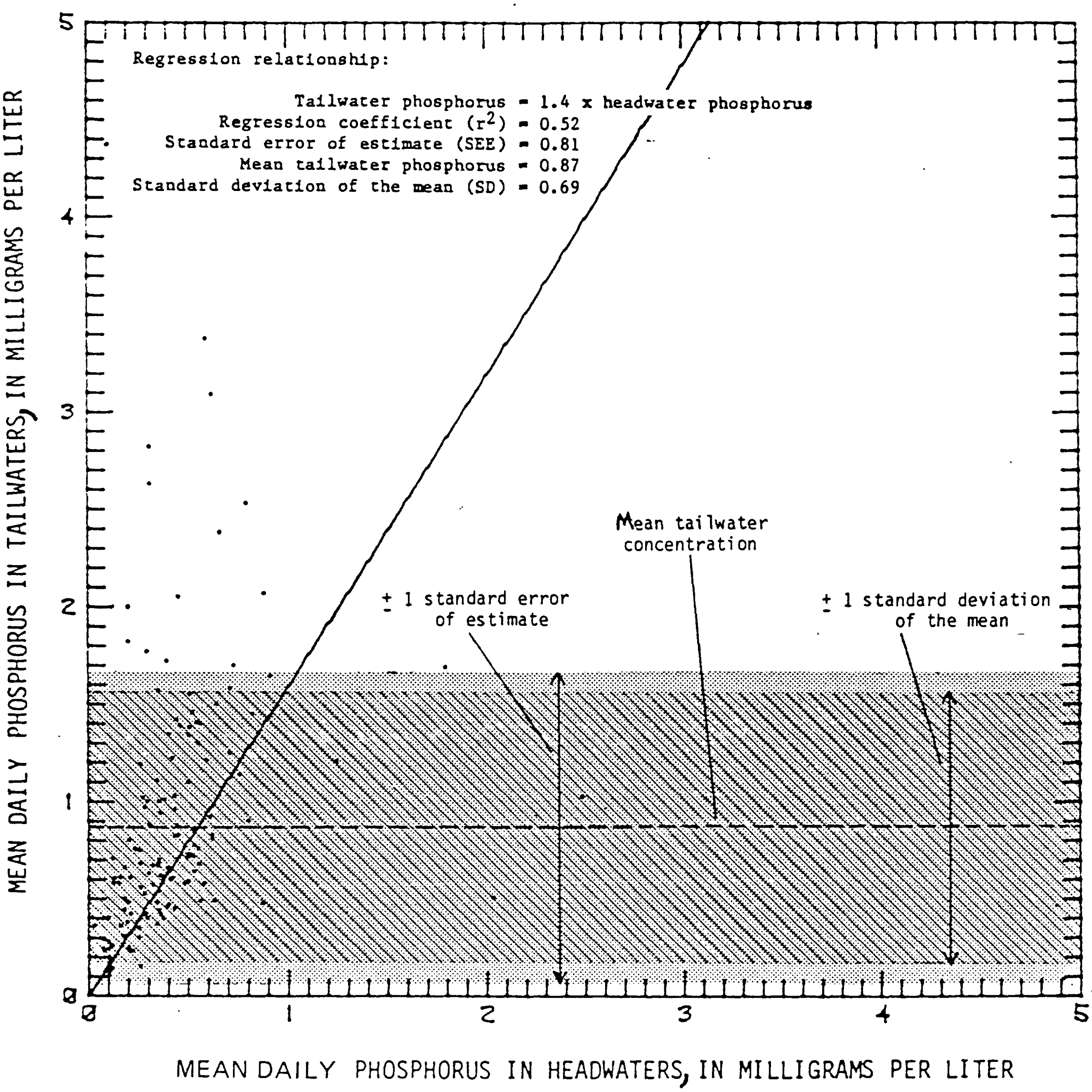

FIGURE B2.--The mean is a better predictor of phosphorus concentrations in irrigation tailwaters than tailwater/headwater ratio.

Comparisons of the quality of irrigation tailwaters measured in the Carson Valley study and the more limited data from the Truckee River may be made with the data in table B2. Some caution should be used in making such comparisons due to differences in methodologies between the two studies. For example, the Truckee data lists specific conductance (at 25° C); the Carson Valley study gives electrical conductivity without reference to temperature. The Truckee data set lists $CBOD_u$ and $CBOD_5$ results from 20-day time series on samples inhibited for nitrification; the Carson Valley study determined BOD_5 by a simple 5-day incubation. Differences in sample collection and analysis procedures for nitrogen and phosphorus in the two studies may preclude direct comparison of these results. In general, however, qualitative comparisons may be made between the two data sets.

The tailwaters from irrigation along the Truckee River were less turbid, had lower concentrations of BOD_5 and higher concentrations of dissolved oxygen and total-nitrogen than found in the Carson Valley study. Conductivities, nitrate-nitrogen, and phosphorus concentrations for irrigation tailwaters were similar between the two data sets. The higher BOD_5 concentrations in the Carson Valley data may be due to the practice of pasturing cattle on the fields between irrigations and to the comingling of dairy wastes with irrigation waters on one of the four test fields, as average BOD_5 concentrations were considerably less in the headwaters (3.8 mg/L) than in the tailwaters (12 mg/L).

CONCLUSIONS

A statistical analysis of data from an intensive study in Carson Valley of the quality of waters applied to and draining from fields watered by simple flood irrigation was performed to test potential relationships between the quality of the head and tailwaters. The statistics suggests that, for several water-quality indicators, the quality of the tailwaters can be described as well or more accurately by a simple mean than by a relationship with the quality of applied irrigation waters. Exceptions were temperature, dissolved oxygen, and electrical conductivity. For these parameters, tailwater/headwater ratios derived from regression analysis had standard error of estimates lower than the standard deviations of the means. Tailwater/headwater ratios (enrichment ratios) for these parameters were 1.0, 0.7, and 1.2 respectively. Varying the time span over which data were averaged from 12 to 24 hours had little effect on the resulting statistics. Nor were the results affected significantly by assuming traveltimes across the fields of 0, 12, or 24 hours. The implications for water-quality modeling are that, with the exception of dissolved oxygen and conductivity (and, by analogy, dissolved solids), the quality of return flows from similar surface irrigation can be better represented by average values than by functions of the quality of the applied waters.

APPENDIX C.--REPRESENTATION OF GROUND-WATER RETURN FLOWS

Ground-water contributions to flows and loads of solutes to the Truckee River may be of significance during periods of low streamflow. For example, the average annual ground-water inflow in the reach between the Wadsworth and Nixon gages has been estimated to be from 16 to 20 ft^3/s (Bratberg, 1980; Van Denburgh and others, 1973). This amounts to 26 to 57 percent of the observed streamflow at the Nixon gage during the August 1979 synoptic sampling.

The following analysis of ground-water inflows to the Truckee River has two objectives in support of the TRWQ model: (1) to estimate the quality of ground-water inflows to the 43 model reaches and (2) to develop methods for estimating the quantity of inflows for the modeled periods.

PREVIOUS STUDIES

A number of studies have considered the hydrogeology of ground waters in the Truckee River basin below Reno. Van Denburgh and others (1973) included budgets for interbasin flow and data on ground-water quality in a general study of the hydrology of the Truckee River basin. Sinclair and Loeltz (1963) described a ground-water flow system in the Fernley area that is recharged by leakage and irrigation from the Truckee Canal and discharges to the Fernley sink and the Truckee River in the vicinity of Wadsworth.

Van Denburgh and Arteaga (1985) refined the earlier budget estimates for Truckee River inflow from the Fernley ground-water system. The ground water resources along the Truckee River below Wadsworth are described in a planning report by the Pyramid Lake Indian Tribal Council (1982). Detailed studies in the basin below Derby Dam include a water-supply investigation in the vicinity of Dead Ox (Campana, 1979), a drainage study near Wadsworth (CH2M-Hill, 1980), and a thesis on the impact of the ground-water system in the vicinity of Dodge Flats to the quality and flows of the Truckee River (Bratberg, 1980).

Of these previous studies, none provide sufficient detail to quantify either ground-water quality or inflows to the river at a level of detail comparable to the river segmentation used in the TRWQ model. Present siting of stream gages precludes detailed analyses of ground-water inflow to the river due to the bypassing of gages by irrigation diversions and associated returns (Bratberg, 1980, page 65). With respect to ground-water quality, few wells are available for sampling along the river below Reno, and the areal distribution of wells is very biased towards limited areas of development in the vicinity of Lockwood, Wadsworth, and Nixon. Analysis of ground-water quality is further impeded by the lack of a coherent and reliable data base.

GAINS AND LOSSES BETWEEN GAGES

Long-term streamflow records at gaging stations have been used to estimate ground-water inflow based on apparent differences between gages. This technique has particulary applied in the reach between the Wadsworth and Nixon gages to estimate ground-water inflow in the Dodge Flat area. Van Denburgh and others (1973, page 37) estimated that the gain in this reach was about 5,000 acre-feet per year (about 7 ft^3/s). Bratberg (1980, page 24) estimated a similar gain based on concurrent flow records for a 15-year period ending October 1978.

Comparison of annual flow records between adjacent gaging stations, however, can be misleading, as the resultant estimates of ground-water inflow ignore the effects of irrigation diversions and returns. For example, the Hill ditch bypasses the gage at Tracy, and the Proctor ditch bypasses the gage at Wadsworth. Seasonal comparisons of daily records between gages, for example in the nonirrigation period, also may be misleading as the calculated differences to not take into account travel-times between gages or differences due do nonsteady flow events. Furthermore, estimated differences between gages may be significantly less in magnitude than the probable error in the gaging station record. For example, at a flow of 200 ft^3/s at gages with records rated "good" (probable error less than 10 percent for 95 percent of the record), the error in rated flows at each gage could be as high as 20 ft^3/s; thus, calculated differences of 5 to 10 ft^3/s between gages would be meaningless.

In an attempt to reduce the effects of such errors, an analysis of differences in measured streamflow at Truckee River gages was made using a highly selective subset of the available record (table C1). Records were examined for the 10-year period November 1972 to October 1982. Records used were limited to those days where the flow at the Vista gage was 300 ft^3/s or less and the flow below Derby dam was 200 ft^3/s or less. Nixon gages average about 8 ft^3/s for the nonirrigation season, most of which is believed to be from the Fernley area.

Table C1 near here

TABLE C1.--Monthly and seasonal gains and losses in stre[illegible] between gages on the Truckee River below Reno

[Gage data for the 10-year period 11/72 to 10/82 were screened to omit days with flows above 300 ft^3/s at Vista or 200 ft^3/s below Derby Dam. Effects of traveltime between gages and changing streamflows were limited by omitting data for days with flow differing by more than 10 percent from the previous day. Results shown are means for the qualified daily discharges, in ft^3/s.]

Mean streamflow in ft^3/s for indicated season or month

Gage or reach		Total record	By season		By month											
			Non-irrigation (Nov-Mar)	Irrigation (Apr-Oct)	Nov 11	Dec 12	Jan 1	Feb 2	Mar 3	Apr 4	May 5	Jun 6	Jul 7	Aug 8	Sep 9	Oct 10
A. VISTA GAGE TO DERBY DAM	Number of qualified days:	257	31	226	14	8	0	0	9	0	3	12	70	78	40	23
Vista gage (RM 52.2)	Mean:	222	161	230	107	113	--	--	287	--	205	246	226	248	240	162
	Standard deviation:	±64	±90	±55	±57	±7	--	--	±8	--	±15	±22	±44	±36	±37	±105
Vista gage to Tracy gage[1]	Mean:	-1.2	-5.6	-0.6	-24	-24	--	--	39	--	-2	3	-6	6	-6	1
	Standard deviation:	±23	±31	±22	±15	±5	--	--	±8	--	±6	±21	±20	±27	±15	±14
Tracy gage (RM 40.6)	Mean:	221	55	230	83	89	--	--	326	--	203	249	220	254	234	163
	Standard deviation:	±76	±120	±63	±72	±5	--	--	±5	--	±9	±30	±50	±50	±42	±117
Tracy gage to Derby Dam[2]	Mean:	-13	7.3	-16	10	-2	--	--	11	--	-4	-1	-20	-25	-0.0	-9
	Standard deviation:	±25	±7.8	±26	±6	±4	--	--	±7	--	±19	±26	±19	±22	±36	±17
Estimated at Derby Dam (RM 3.90)[3]	Mean:	207	162	214	94	87	--	--	337	--	199	247	200	228	234	154
	Standard deviation:	±70	±122	±57	±70	±8	--	--	±8	--	±28	±25	±46	±43	±41	±102
Vista gage to Derby Dam	Mean:	-14	1.7	-17	-13	-26	--	--	50	--	-6	1	-26	-19	-6	-8
	Standard deviation:	±23	±34	±20	±15	±6	--	--	±14	--	±13	±25	±13	±18	±28	±11
B. DERBY DAM TO NIXON GAGE	Number of qualified days:	222	40	182	22	12	--	--	12	6	3	15	53	38	35	32
Gage below Derby Dam (RM 34.5)	Mean:	27	7.9	31	7	7	--	--	12	27	36	37	32	38	39	10
	Standard deviation:	±18	±5.9	±17	±8	±.9	--	--	±.4	±1	±2	±20	±5	±13	±16	±19

TABLE C1.--Monthly and seasonal gains and losses in streamflow between gages on the Truckee River below Reno--Continued

Gage or reach		Total record	By season: Non-irrigation (Nov-Mar)	By season: Irrigation (Apr-Oct)	By month: Nov 11	Dec 12	Jan 1	Feb 2	Mar 3	Apr 4	May 5	Jun 6	Jul 7	Aug 8	Sep 9	Oct 10
Gage below Derby to Wadsworth gage[4]	Mean:	3.3	12	1.3	12	12	—	--	14	5	8	5	-0.2	-1	-4	10
	Standard deviation:	±11	±3.7	±11	±4	±4	--	--	±3	±1	±3	±8	±8	±7	±17	±6
Wadsworth gage (RM 23.1)	Mean:	30	20	33	19	19	--	--	26	31	43	42	32	37	35	20
	Standard deviation:	±14	±5.0	±15	±4	±5	--	--	±3	±2	±1	±18	±10	±15	±14	±15
Wadsworth gage to Nixon gage[5]	Mean:	5.9	8.1	5.5	5	11	--	--	12	12	10	6	4	4	6	6
	Standard deviation:	±7.5	±3.7	±8.0	±3	±1	--	--	±3	±6	±.6	±8	±8	±6	±12	±3
Nixon gage (RM 9.4)	Mean:	36	28	38	24.5	30	--	--	39	43	54	48	37	41	41	26
	Standard deviation:	±14	±7.3	±14	±6.6	±4	--	--	±.5	±7	±2	±23	±9	±15	±11	±14
Gage below Derby to Nixon gage	Mean:	9.2	20	6.7	17.6	22	--	--	26	16	18	11	4	38	2	16
	Standard deviation:	±10	±4.2	±9.5	±2.5	±3	—	--	±.8	±6	±4	±13	±7	±3	±9	±6

[1] Average diversions in reach about 37 ft^3/s, including 4 ft^3/s constant diversion at Tracy power plant for cooling water. Most water from Hill Diversion (average 6 ft^3/s) bypasses gage at Tracy. Estimated agricultural water consumption (estimated 50 percent return) is 24 ft^3/s during irrigation season. Vista and Tracy gages rated "good" (95 percent of record estimated to be within 10 percent accuracy).

