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Estimation of Traveltime Characteristics for Truckee River Between Truckee, California, and Marble Bluff Dam Near Nixon, Nevada, and for Truckee Canal in Nevada

Water-Resources Investigations Report 99-4226

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Cover photo: Closeup view of gasoline tank-truck trailer overturned on Interstate 80 bridge east of Truckee, Calif., on November 28, 1978. Bridge spans Truckee River and transcontinental railroad right of way that parallels river for about 75 miles between Truckee and Wadsworth, Nev. (photograph by James Beazley, Reno Evening Gazette). See figure 1 for overall view of accident scene.

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By Larry R. Bohman

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS, ABBREVIATED WATER-QUALITY UNITS, AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
pound (lb)	0.4536	kilogram
gallon (gal)	3.785	liter
cubic foot (ft^3)	0.02832	cubic meter
foot per mile (ft/mi)	0.1894	meter per kilometer
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile per hour (mi/h)	1.609	kilometer per hour
ounce (oz)	29.57	milliliter

Abbreviated water-quality units used in this report:

g/L, gram per liter

µg/L, microgram per liter

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

SYMBOLS AND UNITS

Symbol	Definition
n	Number of sampling site
t_b	Interval of time for dye concentrations to build up from leading edge to peak, in hours
t_c	Traveltime of centroid of dye-response curve, in hours
t_l	Traveltime of leading edge of dye-response curve, in hours
t_p	Traveltime of peak of dye-response curve, in hours
t_t	Traveltime of trailing edge of dye-response curve, in hours
C_p	Observed peak dye concentration, in micrograms per liter (µg/L)
T_c	Elapsed time to centroid of dye-response curve, in hours
T_d	Duration in time for tracer cloud to pass any one point in section, in hours
T_l	Elapsed time to leading edge of dye-response curve, in hours
T_p	Elapsed time to peak of dye-response curve, in hours
T_t	Elapsed time to trailing edge of dye-response curve, in hours

Estimation of Traveltime Characteristics for Truckee River Between Truckee, California, and Marble Bluff Dam Near Nixon, Nevada, and for Truckee Canal in Nevada

By L.R. Bohman

Abstract

Traveltime characteristics were estimated from dye-study measurements made during 1979–81 and in 1993 along the Truckee River between Truckee, Calif., and Marble Bluff Dam near Nixon, Nev., and along the Truckee Canal in Nevada. Fluorescent rhodamine WT dye was injected into various reaches for average flows ranging from 8.4 to 3,700 cubic feet per second along the Truckee River and from 191 to 664 cubic feet per second along the Truckee Canal.

Tabular data from all the studies and graphical relations between traveltime and distance and between traveltime and flow are presented. Such data or plots may be useful to water-quality modelers or water-resources managers concerned with predicting arrival times of soluble contaminants accidentally spilled into the Truckee River or Truckee Canal. The data provided in this report also could be used to study the dispersion-related characteristics of duration and magnitude of pollutant concentrations that may be expected in the Truckee River and Truckee Canal. In the investigations summarized in this report, the values obtained from relations between traveltime of peak concentrations and flow are additive for successive subreaches. The report also contains examples of applications of the data and a discussion of the limitations and assumptions used in interpreting the data.

INTRODUCTION

The use of dyes and tracing techniques provides a means of measuring the traveltime and dispersion characteristics of streams. Traveltime may be defined as the time it takes for water or soluble constituents introduced into a river to move downstream from one point to another. Introduced constituents also tend to disperse (dilute) as they move downstream, causing peak concentrations to decrease and the length of the solute plume to increase. Dye tracing involves the instantaneous injection of a nontoxic, fluorescent dye at a location along the stream and measurement of the resulting dye plume at locations downstream (Buchanan, 1964; Wilson, 1968). The dye mixes with the flow and moves in the same manner as the flow. A plot of the dye concentration in discrete water samples against time defines a dye-response curve at each sampling site. Traveltime is measured as the time required for movement of the centroid or center of mass of the dye plume between sampling sites. Dispersion is characterized by the time of passage of the solute plume and attenuation of the peak concentration as the plume moves downstream. Dye studies typically are made over a range of flows that are indexed to flows at selected stream-gaging stations.

Information on traveltime of solutes may be required for water-quality modeling and waste-transport studies and also provides an objective means for determining an appropriate course of action in response to the spilling of a soluble toxic substance. For the former purpose, the model results are usually no better quantitatively than the traveltime data used in their development because simulation of biochemical processes in water-quality models involves the calculation of time-dependent reactions. Although mean flow velocity may be computed from flow measurements made at gaging stations, such point data may not adequately characterize an entire stream reach. Extrapolation of such point data may be subject to large errors. For the latter purpose, officials responsible for public safety (including water-supply managers and regulators) and others interested in transient water-quality problems need to predict passage and arrival times or peak concentration of a noxious substance released or spilled upstream. Such a spill happened on November 28, 1978, when a tank-truck trailer overturned on Interstate 80, on a bridge over the Truckee River, east

of Truckee, Calif. (fig. 1). Accurate traveltime information is needed to provide a reasonable basis for deciding whether, when, and how long to suspend operations of public water-supply intakes or how best to handle any perceived threat to the river environment.

Competition for the limited water throughout the Truckee River Basin has increased the need by resources planners for traveltime data and interpretation. The Truckee River in eastern California and western Nevada provides a variety of benefits—serving as a municipal water supply for communities in Nevada, supporting fish and wildlife habitats, generating hydroelectric power, furnishing river and reservoir recreational opportunities, and supplying water for agriculture. The Truckee Canal diverts large amounts of water from the Truckee River for irrigation use by the farmers of the Newlands Project near Fernley and in Lahontan Valley. In addition, Lahontan Reservoir is used for recreation and fishing and is the secondmost visited State park in Nevada. Consideration of traveltime characteristics is fundamental for modeling flow and water-quality characteristics in order to meet desired goals for water quantity and quality at specific points along the Truckee River. Results from previous studies need to be collated with recently collected information to expand the range of flows for which data are available. Comparisons between hydrology data layers within current and previous geographic information systems need to be made to determine if major changes in channel geometry (length, width, or depth) resulted from floods on the Truckee River during the spring of 1983 and winter of 1986. If so, whether or not the traveltime relations derived from the preflood studies are still valid for current use must be assessed.

The need for this type of information led the Truckee–Carson Program of the U.S. Geological Survey (USGS) to make additional traveltime studies during the extremely low flows experienced during the fall of 1993 to supplement and verify the results obtained from earlier studies. The Truckee–Carson Program had been established in 1991 to assist the U.S. Department of the Interior in implementation of the many complex provisions of Title II of Public Law 101–618, the Truckee–Carson–Pyramid Lake Water Rights Settlement Act of 1990. The objectives of the program are to expand and improve the existing gaging-station network and to develop, test, and apply physically based river-basin simulation models in support of water-resources planning and management. Data and relations derived from this summary of dye studies along the Truckee River and Truckee Canal are useful in the development of water-quality models of the system.

Purpose and Scope

This report describes the techniques and results of dye-tracing studies (table 1) made over a range of flows on the Truckee River between State Route 267 at Truckee, Calif., and Marble Bluff Dam near Nixon, Nev. (approximately 3 mi upstream from Pyramid Lake) during 1979–80 and 1993, and on the Truckee Canal during 1979–81. Data from these studies were used to derive traveltime characteristics in support of water-quality modeling and for use in estimating the behavior of soluble contaminants that may be introduced into the Truckee River or Truckee Canal. The report presents

- descriptions of the methods used in data collection and analysis,
- tabulations of basic data from the studies,
- summaries of computed traveltime characteristics,
- graphs depicting traveltimes (from points of injection to subsequent locations downstream) for specific flows and the relation of traveltime to discharge at an index gaging station,
- limitations associated with relations presented in the report, and examples of applications.

Table 1. Dye-tracing studies on Truckee River and Truckee Canal, 1979–80 and 1993

Dates	Number of studies	Range of flows (cubic feet per second)
Truckee River		
May 1979–October 1980	10	32-3,800
November–December 1993	4	8.7-161
Truckee Canal		
May 1979–May 1980	3	110-700

Previous Dye-Tracing Investigations in Study Area

La Camera and others (1985) published, in tabular form, the physical, chemical, and biological data collected as part of the Truckee–Carson river-quality assessment (Nowlin and others, 1980) in support of

Figure 1. Gasoline tank-truck trailer overturned on Interstate 80 bridge east of Truckee, Calif., on November 28, 1978. Bridge spans Truckee River and transcontinental railroad right of way that parallels river for about 75 miles between Truckee and Wadsworth, Nev. (photograph by James Beazley, Reno Evening Gazette).

water-quality modeling and investigations of trout-spawning habitats in the Truckee River system. La Camera and others (1985) reported the results from 13 dye-tracer studies during the period 1979–81 for a wide range of flows in three reaches along the Truckee River—from Truckee, Calif., to Vista, Nev.; Vista to Derby Diversion Dam (hereafter, "Derby Dam") near Wadsworth, Nev.; and Derby Dam to Marble Bluff Dam near Nixon, Nev.—and in the Truckee Canal—from Derby Dam to Lahontan Reservoir.

Brown and others (1986) analyzed the data published by La Camera and others (1985) and provided an overview of the hydrologic system of the Truckee River and Carson River Basins; presented data and computed relations in graphical, tabular, and map form; and interpreted the raw and computed data. The computed relations then were used in equations to relate velocities to flows in 43 reaches of the Truckee River from Sparks to Pyramid Lake and 9 reaches of the Truckee Canal for water-quality modeling (Nowlin, 1987). The velocity–flow relations developed by Nowlin (1987) also were used in more recent water-quality models of the Truckee River (Caupp and others, 1997). The data from Nowlin (1987) and Caupp and others (1997) and from the dye-tracing studies made during November–December 1993 form the basis for the relations presented in this report.

DESCRIPTION OF STUDY AREA

A detailed description of the physical and hydrologic characteristics of the Truckee River was given by Van Denburgh and others (1973), Brown and others (1986), and Jones and others (1991). The following paragraphs briefly describe the physical setting of the Truckee River. A general location map of the study area, including the flow-gaging stations and dye-study sites mentioned later in this report, is shown in figure 2.

The Truckee River watershed is a topographically enclosed basin on the eastern slope of the Sierra Nevada along the California–Nevada border. In the part of the basin that surrounds Lake Tahoe, headwater altitudes exceed 10,000 ft above sea level. The lowest part of the basin is at the river's terminus at Pyramid Lake, where the altitude is approximately 3,795 ft above sea level. The total drainage area of the basin is 3,120 mi^2, but only 1,940 mi^2 contributes streamflow to the 116-mi-long stretch of the Truckee River between the outlet of Lake Tahoe and Marble Bluff Dam (about 3 mi upstream from the mouth at Pyramid Lake).

From the outlet of Lake Tahoe, the Truckee River flows generally north about 15 mi to Truckee, Calif., then northeasterly for about 28 mi across the State line to Verdi, Nev. Downstream from Verdi, the river flows to the east about 21 mi to Vista, Nev. Several major tributaries, all of which are controlled by Federal reservoirs, join the Truckee River downstream from Truckee; they include Prosser Creek, Martis Creek, and the Little Truckee River. Just downstream from the mouth of the Little Truckee River, the Truckee River flows through a deeply incised canyon to the California–Nevada State boundary. About 8 mi east of the State line, the river passes through an alluvial valley bounded by mountain ranges; this area, known as the Truckee Meadows, includes the rapidly growing cities of Reno and Sparks. Although the current economy of the area is dominated by gaming and tourism, Truckee Meadows still contains irrigated agricultural lands. Both municipal and agricultural water needs are satisfied by diversions at several locations along the river within and upstream from the Truckee Meadows.

EXPLANATION

— · · — **Hydrographic-area boundary**

△ 32 **Dye-injection or sampling site**—Number is site number (see below and table 2)

On or near Truckee River:

1 State Highway 267
2 Old U.S. 40 bridge below Truckee
3 Boca Bridge near Truckee
4 Below Farad powerplant
5 Mayberry Drive
6 Near Sparks
7 Reno–Sparks sewage-treatment plant
8 Steamboat Creek
9 Vista
10 Lockwood
11 Patrick
12 Below Tracy
13 Clark
14 Derby Dam
15 Painted Rock Bridge
16 Old U.S. 40 bridge at Wadsworth
17 S–Bar–S Ranch
18 Below S–Bar–S Ranch
19 Dead Ox Wash
20 Numana Dam
21 State Highway 447
22 Marble Bluff Dam
23 Below Marble Bluff Dam

On Truckee Canal:

24 Derby Dam
25 Pyramid Check Dam
26 Near Wadsworth
27 U.S. 95A
28 Anderson Check Dam
29 Allendale Check Dam
30 Mason Check Dam
31 Bango Check Dam
32 U.S. Highway 50

▲ 10350000 **U.S. Geological Survey index streamflow-gaging station**—Number is station number (see table 24)