[2] No agricultural diversions in reach; receives about 3 ft^3/s agricultural return flows from Hill Diversion.

[3] Record at Derby calculated by sum of river flows at gage Below Derby and canal flows as measured at canal gage near Wadsworth. Measured canal flows do not include minor diversions and releases from 2 spillways between Derby Dam and the canal gage, therefore estimated river flows at Derby Dam are underestimated and resultant differences are overestimated by an unknown amount.

[4] Average diversions in reach about 32 ft^3/s. Most water from Proctor Diversion (averages 5 ft^3/s) bypasses gage at Wadsworth. About 14 ft^3/s of diverted water returns to the river. Aditional inflows from agricultural diversions from the Truckee Canal, seepage from unlined portions of the canal, and direct releases from the Derby and Gilpin canal spillways.

[5] Average diversions in reach about 15 ft^3/s plus minor direct pumpage at three sites. About 12 ft^3/s of diverted water (including Proctor diversions) returns to the river.

LOW-FLOW INVESTIGATION

Concurrent stream discharge measurements and samplings during sustained low flows (base flows) are often employed as a technique to measure the quantity and quality of ground-water inflows to a stream reach. Application of this technique to the Truckee River is complicated in most years by the coincidence of low-flow periods with the irrigation season. During periods of active irrigation, apparent gains or losses in streamflow or loads of solutes between measuring points are due to the combined effects of ground-water inflow and irrigation diversions and returns. After the active irrigation period (post-October 15 in most years), Truckee River flows are often augmented by upstream releases from reservoirs to meet flood-control criteria; thus, in most years, there is no "ideal" period for base-flow investigations.

The most extensive low-flow investigation to date on the Truckee River was conducted by the USGS in 1971 (U.S. Geological Survey, 1972). In this study, discharge measurements were made on September 2 at 15 sites from Derby Dam to the Nixon gage, and concurrent measurements of specific conductance were made at 13 sites to estimate changes in solute concentrations. During the 4 days preceding these measurements, releases from Derby Dam were minimal and relatively constant (20-30 ft^3/s). Although not specifically measured, agricultural diversions during this period were believed to be minimal, especially in the reach from Derby Dam to Wadsworth. A summary of these data is listed in table C2.

Table C2 near here

Table C2.--Results of Truckee River low-flow investigation, September 2, 1971

(adapted from U.S. Geological Survey, 1972)

A series of discharge and water-quality measurements was made on Sept. 2, 1971, on the Truckee River between Derby Dam and the gage near Nixon. Most of the flow had been diverted into the Truckee Canal at Derby Dam for 4 days preceding these measurements. The discharge at the Derby Dam, Wadsworth, and Nixon gages was almost constant during the period of measurements. Discharge measurements are accurate within about 5 percent, conductance measurements within about 10 percent. Although diversions were generally minimal during the period of measurements, diversion measurements were not made and apparent gains and(or) losses probably include diversion-return effects as well as ground-water inflows.

Location (Township, range, section, and quarters; see Table C4)	River mile	Time	Water temperature (degrees Celsius)	Discharge (cubic feet per second)	Specific conductance (µS at 25 °C)
Gage below Derby Dam (N20E23 19CB)	34.5	--	--	20 a	--
Painted Rock (N20E23 23AB)	30.0	1055	17.0	32	--
Below Gregory-Monte diversion (N20E24 08DB)	26.0	1145	--	44 b	--
Wadsworth bridge (N20E24 03BCC)	23.7	1015	16.5	52	290
Below Fellnagle Diversion (N21E24 33DBB)	22.6	1150	17.5	55	333
0.8 mi n of Wadsworth (N21E24 33AAA)	22.0	1340	17.5	58	353
1.0 mi n of Wadsworth (N21E24 27CCA)	21.3	1050	18.0	61	375
Near S Bar S diversion (N21 E24 15CAA)	19.9	1655	20.5	61	408
Olinghouse #3 pump Diversion (N21E24 16AAA)	17.5	1650	21.0	65	427
Below S Bar S Ranch (N21 E24 09CCD)	16.8	1540	21.0	62	427

Table C2.--Results of Truckee River low-flow investigation, September 2, 1971--Continued

Location (Township, range, section, and quarters; see Table C4)	River mile	Time	Water temperature (degrees Celsius)	Discharge (cubic feet per second)	Specific conductance (µS at 25 °C)
4.9 mi NNW of Wadsworth (N21E24 08AAB)	15.7	1425	21.0	62	424
5.8 mi NNW of Wadsworth (N21E24 05BDB)	14.6	1100	17.5	60	443
6.3 mi NNW of Wadsworth (N22E24 32CCA)	13.7	1430	20.0	62	444
Dead Ox Wash (N22E24 31AAA)	13.2	1320	19.0	61	478
Below Dead Ox Wash (N22E24 30ACA)	12.0	1230	18.0	65	542
Gage near Nixon (N22E24 18BC)	9.5	1050	18.0	63	619

[a] Mean daily discharge at gage.

[b] Includes estimated 1 ft^3/s bypassing reach in Gregory-Monte ditch.

The results of the study in relation to river miles and stream segments used in the TRWQ model are shown in figure C1. The reach between Derby Dam and the Nixon gage can be divided into four major subreaches based on relatively uniform linear accretions of discharge and solutes. The characteristics of these subreaches are summarized in table C3. Rates of accretion (per unit stream length) of streamflow and solutes (as estimated by specific conductance) for these four major reaches were estimated by linear regression. Estimates of the specific conductance of inflowing ground waters were made by simple mass balance of the observed data at the subreach boundaries. These estimates only provide relative indications of the conductance of the influent ground waters as effects of any surface diversions and returns are ignored in the calculations.

Figure C1 near here

Table C3 near here

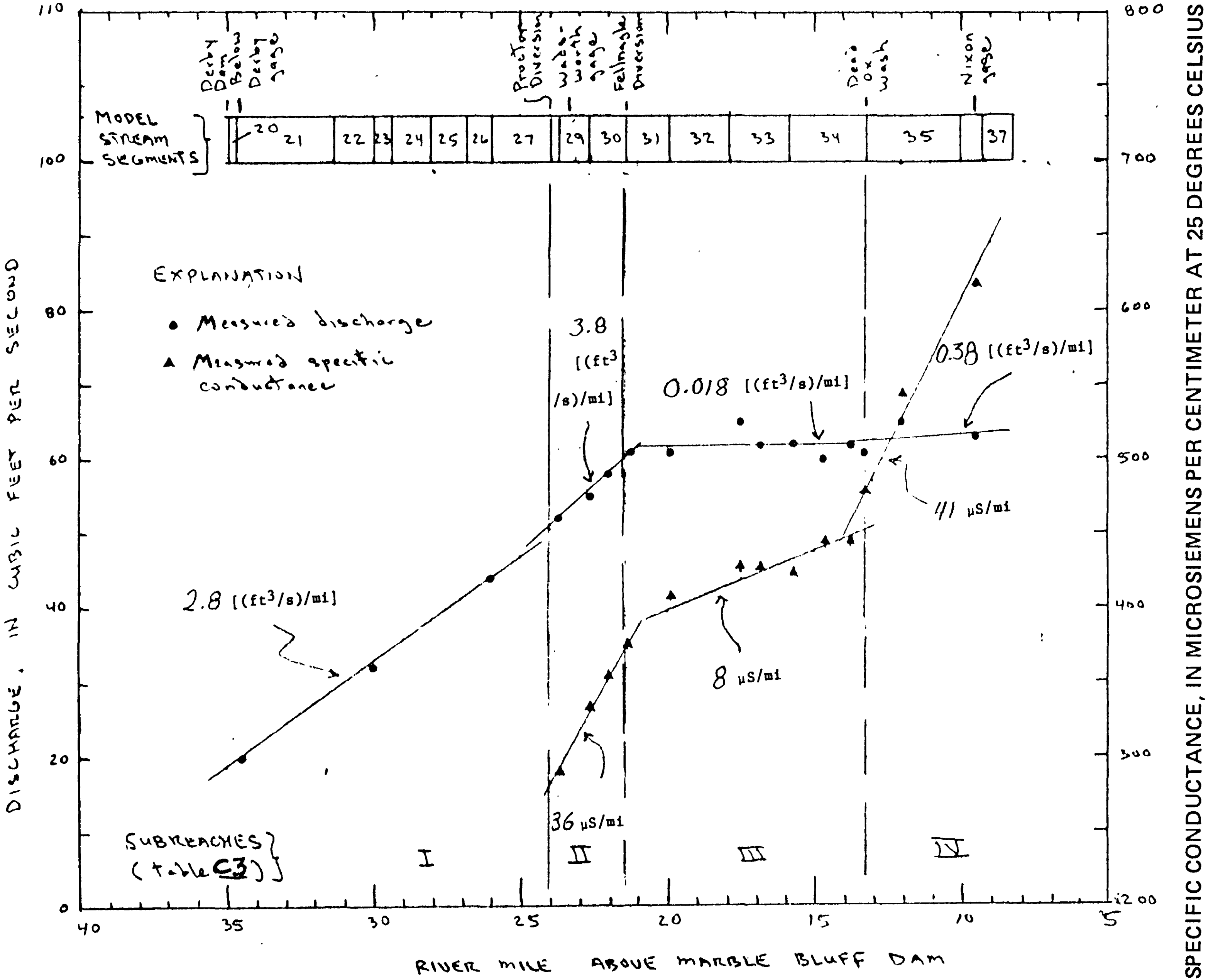

Figure C1.--Synoptic low-flow discharge measurements in September 1971 may be used to estimate ground-water accretions to the Truckee River between Derby Dam and the Nixon gage. Abbreviations: (ft /s)/mi, cubic feet per second, per mile; µS/mi, microsiemens per mile.

TABLE C3.--Estimation of ground-water inflows from 1971 low-flow investigation

[Subreach deliniation based on graphical analysis (fig. C1). Accretion rates based on linear regression of points in indicated subreaches (r^2 shows correlation coefficent for relationship). Calculated inflow conductivities based on simple mass balance between sampling sites (table C2) and do not take into account unmeasured irrigation diversions or surface returns.]

Subreach (figure C1)	River mile	Model segments	Streamflow accretion: Rate (ft^3/s)	Streamflow accretion: r^2	Solute accretion: Rate (µS/cm/mi)	Solute accretion: r^2	Solute accretion: Calculated inflow (µS/cm)	Sources of ground-water inflows
I	35-24	20-27	2.8	1.00	--	--	--	Principal inflow derived from leakage from Truckee Canal and subsurface irrigation returns from diversions from the river and canal.
II	24-21	28-31	3.8	.98	36	1.00	870	Principal inflow from subsurface irrigation returns from the Fernley area (canal diversions). Also subsurface irrigation returns from the Gregory-Monte, Herman, and Pierson diversions from the river.
III	21-14	31-34	.018	.001	8.0	.87	4,650	Inflow from subsurface irrigation returns (Proctor, Fellnagle, S Bar S) and regional ground-water discharge, principally from Dodge Flats.
IV	14-9	34-37	.38	.17	41	.97	11,500	Inflow from regional ground-water discharge and local saline seepage from Lahontan sediments.

The low-flow investigation in 1971 indicates a uniform streamflow accretion between Derby Dam and Wadsworth (subreach I) of about 3 $ft^3/s/mi$. These inflows are principally from leakage from unlined portions of the Truckee Canal and, to a lesser extent, from subsurface irrigation returns from both canal and river diversions. The rate of streamflow accretion increases in the Wadsworth area (subreach II) with ground-water returns from irrigation in the Fernley Farm area. Inflows in this reach approached 4 $ft^3/s/mi$ and also contributed a significant solute load to the river. From Wadsworth to the Nixon gage (subreaches III and IV), inflows were low in magnitude (0.1 to 0.4 $ft^3/s/mi$) but very significant in terms of added solutes. Inflows in subreach III are principally from ground-water discharge from the Dodge Flats area to the west and from subsurface irrigation returns from adjacent ranches. Inflows to subreach IV include regional ground-water discharge and localized springs and seeps with high salinity, principally in the area around Dead OX Wash. Simple mass-balance computations provide rough estimates of the conductivity of influent ground waters for this investigation in subreaches II to IV of 870, 4,600, and 11,500 microsiemens, respectively.

INVENTORY OF DATA ON GROUND-WATER QUALITY

In order to assess the quality of ground water inflows to the river, a data base was compiled from published reports, unpublished USGS files, files of the Nevada Consumer Health Protection Service (NCHPS), and a printout from the WADS computer data base maintained by the Desert Research Institute of the University of Nevada. Included in this compilation were all ground-water analyses from contributing drainage basins within 2 to 6 miles of the Truckee River from McCarran Bridge to Marble Bluff Dam. Of the constituents of interest to the water-quality model, only specific conductance, dissolved solids, nitrate, orthophosphate, and temperature data were available from these sources. Results from analyses for the sulfate and chloride ions were also included in the compilation to provide insight as to the geochemistry of the waters. The ratio of sulfate to chloride was calculated as an index of the basic geochemistry of ground waters in the study area. The resultant compilation contained 427 analyses of ground waters from 337 individual sites collected for the period 1931 to 1983 (table C4).