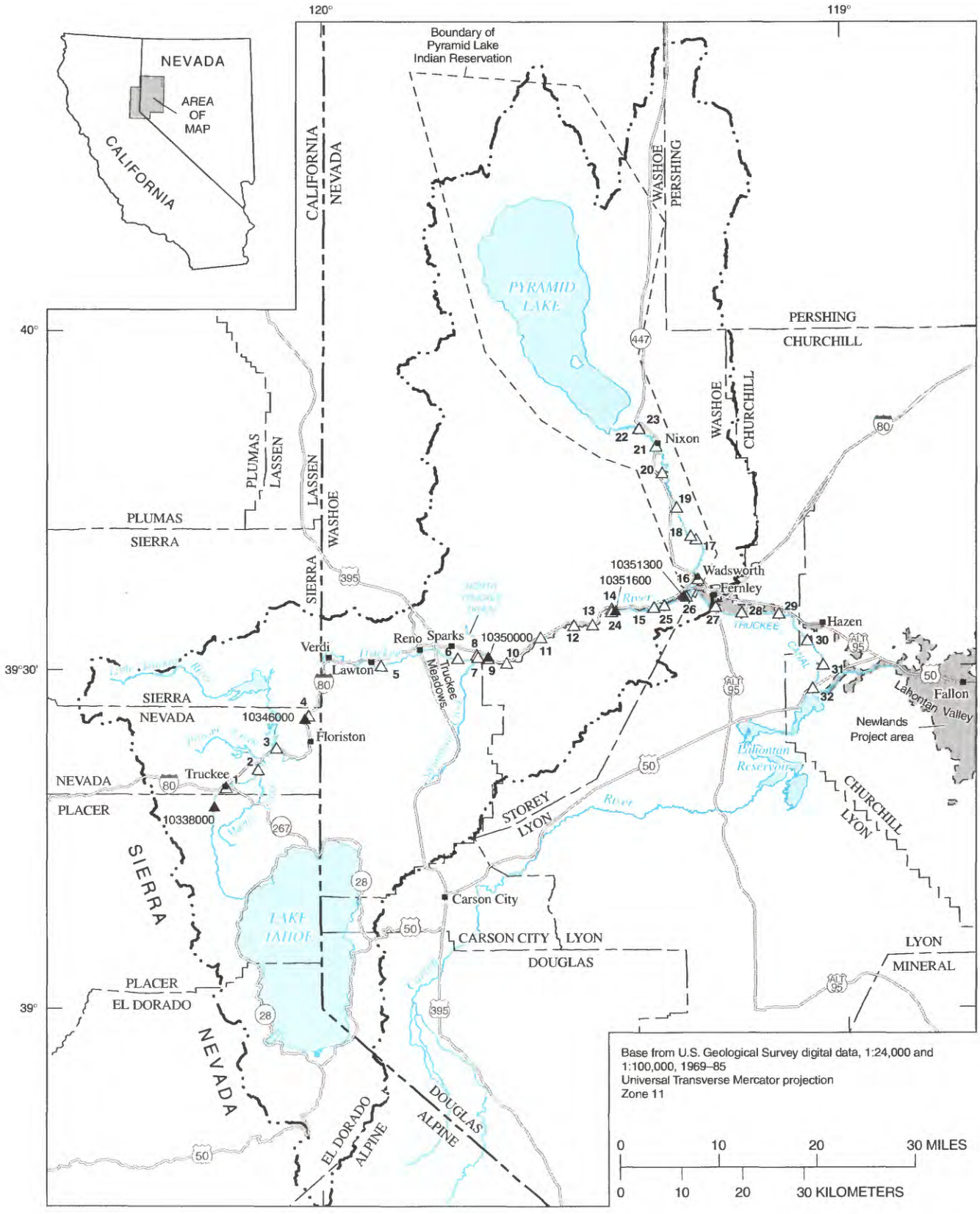

Figure 2. General location of Truckee River, Truckee Canal, gaging stations, and sampling/injection sites used in travel-time studies. Old U.S. Highway 40 (or State Route 427 in parts of Nevada) is not shown on map; at map scale, it roughly parallels Interstate 80. See table 2 for full site names and other alternate route names.

Irrigation return flows from diversions originating on the north side of the river between Verdi and Reno and some natural flow enter the Truckee River via the North Truckee Drain near Vista, just east of Sparks. Treated municipal-sewage effluent, irrigation return flows from diversions farther upstream on the south side of the river, and additional natural flows enter the river from Steamboat Creek, also near Sparks. The Reno–Sparks sewage-treatment plant, now known as the Truckee Meadows Water Reclamation Facility, is near the mouth of Steamboat Creek.

Downstream from the Truckee Meadows, the river parallels Interstate 80 eastward for about 29 mi through arid canyon terrain to Wadsworth, Nev. At Wadsworth, the river turns north and continues for about 23 mi through the Pyramid Lake Indian Reservation to Marble Bluff Dam downstream from Nixon, Nev. Tributaries below Vista, Nev., are ephemeral; large flows are mostly in response to heavy precipitation, usually as summer thunderstorms. Downstream from Wadsworth, the channel is unstable in many areas and therefore is subject to lateral shifting during major floods. Population is sparse, limited to the communities of Wadsworth and Nixon and a few private ranches. The irrigation needs of small ranches bordering the lower Truckee River below Vista are served by 13 diversions. At Derby Dam (17 mi downstream from Vista), the Truckee Canal diverts water from the river southeastward into Lahontan Reservoir in the Carson River watershed. The approximately 31-mi-long canal was constructed by the Bureau of Reclamation (U.S. Department of the Interior) as part of the Newlands Project, the Nation's first project completed under the authority of the Reclamation Act of 1902 (Jones and others, 1991, p. 23). Water released from Lahontan Reservoir is used to supplement Carson River water to irrigate Newlands Project lands.

River gradients vary between the steeper mountain-block area and the lower basin. The gradient of the river is fairly steep above Reno, averaging about 35 ft/mi. Within the 8-mi reach of the river between Reno and Vista, the gradient is relatively flat (about 1.6 ft/mi). From Vista to Marble Bluff Dam, the Truckee River channel slope averages less than 10 ft/mi. The numerous diversion structures have important localized effects on the channel slope. Resultant decreases in flow velocities and increases in flow depths undoubtedly influence both traveltime and dispersion characteristics of the river. The average slope of the Truckee Canal is about 1.1 ft/mi (Nowlin, 1987).

DYE-TRACING THEORY, DATA COLLECTION, AND RESULTS

This report presents the results of four dye-tracing studies made under low-flow conditions between Vista and Marble Bluff Dam during November–December 1993 to verify or extend the relations derived from previous studies. Previous studies include 10 along the Truckee River between State Route 267 at Truckee, Calif., and Marble Bluff Dam near Nixon, Nev., and 3 along the Truckee Canal (La Camera and others, 1985; Brown and others, 1986). This section of the report provides an overview of dye-tracing theory, field and laboratory procedures used to collect and analyze the data, and the results of the tracer studies.

Dye-Tracing Theory

Fluorescent dye injected into a river is transported in solution in the same manner as water particles themselves. By measuring the movement of the dye, one can ascertain the traveltime and dispersion (dilution) characteristics of any soluble constituent introduced into the stream. The dispersion and mixing of the tracer in the river takes place in all three dimensions of the channel. Vertical mixing normally is completed first, and lateral mixing later; which happens first depends on stream-channel characteristics and resultant localized variations in vertical and horizontal velocity. Longitudinal dispersion, the increasing dilution and attenuation of a solute plume as it moves down a channel, continues indefinitely and is the dispersion component of primary interest (Kilpatrick and Wilson, 1989).

Once dye is injected at a point in the stream, a response curve can be defined at each downstream sampling site within the channel cross section for a given stream line by plotting concentration against elapsed time (fig. 3). Response curves for the dye plume depict the time of arrival (leading edge), the maximum concentration (peak), the center of mass (centroid), and the time when the dye was no longer detectable (trailing edge). A typical dye plume commonly travels faster in the center of the stream than along the banks. Complete definition of a stream's response to a dye injection may involve measurement at more than one point or along more than one stream line at each of the several sampling sections involved.

The following equations summarize relations among traveltime measurements (fig. 3; Kilpatrick and Wilson, 1989). The mean traveltime for the flow is the

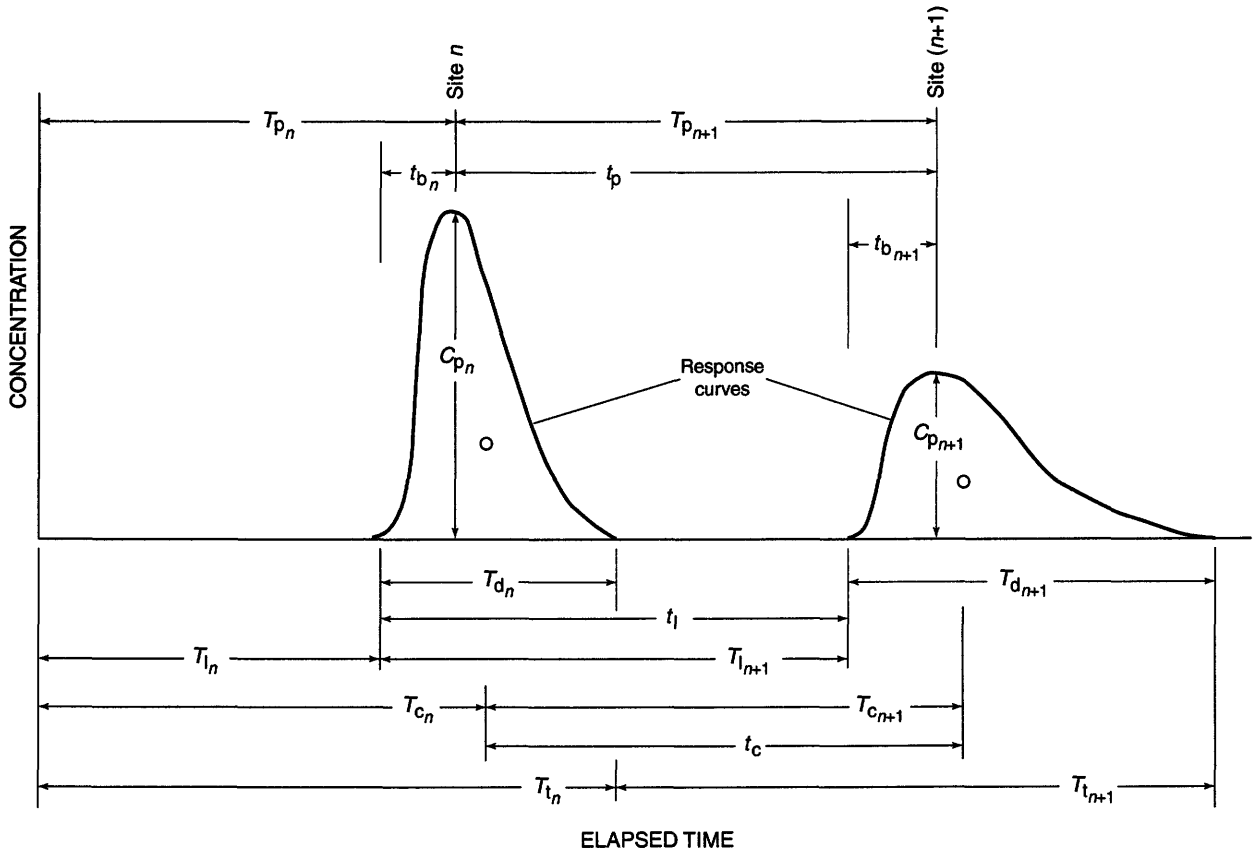

Figure 3. Idealized response curves along selected streamline resulting from instantaneous dye injection (modified from Kilpatrick and Wilson (1989)). Open circles under response curves represent centers of mass, or centroids, of response curves; corresponding times are used to sompute t_c traveltime. Symbols are explained in "Symbols and Units."

difference in elapsed time of the centroids of the time–concentration (response) curves defined upstream and downstream on the same stream line:

$$t_c = T_{c_{(n+1)}} - T_{c_n}. \quad (1)$$

(Symbols are explained in "Symbols and Units.")

Similarly, the traveltimes of the leading edge, peak concentration, and trailing edge along a given stream line are, respectively,

$$t_l = T_{l_{(n+1)}} - T_{l_n}, \quad (2)$$

$$t_p = T_{p_{(n+1)}} - T_{p_n}, \text{ and} \quad (3)$$

$$t_t = T_{t_{(n+1)}} - T_{t_n}. \quad (4)$$

The time necessary for the dye plume to pass a sampling point in a section is given by

$$T_d = T_{t_n} - T_{l_n}. \quad (5)$$

Measurement of traveltimes for the leading edge, peak, centroid, and trailing edge provides insight into dispersion and dilution as well as flow velocity. Constituents in water disperse as they move downstream, some particles lagging along banks and in pools whereas others near the surface in the center of flow move downstream more rapidly. Thus, the plume will elongate or attenuate as it moves downstream. During periods of smaller, sluggish flows, constituents tend to spread out over great distances and remain in a given reach of the river for long periods. During larger, high-velocity streamflows, a plume tends to spread out more slowly and pass through a given reach of the river more quickly. Assuming complete vertical and lateral dispersion in a stream reach and no withdrawals or diversions, the area (corresponding to dye mass) under all response curves downstream from the injection point should be equal for a conservative dye (no losses).

Unfortunately, commonly used fluorescent dyes are not completely conservative because they may be adsorbed on sediments, be absorbed by aquatic vegetation, or decay over time. Dye losses as the plume migrates downstream may be estimated if the entire dye plume is measured at each sampling point and the flow for the stream and all tributaries or diversions is known. The time–concentration curve, adjusted for dye losses, then represents the dispersion characteristics for flow conditions in the reach. Dispersion is quantified by differences in the time of passage and attenuation of peak concentrations from site to site as the dye plume moves downstream.

Data Collection

Field procedures for traveltime and dispersion studies on streams using dye tracers are well documented (Kilpatrick and Wilson, 1989). In general, those procedures were followed closely during the 1979–81 and 1993 studies on the Truckee River and Truckee Canal.

The 1979–81 studies divided the Truckee River into three reaches: Truckee, Calif., to Vista, Nev.; Steamboat Creek to Derby Dam; and Derby Dam to Marble Bluff Dam. During low, sluggish streamflows, long traveltimes and the associated risk of changing flows due to inclement weather or upstream reservoir releases required that sampling reaches be subdivided into shorter subreaches. Under such circumstances, the river below Derby Dam was divided further into two overlapping subreaches from Derby Dam to Dead Ox Wash and from Wadsworth to Marble Bluff Dam. The 1993 studies included only the lower Truckee River below Steamboat Creek (site no. 8, fig. 2). Four shorter subreaches were designated because of the low-flow complications: Steamboat Creek to Derby Dam; Derby Dam to Wadsworth; Wadsworth to Dead Ox Wash; and Dead Ox Wash to Marble Bluff Dam (all in Nevada).

A minimum of two sampling sites downstream from the injection point for each reach (or subreach) were selected. Accessibility and suitability for making streamflow measurements over a range of flows were considered in site selection. Sampling and injection sites for the 1993 study on the lower Truckee River were chosen to coincide generally with sites from the earlier study. Sampling sites for the 17 traveltime studies (table 1) were far enough downstream from the injection sites that complete lateral mixing could be assumed. Tributary inflows, analogous to a side injection of clear water, cause lateral-mixing problems at nearby downstream sampling sites. Dye-measurement sites were chosen to be sufficiently downstream from tributary inflows for the water and dye to be fully mixed. Despite these precautions, Martis Creek and the Little Truckee River inflows may have caused poor mixing below Truckee at the bridge on old U.S. Highway [1]40 (site no. 2) and at Boca Bridge near Truckee (site no. 3), respectively, during some of the studies. (All sampling and dye-injection sites are listed in table 2 and shown in figure 2.)

Single-slug (instantaneous) dye injections usually were made in the center or main thread of flow. Rhodamine WT dye was used in the studies because it is less susceptible than other dye types to loss by contact with aquatic plants, suspended clays, and the streambed and streambanks. For each injection, the type and amount of dye, time and location of injection, and the measured flow were recorded. Concentrations of rhodamine WT dye were 160 g/L and 128 g/L of solution in the 1979–81 and 1993 studies, respectively. The amount of dye to be injected at the upstream end of each study reach was determined by using general empirical relations (Kilpatrick and Wilson, 1989) that are dependent upon the maximum flow anticipated for the reach, velocity, reach length, and dye concentration. These dye amounts typically were chosen so peak concentrations at the downstream end of each study reach or at municipal water intakes did not exceed 10 µg/L.

Fluorometers were used in the field and in the laboratory to determine the presence and concentration of dye in the samples collected. Fluorometers measure the luminescence of a fluorescent substance when that substance is subjected to a light source of an appropriate wavelength. The higher the concentration of the fluorescent substance, the more emitted light the fluorometer detects. Background samples taken at each site before arrival of the dye indicated that no detectable dye was in the river. When the dye plume arrived at a given site, 15 to 50 samples were taken in the main flow of the river at time intervals adequate to define the time–concentration (response) curve. Samples were collected manually at single points in the river or canal in all studies. In some of the 1993 studies, automated

[1] Route is called old U.S. Highway 40 in California, but parts of route in Nevada now are called State Route 427.

samplers were used to define trailing edges of long response curves. This allowed members of the field crew to proceed sooner to the next downstream site. Fluorometer measurements were made in the field at the time of sampling to guide the frequency and duration of sampling for each dye plume. After field measurement, samples were stored out of sunlight in 1-oz glass bottles for later analysis under laboratory conditions.

Flow measurements were made at the injection site and at each sampling site. In those instances where direct flow measurments were not made while dye was present, flow-gaging-station data were substituted or were used to determine a mean index flow within a reach during the period when dye was present.

The samples collected in the field were retested under more-controlled laboratory conditions because sample temperatures experienced in the field varied and were different from those used to calibrate the fluorometer. Aside from dye concentration, sample temperature is the most significant factor affecting the fluorescence of a dilute solution. The fluorometer was calibrated in the lab according to procedures described by Wilson and others (1986) using standard solutions prepared from the same dye lot that had been used in the field. The raw data shown in tables and used in figures in this report are the actual dye-concentration values that were obtained under laboratory conditions; they were not adjusted to conservative values on the basis of dye-recovery percentages.

Dye-Tracing Results

Compilations of data for the 1993 and previous USGS dye studies are shown in tables 3 through 19. These include 10 dye studies along the Truckee River made from May 1979 through October 1980, 4 along the lower Truckee River during November–December 1993, and 3 along the Truckee Canal from May 1979 through May 1980 under various flow conditions. The May 1979 canal study was a continuation of a Truckee River traveltime study initiated at the Truckee Meadows Water Reclamation Facility. By plotting the data in tables 3 through 19, a series of response curves for each dye study may be generated. For example, the attenuation of the dye plume as it proceeded downstream during the period November 29, 1993, to December 1, 1993, between Steamboat Creek and Derby Dam is shown in figure 4. Traveltime information computed from the data in tables 3 through 19 is summarized in tables 20 through 23. The cumulative traveltimes since injection, the durations of dye-plume presence, and the dye-recovery values for the pre-1993 studies are from La Camera and others (1985) and were derived from graphical analyses of the raw data according to the methods described by Kilpatrick and Wilson (1989). For the 1993 studies, the leading edge of the dye plume was considered to be the value of the first-detected dye just prior to a notable increase in concentration over background levels. The trailing edge was estimated to be the time when dye concentrations measured 0.2 µg/L or lower.

River miles used in this report are those used by the previous Truckee Carson River Quality Assessment (Brown and others, 1986; La Camera and others, 1985; Nowlin, 1987). River miles for new locations sampled in this study are referenced to an unpublished database and maps from that assessment (J.O. Nowlin, U.S. Geological Survey, written commun., 1999). An extensive geographic information system was developed in support of river modeling studies in the current Truckee-Carson Program. Sources included digital hydrography, aerial photographs, and satellite imagery compiled for varying dates and scales. Comparison of channel locations in these two databases showed that certain reaches of the Truckee River below Wadsworth had localized changes in channel alignment of as much as several hundred feet that were probably caused by floods (1983, 1986) subsequent to the 1979–81 dye studies. However, a comparison of the two river mile databases shows that differences in total channel length over reaches of 5 miles or more are generally less than two percent. River mile differences in active channel migration reaches below Wadsworth between the two databases were also about 2 percent, the same magnitude as for the rest of the river and canal. Compilation of an updated digital geographic database of consistent scale and accuracy for the entire Truckee River would be of great benefit to future hydrologic research and river restoration projects but was beyond the scope of this current study.

ESTIMATION OF TRAVELTIME CHARACTERISTICS

The data in tables 20 through 23 can be presented graphically to show relations that are useful in predicting traveltimes at other locations and for flows not measured in the studies. This section shows how traveltime–distance and traveltime–flow relations are used

Table 2. Traveltime-study injection and sampling sites

[Site number: see figure 1. —, none]

Site number	Station number	Site name	Location		Purpose of site	Remarks
			River miles[1]	Latitude and longitude		
				Sites on or near Truckee River		
1	10339010	Truckee River at State Route 267 at Truckee, Calif.	100.86	39°19′36″ N. 120°11′00″ W.	Injection	Dye injected from downstream side of bridge.
2	10339498	Truckee River at old U.S. [2]40 bridge below Truckee, Calif.	96.17	39°21′11″ N. 120°07′17″ W.	Sampling	Sampled near right bank just upstream from bridge.
3	10344505	Truckee River at Boca Bridge near Truckee, Calif.	91.24	39°23′07″ N. 120°05′12″ W.	Sampling	Sampled from downstream side of bridge.
4	—	Truckee River below Farad powerplant near Floriston, Calif.	81.28 (1980) 81.09 (1979)	39°25′59″ N. 120°01′34″ W.	Sampling	Sampled near left bank 0.80 mile below U.S. Geological Survey gaging station (no. 10346000) in 1979 and 0.61 mile in 1980.
5	10347690	Truckee River at Mayberry Drive below Lawton, Nev.	65.70	39°30′24″ N. 119°53′17″ W.	Sampling	Sampled from downstream side of bridge.
6	10348200	Truckee River near Sparks, Nev.	56.15	39°31′11″ N. 119°44′27″ W.	Sampling	Sampled at U.S. Geological Survey gaging station (no. 10348200) near left bank upstream from bridge.
7	10349989	Reno–Sparks sewage-treatment plant[3] outfall near Reno, Nev.	53.66	39°31′07″ N. 119°42′13″ W.	Injection	Dye injected at outfall into Steamboat Creek, 675 feet (0.13 mile) above confluence with Truckee River, during 1979–80.
8	—	Steamboat Creek at mouth near Sparks, Nev.	53.53	39°31′15″ N. 119°42′09″ W.	Injection	Dye injected at mouth near right bank of Steamboat Creek in 1993.
9	10350000	Truckee River at Vista, Nev.	52.23	39°31′05″ N. 119°40′58″ W.	Sampling	Sampled pre-1994 site of U.S. Geological Survey gaging station (no. 10350000).
10	10350050	Truckee River at Lockwood, Nev.	50.10 (1993) 50.05 (1979–80)	39°30′36″ N. 119°38′52″ W.	Sampling	Sampled from bridge during 1979–80 and near right bank 250 feet (0.05 mile) upstream from bridge in 1993.
11	10350200	Truckee River at Patrick, Nev.	44.92	39°32′49″ N. 119°34′59″ W.	Sampling	Sampled at bridge at McCarran Ranch.
12	10350400	Truckee River below Tracy, Nev.	40.62	39°33′52″ N. 119°31′02″ W.	Sampling	Sampled at bridge at Tracy powerplant, pre-1997 gaging station site.
13	10350500	Truckee River at Clark, Nev.	38.56	39°33′55″ N. 119°29′02″ W.	Sampling	Sampled near right bank 200 feet (0.04 mile) downstream from bridge.
14	10351000	Truckee River at Derby Dam near Wadsworth, Nev.	34.88 (1979–80) 34.85 (1993)	39°35′08″ N. 119°26′54″ W.	Injection and sampling.	Dye injected 75 feet (0.01 mile) downstream from dam. Sampled in river at upstream side of dam near center gates during 1979–80 and in canal 150 feet (0.03 mile) downstream from dam near left bank in 1993.
15	10351619	Truckee River at Painted Rock Bridge.	30.05 (1993) 29.97 (1979–80)	39°35′28″ N. 119°21′59″ W.	Sampling	Sampled from bridge during 1979–80 and near right bank 400 feet (0.08 mile) upstream in 1993.
16	10351648	Truckee River at old U.S. [2]40 bridge at Wadsworth, Nev.	23.68 (1993) 23.69 (1979–80)	39°37′55″ N. 119°16′54″ W.	Injection and sampling.	Dye injected at downstream side of bridge. Sampled 25 feet downstream from bridge during 1979–80 and near left bank 75 feet (0.01 mile) upstream in 1993.
17	—	Truckee River at S–Bar–S Ranch near Wadsworth, Nev.	17.82 (1979–80)	39°41′27″ N. 119°17′05″ W.	Sampling	Sampled near left bank at irrigation pump.

18	—	Truckee River below S–Bar–S Ranch near Wadsworth, Nev.	17.00	39°41′46″ N. 119°17′40″ W.	Sampling	Sampled near left bank.
19	10351690	Truckee River at Dead Ox Wash near Nixon, Nev.	13.18 (1979–80) 13.02 (1993) 13.01 (1993)	39°44′14″ N. 119°19′24″ W.	Injection and sampling.	Dye injected 350 feet (0.07 mile) downstream from wash in 1993. Sampled near lone cottonwood tree on left bank 1.12 miles below Numana hatchery during 1979–80 and near left bank 300 feet (0.06 mile) downstream from wash in 1993.
20	10351725	Truckee River at Numana Dam near Nixon, Nev.	8.12	39°47′23″ N. 119°20′54″ W.	Sampling	Sampled near left bank 500 feet (0.09 mile) downstream from dam.
21	10351750	Truckee River at State Route 447 at Nixon, Nev.	3.20 (1993) 3.22	39°49′45″ N. 119°21′36″ W.	Sampling	Sampled from bridge during 1979–80 and near left bank 100 feet (0.02 mile) upstream from bridge in 1993.
22	10351775	Truckee River at Marble Bluff Dam near Nixon, Nev.	0.00	39°51′20″ N. 119°23′32″ W.	Sampling	Sampled off left or right wingwall of dam (depending on flow conditions).
23	10351780	Truckee River below Marble Bluff Dam.	-0.05	39°51′11″ N. 119°23′44″ W.	Sampling	Sampled 275 feet (0.05 mile) downstream from dam, near left bank during 1979–80 and near right bank in 1993.
			Sites on Truckee Canal			
24	—	Truckee Canal at Derby Dam near Wadsworth, Nev.	31.42	39°35′11″ N. 119°26′55″ W.	Sampling	Sampled near downstream side of canal gates.
25	—	Truckee Canal at Pyramid Check Dam near Wadsworth, Nev.	25.38	39°35′38″ N. 119°20′47″ W.	Sampling	Sampled at upstream side of dam.
26	10351300	Truckee Canal near Wadsworth, Nev.	22.54	39°36′24″ N. 119°18′36″ W.	Sampling	Sampled at U.S. Geological Survey gaging station (no. 10351300) below end of tunnel no. 3.
27	10351320	Truckee Canal at U.S. Highway 95A near Fernley, Nev.	18.26 (1979–80, 1993) 18.02 (1981)	39°35′28″ N. 119°14′57″ W.	Sampling	Sampled near left bank 150 feet (0.03 mile) upstream from bridge, at diversion gate TC–4, during 1979–80 and in 1993. Sampled from upstream side of Fernley Check Dam, 0.21 mile downstream from bridge, in 1981.
28	—	Truckee Canal at Anderson Check Dam near Fernley, Nev.	15.07	39°34′55″ N. 119°11′54″ W.	Sampling	Sampled from upstream side of check dam.
29	10351367	Truckee Canal at Allendale Check Dam near Hazen, Nev.	11.07	39°34′47″ N. 119°07′39″ W.	Sampling	Sampled from upstream side of check dam.
30	—	Truckee Canal at Mason Check Dam near Hazen, Nev.	6.39	39°32′24″ N. 119°04′26″ W.	Sampling	Sampled from footbridge at check dam.
31	—	Truckee Canal at Bango Check Dam near Hazen, Nev.	3.25	39°30′15″ N. 119°02′39″ W.	Sampling	Sampled from upstream side of check dam.
32	10351590	Truckee Canal at U.S. Highway 50 above Lahontan Reservoir near Fallon, Nev.	0.44	39°28′09″ N. 119°04′00″ W.	Sampling	Sampled at bridge.

[1] River miles above Marble Bluff Dam or canal miles above head of drop structure into Lahontan Reservoir. Indicated miles are for the actual sampling site as indicated in Remarks, which may differ from the named feature.

[2] Old U.S. Highway 40 in California; State Route 427 in parts of Nevada.

[3] Now known as Truckee Meadows Water Reclamation Facility.