Table C4 near here

For published data in table C4, site locations are generally listed as published. Where published locations from different sources differed for the same analysis (or for analyses for the same site), the most detailed location was used. Locations for analyses from NCHPS files were derived by comparing owners' names with data from published sources and by comparing locations given on the analytical report with probable locations on topographic maps or in published reports. This screening process eliminated from consideration many sites with obvious location errors.

TABLE C4.--Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno

Data have been gathered from the indicated sources, screened for duplication and obvious location errors, and assigned model segment and subreach locations based on ground-water flow paths estimated from topographic maps (see text).

Site: Sequential number for sites; *, indicated site not used in subsequent analysis because of uncertain location or distance from the river.

Location: Township north and range east of the Mt. Diablo baseline and meridian. Sections quartered by standard USGS location index (A = NE¼, B = NW¼, C = SW¼, D = SE¼); successive sites in the same subsection assigned an arbitrary sequential number.

Name: Abbreviation of owner's name or other site label from data sources.

Date: Year, month, and day of sample collection.

DS: Dissolved solids. Determination lab-dependent: for U.S. Geological Survey labs, residue on evaporation at 180 °C; for Nevada Bureau of Laboratories and Research, residue on evaporation at 105 °C, for DRI labs, generally calculated based on sum of determined ions; others unknown; e indicates estimation of DS by multiplying specific conductance by the regression factor 0.742 (30 points in regression, correlation coefficient = 0.997, DS mean = 542 mg/L, range = 169 to 3440 mg/L, standard error of estimate = 71 mg/L).

Source of data: B, Bratberg, 1980; C, CH2M-Hill, 1980; F, USGS files; N, Nevada Consumer Health Protecton Service files; P, Pyramid Lake Tribal Council, 1980; V, Van Denburgh and others, 1973; W, DRI "WADS" data base, 1978 retrieval.

Laboratory: B, Brown and Caldwell; C, Curtis Abs; D, DRI; E, Edna Wood; G, U.S. Geological Survey; H, CH2M-Hill; P, Southern Pacific Railroad; R, U.S. Bureau of Reclamation; --, unknown.

Site	Location: Nevada identification system	Location: Model stream segment	Location: Subreach	Name	Date	Well depth (ft)	Water temperature (°C)	Specific conductance (µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
1	N19E20 01B	2	A	WESTBY, A	731127	175	--	--	270	1.15	--	54	14	3.9	N	N
2	N19E20 01B	2	A	WESTBY, A	780627	184	--	--	301	1.06	--	50	12	4.2	N	N
3	N19E20 01C	2	A	--	790524	175	--	--	277	8.13	--	53	13	4.1	N	N
4	N19E20 01C	2	A	--	790924	177	--	--	341	3.16	--	57	23	2.5	N	N
5	N19E20 01C	2	A	BEELEN,C	810204	265	--	--	358	.52	--	139	13	10.7	N	N
6	N19E20 01C	2	A	BROWN, J	781030	91	--	--	295	2.08	--	19	8	2.4	N	N
7	N19E20 01C	2	A	BROWNFIELD	751208	120	--	--	316	.70	--	117	57	2.0	N	N
8	N19E20 01C	2	A	CHARLES, B	811229	265	--	--	349	.54	--	135	14	9.6	N	N
9	N19E20 01C	2	A	CURRY, A	711207	--	--	--	486	3.61	--	26	65	.4	N	N
10	N19E20 01C	2	A	KELLERS WR	720411	140	--	--	559	2.01	--	179	40	4.5	W	N

TABLE C4.--Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Sub-reach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (~~umhos~~ µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
11	N19E20	01C	2	A	KOUNNDA, G	810610	325	—	—	321	.84	—	67	13	5.2	N	N
12	N19E20	01C	2	A	LONGE, G	800728	400	—	—	298	.02	—	59	11	5.4	N	N
13	N19E20	01C	2	A	MARTINEZ	761116	188	—	—	322	4.29	—	57	20	2.8	N	N
14	N19E20	01C	2	A	MCKENSIE, B	761220	320	—	—	320	.93	—	60	20	3.0	N	N
15	N19E20	01C	2	A	PRICKETT, C	790620	277	—	—	248	1.02	—	85	14	6.1	N	N
16	N19E20	01C	2	A	STANWELL, W	770516	240	—	—	327	.77	—	130	15	8.7	N	N
17	N19E20	01C	2	A	THOMAS, A	820118	277	—	—	254	1.06	—	92	12	7.7	N	N
18	N19E20	02	2	A	—	770916	—	—	—	292	.36	—	56	18	3.1	N	N
19	N19E20	02	2	A	—	780307	254	—	—	356	.72	—	151	7	21.6	N	N
20	N19E20	02	2	A	—	780714	275	—	—	182	.25	—	49	15	3.3	N	N
21	N19E20	02	2	A	—	790823	320	—	—	339	.20	—	127	13	9.8	N	N
22	N19E20	02	2	A	BAILEY CAN	701004	—	—	—	537	.05	—	187	6	31.2	W	N
23	N19E20	02	2	A	BANKS, R	770617	140	—	—	289	1.13	—	52	14	3.7	N	N
24	N19E20	02	2	A	BUGICA, V	740308	162	—	—	290	.97	—	51	15	3.4	N	N
25	N19E20	02	2	A	COOPER, J	800820	—	—	—	179	.02	—	9	2	4.5	N	N
26	N19E20	02	2	A	CRANE	780113	110	—	—	315	.14	—	71	10	7.1	N	N
27	N19E20	02	2	A	DIGENNARE	780216	177	—	—	311	.81	—	120	16	7.5	N	N
28	N19E20	02	2	A	GEORGE, R	770605	180	—	—	287	.97	—	53	14	3.8	N	N
29	N19E20	02	2	A	HORNING, L	770627	174	—	—	297	1.38	—	56	15	3.7	N	N
30	N19E20	02	2	A	HOUGHT, D	720831	156	—	—	346	2.48	—	84	15	5.6	N	N
31	N19E20	02	2	A	MARTINI, B	750525	250	—	—	815	20.32	—	225	108	2.1	N	N
32	N19E20	02	2	A	MOORE, B	750626	135	—	—	264	16.93	—	44	18	2.4	N	N
33	N19E20	02	2	A	NV NATL BK	770720	174	—	—	288	1.17	—	51	15	3.4	N	N
34	N19E20	02	2	A	ONBASE, L	711009	175	—	—	247	1.08	—	51	16	3.2	N	N
35	N19E20	02	2	A	PAGNI	771006	—	—	—	307	.32	—	65	18	3.6	N	N
36	N19E20	02	2	A	RIPPINGHAM	790801	150	—	—	319	3.39	—	60	23	2.6	N	N
37	N19E20	02	2	A	SELDIN	771215	92	—	—	192	.00	—	42	15	2.8	N	N
38	N19E20	02	2	A	SMITH, J	800317	320	—	—	320	.34	—	120	10	12.0	N	N
39	N19E20	02	2	A	TAYLOR	711119	—	—	—	6212	.18	—	234	2100	.1	N	N
40	N19E20	02	2	A	THORSON, F	770324	254	—	—	254	.50	—	144	15	9.6	N	N
41	N19E20	02AD 1	2	A	PAGNI, J	580513	210	17	433	259	.41	.03	59	24	2.5	F	G
	N19E20	02AD 1	2	A	PAGNI, J	651901	210	—	—	244	2.26	—	48	21	2.3	N	N
	N19E20	02AD 1	2	A	PAGNI, J	660119	210	—	—	457	5.64	—	86	14	6.1	N	N
	N19E20	02AD 1	2	A	PAGNI, J	710519	210	—	—	454	1.51	—	25	10	2.5	N	N
42	N19E20	02BCC	2	A	KOH RADIO	710715	—	—	—	331	.00	—	105	5	21.0	N	N

TABLE C4.—Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
43	N19E20	02CB	2	A	MARTINI, B	720323	142	—	—	884	17.61	--	248	140	1.8	N	N
44	N19E20	02CB	2	A	MARTINI, B	720604	110	—	—	395	3.16	—	88	24	3.7	N	N
45	N19E20	03	3	A	—	780530	351	--	--	466	4.06	—	75	18	4.2	N	N
46	N19E20	03	3	A	—	780711	184	—	--	219	1.11	--	46	6	7.7	N	N
47	N19E20	03	3	A	LUCHITTI	750908	100	—	--	401	.05	—	130	28	4.6	N	N
48	N19E20	03CA 1	3	A	NICHOLS, A	580213	213	14	323	256	.00	.03	66	6.5	10.2	F	G
49	N19E20	04	1	A	ALLARD, F	700109	50	—	--	397	1.63	—	39	10	3.9	N	N
50	N19E20	04	1	A	CARISON, E	761006	65	--	—	273	.81	—	34	7	4.9	N	N
51	N19E20	04	1	A	H. REALTY	781207	—	—	—	2104	.88	—	1185	29	40.9	N	N
52	N19E20	04	1	A	NELSON	690603	65	—	—	292	.27	—	31	3	10.3	N	N
53	N19E20	04AA	1	A	1300 N TRU	631123	—	—	—	270	.45	—	38	9	4.2	W	N
54	N19E20	04DC 1	1	A	T78 STANFO	580718	402	14	270	218	.23	--	49	5	9.8	W	-
	N19E20	04DC 1	1	A	T78 STANFO	680807	402	—	331	312	.00	.18	68	4.9	13.9	W	D
55	N19E20	04DCBD	1	A	SPPCO 3B	600809	662	22	395	300	—	—	84	8	10.5	F	C
	N19E20	04DCBD	1	A	SPPCO 3B	601210	662	18	352	255	—	1.63	—	76	—	F	C
	N19E20	04DCBD	1	A	SPPCO 3B	691111	662	—	343	268	.54	—	70	8	8.8	V	B
56	N19E20	04DCC	1	A	SPPCO 3B	600802	131	17	247	267	.32	—	34	6	5.7	W	-
57	N19E20	04DCC	1	A	SPPCO 3B	600809	582	22	582	351	.32	—	83	8	10.4	W	-
58	N19E20	04DCC	1	A	SPPCO 3B	601210	437	18	352	316	.32	—	75	5	15.0	W	-
59	N19E20	04DD	1	A	PRATER W	651013	—	--	--	1081	—	—	192	32	6.0	W	N
60	N19E20	09	1	A	COOK, W	721219	150	—	—	237	2.71	--	15	15	1.0	N	N
61	N19E20	09	1	A	HOME GARD.	730504	—	—	—	825	.00	—	62	23	2.7	W	N
62	N19E20	09	1	A	PRICE, D	810819	150	—	—	520	1.90	—	208	19	11.0	N	N
63	N19E20	10	1	A	—	800528	160	—	—	303	2.71	—	17	12	1.4	N	N
64	N19E20	10	1	A	—	800616	283	—	--	308	7.00	—	16	29	.6	N	N
65	N19E20	10	1	A	CUTLER	770119	100	—	—	367	.00	—	105	24	4.4	N	N
66	N19E20	10	1	A	DES MOINES	740429	90	—	—	252	.00	—	11	.6	18.3	N	N
67	N19E20	10	1	A	HODGERS	661216	200	—	—	285	.00	—	106	130	.8	N	N
68	N19E20	10	1	A	KLEPPE, A	760129	90	—	—	244	.05	--	15	8	1.9	N	N
69	N19E20	10	1	A	N HWY DEPT	721005	100	—	—	187	1.47	--	19	8	2.4	N	N
70	N19E20	10	1	A	WHITEMAINE	800528	80	—	—	327	.00	—	100	23	4.4	N	N
71	N19E20	10BA	1	A	GERING PROD	790702	141	—	—	241	.45	--	67	9	7.4	N	N
72	N19E20	10D	1	A	KLEPPE LN	640624	—	—	—	194	.45	--	19	15	1.3	W	N
73	N19E20	10DC 1	1	A	PURINA #2	710623	40	—	—	329	.00	—	12	6	2.0	N	N
74	N19E20	10DC 2	1	A	PURINA #3	710623	40	—	—	311	.00	--	17	7	2.4	N	N
75	N19E20	10DC3	1	A	PURINA #4	710623	40	—	—	363	.00	—	16	6	2.7	N	N