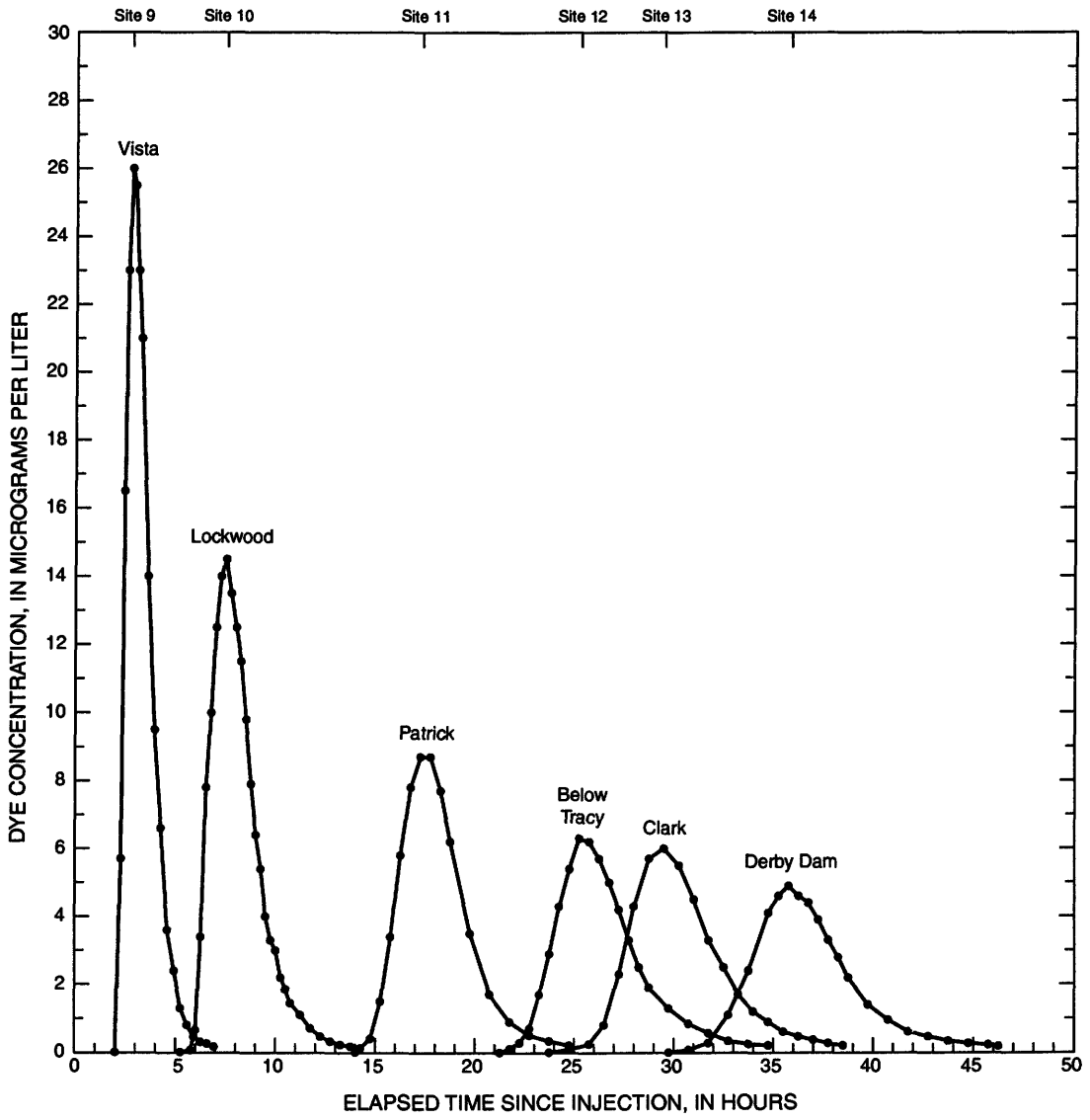

Figure 4. Observed response curves for Truckee River reach between Steamboat Creek at mouth near Sparks, Nev. (site 8), and Derby Dam (site 14) near Wadsworth, Nev., November 29–December 1, 1993. See table 2 for full site names.

to predict traveltime properties for various reaches of the Truckee River and Truckee Canal and illustrates proper use of the relations by example. Limitations on the use of these relations, the assumptions used to interpret traveltime from the dye-study data, the unique features of the Truckee River, and the manner and conditions under which the data were collected are provided in the section titled "Limitations of Data and Procedures Used in Study."

Traveltime–Distance Relations

Traveltimes of the leading edge, centroid, and trailing edge of the dye-response curve are plotted against distance upstream from Marble Bluff Dam and Lahontan Reservoir, respectively, in figures 5 and 6. Although one could combine the traveltime–distance data for adjacent reaches and plot cumulative traveltime against total distance, streamflows varied considerably from reach to reach. Therefore, the traveltimes are not cumulative, and results are shown only for individual reaches and not for the entire length of the river. The streamflows shown are the average flow over the study period at representative (index) gaging stations in or near the study reach. The index gaging stations used for these studies are shown in figure 2 and are listed in table 24.

These traveltime–distance relations may be used only for the individual reaches when streamflows are equal to or nearly the same as those observed during the

studies. (For estimates of traveltimes at streamflows other than those measured in the study, see the section titled "Traveltime–Flow Relations.") As an example of using the traveltime–distance relations, suppose an injection or spill happens at State Route 267 in Truckee, Calif. (in the farthest upstream reach, fig. 5), during a time when streamflows are about 380 ft^3/s and centroid traveltime information is desired at Mayberry Drive below Lawton, Nev. Entering the abscissa of the low-flow graph (fig. 5*C*) at Mayberry Drive (site 5, 65–70 mi upstream from Marble Bluff Dam), the elapsed time for the centroid is about 37 h. Similarly, elapsed time for the centroid near Truckee at the Boca Bridge (site 3, 91.24 mi above Marble Bluff Dam) is about 17 h. Thus, the centroid traveltime between the two sites in this example would be about 20 h.

Traveltime–Flow Relations

Because the dye studies were made over a range of flows, the traveltime data can be graphed to show the variation with flow through a reach. These data are plotted in figures 7 through 11 as families of curves (one for each sampling site in the study) that depict centroid traveltime over a range of flows. For a range of flows (at an index flow-gaging station) along a reach that is fairly uniform with regard to geometry and roughness, the relations will typically plot as straight and approximately parallel lines on logarithmic graph paper. The Truckee Canal graph (fig. 11) contains several roughly parallel lines that reflect the fairly uniform channel characteristics of the canal. Therefore, the centroid will travel at a constant velocity for a given flow between any two points. To estimate traveltime between two locations not identified on the graph, a user need only determine the velocity between any two locations on the graph and apply that velocity to any desired distance along the canal to get a traveltime estimate.

Only the traveltimes for the response-curve centroids are truly additive when summing the data for individual subreaches. The peak and the leading and trailing edges are all affected by dispersion; however, the time interval between passage of the peak concentration at two successive sites is virtually the same as the time interval between the centroids of the time–concentration curves and thus may be added to approximate the timing expected for a single injection.

Unfortunately, no conclusions can be drawn concerning any relation between the 1979–80 and 1993 Truckee River studies. Although the graphed data (fig. 10) show a change in slope (between the old relations at greater streamflows and the new relations at smaller streamflows) representing a decrease in traveltimes between old U.S. Highway 40 at Wadsworth and Marble Bluff Dam from what would have been expected by simple extrapolation of relations from the older study, the exact reason cannot be determined from available information. Common preflood and postflood traveltime data were not available for analysis below Derby Dam at rates other than 50 ft^3/s. Because the flows for the old and new studies do not overlap, no conclusions can be drawn on the validity of the old curves for making present-day estimates at streamflows greater than about 50 ft^3/s. Put another way, the 1979–80 relations for streamflows greater than those during the 1993 studies may have changed and cannot be verified on the basis of the more recent results. The only viable conclusion is that extending the old curves to rates less than 50 ft^3/s below Derby Dam results in overestimation of traveltimes and underestimation of velocities. Increased velocities can be explained for at least a part of the lower Truckee River. The pool behind Marble Bluff Dam was deeper and provided some storage during the 1979–80 studies. Because this pool has silted in and has provided little effective water storage since then, traveltimes in that reach have decreased. Therefore, the results for medium to low streamflows between Wadsworth and Marble Bluff Dam from the 1979–80 studies should be considered approximate only.

Example Application

The traveltime–distance plots in figures 5 and 6 are useful primarily in presenting traveltime data for flows measured during the Truckee River and Truckee Canal dye-tracing studies. They also are useful in illustrating longitudinal dispersion by showing the ever-increasing passage time of the solute plume (from leading to trailing edge) as it drifts downstream.

Most traveltime information required for practical applications, such as estimating the movement of contaminant spills, can be obtained from figures 7 through 11, which depict peak concentration traveltime over a range of flows. The values obtained for each subreach are additive, which means the user can predict, for example, the arrival of the peak concentration

from a spill at Truckee, Calif., several subreaches downstream at Vista or Marble Bluff Dam. For example, suppose a spill happens at the State Route 267 bridge at Truckee, Calif. Estimated streamflows at the two index gaging stations Truckee River near Truckee, Calif. (station no. 10338000) and Truckee River at Farad (station no. 10346000) can be obtained from the U.S. District Court Water Master or the USGS (World Wide Web address of Water Resources Division in Nevada, http://nevada.usgs.gov). For instance, an estimate of the arrival time of the peak concentration is desired at Vista, Nev., given estimated streamflows of 600 ft^3/s at the two index gaging stations. First enter the abscissa or horizontal axis of the graph in figure 7 at the estimated streamflow, 600 ft^3/s in this example, and draw a vertical line to the Boca Bridge curve. From that point draw a horizontal line that intersects the ordinate or vertical axis and read the estimated peak traveltime, about 4.3 h in this example. Similarly, enter the graph in figure 8 on the abscissa at 600 ft^3/s and draw a vertical line to the Vista gaging-station curve. From that point draw a horizontal line that intersects the ordinate and obtain an estimate of 28 h for the peak traveltime from Boca Bridge to the gaging station Truckee River at Vista, Nev. The traveltimes of 4.3 h from figure 7 and 28 h from figure 8 are then added to get the cumulative total traveltime of about 32 h from Truckee to the Vista gaging station for a flow of 600 ft^3/s. This example predicts the elapsed time to peak concentration, not the elapsed time to the leading edge of the contaminant plume, which also may be of interest for decisions relating to the closing of water intakes in the Reno–Sparks municipal area.

LIMITATIONS OF PROCEDURES USED AND OF DATA COLLECTED

The collection and presentation of data and techniques for this report required several assumptions that may influence the reliability of values estimated by using the described procedures. Differences between field conditions under consideration by the user, unique conditions experienced during field data collection for the summarized studies, and ideal conditions upon which the theories and techniques are based may be significant. Many subjective judgments may have to be made to apply the data and described relations successfully. As with any empirical relations, caution should be exercised in extrapolating the relations beyond the range of the data collected for this study.

The results presented herein are intended to complement water-quality modeling studies and to be used as a guide in estimating the movement of a soluble material in the Truckee River or Truckee Canal. In the event of an accidental spill, extensive technical and manpower resources would be necessary to collect and analyze samples, measure the flow in the river or canal, and to track the actual movement of the contaminant plume as it migrated downstream. The procedures presented in this report would allow a quick assessment of the potential magnitude of the problem and assist in scheduling the necessary monitoring activities.

Taylor and others (1984) concluded that "the ideal situation for studying longitudinal dispersion would be one in which: (1) the total reach could be studied without segmentation; and (2) complete lateral mixing could be assumed to exist after the initial mixing period." However, low-flow conditions (where traveltimes may be measured in weeks rather than hours), sampling logistics, possible flow changes (due to reservoir regulation or precipitation), and control of maximum dye concentrations at water intakes required that the Truckee River reach be divided into shorter subreaches.

Gaged and ungaged inflows and flow losses take place at numerous locations along the Truckee River in the form of diversions, return flows, tributaries, and gains from or losses to ground water. Inflows and outflows along a stream reach work against the ideal concept of having complete lateral mixing and

EXPLANATION

Dye plume

---------- Trailing edge
———— Centroid
– – – – – Leading edge

Site (see table 2)

1	State Highway 267
2	Old U.S. 40 bridge below Truckee
3	Boca Bridge near Truckee
4	Below Farad powerplant
5	Mayberry Drive
6	Near Sparks
8	Steamboat Creek
9	Vista
10	Lockwood
11	Patrick
12	Below Tracy
13	Clark
14	Derby Dam
15	Painted Rock Bridge
16	Old U.S. 40 bridge at Wadsworth
17	S–Bar–S Ranch
19	Dead Ox Wash
20	Numana Dam
21	State Highway 447
22	Marble Bluff Dam

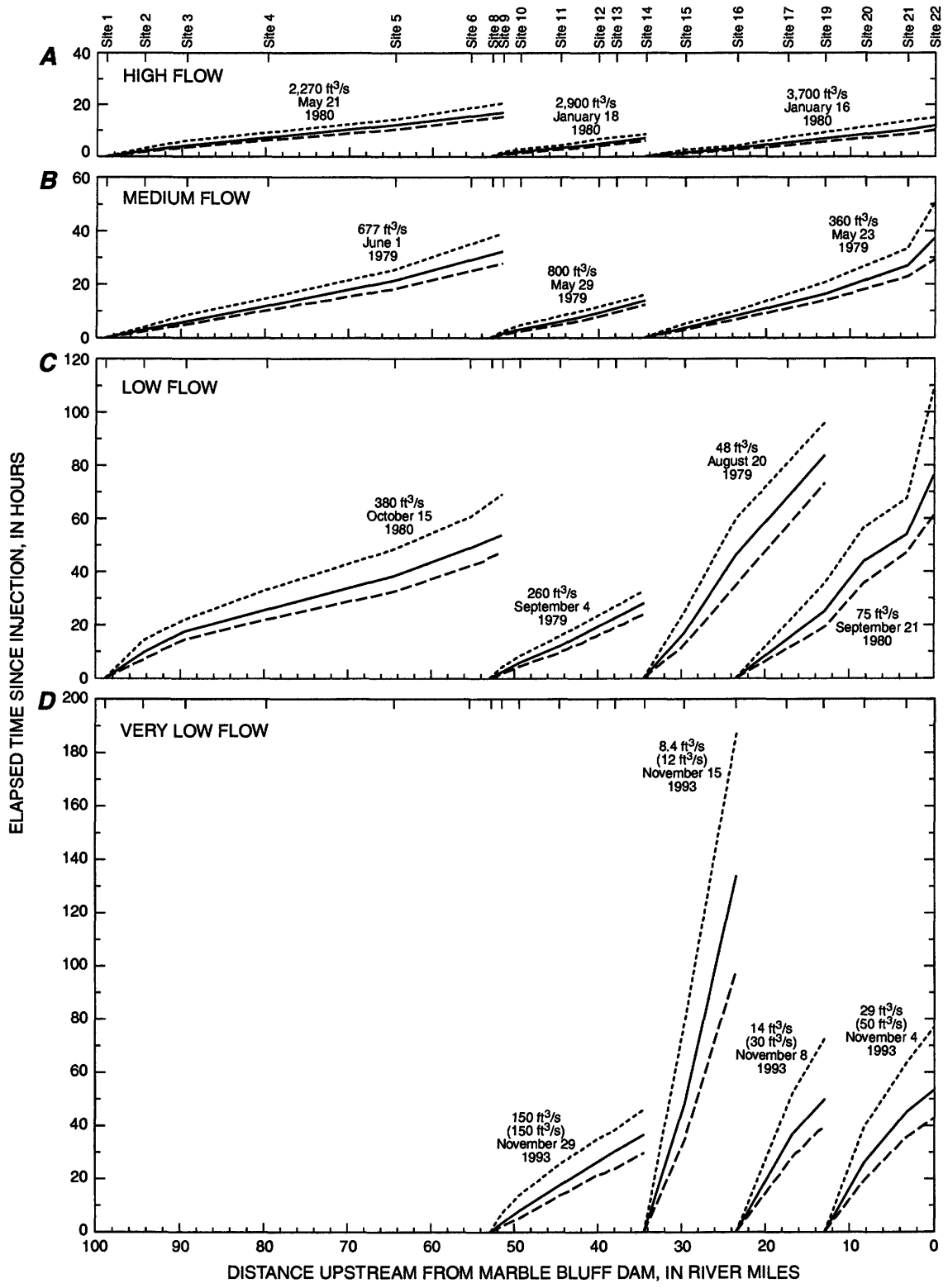

Figure 5. Traveltime–distance relations and dispersion characteristics for Truckee River at high *(A)*, medium *(B)*, low *(C)*, and very low *(D)* flows. Dates and magnitudes of peak flow rates at nearest upstream index gaging stations are shown for each injection. Data for 1979–80 from La Camera and others (1985, p. 178–180). For 1993 data, flow rate in parentheses is estimate of actual flow in reach, including groundwater accretions. See table 2 for full site names and alternate route names and table 24 for more information about index gaging stations.