TABLE C4.—Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno—Continued

Site	Township	Section and quar-ters	Model stream seg-ment	Sub-reach	Name	Date	Well depth (ft)	Temp-era-ture (°C)	Spec-ific con-duc-tance (μS at 25 °C)	DS (mg /L)	Nitrate (mg/L as N)	Ortho-phos-phorus (mg/L as P)	Sul-fate (mg/ L)	Chlor-ide (mg/L)	Sul-fate/ chlor-ide ratio	Source	Lab-ora-tory
76	N19E20	11	2	A	—	671101	—	—	—	266	2.26	—	19	9	2.1	N	N
77	N19E20	11	2	A	—	721129	—	—	—	212	.25	—	36	12	3.0	N	N
78	N19E20	11	2	A	6000 KLEPP	730706	100	—	—	239	.05	—	56	10	5.6	W	N
79	N19E20	11	2	A	COSH, W	790531	130	—	—	340	3.84	—	56	13	4.3	N	N
80	N19E20	11	2	A	CUTLER, F	721208	70	—	—	346	.00	—	8	8	1.0	N	N
81	N19E20	11	2	A	MORRIS	740508	132	—	—	235	.90	—	26	21	1.2	N	N
82	N19E20	11	2	A	PIPER	730424	205	—	—	247	2.26	—	28	40	.7	W	N
83	N19E20	11A	2	A	MARTINI BR	720905	108	—	—	273	3.16	—	34	17	2.0	N	N
	N19E20	11A	2	A	MARTINI BR	740723	108	—	—	277	3.16	—	44	21	2.1	N	N
84	N19E20	11BAD 1	2	A	—	—	340	—	—	1591	—	—	785	93	8.4	W	N
85	N19E20	11BC 1	2	A	VISTA ROCK	580213	340	—	673	467	.11	.23	153	33	4.6	F	G
86	N19E20	11DA	2	A	DONATI	710128	70	—	—	767	2.26	—	274	54	5.1	N	N
	N19E20	11DA	2	A	DONATI	721208	70	—	—	346	—	—	70	8	8.8	W	N
87	N19E20	12	2	A	—	721129	—	—	—	224	.29	—	39	14	2.8	N	N
88	N19E20	12	3	A	BAILEY	790521	—	—	—	189	6.09	—	14	2	7.0	N	N
89	N19E20	13	3	A	BRITTINGHA	691105	—	—	—	937	2.48	—	258	110	2.4	W	N
90	N19E20	13	3	A	BUSBY, V	710622	175	—	—	181	1.74	—	2	2	1.0	N	N
91	N19E20	13	3	A	PFENNING, I	770420	80	—	—	827	1.85	—	425	20	21.2	N	N
92	N19E20	13ADDA	4	B	N HWY DEPT	690730	170	23	1500	1110e	—	—	247	93	2.7	V	G
	N19E20	13ADDA	4	B	N HWY DEPT	691105	170	—	—	937	2.48	—	258	11	23.4	N	N
	N19E20	13ADDA	4	B	N HWY DEPT	710727	170	—	—	860	1.56	—	230	80	2.9	W	N
	N19E20	13ADDA	4	B	N HWY DEPT	710809	170	—	—	832	1.67	—	240	81	3.0	N	N
	N19E20	13ADDA	4	B	N HWY DEPT	730131	170	—	—	874	1.22	—	234	77	3.0	W	N
	N19E20	13ADDA	4	B	N HWY DEPT	740123	170	—	—	952	1.96	—	267	85	3.1	N	N
	N19E20	13ADDA	4	B	N HWY DEPT	740131	170	—	—	931	1.60	—	267	85	3.1	N	N
	N19E20	13ADDA	4	B	N HWY DEPT	750106	170	—	—	1011	2.12	—	323	92	3.5	N	N
	N19E20	13ADDA	4	B	N HWY DEPT	790726	170	—	—	1021	1.94	—	332	96	3.5	N	N
93	N19E20	15	1	A	BOGARD, J	781109	—	—	—	208	.32	—	13	2	6.5	N	N
	N19E20	15	1	A	BOGARD, J	781207	—	—	—	205	.45	—	13	23	.6	N	N
94	N19E20	15	1	A	JONES	661103	125	—	—	554	1.49	—	110	112	1.0	N	N
95	N19E20	15	1	A	UNR FARMS	791017	185	—	—	778	.20	—	121	165	.7	N	N
96	N19E20	15	1	A	UNR FARMS	791217	—	—	—	267	1.11	—	26	10	2.6	N	N
97	N19E20	15	1	A	UNR FARMS	791217	66	—	—	348	.00	—	19	10	1.9	N	N
98	N19E20	15	1	A	UNR FARMS	810609	160	—	—	714	.23	—	99	165	.6	N	N
99	N19E20	15	1	A	UNR FARMS	791217	—	—	—	319	.14	—	109	10	10.9	N	N
100	N19E20	16	1	A	—	750530	—	—	—	238	.81	—	17	6	2.8	N	N
101	N19E20	16	1	A	—	781030	—	—	—	207	1.11	—	38	10	3.8	N	N

TABLE C4.--Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance ~~(umhos~~ µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
102	N19E20	16	1	A	ANDERSON,	580528	60	—	—	211	.11	—	26	4	6.5	N	N
103	N19E20	16	1	A	AZCARTE, C	781024	—	—	—	203	2.26	—	56	11	5.1	N	N
104	N19E20	16	1	A	BOGARD, J	781023	—	—	—	244	.32	—	14	4	3.5	N	N
105	N19E20	16	1	A	BROWN	661103	35	—	—	206	3.39	—	29	5	5.8	N	N
106	N19E20	16	1	A	CADOTTE, R	731109	230	—	—	484	.41	—	157	9	17.4	N	N
107	N19E20	16	1	A	CALDWELL	781024	—	—	—	259	1.65	—	89	20	4.4	N	N
108	N19E20	16	1	A	CARTER	740425	110	—	—	207	.02	—	9	6	1.5	N	N
109	N19E20	16	1	A	CRICK, B	780628	300	—	—	439	.52	—	14	135	.1	N	N
110	N19E20	16	1	A	FEHR, H	791124	148	—	—	202	.07	—	19	9	2.1	N	N
111	N19E20	16	1	A	FRANDSEN, R	781030	150	—	—	381	3.61	—	18	12	1.5	N	N
112	N19E20	16	1	A	GRAHAM, F	770721	165	—	—	849	.00	—	383	25	15.3	N	N
113	N19E20	16	1	A	MILLER, R	780927	150	—	—	211	.00	—	27	3	9.0	N	N
114	N19E20	16	1	A	NASH, M	781030	120	—	—	193	.36	—	34	5	6.8	N	N
115	N19E20	16	1	A	UNR FARMS	791217	—	—	—	1012	.16	—	129	173	.8	N	N
116	N19E20	16	1	A	UNR FARMS	791217	75	—	—	692	.00	—	348	27	12.9	N	N
117	N19E20	16	1	A	UNR FARMS	791217	105	—	—	205	1.92	—	19	8	2.4	N	N
118	N19E20	16	1	A	UNR FARMS	791217	160	—	—	159	3.61	—	14	6	2.3	N	N
119	N19E20	16	1	A	UNR FARMS	791217	186	—	—	293	.11	—	109	11	9.9	N	N
120	N19E20	16	1	A	UNR FARMS	600215	—	—	—	183	1.35	—	26	5	5.2	W	N
121	N19E20	16	1	A	UNR FARMS	671023	—	—	—	167	2.71	—	29	3	9.7	N	N
122	N19E20	16	1	A	WRIGHT, E	780927	250	—	—	217	.07	—	28	4	7.0	N	N
123	N19E20	16ACA 1	1	A	UNR FARMS	561105	500	14	459	320	.00	—	111	12	9.2	F	R
124	N19E20	16CDD 1	1	A	UNR FARMS	560510	210	12	490	339	.11	—	120	13	9.2	F	R
125	N19E20	16DB 1	1	A	UNR FARMS	580519	18	—	333	224	1.02	.07	25	7. 2	3.5	F	G
126	N19E20	21	1	A	—	801211	—	—	—	216	.05	—	15	0	—	N	N
127	N19E20	21	1	A	—	811229	—	—	—	275	.00	—	57	6	9.5	N	N
128	N19E20	21	1	A	CAMPBELL	800208	50	—	—	223	.36	—	13	3	4.3	N	N
129	N19E20	21	1	A	COOPER, J	791105	93	—	—	210	.02	—	10	2	5.0	N	N
130	N19E20	21	1	A	EVERHEART	810515	80	—	—	187	.11	—	12	2	6.0	N	N
131	N19E20	21	1	A	HULL, C	791123	95	—	—	197	.11	—	9	2	4.5	N	N
132	N19E20	21	1	A	MANKEY	810406	20	—	—	283	.95	—	22	4	5.5	N	N
133	N19E20	21	1	A	ROGERS	800528	165	—	—	219	.09	—	14	3	4.7	N	N
134	N19E20	21	1	A	SCOTT	810521	—	—	—	204	.02	—	14	1	14.0	N	N
135	N19E20	21BCB	1	A	LAND CORP	691111	346	—	371	272	.00	—	45	8	5.6	V	N
136	N19E20	22DA 1	3	A	—	590813	75	18	1460	913	.41	—	175	315	.6	F	G

TABLE C4.--Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (μS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
137	N19E21	01A 1	2	D	MCCARRAN R	760123	—	—	—	205	.32	—	34	10	3.4	N	N
138	N19E21	01A 1	2	D	PAGNI RANC	710310	200	—	—	238	.68	—	58	21	2.8	W	N
139	N19E21	09	8	C	GRAHAM, G	650103	—	—	—	884	.00	—	624	24	26.0	N	N
140	N19E21	09	8	C	HEIMERMAN	750909	253	—	—	697	5.42	--	214	40	5.3	N	N
141	N19E21	09D	8	C	MSTNG BAR	741010	185	—	--	650	6.09	—	214	37	5.8	N	N
	N19E21	09D	8	C	MSTNG BAR	760310	185	—	--	675	7.00	—	203	38	5.3	N	N
	N19E21	09D	8	C	MSTNG BAR	760629	185	—	--	700	6.32	—	205	37	5.5	N	N
	N19E21	09D	8	C	MSTNG BAR	760720	185	—	--	675	6.55	—	205	37	5.5	N	N
	N19E21	09D	8	C	MSTNG BAR	770614	185	—	—	670	6.55	—	211	39	5.4	N	N
142	N19E21	09DA	8	C	MSTNG LND F	690219	285	—	—	378	4.97	—	96	26	3.7	N	N
143	N19E21	09DAD	8	C	MSTNG LND F	700305	330	—	590	440 e	--	--	103	34	3.0	V	G
	N19E21	09DAD	8	C	MSTNG LND F	710511	330	—	--	409	2.23	—	83	27	3.1	N	N
	N19E21	09DAD	8	C	MSTNG LND F	760719	330	—	—	415	2.48	—	76	27	2.8	N	N
	N19E21	09DAD	8	C	MSTNG LND F	770823	330	—	—	383	1.35	—	77	20	3.8	N	N
	N19E21	09DAD	8	C	MSTNG LND F	781019	330	—	--	391	2.26	—	78	26	3.0	N	N
	N19E21	09DAD	8	C	MSTNG LND F	830222	330	—	--	394	2.05	—	61	22	2.8	N	N
144	N19E21	09DD	8	C	MSTNG AUTO	750505	165	—	—	648	.14	—	231	32	7.2	N	N
145	N19E21	15AC 1	8	C	CONFORTE, J	750815	100	—	—	319	.00	—	53	17	3.1	N	N
146	N19E21	15AC 2	8	C	CONFORTE, J	811020	110	—	—	329	.09	—	—	19	—	N	N
147	N19E21	15BB	8	C	MYLAN, L	600727	181	—	--	139	.56	—	253	30	8.4	N	N
148	N19E21	16	8	C	PETERSON, P	800701	—	—	—	315	.86	—	70	10	7.0	N	N
149	N19E21	16	8	C	PORTER, H	640730	130	—	—	870	.00	—	432	27	16.0	N	N
150	N19E21	16A	8	C	LIBERTY VIL	790618	—	—	—	464	1.17	—	195	12	16.2	N	N
151	N19E21	16C	8	C	LAGOMAR CN	580425	—	—	—	132	—	—	31	13	2.4	W	N
152	N19E21	16C	8	C	LAGOMAR CN.	580425	—	—	--	448	4.29	—	120	12	10.0	W	N
153	N19E21	16CA	8	C	NN RACING	800926	300	—	—	2010	.11	—	1220	14	87.1	N	N
	N19E21	16CA	8	C	NN RACING	801010	300	—	—	2050	—	—	1190	—	—	N	N
154	N19E21	16CB	8	C	TRIPLE M	800630	235	—	—	324	.14	—	40	12	3.3	N	N
155	N19E21	16CC	8	C	DODD, J	718112	90	—	—	1334	.00	—	653	15	43.5	N	N
156	N19E21	16CC 1	7	B	CONFORTE TP	700505	165	—	—	892	.18	--	530	13	40.8	N	N
	N19E21	16CC 1	7	B	CONFORTE TP	720511	165	—	—	1085	.11	—	760	17	44.7	W	N
	N19E21	16CC 1	7	B	CONFORTE TP	720712	165	—	—	1039	.16	—	733	18	40.7	W	N
	N19E21	16CC 1	7	B	CONFORTE TP	730813	165	—	—	1103	.20	—	591	18	32.8	W	N
	N19E21	16CC 1	7	B	CONFORTE TP	730813	165	—	—	977	.25	--	557	17	32.8	W	N

TABLE C4.--Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
157	N19E21	16CC 2	4	B	LCKWD DUMP	760831	--	--	--	1516	.56	--	832	20	41.6	N	N
158	N19E21	16CC 2	8	C	NN RACING	801112	100	--	--	708	--	--	410	--	--	N	N
159	N19E21	16CC 2	8	C	NN RACING	801112	200	--	--	1265	--	--	725	--	--	N	N
160	N19E21	16CC3	8	C	SPINK CORP	811222	140	--	--	267	--	--	--	--	--	N	N
161	N19E21	16DB 1	8	C	CONFORTE TP	741104	88	--	--	287	1.53	--	52	10	5.2	N	N
	N19E21	16DB 1	8	C	CONFORTE TP	770907	88	--	--	246	1.40	--	57	14	41 7	N	N
	N19E21	16DB 1	8	C	CONFORTE TP	780418	88	--	--	310	1.22	--	110	10	11.0	N	N
	N19E21	16DB 1	8	C	CONFORTE TP	780724	88	--	--	293	1.63	--	74	10	7.4	N	N
	N19E21	16DB 1	8	C	CONFORTE TP	800219	88	--	--	322	1.63	--	59	14	4.2	N	N
162	N19E21	16DBD	8	C	PERI BROS	690728	122	15	770	570e3	1.15	--	75	48	1.6	V	G
163	N19E21	16DD 1	8	C	KEARNEY,F	660216	178	--	--	327	.00	--	82	14	5.9	N	N
164	N19E21	17	6	B	6MI E SPAR	600808	--	--	--	364	.56	--	91	37	2.5	W	N
165	N19E21	17	6	B	GREEN, S	571217	40	--	--	1172	4.29	--	360	120	3.0	N	N
166	N19E21	17	6	B	HAPPY VALE	650314	79	14	--	2015	.68	--	1200	30	40.0	F	N
167	N19E21	17	6	B	HAPPY VALE	600809	--	--	--	908	.56	--	312	99	3.2	W	N
168	N19E21	17	6	B	JOHNSTON, A	700506	--	--	--	429	1.26	--	102	46	2.2	W	N
169	N19E21	17	6	B	RUDE, R	790521	--	--	--	331	2.48	--	35	89	.4	N	N
170	N19E21	17	6	B	WILSON, J	720710	100	--	--	1968	5.19	--	733	405	1.8	N	N
	N19E21	17	6	B	WILSON, J	720710	100	--	--	2114	7.00	--	767	425	1.8	N	N
171	N19E21	17C	6	B	49 LCKWD R	720817	68	--	--	602	.16	--	180	75	2.4	N	N
172	N19E21	17C	6	B	49 LCKWD RD	750314	--	--	--	1290	.18	--	444	142	3.1	N	N
173	N19E21	17D	6	B	15 LKWD RD.	780214	85	--	--	1442	5.64	--	452	200	2.3	N	N
174	N19E21	17D	6	B	23 LCKWD RD	800202	--	--	--	1170	17.16	--	300	263	1.1	N	N
175	N19E21	17D	6	B	BARLTETT, L	761026	--	--	--	300	.52	--	67	24	2.8	N	N
176	N19E21	17D	6	B	LAGO. BR.	600205	--	--	--	852	--	--	250	80	3.1	W	N
177	N19E21	17D	6	B	LOCKWOOD R	710610	40	--	--	1934	10.61	.09	530	360	1.5	W	N
178	N19E21	17D	6	B	MASON, R	630204	--	--	--	5452	16.70	--	1200	850	1.4	W	N
179	N19E21	17D	6	B	MASON, R	630303	--	--	--	2183	.23	--	192	260	.7	W	N
180	N19E21	17DC 1	6	B	ELMER'S TP	600809	123	--	--	909	.02	--	312	100	3.1	N	N
181	N19E21	17DC 2	6	B	COUNTRY TP	781009	--	--	--	582	.99	--	163	66	2.5	N	N
182	N19E21	17DC 4	6	B	LONGRDG TP	790123	85	--	--	391	1.20	--	88	46	1.9	N	N
183	N19E21	17DC3	6	B	TRKE. R. TP	780714	--	--	--	470	1.02	--	110	51	2.2	N	N
	N19E21	17DC3	6	B	TRKE. R. TP	800915	--	--	--	563	2.48	--	139	113	1.2	N	N
184	N19E21	17DDA 1	6	B	RENO RENDE	800610	165	--	--	1117	--	--	330	164	2.0	N	N