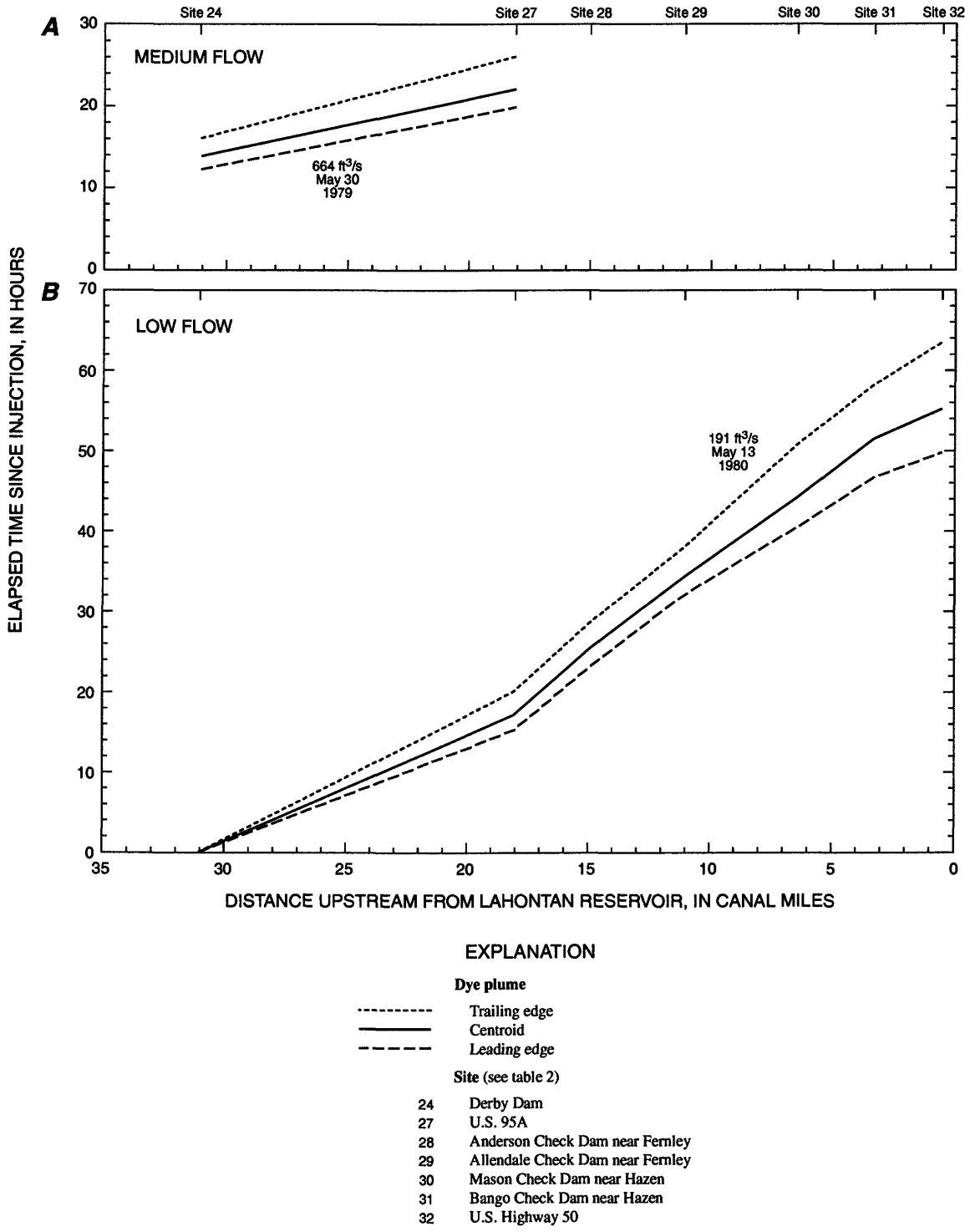

Figure 6. Traveltime–distance relations and dispersion characteristics for Truckee Canal at medium *(A)* and low *(B)* flows. Data from La Camera and others (1985, p. 181). See table 2 for full site names and alternate route names.

conservation of mass. The most accurate definition of the time–concentration curve requires multiple point sampling across the river and weighting of each time–concentration curve by the streamflow corresponding to that lateral subsection of the river. In this study, only one point in the river cross section was sampled at each sampling location. Complete lateral mixing was assumed, based on theoretical calculations.

Related to mixing is the type of substance under consideration. The behavior of immiscible substances such as oil or other floating materials cannot be determined using procedures derived from the data in this study. The peak concentrations for such floating substances tend to be greater than for soluble substances as the former tend to disperse in only two dimensions at the stream surface whereas solutes dilute and disperse in three dimensions as they proceed downstream. Similarly, the data in this report cannot be used directly to predict the concentration of biologically or chemically degraded substances such as nutrients and dissolved gases unless their decay properties are known.

Several factors contribute to decreased recovery of dye as it moves downstream. All computations and techniques concerning concentration assume conservation of mass. In reality, many physical, chemical, and biological processes, in addition to ordinary dilution, might cause decreasing concentrations. Unpredictable dye losses can take place within very long reaches of streams carrying very fine grained suspended sediment such as clay or flocculent organic particles (Kilpatrick and Cobb, 1985). Additionally, uptake by abundant algal growth in the lower Truckee River and lower Truckee Canal may contribute to dye losses in some of the studies. Concentration also can decrease unexpectedly over extended periods of time (several days). Tests by R.E. Rathbun (U.S. Geological Survey, written commun., 1983) indicated that losses of rhodamine WT dye may occur where diluted concentrations are exposed to sunlight for several hours. Photochemical decay rates tend to be large in rivers (about 5 percent per day), especially shallow ones such as the Truckee River, according to F.A. Kilpatrick (U.S. Geological Survey, written commun., 1988). Some Truckee River dye studies yielded traveltimes exceeding 5 days.

Traveltime or dispersion relations cannot be used reliably when flow conditions in the river are unstable. Diurnally varying effluent discharges from the Truckee Meadows Water Reclamation Facility caused unavoidable flow fluctuations during the 1993 low-flow dye studies on the Truckee River for the reach between Steamboat Creek and Derby Dam that may have affected study results. The effects of flood waves on water-particle movement are indeterminate within the scope and dye-tracing procedures used in these studies. The techniques presented in this report should be used with caution when flow conditions in the system are unstable. Large changes in reservoir releases or sudden runoff from an intense thunderstorm upstream may cause such conditions.

Abrupt changes in flow along the Truckee River or Truckee Canal are possible as a result of multiple diversions such as for municipal or irrigation use. Traveltime estimates and recovery percentages in such instances may not be valid. About 30 to 40 diversions may have been active during some of the Truckee River dye studies made in 1979–80.

Changes in the physical configuration of the watercourse also may affect the relations presented. The addition, removal, or modification of check dams may change relations in certain subreaches. Lateral channel shifts resulting from major floods may also alter relations. The user is encouraged to investigate these potential sources of error if accurate estimates are imperative. Finally, many of the graphs in this report show log-linear relations, which assume uniform channel characteristics for the reach under consideration.

The data from these traveltime studies also could be used to derive graphical relations that would provide a tool for predicting certain dispersion properties at locations and for flows not measured in the studies. The most-detailed effort would involve calibration of a one-dimensional diffusion model as described by Jobson and Schoellhamer (1987). A simpler approach would be to use tracer-response curves (Kilpatrick and Taylor, 1986; Kilpatrick, 1993) as building blocks in conjunction with the superposition principle (from the unit-hydrograph theory (Linsley and others, 1958)) to simulate the downstream change in loading pattern resulting from any soluble contaminant input upstream. Kilpatrick (1993) also explained how to handle dispersion estimates in situations involving either steady or variable loadings into a reach over extended time periods. Such situations might result from continuous but variable effluent discharge from a sewage-treatment facility or a prolonged leak from an industrial operation adjacent to the river.

SUMMARY

Traveltime characteristics were determined for reaches along the Truckee River and Truckee Canal on the basis of 17 dye studies done during 1979–81 and 1993. The 1993 studies were associated with extremely low streamflows in the Truckee River downstream from Steamboat Creek near Sparks, Nev. Data from the 1993 study were collated with the previous study results to expand the range of measured flows over which the relations may apply.

The results of the dye studies include both measured and computed traveltime properties for the Truckee River. In general, these results indicate that low-flow extension of the 1979–80 traveltime–discharge relations, based on the 1993 studies, is possible for the reach from Vista, Nev., to Derby Dam near Wadsworth, Nev. The results indicate that extending the previous curves to less than 50 ft^3/s overestimates traveltimes for the reach below Derby Dam for 1993. Additionally, because the ranges of streamflows in the 1979–80 and 1993 studies do not overlap, no verification of the relations from the earlier study was possible. Stream lengths measured in 1993 confirm that in spite of some localized channel shifting downstream from Wadsworth over the previous decade, total stream lengths remain mostly unchanged. Graphical relations are presented for the user to predict peak-concentration traveltimes at various levels of flow. Because the values obtained by using the traveltime–flow relations for reaches are additive, arrival of the peak concentration (not the leading edge) can be predicted after a spill in an upstream reach.

A limitation of the dye-study results is that they are not applicable to chemically or biologically degradable substances or to insoluble materials. Additionally, the following assumptions were made in collection and interpretation for the dye studies:

- Conservation of mass
- Instantaneous injection
- Physical stability of channel characteristics over time
- Tracer solubility
- Complete lateral mixing at sampling sites
- Steady flows
- Channel uniformity (ability to use log-linear relations)

Insofar as such conditions may not have prevailed during the studies, the accuracy of the derived relations may have been compromised. However, the data and graphs in this report are intended to complement more-detailed water-quality modeling studies and may be used as a rule-of-thumb guide in assessing contaminant spills and in planning associated monitoring activities.

REFERENCES CITED

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.

Buchanan, T.J., 1964, Time of travel of soluble contaminants in streams: American Society of Civil Engineers Proceedings, Journal of the Hydraulics Division, v. 90, no. SA3, p. 1–12.

Caupp, C.L., Brock, J.T., and Runke, H.M., 1997, Application of the dynamic stream simulation and assessment model (DSSAMt) to the Truckee River below Reno, Nevada—Model formulation and overview: Boise, Idaho, Rapid Creek Research Technical Report No. RCR96–1.1, 107 p.

Jobson, H.E., and Schoellhamer, D.H., 1987, Users manual for a branched Langrangian transport model: U.S. Geological Survey Water-Resources Investigations Report 87–4163, 73 p.

Jones, Jeanine, Maxwell, S.R., and Hayward, Patricia, 1991, Truckee River atlas: California Department of Water Resources, 128 p.

Kilpatrick, F.A., 1993, Simulation of soluble waste transport and buildup in surface waters using tracers: U.S. Geological Survey Techniques of Water-Resources Investigations, bk. 3, chap. A20, 37 p.

Kilpatrick, F.A., and Cobb, E.D., 1985, Measurement of discharge using tracers: U.S. Geological Survey Techniques of Water-Resources Investigations, bk. 3, chap. A16, 52 p.

Kilpatrick, F.A., and Taylor, K.R., 1986, Generalization and applications of tracer dispersion data: Water Resources Bulletin, v. 22, no. 4, p. 537–548.

Kilpatrick, F.A., and Wilson, J.F., Jr., 1989, Measurement of time of travel in streams by dye tracing: U.S. Geological Survey Techniques of Water-Resources Investigations, bk. 3, chap. A9, 27 p.

La Camera, R.J., Hoffman, R.J., Nowlin, J.O., Smith, L.H., and Lima, S.M., 1985, Data on surface-water quality and quantity, Truckee River system, Nevada and California, 1979–81: U.S. Geological Survey Open-File Report 84–238, 191 p.

Linsley, R.K., Kohler, M.A., and Paulhus, J.L.H., 1958, Applied hydrology: New York, McGraw-Hill, 340 p.

Nowlin, J.O., 1987, Modeling nutrient and dissolved-oxygen transport in the Truckee River and Truckee Canal downstream from Reno, Nevada: U.S. Geological Survey Water-Resources Investigations Report 87–4037, 487 p.

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.

Taylor, K.R., James, R.W., Jr., and Helinsky, B.M., 1984, Traveltime and dispersion in the Potomac River, Cumberland, Maryland, to Washington, D.C.: U.S. Geological Survey Open-File Report 83–861, 55 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.

Wilson, J.F., Jr., 1968, Time-of-travel measurements and other applications of dye tracing, *in* International Union of Geodesy and Geophysics Commission of Surface Waters, Hydrological aspects of the utilization of water: International Association of Scientific Hydrology Publication 76, p. 252–265.