TABLE C4.—Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
185	N19E21	17DDB 1	6	B	LCKWD STORE	730129	—	—	—	1626	13.09	—	533	172	3.1	N	N
	N19E21	17DDB 1	6	B	LCKWD STORE	741009	—	—	—	1513	6.77	—	450	183	2.5	N	N
	N19E21	17DDB 1	6	B	LCKWD STORE	760112	—	—	—	1134	.97	—	294	136	2.2	N	N
	N19E21	17DDB 1	6	B	LCKWD STORE	770328	—	—	—	1236	1.06	—	301	180	1.7	N	N
	N19E21	17DDB 1	6	B	LCKWD STORE	790302	—	—	—	1231	1.20	—	296	215	1.4	N	N
	N19E21	17DDB 1	6	B	LCKWD STORE	790321	—	—	—	1217	—	—	—	—	—	N	N
186	N19E21	21	8	C	BLAND, H	780418	—	—	—	1336	3.61	—	446	177	2.5	N	N
187	N19E21	21	8	C	HILL, S	591021	30	—	—	1350	.00	—	960	15	64.0	N	N
188	N19E21	21AC	8	C	T116 L. SP	700331	—	8	—	921	—	—	416	22	18.9	W	D
189	N19E21	21ACB	8	C	BEM CORP	691123	94	—	—	1190	4.51	—	350	25	14.0	V	N
190	N19E21	22	8	C	BENNETT, C	640408	58	—	—	260	.00	—	62	17	3.6	N	N
191	N19E21	22	8	C	FOOTE, T.	791105	495	—	—	1081	.11	—	675	13	51.9	N	N
192	N20E22	27CC 1	16	D	SPPCO TW13	600928	622	19	280	198	—	—	19	9	2.1	F	C
193	N20E22	27CC 2	16	D	SPPCO TW14	601012	461	17	255	181	—	—	23	11	2.1	F	C
194	N20E22	28BCC	16	D	BLM STEIDL	700305	141	—	190	140e	—	—	8	6	1.3	V	G
195	N20E22	33B	14	D	TRACY	700312	200	—	—	322	2.26	—	59	66	.9	W	N
196	N20E22	33BAB	14	D	SPPCO	610530	133	14	306	215	—	—	23	15	1.5	V	C
197	N20E22	35A	17	D	EAGLE PITC	730514	200	—	—	426	1.85	—	140	28	5.0	W	N
198	N20E22	35B	16	D	SPPC TH 13	600928	—	19	280	261	—	—	19	9	2.1	W	N
199	N20E22	35B	16	D	SPPC TH 14	601012	370	17	—	326	.23	—	19	15	1.3	W	N
200	N20E23	21	21	E	SEAY, J	730717	42	—	—	195	.45	—	13	8	1.6	W	N
201	N20E23	21DAA	21	E	LUTZOW, R	700305	76	—	240	180e	—	—	10	11	.9	V	G
202	N20E23	22	22	E	ORCHARD EX	—	65	—	—	265	.34	—	52	16	3.2	W	N
	N20E23	22	22	E	ORCHARD EX	610405	65	—	—	340	.68	—	72	30	2.4	W	N
	N20E23	22	22	E	ORCHARD EX	710324	65	—	—	270	.84	—	65	15	4.3	W	N
203	N20E23	23B	22	E	9MI W WADS	730727	375	—	—	353	—	—	15	17	.9	W	N
204	N20E23	23B	22	E	PAINTED R	710429	30	—	—	186	1.06	—	17	10	1.7	W	N
205	N20E24	03B	29	G	SPRING	790302	—	—	860	640e	—	—	222	33	6.7	W	D
206	N20E24	03B	29	G	WADS INDI	571118	—	—	—	510	.56	—	183	21	8.7	W	G
207	N20E24	03BB 1	28	G	S.P. RR	390204	30	—	—	318	—	—	—	—	—	S	P
	N20E24	03BB 1	28	G	S.P. RR	400528	30	—	467	350e	—	—	43	22	2.0	F	P
	N20E24	03BB 1	28	G	S.P. RR	480528	30	—	490	360e	—	—	37	21	1.8	F	P
	N20E24	03BB 1	28	G	S.P. RR	480528	30	—	490	360e	—	—	37	21	1.8	F	P
	N20E24	03BB 1	28	G	S.P. RR	610520	30	—	302	220e	4.97	—	29	26	1.1	F	N
	N20E24	03BB 1	28	G	S.P. RR	610520	30	—	302	220e	4.97	—	29	26	1.1	F	N

TABLE C4.—Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno—Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (~~µmhos~~ µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
208	N20E24	03CC	27	F	CONFORTI	660815	—	—	—	200	1.13	—	28	13	2.2	W	N
209	N20E24	03DD [1]	27	F	SPRING	490827	—	—	—	850	—	—	—	40	—	S	N
210	N20E24	04	29	G	COMM#2	750505	—	—	—	371	1.42	—	107	21	5.1	P	N
211	N20E24	04	29	G	GRAHAM, L	730725	55	—	—	380	.88	—	28	21	1.3	W	N
212	N20E24	04	29	G	WADSWORTH	610520	—	—	—	583	2.26	—	557	30	18.6	W	G
213	N20E24	04	29	G	WADSWORTH	710528	120	—	—	402	1.99	—	106	17	6.2	W	N
214	N20E24	04	29	G	WADSWORTH	710910	70	17	—	394	—	—	12	21	.6	W	N
215	N20E24	04	29	G	WADSWORTH	730122	160	—	—	340	1.35	—	38	24	1.6	W	N
216	N20E24	04AA [1]	29	G	STIPES, L	—	33	—	—	434	—	—	23	0	—	S	N
217	N20E24	04AAA	29	G	NATCHEZ SCH	740823	120	—	—	435	2.48	—	58	51	1.1	P	N
218	N20E24	04AAA	29	G	WADSW. SCH	620521	90	—	—	514	5.87	—	96	24	4.0	V	N
229	N20E24	04CB	29	G	DEPAOLI BR	730301	35	—	—	429	.45	—	56	26	2.2	W	N
220	N20E24	09	27	F	HART, J	720901	60	—	—	364	1.87	—	24	16	1.5	F	N
221	N20E24	09DA [1]	27	F	TCID	470213	115	—	—	232	—	—	—	—	—	S	N
222	N20E24	10	27	F	BEAVER, R	760505	155	—	—	578	.07	—	197	111	1.8	F	N
	N20E24	10	27	F	BEAVER, R	760512	155	—	—	589	.09	—	206	110	1.9	F	N
223	N20E24	10	27	F	CARLYLE, W	790315	—	—	—	357	1.72	—	88	30	2.9	F	N
224	N20E24	10	27	F	GNADIG, E	730315	170	—	—	399	1.76	—	110	27	4.1	F	N
	N20E24	10	27	F	GNADIG, E	760304	170	—	—	468	.68	—	144	52	2.8	F	N
225	N20E24	10	27	F	HEATER, V	770415	65	—	—	264	2.71	—	53	17	3.1	F	N
226	N20E24	10	27	F	LAW, K	701004	75	—	—	400	2.10	—	69	27	2.6	W	N
227	N20E24	10	27	F	OSTRANDER	751015	140	—	—	227	.70	—	28	15	1.9	F	N
	N20E24	10	27	F	OSTRANDER	780314	140	—	—	283	2.48	—	36	18	2.0	F	N
228	N20E24	10	27	F	ROGERS, R	770118	55	—	—	339	.47	—	64	43	1.5	F	N
	N20E24	10	27	F	ROGERS, R	780114	55	—	—	333	.41	—	77	40	1.9	F	N
229	N20E24	10	27	F	TUTTLE, S	770316	276	—	—	485	.56	—	158	50	3.2	F	N
	N20E24	10	27	F	TUTTLE, S	790402	276	—	—	503	.79	—	150	50	3.0	F	N
230	N20E24	10CADD	27	F	PORTER, R.	740121	90	—	—	274	1.38	—	32	15	2.1	F	N
	N20E24	10CADD	27	F	PORTER, R.	740215	90	—	—	268	1.24	—	34	18	1.9	F	N
231	N20E24	10CADD	27	F	RODGERS, RW	680519	41	—	—	245	1.49	—	19	13	1.5	F	N
232	N20E24	10CADD	27	F	ROGERS, RW	690724	87	—	—	253	.47	—	17	17	1.0	F	N
233	N20E24	10CDDD	27	F	GELMSTEDT	730429	170	—	—	491	.02	—	22	84	.3	F	N
234	N20E24	10DA [2]	27	F	DAY, J	520407	40	—	—	557	—	—	—	28	—	S	N
235	N20E24	10DBBB	27	F	ZURFIUH, F	781109	155	—	—	233	1.13	—	30	12	2.5	F	N
236	N20E24	10DCAB	27	F	DODD, F	770322	115	—	—	679	1.58	—	287	52	5.5	F	N
237	N20E24	10DCCB	27	F	HILL, L.	770330	118	—	—	255	2.21	—	33	22	1.5	F	N
238	N20E24	10DCCC	27	F	FERRELL, C	711029	70	—	—	240	.70	—	30	12	2.5	F	N

TABLE C4.--Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (~~umhos~~ µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
239	N20E24	10DCCC	27	F	PETERSON, F	720821	72	—	—	319	1.96	—	49	21	2.3	F	N
240	N20E24	10DDDC	27	F	FERRELL, C	780116	70	—	—	275	1.81	—	41	13	3.2	F	N
241	N20E24	10DDDD	27	F	PRITCHARD	711201	60	—	—	254	.61	—	27	13	2.1	F	N
242	N20E24	11	28	G	—	700323	70	—	—	—	.79	—	314	27	11.6	W	N
243	N20E24	11	28	G	ENGEL, F	690911	—	—	—	171	.32	—	18	11	1.6	W	N
244	N20E24	11	28	G	JAMES, R	770711	—	—	—	654	3.16	—	142	19	7.5	F	N
245	N20E24	11	28	G	JOHNSON	760426	60	—	—	235	1.58	—	27	15	1.8	F	N
246	N20E24	11	28	G	LYON, A	730207	67	—	—	377	2.48	—	21	60	.4	F	N
247	N20E24	11	28	G	RAMSEIER	690916	—	—	—	650	1.65	—	269	22	12.2	W	N
248	N20E24	11	28	G	TRAMANE	760426	270	—	—	468	.88	—	148	53	2.8	F	N
249	N20E24	11	28	G	TRUCKEE LN	730207	67	—	—	337	2.48	—	60	21	2.9	W	N
250	N20E24	11BADC	28	G	NV CEMENT	770902	598	—	—	520	.56	—	188	32	5.9	F	N
	N20E24	11BADC	28	G	NV CEMENT	780414	598	—	—	473	1.53	—	167	27	6.2	F	N
251	N20E24	11BBDB	28	G	NV CEMENT	680709	252	20	—	622	2.71	—	224	22	10.2	V	G
	N20E24	11BBDB	28	G	NV CEMENT	750915	252	—	—	439	1.65	—	74	15	4.9	F	N
	N20E24	11BBDB	28	G	NV CEMENT	750917	252	—	—	586	.72	—	171	33	5.2	F	N
	N20E24	11BBDB	28	G	NV CEMENT	780602	252	—	—	475	1.53	—	128	26	4.9	F	N
	N20E24	11BBDB	28	G	NV CEMENT	790607	252	—	—	503	.07	—	154	34	4.5	F	N
252	N20E24	11CCCC	28	G	N HWY DEPT	700323	70	—	—	758	.79	—	314	27	11.6	F	N
	N20E24	11CCCC	28	G	N HWY DEPT	700528	70	—	—	651	.86	—	230	27	8.5	F	N
	N20E24	11CCCC	28	G	N HWY DEPT	710331	70	—	—	543	.54	—	201	23	8.7	F	N
253	N20E24	11CD 1	28	G	LYON CO.	730921	150	—	—	442	2.03	—	103	18	5.7	F	N
254	N20E24	11CD 2	28	G	GARDEN MTL	460914	35	—	—	655	—	—	185	34	5.4	S	G
255	N20E24	11DC3	28	G	GARDEN MTL	390116	30	—	—	415	—	—	115	12	9.6	S	G
256	N20E24	11DD4	28	G	JENNINGS, R	500424	42	—	—	1240	—	—	—	80	—	S	N
257	N20E24	11DD6	28	G	CAMPBELL, G	310418	44	—	—	2960	—	—	1590	148	10.7	S	G
258*	N20E24	14AA 1	27	F	WILLIAMS, D	490615	31	—	—	2720	—	—	—	—	—	S	N
259*	N20E24	14AAA 1	27	F	WILLIAMS, V	770718	28	—	—	5800	3.16	—	2402	940	2.6	F	N
260*	N20E24	14AAA 2	27	F	STRAUS, J	481231	133	—	—	2030	—	—	1110	50	22.2	S	N
261*	N20E24	14AC 1	27	F	MCCART, P	510417	84	—	—	678	—	—	—	26	—	S	N
262*	N20E24	14BAB 1	27	F	JACKSON, D	470204	23	—	—	312	—	—	74	21	3.5	F	G
263*	N20E24	14CCBC	27	F	JOHNSON DV	781103	465	—	—	487	.07	—	155	40	3.9	F	N
264*	N20E24	14CCBC	27	F	JOHNSON DV	790205	225	—	—	213	.05	—	13	12	1.1	F	N

TABLE C4.--Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
265	N20E24	14CD	27	F	WITT, P	510131	80	--	--	682	--	--	--	31	--	S	N
266	N20E24	14DC	27	F	FERREL, L	570220	76	--	--	362	--	--	--	13	--	S	N
267*	N20E24	15A	27	F	CURTIS, D	761064	72	--	--	486	1.08	--	142	30	4.7	F	N
	N20E24	15A	27	F	CURTIS, D	770303	72	--	--	463	1.31	--	117	28	4.2	F	N
268*	N20E24	15AA 1	27	F	BEACH, R&M	730418	63	--	--	331	3.39	--	83	21	4.0	F	N
269*	N20E24	15AACD	27	F	MCCOY, B	770603	70	--	--	458	.74	--	165	29	5.7	F	N
270*	N20E24	15ABCD	27	F	BANKS, V	780912	30	--	--	421	2.10	--	77	54	1.4	F	N
271*	N20E24	15AC 1	27	F	HENSLEY, E	760728	62	--	--	277	.38	--	34	20	1.7	F	N
272*	N20E24	15BADD	27	F	JACKSON, R	770823	65	--	--	349	.79	--	74	35	2.1	F	N
273	N20E24	18	25	F	ALBANESE, T	760602	42	--	--	410	2.48	--	37	13	2.8	F	N
274	N20E24	18	25	F	SNEDDES	740918	--	--	--	394	2.48	--	39	30	1.3	F	N
275	N20E24	18	25	F	WADSWORTH	700404	60	--	--	284	.84	--	34	20	1.7	W	N
276	N20E24	18B	25	F	N HWY DEPT	701211	60	--	--	287	.52	--	35	27	1.3	W	N
	N20E24	18B	25	F	N HWY DEPT	710419	60	--	--	306	.45	--	35	16	2.2	W	N
	N20E24	18B	25	F	N HWY DEPT	720315	60	--	--	304	.50	--	32	22	1.4	W	N
	N20E24	18B	25	F	N HWY DEPT	730131	60	--	--	332	.52	--	35	21	1.7	W	N
277*	N21E23	13DCC	33	H	DEPAOLI	700410	85	--	1300	970 e	--	--	416	70	5.9	V	G
278*	N21E23	35	33	H	SILAS, L	790720	400	--	--	256	.00	--	68	16	4.2	N	N
279*	N21E23	36	33	H	BARNES, S	790621	275	--	--	299	.18	--	93	20	4.6	N	N
280	N21E24	04	34	H	WADS MDBEN	721823	121	--	--	375	1.49	--	35	23	1.5	W	N
281	N21E24	05B	34	H	SPRING	780101	--	--	350	260 e	--	--	34	19	1.8	B	D
282	N21E24	09	33	H	WADSWORTH	710409	--	--	--	1084	.45	--	42	520	.1	W	N
283	N21E24	09CC	33	H	KOCHAMP, J	781208	142	--	--	1823	.09	--	179	780	.2	P	N
	N21E24	09CC	33	H	KOCHAMP, J	801208	142	--	--	1955	.09	--	191	850	.2	N	N
	N21E24	09CC	33	H	KOCHAMP, J	810116	142	--	--	1948	.07	--	201	840	.2	N	N
284	N21E24	15	32	H	GONZALAS, S	801207	156	--	--	201	.05	--	17	21	.8	N	N
285	N21E24	15	32	H	JAMES, R	780802	165	--	--	375	.00	--	25	55	.4	N	N
	N21E24	15	32	H	JAMES, R	781512	165	--	--	384	.05	--	26	55	.5	P	N
	N21E24	15	32	H	JAMES, R	801208	165	--	--	370	.02	--	25	53	.5	N	N
	N21E24	15	32	H	JAMES, R	810126	165	--	--	348	.02	--	26	53	.5	N	N
286	N21E24	15ACC	32	H	N2A	791020	92	17	420	242	.00	--	16	73	.2	B	H

TABLE C4.--Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (~~umhos~~ µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
287	N21E24	15ACC	32	H	N2B	791025	17	18	4720	3438	.01	—	128	541	.1	B	H
288	N21E24	15BC	32	H	TETON, P	781208	132	—	—	1818	.09	—	56	950	.1	B	H
	N21E24	15BC	32	H	TETON, P	810106	132	—	—	1509	.00	—	54	810	.1	P	N
289	N21E24	15D	32	H	COPELAND, R	781208	125	—	—	156	.00	—	23	27	.8	P	N
	N21E24	15D	32	H	COPELAND, R	801207	125	—	—	185	.00	—	18	17	1.1	N	N
	N21E24	15D	32	H	COPELAND, R	810116	125	—	—	161	.02	—	14	6	2.3	N	N
	N21E24	15D	32	H	COPELAND, R	810126	125	—	—	175	.00	—	1.7	4	.4	N	N
290	N21E24	15DC	32	H	COPELAND, E	770119	140	—	—	2700	.00	—	134	350	.1	P	N
	N21E24	15DC	32	H	COPELAND, E	781208	140	—	—	171	.00	—	13	9	1.4	N	N
	N21E24	15DC	32	H	COPELAND, E	801207	140	—	—	171	.09	—	14	5	2.8	N	N
291	N21E24	16	33	H	JAMES, A	750422	—	—	—	449	1.63	—	175	41	4.3	P	N
292	N21E24	16A	33	H	S-S RANCH	790611	380	—	—	354	.09	—	46	31	1.5	N	N
	N21E24	16A	33	H	S-S RANCH	791025	380	—	—	322	.05	—	35	35	1.3	N	N
293	N21E24	16ACA	33	H	S-S RANCH	700220	410	—	1700	1260 e	—	—	47	464	.1	V	G
294	N21E24	16ACA	33	H	S-S RANCH	760504	410	—	—	267	.11	—	18	9	2.0	N	N
	N21E24	16ACA	33	H	S-S RANCH	760601	410	—	—	261	.11		23	12	1.9	N	N
295	N21E24	22	32	H	GARCIA, P	810122	165	—	—	176	.00	—	16	8	2.0	N	N
296	N21E24	22	32	H	GARCIA, R	770119	—	—	—	252	.00	—	66	15	4.4	P	N
297	N21E24	22	32	H	JOHNS, F	770119	—	—	—	240	.00	—	58	20	2.9	P	N
298	N21E24	22ABD	32	H	NC	791025	17	18	1660	1176	.02	—	64	383	.2	B	H
299	N21E24	22D	32	H	POND	791025	—	—	2314	1933	.00	—	839	117	7.2	B	H
300	N21E24	22DA	32	H	C3A	791021	122	17	224	169	.00	—	20	8.3	2.4	B	H
301	N21E24	22DA	32	H	C3B	791021	17	16	960	710	.02	—	244	30	8.1	B	H
302	N21E24	22DD	32	H	C4	791018	38	14	653	506	.00	—	180	237	7.8	B	H
303	N21E24	23	32	H	COPELAND, S	780408	156	—	—	2768	.09	—	174	350	.1	P	N
304	N21E24	23	32	H	GENEVIEVE	780607	150	—	—	390	4.51	—	42	31	1.4	N	N
305	N21E24	23	32	H	P.P. GRAVE	810227	110	—	—	524	2.26	—	213	34	6.3	N	N
306	N21E24	23CC	32	H	C1	791020	45	16	1000	740 e	—	—	—	—	—	B	H
307	N21E24	23CC	32	H	C2A	791021	92	—	340	258	.00	—	71	13	5.5	B	H
308	N21E24	27	31	G	GARCIA, R	801208	—	—	—	176	.05	—	16	6	2.7	P	N
309	N21E24	27CB	31	G	JOHN, CM	801216	156	—	—	417	1.02	—	159	28	5.7	P	N
310	N21E24	27	31	G	JOHN, J	801216	100	—	—	1021	.02	—	499	37	13.5	P	N
311	N21E24	27A	31	G	BURNS, C	780512	—	—	—	326	.05	—	106	22	4.8	P	N
312	N21E24	27A	31	G	GARCIA, D	780518	179	—	—	184	.05	—	8	17	.5	P	N
313	N21E24	27CDC	30	G	SC	791024	32	14	1240	1087	.02	—	503	33	15.2	B	H
314	N21E24	28DDC	30	G	CERESOLA	700219	12	—	450	330 e	—	—	35	18	1.9	V	G

TABLE C4.—Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno--Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (~~µmhos~~ µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
315	N21E24	31	30	I	TOBEY, K	781228	470	—	—	303	.63	—	67	23	2.9	P	N
316	N21E24	33	39	G	USPHS	660913	100	—	—	427	3.16	—	206	21	9.8	N	N
317	N21E24	33AA	30	G	BIGPOND, K	790105	110	—	—	528	.09	—	220	52	4.2	P	N
	N21E24	33AA	30	G	BIGPOND, K	801207	110	—	—	551	2.03	—	218	38	5.7	N	N
	N21E24	33AA	30	G	BIGPOND, K	810116	110	—	—	560	1.92	—	229	41	5.6	N	N
318	N21E24	33AC	30	G	S3	791024	17	17	753	551	1.63	—	208	33	6.3	B	H
319	N21E24	33B	30	G	NEVACCO IND	711105	—	—	—	257	.50	—	33	15	2.2	W	N
320	N21E24	33CA	29	G	COMM#1	790418	—	—	—	372	2.17	—	40	24	1.7	P	N
321	N21E24	33CA	29	G	LEYVA, R	790105	135	—	—	136	.09	—	30	11	2.7	P	N
	N21E24	33CA	29	G	LEYVA, R	810116	135	—	—	205	.27	—	40	2	20.0	N	N
322	N21E24	33DB	29	G	NEVACCO IND	730122	600	—	—	264	.50	—	40	14	2.9	P	N
323	N21E24	33DCB	30	G	PL TRIBE	681101	470	—	—	184	.11	—	45	12	3.8	V	G
324	N21E24	34	29	G	BOX 10	720425	287	—	—	402	1.58	—	138	23	6.0	W	N
325	N21E24	34	29	G	JAMES, T	770119	141	—	—	534	1.74	—	198	26	7.6	P	N
326	N21E24	34	29	G	JAMES, T	780510	141	—	—	744	2.71	—	306	56	5.5	P	N
327	N21E24	34	29	G	JAMES, T	801207	141	—	—	683	2.71	—	284	50	5.7	N	N
328	N21E24	34C	29	G	JAMES, T	810116	95	—	—	673	2.48	—	260	53	4.9	N	N
329	N22E23	01	40	J	LITTLE NIX	660913	—	—	—	915	10.61	—	158	195	.8	W	N
330	N22E23	01BDA	40	J	L NIXON PS	620521	60	—	—	687	.00	—	67	160	.4	V	N
331	N22E23	35	34	H	PL TRIBE	770401	95	—	—	274	.00	—	41	30	1.4	N	N
332	N22E23	35	34	H	WADSWORTH	780512	—	—	—	539	.18	—	71	82	.9	P	N
333	N22E24	05B	40	J	—	780201	102	—	580	440 e	—	—	131	30	4.4	B	D
334	N22E24	05B	40	J	—	780301	294	—	430	330 e	—	—	92	23	4.0	B	DN
335	N22E24	09BAD	40	J	CERESOLA	700218	200	20	970	730 e	—	—	12	95	.1	V	G
336	N22E24	31A 1	35	I	DOW.2	780201	21	—	2400	1790e	—	—	85	595	.1	B	D
337	N22E24	31A 1	35	I	DOW.3	780201	103	—	2380	1770 e	—	—	83	615	.1	B	D
338	N22E24	31A 2	35	I	O'DAYE, E	790117	100	—	—	1411	.18	—	77	690	.1	N	N
	N22E24	31A 2	35	I	O'DAYE, E	810106	100	—	—	1502	.02	—	75	720	.1	P	N
339*	N22E24	36	34	H	ALVIN, J	780410	—	—	—	473	1.72	—	202	40	5.0	N	N
340	N23E23	—	40	J	HARRY, N	801208	204	—	—	493	.07	—	44	65	.7	P	N
341	N23E23	—	43	J	HENRY, TOM	620521	—	—	—	859	—	—	158	227	.7	W	N
342	N23E23	—	43	J	N HIGHWAY	660928	—	—	—	578	.90	—	98		24.5	W	N
343	N23E23	—	43	J	NIXON	610401	—	—	—	664	—	—	96	132	.7	W	N
344	N23E23	—	43	J	PAULINE	700709	—	—	—	412	.23	—	16	28	.6	P	N
345	N23E23	—	43	J	WARDEN, RA	690326	—	—	—	—	2.17	—	187	134	1.4	W	N

TABLE C4.—Inventory of selected data on the quality of ground waters adjacent to the Truckee River below Reno—Continued