Wilson, J.F., Jr., Cobb, E.D., and Kilpatrick, F.A., 1986, Fluorometric procedures for dye tracing: U.S. Geological Survey Techniques of Water-Resources Investigations, bk. 3, chap. A12, 41 p.

Table 3. Dye-concentration data from traveltime study on Truckee River between Truckee, Calif., and Vista, Nev., May 31–June 1, 1979

[Modified from La Camera and others (1985, table 11). See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at State Highway 267 at Truckee, Calif. (site number 1)
Date and time of injection: May 31, 1979, at 0935
Volume of injected dye, in liters: 10.0

Sampling site:					
Name	Truckee River at old U.S. 40 bridge below Truckee, Calif.	Truckee River at Boca Bridge near Truckee, Calif.	Truckee River below Farad powerplant near Floriston, Calif.	Truckee River at Mayberry Drive below Lawton, Nev.	Truckee River at Vista, Nev.
Number	2	3	4	5	9
Distance downstream from injection site, in river miles.	4.69	9.62	19.77	35.16	48.63
Estimated streamflow during sampling period, in cubic feet per second.	440	520	680	510	450
Date	May 31, 1979	May 31, 1979	May 31, 1979	June 1, 1979	June 1, 1979

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1158	0.00	1436	0.00	1940	0.00	0343	0.00	1350	0.00
1200	.4	1438	.1	1952	.3	0354	.2	1420	.4
1202	.8	1440	.1	2000	.9	0403	.2	1440	.6
1204	1.6	1442	.3	2010	2.3	0413	.5	1500	1.0
1206	3.5	1444	.5	2020	4.0	0423	.8	1525	1.2
1208	6.9	1446	.8	2030	6.4	0433	1.0	1540	1.6
1210	12	1448	1.3	2040	8.4	0443	1.5	1600	1.9
1212	20	1450	2.0	2050	10	0453	2.0	1620	2.2
1214	25	1452	3.3	2100	11	0503	2.6	1640	2.4
1216	34	1454	4.7	2110	10	0513	3.2	1700	2.2
1218	42	1456	13	2120	9.6	0523	3.1	1720	2.2
1220	44	1458	13	2140	7.8	0533	3.8	1825	1.6
1222	52	1502	8.8	2200	6.3	0543	3.8	1910	1.2
1224	44	1504	7.5	2220	4.4	0553	4.2	1950	.9
1226	58	1506	6.5	2240	2.5	0603	4.1	2030	.7
1228	51	1508	14	2300	1.7	0613	4.3	2125	.4
1230	61	1510	20	2320	.9	0623	4.3	2200	.4
1232	59	1512	18	2340	.6	0634	4.3	2230	.2
1234	62	1515	21	2400	.4	0644	4.3	2300	.2
1236	56	1520	32			0653	4.1	2330	.0
1238	52	1525	33			0703	3.8		
1240	49	1530	33			0723	3.7		
1242	44	1535	30			0743	3.2		
1244	40	1545	24			0803	2.9		
1248	29	1555	16			0823	2.1		
1252	22	1605	8.6			0843	1.8		
1256	16	1615	6.5			0903	1.5		
1300	11	1626	2.1			0926	1.0		
1304	9.7	1635	1.8			0943	.8		
1308	5.7	1645	1.0			1003	.6		
1312	4.0	1655	.6						
		1705	.5						
		1715	.5						
		1730	.3						

Table 4. Dye-concentration data from traveltime study on Truckee River between Truckee, Calif., and Vista, Nev., May 21–22, 1980

[Modified from La Camera and others (1985, table 11). See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at State Highway 267 at Truckee, Calif. (site number 1)
Date and time of injection: May 21, 1980, at 0735
Volume of injected dye, in liters: 21.5

Sampling site:					
Name	Truckee River at old U.S. 40 bridge below Truckee, Calif.	Truckee River at Boca Bridge near Truckee, Calif.	Truckee River below Farad powerplant near Floriston, Calif.	Truckee River at Mayberry Drive below Lawton, Nev.	Truckee River at Vista, Nev.
Number	2	3	4	5	9
Distance downstream from injection site, in river miles.	4.69	9.62	19.58	35.16	48.63
Estimated streamflow during sampling period, in cubic feet per second.	740	1,700	2,300	2,300	2,400
Date	May 21, 1980	May 21, 1980	May 21, 1980	May 21, 1980	May 21–22, 1980

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
0915	0.00	1030	0.00	1330	0.00	1755	0.00	2255	0.00
0917	.06	1045	.01	1340	.01	1810	.03	2300	.2
0919	.5	1056	.03	1345	.01	1818	.1	2305	.4
0921	1.9	1100	.2	1350	.1	1823	.2	2310	.5
0923	5.5	1104	.9	1355	.4	1828	.3	2315	.8
0925	11	1110	4.6	1400	1.0	1833	.6	2325	1.2
0927	19	1112	7.0	1405	2.0	1838	1.0	2330	2.1
0929	29	1114	9.6	1410	3.9	1843	1.5	2350	4.5
0931	36	1116	13	1415	6.1	1848	2.3	0005	5.4
0933	44	1118	17	1420	4.3	1853	3.1	0010	5.5
0935	51	1122	23	1425	10	1858	4.2	0015	5.5
0937	57	1124	26	1430	12	1903	5.1	0020	5.4
0939	59	1126	30	1435	13	1908	5.8	0025	5.1
0941	59	1128	31	1440	14	1913	6.6	0051	3.0
0943	56	1130	32	1445	13	1918	7.2	0120	1.3
0945	50	1132	34	1453	10	1923	7.6	0135	2.9
0949	40	1134	34	1455	9.6	1928	7.6	0205	.4
0953	29	1136	32	1500	8.0	1933	7.6	0220	.3
0957	20	1138	31	1510	5.0	1938	7.2		
1001	14	1140	28	1520	2.7	1948	6.6		
1005	8.0	1142	26	1530	1.6	1958	5.1		
1009	5.0	1144	25	1540	.9	2008	3.7		
1013	2.8	1146	23	1550	.6	2018	2.6		
1017	1.9	1148	20	1600	.4	2028	1.8		
1021	1.2	1150	18	1610	.3	2038	1.3		
1025	.7	1154	13	1625	.2	2048	1.3		
1029	.5	1156	11						
		1158	9.6						
		1200	8.3						
		1202	6.7						
		1206	4.8						
		1210	3.3						
		1214	2.2						
		1222	1.0						

Table 5. Dye-concentration data from traveltime study on Truckee

[Modified from La Camera and others (1985, table 13).

Injection site: Truckee River at State Highway 267 at Truckee, Calif. (site number 1)
Date and time of injection: October 14, 1980, at 0722
Volume of injected dye, in liters: 12.5

Sampling site:			
Name	Truckee River at old U.S. 40 bridge below Truckee, Calif.	Truckee River at Boca Bridge near Truckee, Calif.	Truckee River below Farad powerplant near Floriston, Calif.
Number	2	3	4
Distance downstream from injection site, in river miles.	4.69	9.62	19.58
Estimated streamflow during sampling period, in cubic feet per second.	40	310	380
Date	October 14, 1980	October 14, 1980	October 15, 1980	October 15, 1980

Rhodamine WT dye, in micrograms per liter									
Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1430	0.00	1644	[a]100	2135	0.00	0005	23	0435	0.00
1434	.03	1646	[a]100	2140	.03	0010	23	0525	.03
1446	.13	1648	[a]99	2145	.03	0015	24	0535	.06
1510	3.5	1650	[a]99	2150	.06	0020	25	0545	.06
1514	5.4	1652	[a]99	2155	.10	0025	25	0555	.13
1518	7.7	1654	[a]95	2200	.16	0030	25	0605	.22
1520	8.9	1656	[a]95	2205	.16	0035	26	0615	.35
1524	12	1658	[a]95	2215	.57	0040	25	0625	.60
1528	16	1700	93	2220	.79	0045	25	0635	.92
1532	21	1710	86	2225	1.2	0050	24	0645	1.4
1538	29	1720	78	2230	1.6	0055	24	0655	2.0
1544	39	1730	67	2235	2.1	0100	23	0705	5.9
1550	50	1740	57	2240	2.5	0110	21	0715	6.9
1554	56	1750	49	2245	3.4	0120	18	0725	7.8
1556	61	1800	40	2250	4.3	0130	17	0735	8.6
1600	68	1810	33	2255	5.2	0140	15	0745	9.3
1602	71	1820	27	2300	6.5	0150	13	0755	9.6
1604	71	1831	21	2305	7.4	0200	11	0805	9.5
1608	79	1840	18	2310	8.8	0210	10	0815	9.5
1610	82	1850	14	2315	10	0220	8.9	0825	9.5
1612	86	1900	12	2320	11	0230	7.6	0835	9.2
1614	90	1910	9.8	2325	13	0240	6.4	0845	8.5
1616	92	1920	8.2	2330	15	0250	5.6	0855	8.2
1618	93			2335	16	0300	4.7	0905	7.8
1620	94			2340	18	0310	4.0	0925	6.6
1622	[a]95			2345	20	0320	3.4	0945	5.4
1624	[a]101			2350	20	0330	3.0	1005	4.2
1626	[a]101			2400	22	0340	2.6	1025	3.2
1628	[a]101					0350	2.3	1045	2.5
1630	[a]101					0400	2.1	1105	2.0
1632	[a]101					0410	1.8	1125	1.6
1634	[a]100							1145	1.3
1636	[a]100							1205	1.0
1638	[a]100							1225	.86
1640	[a]100							1320	.57
1642	[a]100							1340	.51

[a]Concentration less accurate because above range of instrument calibration.

River between Truckee, Calif., and Vista, Nev., October 14–16, 1980

See table 2 for detailed information about sites and current road designations]

Truckee River at Mayberry Drive below Lawton, Nev.	Truckee River near Sparks, Nev.	Truckee River at Vista, Nev.
5	6	9
35.16	44.71	48.63
240	240	420

October 15, 1980		October 16, 1980		October 16, 1980				October 16, 1980	
Rhodamine WT dye, in micrograms per liter									
Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1800	2.2	0015	1.1	0010	0.00	1310	0.70	0620	0.00
1810	2.5	0030	1.1	0030	.03	1330	.70	0640	.04
1825	3.0	0045	1.0	0050	.03	1350	.63	0700	.10
1840	3.5	0100	1.0	0110	.03	1410	.60	0720	.19
1855	3.9	0115	.98	0130	.03	1430	.54	0740	.26
1910	4.2	0130	.95	0150	.06	1450	.51	0800	.45
1925	4.3	0145	.92	0210	.13	1510	.48	0820	.64
1940	4.4	0200	.89	0230	.22	1525	.41	0840	.83
1955	4.4	0215	.83	0250	.38	1605	.38	0900	1.0
2010	4.2	0230	.78	0310	.66	1645	.35	0920	1.3
2025	4.2	0245	.78	0330	.98	1725	.32	0940	1.4
2040	4.0	0300	.72	0350	1.4	1805	.29	1000	1.6
2055	3.8	0315	.66	0410	1.8	1845	.25	1020	1.6
2110	3.4	0330	.63	0430	2.3	1925	.22	1040	1.7
2125	3.1	0345	.56	0450	2.6	2005	.19	1100	1.6
2140	2.8	0400	.53	0510	3.0			1120	1.5
2155	2.5	0415	.53	0530	3.2			1140	1.4
2210	2.3	0430	.50	0550	3.3			1145	1.4
2225	2.0	0445	.47	0610	3.4			1220	1.2
2240	1.8	0500	.44	0730	2.8			1300	1.0
2255	1.6	0515	.44	0750	2.7			1340	.80
2310	1.5	0530	.41	0810	2.4			1420	.67
2325	1.3	0545	.38	0830	2.2			1500	.58
2340	1.3	0600	.38	0850	2.0			1540	.51
2355	1.1			0910	1.7			1620	.48
				0930	1.6			1700	.45
				0950	1.5			1740	.42
				1010	1.3			1820	.38
				1030	1.2			1900	.32
				1050	1.1			1940	.32
				1110	1.0			2020	.26
				1130	1.0			2100	.26
				1150	.95			2140	.23
				1210	.89			2220	.23
				1230	.83			2300	.19
				1250	.76			2340	.16

Table 6. Dye-concentration data from traveltime study on Truckee River between Reno–Sparks sewage-treatment plant outfall near Reno, Nev., and Derby Dam near Wadsworth, Nev., May 29–30, 1979

[Modified from La Camera and others (1985, table 13). See table 2 for detailed information about sites and current road designations]

Injection site: Reno–Sparks sewage-treatment plant outfall near Reno, Nev. (site number 7)
Date and time of injection: May 29, 1979, at 1158
Volume of injected dye, in liters: 12.0

Sampling site:					
Name	Truckee River at Vista, Nev.	Truckee River at Lockwood, Nev.	Truckee River at Patrick, Nev.	Truckee River below Tracy, Nev.	Truckee River at Derby Dam
Number	9	10	11	12	14
Distance downstream from injection site, in river miles.	1.43	3.61	8.74	13.04	18.78
Estimated streamflow during sampling period, in cubic feet per second.	800	780	770	770	760
Date	May 29, 1979	May 29, 1979	May 29, 1979	May 29, 1979	May 30, 1979

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1302	0.00	1414	0.00	1657	0.00	1943	0.00	0013	0.00
1304	.8	1419	.8	1700	.5	1953	.8	0018	1.2
1306	5.7	1424	5.1	1702	.6	2003	2.6	0023	1.4
1307	14	1429	12	1704	1.0	2013	5.6	0028	2.4
1310	19	1439	23	1706	1.3	2023	8.0	0033	3.1
1312	41	1444	28	1708	2.0	2033	12	0038	4.0
1314	43	1446	29	1710	2.4	2043	12	0048	5.6
1316	47	1449	28	1712	2.9	2053	14	0053	5.8
1319	48	1454	29	1714	3.9	2103	14	0103	7.6
1324	44	1501	28	1716	4.9	2115	12	0113	8.5
1329	32	1504	22	1718	5.9	2123	10	0123	10
1334	25	1517	18	1720	6.5	2153	6.0	0133	11
1339	19	1522	13	1722	7.7	2213	3.2	0143	12
1341	12	1527	10	1724	8.5	2235	1.5	0153	9.4
1345	8.0	1537	7.6	1726	9.3	2253	.7	0213	7.4
1355	4.2	1547	4.5	1728	11	2313	.3	0233	4.6
1400	1.8	1557	2.4	1730	11			0302	3.4
1410	1.2	1607	1.2	1732	12			0320	2.0
		1617	.7	1734	13			0340	1.0
		1627	.2	1736	14				
		1630	.1	1738	16				
				1740	16				
				1742	18				
				1744	18				
				1747	20				
				1750	21				
				1755	19				
				1800	18				
				1805	16				
				1810	14				
				1815	13				
				1826	10				
				1830	8.5				
				1835	7.7				
				1840	6.7				
				1845	5.3				
				1850	4.6				
				1855	3.9				
				1900	3.0				
				1905	2.2				
				1925	.9				

Table 7. Dye-concentration data from traveltime study on Truckee River between Reno–Sparks sewage-treatment plant outfall near Reno, Nev., and Derby Dam near Wadsworth, Nev., September 4–5, 1979

[Modified from La Camera and others (1985, table 15). See table 2 for detailed information about sites and current road designations]

Injection site: Reno–Sparks sewage-treatment plant outfall near Reno, Nev. (site number 7)
Date and time of injection: September 4, 1979, at 0900
Volume of injected dye, in liters: 4.5

Sampling site:				
Name	Truckee River at Vista, Nev.	Truckee River at Lockwood, Nev.	Truckee River at Patrick, Nev.	Truckee River at Derby Dam
Number	9	10	11	14
Distance downstream from injection site, in river miles.	1.43	3.61	8.74	18.78
Estimated streamflow during sampling period, in cubic feet per second.	260	240	230	220
Date	September 4, 1979	September 4, 1979	September 4, 1979	September 5, 1979	September 5, 1979

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1036	3.8	1305	0.00	1850	0.00	0005	0.7	0845	0.00
1039	8.6	1345	6.5	1900	1.0	0015	.7	0902	.1
1042	18	1350	8.7	1910	1.8	0025	.6	0917	.1
1044	24	1355	10	1920	2.6	0035	.4	0930	.4
1046	26	1400	11	1930	3.4	0045	.3	0945	.5
1048	29	1405	13	1940	4.4	0055	.2	1000	1.0
1050	29	1410	14	1950	4.4			1015	1.2
1052	32	1415	14	2000	6.0			1030	1.7
1054	32	1420	14	2010	6.7			1045	2.0
1056	31	1425	14	2020	7.1			1100	2.5
1058	31	1430	14	2030	7.1			1115	2.8
1100	29	1440	13	2040	7.2			1130	3.0
1102	28	1450	11	2050	7.2			1145	2.9
1104	28	1500	9.5	2100	7.3			1200	3.3
1106	25	1510	8.1	2110	6.9			1215	3.7
1108	24	1520	6.7	2120	6.4			1230	3.6
1110	23	1530	5.2	2130	6.0			1245	3.6
1115	19	1540	4.5	2140	5.5			1300	3.6
1120	15	1550	3.5	2150	5.2			1315	3.4
1125	14	1600	2.8	2200	4.7			1330	3.3
1130	10	1610	2.1	2210	4.2			1345	3.1
1135	9.2	1620	1.6	2220	3.8			1400	2.9
1140	6.8	1630	1.1	2230	3.3			1415	2.8
1145	5.6	1640	.9	2240	2.9			1430	2.7
1150	4.4			2250	2.6			1445	2.2
1155	3.8			2300	2.3			1500	2.1
1200	2.5			2310	1.9			1515	1.9
1205	2.5			2320	1.7			1530	1.8
1215	1.9			2330	1.4			1545	1.6
1220	1.3			2340	1.2			1600	1.3
1225	.7			2355	1.0			1630	1.3
1230	.7							1700	.9
								1730	.7
								1800	.4

Table 8. Dye-concentration data from traveltime study on Truckee River between Reno–Sparks sewage-treatment plant outfall near Reno, Nev., and Derby Dam near Wadsworth, Nev., January 18, 1980

[Modified from La Camera and others (1985, table 15). See table 2 for detailed information about sites and current road designations]

Injection site: Reno–Sparks sewage-treatment plant outfall near Reno, Nev. (site number 7)
Date and time of injection: January 18, 1980, at 0820
Volume of injected dye, in liters: 16.0

Sampling site:					
Name	Truckee River at Vista, Nev.	Truckee River at Lockwood, Nev.	Truckee River at Patrick, Nev.	Truckee River below Tracy, Nev.	Truckee River at Derby Dam
Number	9	10	11	12	14
Distance downstream from injection site, in river miles.	1.43	3.61	8.74	13.04	18.78
Estimated streamflow during sampling period, in cubic feet per second.	2,900	2,900	3,200	3,200	3,300
Date	January 18, 1980	January 18, 1980	January 18, 1980	January 18, 1980	January 18, 1980

Rhodamine WT dye, in micrograms per liter									
Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
0900	0.00	0900	0.00	1058	0.00	1210	0.00	1422	0.00
0901	.2	0942	.09	1100	.03	1220	.06	1425	.06
0902	.6	0944	.2	1102	.2	1228	.3	1432	.3
0903	1.9	0945	.3	1104	.4	1230	.6	1445	2.8
0904	3.0	0946	.7	1106	1.0	1235	1.4	1455	5.8
0905	5.6	0947	1.7	1108	1.7	1240	2.9	1500	5.8
0906	10	0948	3.0	1110	2.8	1245	5.2	1505	6.1
0907	13	0949	4.7	1112	3.7	1250	7.4	1510	6.4
0908	16	0950	6.0	1114	5.8	1256	8.4	1515	6.4
0909	19	0951	7.3	1116	6.8	1303	8.4	1520	6.2
0910	19	0952	8.2	1118	8.0	1308	7.4	1525	5.8
0911	19	[1]0953	9.7	1120	8.6	1313	6.2	1530	4.8
0913	21	[1]0954	10	1122	9.6	1318	5.2	1540	3.5
0915	21	[1]0956	12	1124	10	1323	4.4	1550	2.0
0916	19	[1]0957	12	1126	10	1330	3.3	1600	1.5
0917	19	[1]0958	13	1128	10	1340	2.3	1610	1.1
0918	17	[1]0959	14	1130	10	1350	.9	1620	.7
0920	15	[1]1000	14	1132	10	1400	.5	1630	.4
0922	13	[1]1001	15	1135	10	1410	.3		
0924	11	1012	7.3	1140	8.6	1420	.3		
0926	8.7	1013	6.4	1145	6.8	1430	.2		
0928	7.2	1015	6.0	1150	5.2	1440	.1		
0930	5.7	1016	5.3	1155	3.9	1450	.09		
0932	4.4	1018	4.8	1201	2.5	1500	.06		
0934	3.6	1019	4.6	1205	1.9				
0936	3.0	1020	4.2	1210	1.4				
0938	2.3	1022	3.6	1215	1.0				
0940	1.9	1024	2.9	1220	.7				
0942	1.7	1026	2.5						
0944	1.3	1028	1.8						
0946	1.1	1030	1.5						
		1032	1.4						
		1034	1.0						
		1036	.9						
		1038	.8						
		1040	.6						
		1042	.5						
		1044	.4						

[1]Approximate time based on graphical analysis of data.

Table 9. Dye-concentration data from traveltime study on Truckee River between Derby Dam near Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., May 23–25, 1979

[Modified from La Camera and others (1985, table 17). See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at Derby Dam (site number 14)
Date and time of injection: May 23, 1979, at 1136
Volume of injected dye, in liters: 15.0

Sampling site:						
Name	Truckee River at Painted Rock Bridge	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	Truckee River at Dead Ox Wash near Nixon, Nev.	Truckee River at State Highway 447 at Nixon, Nev.	Truckee River at Marble Bluff Dam	Truckee River below Marble Bluff Dam
Number	15	16	19	21	22	23
Distance downstream from injection site, in river miles.	4.91	11.19	21.70	31.66	34.48	34.93
Estimated streamflow during sampling period, in cubic feet per second.	370	370	310	270	240	
Date	May 23, 1979	May 23, 1979	May 24, 1979	May 24, 1979	May 24, 1979	May 25, 1979

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1430	0.00	1822	0.00	0123	0.00	1035	0.00	1645	0.00	0010	2.9
1435	1.8	1832	.8	0138	.3	1050	.2	1710	.3	0030	3.0
1440	10	1842	4.1	0153	1.6	1105	.6	1730	.9	0050	3.0
1445	24	1852	9.3	0208	3.7	1120	1.4	1750	1.8	0110	3.0
1450	35	1902	20	0223	7.0	1135	2.3	1810	2.8	0130	2.8
1455	60	1912	24	0238	10	1150	3.6	1830	4.7	0150	2.8
1500	66	1922	34	0253	15	1205	5.2	1850	6.2	0210	2.7
1505	67	1932	37	0308	20	1220	6.8	1910	5.3	0250	2.9
1510	69	1942	39	0323	22	1235	8.5	1930	6.1	0312	2.9
1515	65	1952	29	0338	23	1250	10	1950	5.6	0350	2.7
1520	61	2002	27	0353	22	1305	11	2010	4.0	0430	2.6
1525	54	2012	23	0408	20	1320	14	2030	2.5	0510	1.3
1535	41	2022	20	0425	15	1322	15	2050	3.5	0550	1.5
1544	30	2032	16	0438	14	1350	15	2110	4.0	0712	1.3
1550	19	2042	12	0453	11	1405	16	2130	3.8	0750	1.2
1602	12	2102	6.2	0508	8.0	1425	16	2150	3.8	0850	1.5
1610	7.7	2122	3.3	0538	5.4	1440	12	2210	3.9	0950	1.5
1620	4.7	2123	3.0	0608	3.4			2230	4.0	1057	1.0
1630	2.6			0638	2.9			2250	3.9	1127	1.0
1640	2.6			0713	1.4			2330	3.1	1150	.5
				0741	1.0			2350	3.1	1220	.8
				0810	.7					1250	1.1
										1320	.3
										1350	.2

Table 10. Dye-concentration data from traveltime study on Truckee River between Derby Dam near Wadsworth, Nev., and Dead Ox Wash near Nixon, Nev., August 20–24, 1979

[Modified from La Camera and others (1985, table 17). See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at Derby Dam (site number 14)
Date and time of injection: August 20, 1979, at 0900
Volume of injected dye, in liters: 2.0

Sampling site:			
Name	Truckee River at Painted Rock Bridge	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	Truckee River at Dead Ox Wash near Nixon, Nev.
Number	15	16	19
Distance downstream from injection site, in river miles.	4.91	11.19	21.70
Estimated streamflow during sampling period, in cubic feet per second.	47	38	36

Date	August 20, 1979		August 21, 1979		August 21, 1979		August 22, 1979		August 23, 1979		August 24, 1979	
	Rhodamine WT dye, in micrograms per liter											
	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
	2123	0.00	0010	6.2	1945	0.00	0030	0.9	1030	0.00	0040	0.3
	2200	.2	0020	5.8	2000	.1	0100	1.1	1145	.1	0203	.3
	2210	.4	0030	6.2	2015	.1	0130	1.3	1230	.2	0307	.3
	2220	.7	0040	6.5	2025	.1	0200	1.4	1330	.2	0405	.1
	2230	1.1	0050	6.5	2030	.2	0230	1.6	1430	.3	0501	.1
	2240	1.5	0100	6.3	2050	.2	0300	1.7	1530	.4	0610	.1
	2250	2.0	0110	6.6	2100	.2	0330	1.8	1630	.5	0718	.1
	2300	2.4	0120	6.5	2115	.2	0400	1.7	1745	.4	0810	.1
	2310	2.9	0130	6.4	2130	.2	0430	1.7	1830	.5		
	2320	3.5	0140	6.2	2145	.2	0500	1.7	2000	.4		
	2330	3.9	0150	6.0	2200	.3	0530	1.6	2100	.5		
	2340	5.2	0200	5.8	2215	.3	0600	1.6	2203	.5		
	2350	5.7	0210	5.3	2230	.4	0630	1.5	2310	.3		
	2400	7.0	0230	4.9	2245	.4	0700	1.3				
			0250	4.5	2300	.4	0800	1.2				
			0310	3.8	2330	.5	0900	1.2				
			0330	3.3	2400	.8	1000	.9				
			0350	2.8			1100	.6				
			0400	2.4			1200	.5				
			0430	2.1			1300	.4				
			0450	1.8			1400	.6				
			0510	1.4			1500	.5				
			0530	1.2			1600	.5				
			0610	1.0			1700	.4				
			0630	.8			1800	.3				
			0700	.6			1900	.3				
			0732	.5			2100	.2				

Table 11. Dye-concentration data from traveltime study on Truckee River between Derby Dam near Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., January 16, 1980

[Modified from La Camera and others (1985, table 19). See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at Derby Dam (site number 14)
Date and time of injection: January 16, 1980, at 0914
Volume of injected dye, in liters: 20.0

Sampling site: Name	Truckee River at Painted Rock Bridge	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	Truckee River at S–Bar–S Ranch near Wadsworth, Nev.	Truckee River at Dead Ox Wash near Nixon, Nev.	Truckee River at State Highway 447 at Nixon, Nev.	Truckee River below Marble Bluff Dam
Number	15	16	17	19	21	23
Distance downstream from injection site, in river miles.	4.91	11.19	17.06	21.70	31.66	34.93
Estimated streamflow during sampling period, in cubic feet per second.	3,700	3,700	3,800	3,800	3,800	3,800
Date	January 16, 1980	January 16, 1980	January 16, 1980	January 16, 1980	January 16, 1980	January 16, 1980