Site	Township	Section and quarters	Model stream segment	Subreach	Name	Date	Well depth (ft)	Temperature (°C)	Specific conductance (~~µmhos~~ µS at 25 °C)	DS (mg/L)	Nitrate (mg/L as N)	Orthophosphorus (mg/L as P)	Sulfate (mg/L)	Chloride (mg/L)	Sulfate/chloride ratio	Source	Laboratory
346	N23E23	15CAD	43	J	GREENE, G	720219	115	—	2400	1790 e	—	—	581	201	2.9	V	G
347	N23E23	23BCB	42	J	WINNEMUCCA	700219	136	—	840	620 e	—	—	0	27	.0	V	G
348	N23E23	25	42	J	NIXON WELL	710528	300	—	—	449	.05	—	71	79	.9	W	N
349	N23E23	25	42	J	P LK B NIX	720727	—	—	—	310	.20	—	14	27	.5	W	N
350	N23E23	25	42	J	P LK B NIX.	720727	—	—	—	389	.11	—	12	25	.5	W	N
351	N23E23	25	42	J	PYR LK RES	720406	120	—	—	303	.00	—	38	45	.8	N	N
352	N23E23	25B	42	J	ABE&SUE	690326	400	—	—	430	—	—	90	74	1.2	W	N
353	N23E23	25BCD	42	J	NIXON PS	620521	350	—	—	809	—	—	52	127	.4	W	N
	N23E23	25BCD	42	J	NIXON PS	651111	350	—	—	375	.00	—	72	60	1.2	P	N
	N23E23	25BCD	42	J	NIXON PS	670930	350	22	—	—	.00	.39	69	66	1.0	F	D
	N23E23	25BCD	42	J	NIXON PS	700219	350	—	700	520 e	—	—	65	75	.9	V	G
	N23E23	25BCD	42	J	NIXON PS	711104	350	—	—	443	.09	—	52	79	.7	W	N
	N23E23	25BCD	42	J	NIXON PS	720111	350	—	—	464	.20	—	156	80	2.0	P	N
	N23E23	25BCD	42	J	NIXON PS	730410	350	—	—	391	.32	—	27	46	.6	P	N
	N23E23	25BCD	42	J	NIXON PS	730821	350	—	—	454	.14	—	74	85	.9	P	N
	N23E23	25BCD	42	J	NIXON PS	751113	350	—	—	515	.18	—	86	93	.9	P	N
354	N23E23	25CBA	42	J	NIXON SCH	620521	287	—	—	353	.00	—	24	64	.4	F	N
355	N23E23	26DDC	42	J	N HWY DEPT	660928	170	14	—	578	.90	—	125	98	1.3	V	N
356	N23E23	36DDC	40	J	ALECK, A	700218	60	—	1100	820e	—	—	118	136	.9	V	G

Duplications of analyses from various sources were screened by sorting the data by date of collection and by values of reported constituents. Where the same analysis was found reported with differing locations or names, the most detailed location and most appropriate name was retained in the data base.

The data-screening process described above was unavoidably subjective, however, the resulting data base is the most comprehensive set of ground-water quality data available for the area, and the locations thus derived are of sufficient accuracy to allow some meaningful statistical interpretation of the data.

A statistical reduction of the compiled data base was made by averaging all data by site to produce one set of data for each well or spring. Under the assumption that deep ground waters may represent regional flow systems that may not discharge to the Truckee River near the sampling site, data were ommitted from consideration for wells with depths exceeding 200 feet. In an attempt to remove the bias of adjacent data points on the average values for a model stream segment, a simple grinding technique was used by averaging data within a section (approximately 1 mi^2), and then averaging the data for the model stream segments.

Listed in table C5 are the resulting "gridded" averaged data for the modeled stream segments. Data with known well depths were available at a total of 193 sites. The areal distribution of the resulting data points was highly biased towards four centers of development: the eastern edge of the Truckee Meadows between the McCarran Bridge and Vista, the vicinity of Lockwood, and near the communities of Wadsworth and Nixon. Along other reaches of the river, data were sparse; 17 of the 43 model segments had no data, and 7 of the remaining 26 segments had only one site with data.

Table C5 near here

In reviewing the data averages by model segment, it becomes apparent that there are some general trends in quality between aggregrated subreaches containing one or more model segments. Based on these trends, and the results of the low-flow analysis discussed above, a final division of the data was made into 11 subreaches as shown in table C6.

Table C6 near here

Areal changes in quality among the 11 subreaches are shown in the map in figure C2. Average concentrations of dissolved solids, nitrate, sulfate, and chloride and the sulfate/chloride ratio are shown as indicies of ground-water quality. Average dissolved solids vary from 220 to 1,790 mg/L. Concentrations are high in the vicinity of Lockwood (subreach B), and below Wadsworth (subreaches H, I, K). Dissolved solids in ground waters tend to increase in a downstream direction along the Truckee River below Tracy. The exception is subreach E, where diversions and leakage from the Truckee Canal recharges the ground water with river water.

Figure C2 near here

The relative contribution of sulfate and chloride to the dissolved solids is indicated by the sulfate/chloride ratio. For most subreaches this ratio is in the range from 1 to 3. Subreaches receiving mineralized waters high in sulfates (usually from volcanic rocks) have higher ratios; an example is subreach B which contains mineralized waters in the vicinity of Lockwood. Subreaches receiving waters from sediments containing chlorides have lower ratios such as the 0.1 in subreach I which receives saline springs from the surrounding Lahonton sediments.

TABLE C5.--Average ground-water quality data for modeled stream segments

[Data from table C4, limited to sites with reported depths less than 200 feet. Data averaged first by site, then by section to approximate a 1-mile areal grid. Mean values for sections were then averaged by model segment based on ground-water flow paths estimated from topographic maps. Numbers and ranges for each constituent are for total number of sites averaged for each model segment.]

Stream segments	Starting river mile	Number of sites		Well depth (ft)	Water temperature (°C)	Dissolved solids (mg/L)	Nitrate (NO_3-N) (mg/L)	Phosphate (PO_4-P) (mg/L)	Sulfate (SO_4) (mg/L)	Chloride (Cl) (mg/L)	Sulfate/chloride ratio
01 McCarran Bridge	56.12	40	Mean:	110	18	351	.89	.07	62	28	4.8
			Number:	40	1	40	40	1	40	40	40
			Range:	18-200	—	159-849	.00-3.61	—	9-383	.6-165	.6-18
02 North Truckee Drain	53.66	28	Mean:	135	—	335	2.73	—	70	22	3.6
			Number:	28	0	28	28	0	28	28	28
			Range:	70-188	—	192-884	.00-17.6	—	8-248	8-140	1.0-7.5
03 Steamboat Creek	53.53	5	Mean:	115	18	576	.93	—	159	114	6.0
			Number:	5	1	5	5	0	5	5	5
			Range:	75-184	—	181-913	.05-1.88	—	2-425	2-315	.56-21.2
04 Vista Gage	52.23	1	—	170	23	948	1.82	—	266	78	5.4
05 Largomarsino Diversions	51.25	0	—	—	—	—	—	—	—	—	—
06 Below Largomarsino Diversions	50.90	9	Mean:	87	14	1290	3.59	.09	467	168	6.4
			Number:	9	1	9	8	1	9	9	9
			Range:	40-165	—	391-2041	.02-10.6	—	88-1200	30-415	1.5-40.0
07 Lockwood Bridge	50.05	1	—	165	15	1019	.18	—	634	17	14
08 Groton Diversion	49.90	16	Mean:	111	15	631	2.46	—	288	23	14
			Number:	16	1	16	13	0	14	13	12
			Range:	30-200	—	139-1350	.00-31.2	—	53-960	12-48	1.6-64
09 Mustang Bridge #1	48.25	0	—	—	—	—	—	—	—	—	—
10 McCarran pool	46.68	0	—	—	—	—	—	—	—	—	—
11 McCarran Diversion	46.35	0	—	—	—	—	—	—	—	—	—
12 Patrick Bridge	44.92	1	—	200	—	238	.68	—	58	21	2.8
13 SP railroad Bridge	42.88	0	—	—	—	—	—	—	—	—	—
14 Hill Diversion	42.02	2	Mean:	166	14	268	2.26	—	41	40	1.2
			Number:	2	1	2	1	0	2	2	2
			Range:	133-200	—	215-322	—	—	23-59	15-66	.9-1.5
15 Tracy Diversion	40.76	0	—	—	—	—	—	—	—	—	—
16 Tracy Bridge	40.62	1	—	141	—	140	—	—	8.0	6.0	1.3
17 Clark Bridge	38.60	1	—	200	—	426	1.85	—	140	28	5.0
18 RM 37.1	37.10	0	—	—	—	—	—	—	—	—	—
19 I-80 oxbow	35.60	0	—	—	—	—	—	—	—	—	—
20 Derby Dam	34.88	0	—	—	—	—	—	—	—	—	—
21 Gage below Derby	34.52	2	Mean:	59	—	188	.45	—	12	9.5	1.3
			Number:	2	0	2	1	0	2	2	2
			Range:	42-76	—	180-195	—	—	10-13	8-11	.9-1.6
22 Washburn Diversion	31.28	2	Mean:	48	—	239	.84	—	40	15	2.5
			Number:	2	0	2	2	0	2	2	2
			Range:	30-65	—	186-292	.62-1.06	—	17-63	10-20	1.7-3.3
23 Painted Rock Bridge	29.97	0	—	—	—	—	—	—	—	—	—

TABLE C5.--Average ground-water quality data for modeled stream segments--Continued

	Stream segments	Starting river mile	Number of sites		Well depth (ft)	Water temp-erature (°C)	Dis-solved solids (mg/L)	Nitrate (NO_3-N) (mg/L)	Phos-phate (PO_4-P) (mg/L)	Sul-fate (SO_4) (mg/L)	Chlor-ide (Cl) (mg/L)	Sulfate/chloride ratio
24	Gregory-Monte Diversion	29.35	0	—	—	—	—	—	—	—	—	—
25	RM 28.0	28.00	3	Mean:	54	—	334	1.27	—	35	18	2.1
				Number:	3	0	3	3	0	3	3	3
				Range:	42-	—	284-	.50-	—	34-	13-	1.6-
					60		410	2.48		37	22	2.8
26	Herman Diversion	26.75	0	—	—	—	—	—	—	—	—	—
27	Pierson Diversion	25.95	20	Mean:	92	—	325	1.57	—	46	23	1.9
				Number:	20	0	20	20	0	20	20	21
				Range:	40-	—	232-	.02-	—	17-	12-	.26-
					170		679	2.71		287	110	5.5
28	Proctor Diversion	23.90	11	Mean:	47	—	562	3.32	—	166	34	4.0
				Number:	11	0	10	7	0	10	11	10
				Range:	30-	—	235-	.73-	—	21-	12-	.35-
					150		2960	4.97		1590	148	12
29	Wadsworth Bridge	23.69	12	Mean:	110	17	419	1.99	—	139	25	7.3
				Number:	12	1	12	10	0	12	12	11
				Range:	30-	—	170-	.18-	—	12-	0-	.6-
					150		673	5.87		263	53	11
30	Fellnagle Diversion	22.55	4	Mean:	36	16	655	.76	—	251	30	7.6
				Number:	4	2	4	3	0	4	4	4
				Range:	12-	14	330-	.02-	—	35-	18-	1.9-
					110	17	1090	1.63		503	44	15.2
31	RM 21.4	21.40	3	Mean:	145	—	541	.36	—	222	27	6.6
				Number:	3	0	3	3	0	3	3	3
				Range:	100-	—	184-	.02-	—	8-	17-	.5-
					179		1020	1.02		499	37	13.5
32	S-bar-S Diversion	19.84	17	Mean:	100	17	832	.58	—	91	294	2.7
				Number:	17	7	17	16	0	16	16	16
				Range:	17-	14	169-	.00-	—	14-	8-	.1-
					165	18	3440	4.51		244	1540	8.1
33	S-bar-S Pump	17.82	1	—	142	—	1910	.08	—	190	823	.23
34	RM 15.8	15.82	2	Mean:	108	—	324	.74	—	38	26	1.4
				Number:	2	0	2	2	0	2	2	2
				Range:	95-	—	274-	.00-	—	35-	23-	1.4-
					121	—	375	1.49		41	30	1.5
35	Dead Ox Wash	13.18	3	Mean:	175	—	1670	.10	—	81	638	.13
				Number:	3	0	3	1	0	3	3	3
				Range:	21-	—	1460-	—	—	76-	595-	.1-
					103	—	1790	—	—	85	705	.1
36	RM 10.0	10.0	0	—	—	—	—	—	—	—	—	—
37	RM 9.2	9.20	0	—	—	—	—	—	—	—	—	—
38	Numana Dam	8.21	0	—	—	—	—	—	—	—	—	—
39	RM 7.6	7.60	0	—	—	—	—	—	—	—	—	—
40	RM 6.8	6.80	4	Mean:	106	20	669	.00	—	82	105	1.4
				Number:	4	1	4	1	0	4	4	4
				Range:	60-	—	440-	—	—	12-	23-	.13-
					200		820			131	160	4.4
41	RM 4.0	4.00	0	—	—	—	—	—	—	—	—	—
42	Nixon Bridge	3.22	3	Mean:	142	14	500	.45	—	54	57	.71
				Number:	7	1	3	7	0	3	3	3
				Range:	120-	—	303-	.00-	—	0-	27-	.00-
					178		620	.90		125	98	1.3
43	Marble Bluff pond	1.00	1	—	115	—	1790	—	—	581	201	2.9
	Average of all sites:		193	Mean:	109	17	581	1.38	.08	143	84	5.2
				Number:	193	18	192	169	2	187	188	184
				Range:	12-	14-	139-	.00-	.07-	0-	0-	0-
					200	23	3440	31	.09	1590	1540	64

Table C6.—Average quality of ground waters adjacent to the Truckee River below Reno

[Data from table C4, limited to sites with reported depths less than 200 feet. Data averaged first by site, then by section to approximate a 1-mile areal grid. Mean values for sections were then averaged by subreaches based on ground-water flow paths from topographic maps. Subreaches chosen to aggregate model segments by consistent trends in ground-water quality and in rates of ground-water inflow (table C1, figure C1).]

Subreach		Model segments	Starting river mile	Number of sites		Well depth (ft)	Water temperature (deg C)	Dissolved solids (mg/L)	Nitrate (NO_3-N) (mg/L)	Phosphate (PO_4-P) (mg/L)	Sulfate (SO_4) (mg/L)	Chloride (Cl) (mg/l)	Sulfate/chloride ratio
A	01-04	McCarran Bridge to Largomarsino Diversions	56.12	73	Mean:	117	18	403	1.36	.07	88	48	4.8
					Number:	73	10	73	73	1	73	73	73
					Range:	18-200	12-22	159-913	.00-17.6	—	2-425	.6-315	1.5-40
B	05-07	Largomarsion Diversion to Groton Diversion	51.25	11	Mean:	141	19	1090	1.86	.09	456	87	17
					Number:	11	2	11	10	1	11	11	11
					Range:	40-170	14-23	391-2041	.02-10.6	—	88-1200	17-415	.92-41.6
C	08	Groton Diversion to Mustang Bridge #1	49.90	16	Mean:	111	15	631	2.46	—	288	23	14
					Number:	16	1	16	13	0	14	13	12
					Range:	30-200	—	139-1350	.00-31.2	—	53-960	12-48	1.6-64
D	09-19	Mustang Bridge #1 to Derby Dam	48.25	5	Mean:	177	14	268	1.60	—	62	24	2.6
					Number:	5	1	5	5	0	5	5	5
					Range:	133-200	—	140-426	.23-2.26	—	8-140	6-66	.89-5.0
E	20-24	Derby Dam to RM 28.0	34.88	4	Mean:	51	—	221	.71	—	30	13	2.1
					Number:	4	0	4	3	0	4	4	4
					Range:	30-76	—	180-292	.45-1.06	—	10-63	8-20	.91-3.3
F	25-27	RM 28.0 to Proctor Diversion	28.00	23	Mean:	80	—	328	1.47	—	42	22	2.0
					Number:	23	0	23	21	0	21	22	21
					Range:	40-170	—	232-679	.02-2.71	—	17-287	12-110	.26-5.5
G	28-30	Proctor Diversion to RM 21.4	23.90	26	Mean:	67	16	542	1.85	—	179	29	6.3
					Number:	26	3	25	19	0	25	26	24
					Range:	12-160	14-17	170-2960	.02-5.87	— —	12-1590	26-148	35-15
H	31-33	RM 21.4 to Dead Ox Wash	21.40	23	Mean:	115	17	799	.53	—	109	255	2.5
					Number:	22	7	23	22	0	22	22	22
					Range:	17-179	14-18	169-3440	.00-4.51	—	8-499	8-1541	.06-14
I	34-37	Dead Ox Wash to Numana	13.18	3	Mean:	75	—	1670	.10	—	81	638	.13
					Number:	3	0	3	1	0	3	3	3
					Range:	21-103	—	1460-1790	—	—	76-85	595-705	.11-.14
J	38-42	Numana Dam to RM 1.0	8.21	8	Mean:	119	17	576	1.02	—	87	76	2.2
					Number:	8	2	8	4	0	8	8	8
					Range:	60-200	14-20	303-820	.00-3.16	—	0-206	21-160	.0-9.8
K	43	RM 1.0 to Marble Bluff Dam	1.00	1	—	115	17	1790	—	—	581	201	2.9

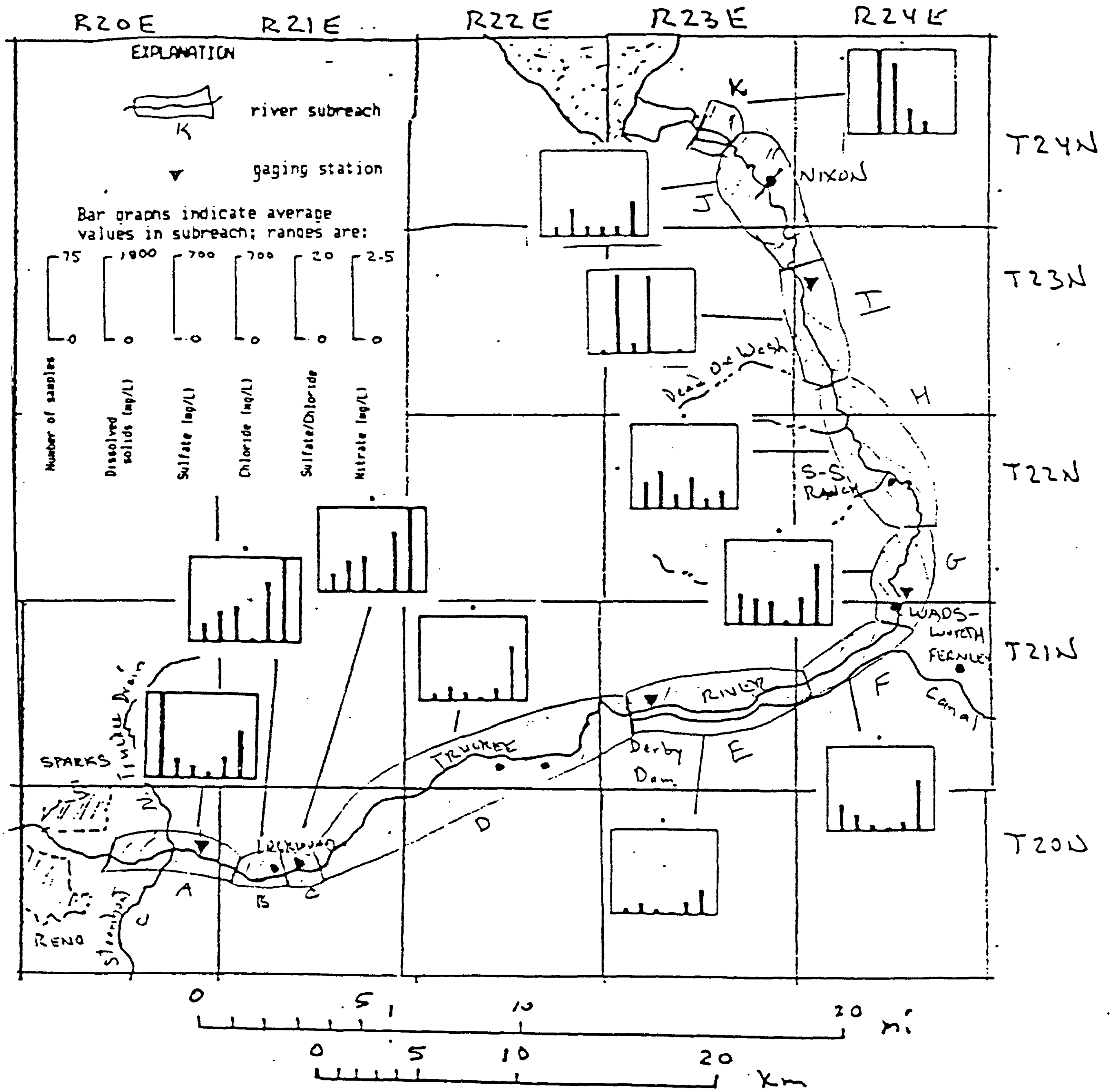

Figure C2.--The quality of ground waters adjacent to the Truckee River below Reno is highly variable.

Average nitrate concentrations in the 11 subreaches vary from 0.10 to 2.5 mg/L, with the highest concentrations in subreaches with the greatest population density along the river: below the Reno-Sparks area, in the vicinity of Lockwood and Mustang, and in the vicinity of Wadsworth and Nixon.

REPRESENTATION FOR MODELING

Estimates of ground-water inflows used in initial model calibration are listed in table C7. Based on the preceding seasonal analysis of differences between gaging stations, ground-water inflows to the river above Derby Dam were considered to be negligible for normal flow regimes. In the final model calibration, other assumptions had to be made for the June 1980 data set (see text, section "Ground-water Inflows"). Ground-water inflows for model segments below Derby Dam were developed from the preceding analysis of seasonal differences in flow between gaging stations and the linear rates of inflow per stream length developed from the low-flow seepage run. Initially, average inflows were estimated to be 12 ft^3/s for Derby Dam to Wadsworth and 8 ft^3/s for Wadsworth to the Nixon gage based on data for the nonirrigation season in table C1. Inflows were then prorated to individual model segments by the linear rates of accretion from the preceding low-flow seepage analysis (table C3). In the calibration process, the ground-water inflows were adjusted to total 12.4 ft^3/s in the reach from Derby Dam to Wadsworth and 11.1 ft^3/s in the reach from Wadsworth to the Nixon gage. Ground-water inflows from the Nixon gage to the Nixon bridge were estimated to be 1.5 ft^3/s, and for the Nixon bridge to Marble Bluff Dam to be 1.0 ft^3/s. Inflows below the Nixon gage were linearly prorated to individual model segments by segment length.

Table C7 near here

TABLE C7.--Estimated ground-water inflows to the Truckee River below Reno

[Estimates based on seasoned analysis of differences in flow between gaging stations and on low-flow seepage measurements. Estimates for a given model data set may be revised based on flow balance and dissolved solids calibration (see text).]

Model segment		Starting river mile	Estimated inflow (ft^3/s)
1-19	McCarran Bridge to Derby Dam	56.12	a
20	Derby Dam	34.88	0.4
21	Gage below Derby	34.52	3.6
22	Washburn diversion	31.28	1.4
23	Painted Rock bridge	29.97	.7
24	Gregory-Monte diversion	29.35	1.4
25	RM 28.0	28.00	1.4
26	Herman diversion	26.75	.9
27	Pierson diversion	25.95	2.3
28	Proctor diversion	23.90	.3
Subtotal, Derby to Wadsworth:			12.4
29	Wadsworth bridge	23.69	4.4
30	Fellnagle diversion	22.55	4.5
31	RM 21.4	21.40	.2
32	S Bar S diversion	19.84	.3
33	S Bar S pump	17.82	.3
34	RM 15.8	15.82	.4
35	Dead Ox Wash	13.18	.8
36	RM 10.0	10.0	.2
Subtotal, Wadsworth to Nixon gage:			11.1
37	RM 9.2	9.20	.2[b]
38	Numana Dam	8.21	.2[b]
39	RM 7.6	7.60	.2[b]
40	RM 6.8	6.80	.7[b]
41	RM 4.0	4.00	.2[b]
42	Nixon bridge	3.22	.7[c]
43	Marble Bluff pond	1.00	.3[c]
Subtotal, Nixon gage to Marble Bluff Dam:			2.5

[a] Insufficient data to define inflow for individual segments. Net gain for reach estimated to be negligible.

[b] Estimate from average gain per mile in segments 34-36.

[c] Estimated from flow balances for synoptic studies.

Initial estimates of ground-water quality for model calibration are listed in table C8. Estimates of water temperatures, dissolved solids, nitrate-nitrogen, and orthophosphorus were derived from the data in table C6. Average specific conductance of ground waters was estimated by a regression relationship between observed values of specific conductance and dissolved solids in the compiled data base (see headnote in table C4 and footnote in table C6). Because of the limited data available for temperatures and phosphorus concentrations in ground waters, the average values (table C5) were used for all subreaches. Total phosphorus was estimated to equal orthophosphorus under the assumption that virtually all phosphorus in ground water would be oxidized to the ortho state. Similarly, all nitrogen in ground waters was assumed to be in the nitrate form.

Table C8 near here

No data were found for concentrations of dissolved oxygen or CBOD in ground-waters in the Truckee River basin. An estimated oxygen concentration of 0.5 mg/L was used for all subreaches based on data observed in river bottom gravels in the lower Truckee River during late summer low flows when associated specific conductance measurements indicated that the test reach was receiving significant ground-water inflows (Hoffman and Scoppettone, 1984). A $CBOD_4$ concentration of 1.0 mg/L was assumed for all subreaches.

Table C8.--Estimated quality of nonpoint ground-water inputs to the Truckee River

Sub-reach	Model segment	Water temp. (°C)[a]	Dissolved oxygen (mg/L)[b]	Dissolved solids (mg/L)[c]	Specific conductance (umhos)[d]	$CBOD_u$ (mg/L)[e]	Nitrogen (mg/L as N)[f]					Phosphorus (mg/L as P)	
							Organic	Ammonia	Nitrite	Nitrate	Total	Ortho	Total
A	1-4	17	.5	400	530	1.0	.0	.0	.0	1.4	1.4	.1	.1
B	5-7	17	.5	1,090	1,470	1.0	.0	.0	.0	1.9	1.9	.1	.1
C	8	17	.5	630	850	1.0	.0	.0	.0	2.5	2.5	.1	.1
D	9-19	17	.5	270	360	1.0	.0	.0	.0	1.6	1.6	.1	.1
E	20-24	17	.5	220	300	1.0	.0	.0	.0	.7	.7	.1	.1
F	25-27	17	.5	330	440	1.0	.0	.0	.0	1.5	1.5	.1	.1
G	28-30	17	.5	540	730	1.0	.0	.0	.0	1.8	1.8	.1	.1
H	31-34	17	.5	800	1,080	1.0	.0	.0	.0	.5	.5	.1	.1
I	35-37	17	.5	1,670	2,250	1.0	.0	.0	.0	.1	.1	.1	.1
J	38-42	17	.5	580	780	1.0	.0	.0	.0	1.0	1.0	.1	.1
K	43	17	.5	1,790	2,410	1.0	.0	.0	.0	1.0	1.0	.1	.1

a Average of 18 measurements (table C5), assumed constant for all subreaches.

b Estimate based on observations at 23 cm depth in bottom gravels at Dead Ox (Hoffman and Scoppettone, 1984).

c Rounded mean values from table C6.

d Estimates based on dissolved solids/specific conductance ratio of 0.742 (see headnote in table C4).

e Assumed values.

f All nitrogen in ground water assumed to have been oxidized to nitrate.

g Average of 2 analyses for orthophosphate (table C6). All phosphprus assumed to be oxidized to orthophosphate.

NEED FOR FUTURE STUDIES

The modeling effort on the Truckee River indicates that, at low flows in the reaches below Derby Dam, ground-water inflows have significant impact on dissolved solids concentrations in the river. The model is also sensitive to estimated concentrations of nitrogen, phosphorus, and CBOD in these reaches during low flows. If predictive modeling of water quality is going to be used for management purposes for the river below Derby Dam, data should be collected to verify the assumptions on the quantity and quality of ground-water inflows in this reach. Needed investigations include low-flow seepage surveys during both the irrigation and nonirrigation seasons to better quantify inflows, and water-quality surveys of shallow wells and springs to provide better estimates of oxygen demands and nitrogen and phosphorus speciation.