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
0915	0.00	1134	0.00	1324	0.00	1442	0.00	1725	0.00	1950	1.1
1020	.03	1150	.06	1330	.1	1457	.09	1750	.01	2001	1.4
1022	.5	1152	.2	1335	.3	1500	.2	1800	.08	2010	1.9
1024	2.6	1154	.2	1340	.8	1505	.4	1810	.3	2023	2.7
1026	4.9	1156	.4	1345	1.6	1510	.7	1820	1.0	2040	2.6
1029	11	1158	.7	1350	2.7	1515	1.3	1830	2.0	2050	2.9
1030	13	1200	.9	1355	4.0	1520	1.9	1840	3.0	2110	2.2
1032	16	1204	8.9	1400	5.5	1525	2.9	1850	4.2	2130	1.9
1034	19	1206	8.9	1405	6.8	1530	3.7	1900	4.8	2145	1.2
1036	20	1208	12	1410	7.7	1535	4.4	1910	5.0	2200	1.0
1038	20	1210	12	1415	8.0	1540	5.0	1930	3.2	2217	.7
1040	19	1213	13	1420	8.0	1545	5.8	1940	2.6	2230	.5
1045	15	1215	13	1425	8.1	1550	6.0	1950	2.0	2245	.4
1050	10	1217	13	1430	6.8	1555	6.1	2003	1.5	2300	.3
1055	6.8	1219	13	1440	5.0	1600	5.9	2010	1.2	2315	.3
1100	4.4	1221	12	1450	3.5	1605	5.7	2020	.9		
1105	3.1	1223	12	1500	2.5	1610	5.1	2030	.8		
1110	1.9	1225	12	1510	1.7	1615	4.8	2045	.6		
1115	1.4	1227	11	1520	1.1	1620	4.4	2100	.5		
1120	1.0	1229	10	1530	.8	1630	3.4	2115	.3		
1125	.7	1230	9.5	1540	.6	1640	2.3	2135	.2		
1130	.5	1236	7.7	1550	.5	1650	1.7	2200	.2		
		1241	6.5	1600	.3	1700	1.2	2237	.1		
		1246	5.8			1710	.9				
		1251	3.4			1720	.6				
		1256	2.4			1730	.5				
		1301	1.6			1740	.4				
						1750	.4				
						1800	.3				

Table 12. Dye-concentration data from traveltime study on Truckee River between old U.S. Highway 40 bridge at Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., September 21–26, 1980

[Modified from La Camera and others (1985, table 19). See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at old U.S. 40 bridge at Wadsworth, Nev. (site number 16)
Date and time of injection: September 21, 1980, at 1900
Volume of injected dye, in liters: 10.00

Sampling site:				
Name	Truckee River at Dead Ox Wash near Nixon, Nev.	Truckee River at Numana Dam near Nixon, Nev.	Truckee River at State Highway 447 at Nixon, Nev.	Truckee River below Marble Bluff Dam
Number	19	20	21	23
Distance downstream from injection site, in river miles.	10.51	15.58	20.47	23.74
Estimated streamflow during sampling period, in cubic feet per second.	76	80	71	71
Date	September 22–23, 1980	September 23–24, 1980	September 23–24, 1980	September 24–26, 1980

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1345	0.00	0620	0.00	1900	1.9	0935	1.4
1400	.02	0640	.01	1930	3.0	1020	1.6
1415	.03	0700	.10	2000	4.2	1105	1.7
1430	.21	0720	.19	2030	5.3	1150	1.9
1445	.56	0740	.38	2100	6.0	1235	2.0
1500	1.1	0800	.76	2130	7.3	1320	2.1
1515	2.0	0820	1.1	2200	8.0	1405	2.1
1530	2.9	0840	1.6	2230	8.6	1500	2.0
1545	4.5	0900	2.1	2300	8.6	1545	2.0
1600	6.2	0920	3.0	2330	8.6	1630	2.1
1615	8.2	0940	4.0	2400	8.6	1715	2.2
1630	10	1000	5.4	0030	8.3	1800	2.1
1645	12	1020	6.6	0100	8.0	1845	2.0
1700	14	1040	7.8	0130	7.3	1930	1.9
1715	16	1100	8.8	0200	6.7	2015	1.7
1730	17	1120	9.7	0230	6.4	2100	1.6
1745	18	1140	11	0300	5.9	2230	1.3
1800	19	1200	11	0330	5.3	2400	1.2
1815	18	1220	11	0400	4.7	0130	1.1
1830	18	1240	12	0430	4.1	0300	1.1
1845	18	1300	12	0500	3.6	0430	1.1
1900	18	1320	12	0530	3.1	0600	1.1
1915	16	1340	11	0600	2.7	0730	.98
1930	16	1400	11	0705	1.9	1115	.98
2000	14	1420	11	0805	1.5	1245	.86
2030	12	1440	10	0905	1.1	1415	.73
2100	11	1500	10	1005	.85	1545	.54
2130	9.8	1520	9.4	1105	.55	1715	.37
2200	8.8	1540	9.1			1845	.37
2230	8.2	1600	8.8			2015	.34
2300	7.5	1620	8.1			2145	.28
2330	6.3	1640	7.8			2315	.22
2400	5.8	1700	7.5			0045	.15
0030	5.0	1720	6.9			0215	.15
0100	4.2	1740	6.2			0345	.12
0130	3.6	1800	6.3			0515	.15
0200	2.9	1820	5.7			0645	.15
0230	2.4	1900	4.6			0815	.12
0300	1.9	1940	3.8				
0330	1.7	2020	3.0				
0400	1.4	2100	2.5				
0430	1.1	2140	1.9				
		2220	1.6				
		2300	1.4				
		2340	1.1				
		0020	.92				

Table 13. Dye-concentration data from traveltime study on Truckee River between Steamboat Creek at mouth near Sparks, Nev., and Derby Dam near Wadsworth, Nev., November 29–December 1, 1993

[See table 2 for detailed information about sites and current road designations]

Injection site: Steamboat Creek at mouth near Sparks, Nev. (site number 8)
Date and time of injection: November 29, 1993, at 1015
Volume of injected dye, in liters: 4.0

Sampling site:						
Name	Truckee River at Vista, Nev.	Truckee River at Lockwood, Nev.	Truckee River at Patrick, Nev.	Truckee River below Tracy, Nev.	Truckee River at Clark, Nev.	Truckee River at Derby Dam
Number	9	10	11	12	13	14
Distance downstream from injection site, in river miles.	1.30	3.43	8.61	12.91	14.97	18.68
Estimated streamflow during sampling period, in cubic feet per second.	134	135	154	159	159	161
Date	November 29, 1993	November 29, 1993	November 30, 1993	November 30, 1993	November 30–December 1, 1993	November 30–December 1, 1993

Rhodamine WT dye, in micrograms per liter											
Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1215	[a]0.0	1530	0.0	0015	0.0	0730	0.0	1000	0.0	1600	0.0
1231	5.7	1600	.1	0035	.1	0800	.1	1100	.1	1700	.1
1240	16	1615	.6	0100	.4	0830	.3	1200	.2	1800	.3
1250	23	1630	3.4	0130	1.5	0900	.7	1245	.8	1900	1.1
1302	26	1645	7.8	0200	3.4	0930	1.7	1330	2.3	2000	2.4
1310	25	1700	10	0230	5.8	1000	2.9	1415	4.3	2100	4.1
1320	23	1715	12	0300	7.8	1030	4.3	1500	5.7	2130	4.6
1330	21	1730	14	0330	8.7	1100	5.4	1545	6.0	2200	4.9
1351	14	1745	15	0400	8.7	1130	6.3	1630	5.5	2230	4.6
1410	9.6	1800	14	0430	7.7	1200	6.2	1715	4.5	2300	4.4
1430	6.6	1815	12	0500	6.2	1230	5.7	1800	3.3	2330	3.9
1450	3.6	1830	11	0600	3.5	1300	5.0	1845	2.5	2400	3.3
1510	2.4	1845	9.8	0700	1.7	1330	4.2	1930	1.7	0030	2.8
1530	1.3	1900	7.9	0800	.9	1400	3.3	2015	1.2	0100	2.2
1550	.8	1915	6.4	0900	.5	1430	2.5	2100	.9	0200	1.4
1610	.4	1930	5.4	1000	.3	1500	1.9	2145	.6	0300	1.0
1630	.3	1945	4.0	1100	.2	1600	1.3	2230	.5	0400	.6
1650	.2	2000	3.3			1700	.8	2315	.4	0500	.5
1710	.2	2015	3.0			1800	.6	2400	.3	0600	.3
		2030	2.2			1900	.3	0045	.2	0700	.3
		2045	1.8			2000	.2			0800	.2
		2100	1.4			2100	.2			0830	.2
		2130	1.1								
		2200	.7								
		2230	.5								
		2300	.3								
		2330	.2								
		2400	.2								

[a]Trace (less than 0.05 micrograms per liter) was present in first sample.

Table 14. Dye-concentration data from traveltime study on Truckee River between Derby Dam near Wadsworth, Nev., and old U.S. Highway 40 bridge at Wadsworth, Nev., November 15–23, 1993

[See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at Derby Dam (site number 14)
Date and time of injection: November 15, 1993, at 1105
Volume of injected dye, in liters: 2.0

Sampling site:		
Name	Truckee River at Painted Rock Bridge	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.
Number	15	16
Distance downstream from injection site, in river miles.	4.90	11.19
Estimated streamflow during sampling period, in cubic feet per second.	12	14

Date	November 16–17, 1993		November 18, 1993		November 19–20, 1993		November 21–23, 1993	
	Rhodamine WT dye, in micrograms per liter							
	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
	2200	0.0	0100	1.1	1340	0.0	0100	2.6
	2300	.1	0200	.9	1400	[a].0	0200	2.6
	2400	.2	0300	.8	1500	.1	0300	2.6
	0100	.7	0400	.7	1600	.1	0400	2.6
	0200	1.5	0500	.6	1700	.2	0500	2.5
	0300	2.8	0600	.5	1800	.2	0600	2.4
	0400	4.8	0700	.5	1900	.3	0700	2.3
	0500	6.2	0800	.4	2000	.3	0800	2.2
	0600	8.0	0900	.4	2100	.3	0900	2.2
	0638	9.2	1000	.3	2200	.4	1000	2.0
	0700	9.4	1100	.3	2300	.5	1100	2.0
	0730	9.8	1200	.3	2400	.6	1200	2.0
	0800	10	1300	.3	0100	.7	1300	1.9
	0830	10	1400	.3	0200	.7	1400	1.6
	0900	10	1500	.2	0300	.8	1600	1.5
	0930	10	1600	.2	0400	.9	1800	1.4
	1000	10	1700	.2	0500	.9	2000	1.2
	1030	10	1800	.2	0600	1.0	2200	1.0
	1100	10			0700	1.2	2400	.8
	1130	9.5			0800	1.4	0200	.7
	1200	9.2			0900	1.5	0400	.6
	1230	8.9			1000	1.7	0600	.5
	1300	8.4			1100	1.7	0800	.5
	1330	8.0			1200	1.8	1000	.4
	1400	7.3			1300	1.9	1200	.4
	1500	6.7			1400	2.0	1400	.3
	1600	5.7			1500	2.2	1600	.3
	1700	5.0			1600	2.2	1800	.3
	1800	4.2			1700	2.2	2000	.3
	1900	3.4			1800	2.4	2200	.3
	2000	2.5			1900	2.4	2400	.3
	2100	2.3			2000	2.5	0200	.2
	2200	2.0			2100	2.6	0400	.2
	2300	1.6			2200	2.6		
	2400	1.3			2300	2.6		
					2400	2.6		

[a] Trace (less than 0.05 micrograms per liter) was present in this sample.

Table 15. Dye-concentration data from traveltime study on Truckee River between old U.S. Highway 40 bridge at Wadsworth, Nev., and Dead Ox Wash near Nixon, Nev., November 8–11, 1993

[See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at old U.S. 40 bridge at Wadsworth, Nev. (site number 16)
Date and time of injection: November 8, 1993, at 0920
Volume of injected dye, in liters: 1.5

Sampling site:		
Name	Truckee River below S–Bar–S Ranch near Wadsworth, Nev.	Truckee River at Dead Ox Wash near Nixon, Nev.
Number	18	19
Distance downstream from injection site, in river miles.	6.70	10.68
Estimated streamflow during sampling period, in cubic feet per second.	29	31
Date	November 9–10, 1993	November 10–11, 1993

	Rhodamine WT dye, in micrograms per liter			
	Time of day	Concentration	Time of day	Concentration
	1330	0.0	0130	0.0
	1400	[a].0	0215	.1
	1430	.1	0300	.3
	1500	.3	0345	.5
	1530	.5	0430	.8
	1600	.6	0515	1.4
	1630	.9	0600	1.8
	1700	1.5	0645	2.4
	1730	1.9	0730	3.1
	1800	2.4	0815	3.5
	1830	3.1	0900	3.8
	1900	3.6	0945	3.9
	1930	4.1	1030	4.0
	2000	4.4	1115	3.8
	2030	4.9	1200	3.5
	2100	5.0	1300	2.9
	2130	5.1	1430	2.4
	2200	5.0	1600	1.7
	2230	4.9	1730	1.3
	2300	4.5	1900	.9
	2330	4.2	2030	.6
	2400	3.5	2200	.5
	0100	3.2	2330	.4
	0200	2.6	0100	.3
	0300	2.0	0230	.3
	0400	1.6	0400	.3
	0500	1.2	0530	.3
	0600	.9	0700	.2
	0700	.8	0830	.2
	1000	.4		
	1100	.4		
	1200	.3		
	1300	.2		
	1330	.2		

[a]Trace (less than 0.05 micrograms per liter) was present in this sample.

Table 16. Dye-concentration data from traveltime study on Truckee River between Dead Ox Wash and Marble Bluff Dam near Nixon, Nev., November 4–7, 1993

[See table 2 for detailed information about sites and current road designations]

Injection site: Truckee River at Dead Ox Wash near Nixon, Nev. (site number 19)
Date and time of injection: November 4, 1993, at 1010
Volume of injected dye, in liters: 2.0

Sampling site:			
Name	Truckee River at Numana Dam near Nixon, Nev.	Truckee River at State Highway 447 at Nixon, Nev.	Truckee River below Marble Bluff Dam
Number	20	21	23
Distance downstream from injection site, in river miles.	4.89	9.81	13.06
Estimated streamflow during sampling period, in cubic feet per second.	49	50	50
Date	November 5–6, 1993	November 5–7, 1993	November 6–7, 1993

	Rhodamine WT dye, in micrograms per liter					
	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
	0600	0.0	2200	0.0	0500	0.0
	0630	.1	2230	.1	0600	.1
	0700	.2	2300	.2	0700	.4
	0730	.5	2330	.3	0800	.8
	0800	1.3	2400	.5	0900	1.4
	0830	2.2	0030	.7	1000	2.1
	0900	3.4	0100	1.2	1100	3.0
	0930	5.1	0130	1.6	1130	3.3
	1000	8.0	0200	2.2	1200	3.7
	1030	9.1	0230	2.6	1230	4.0
	1100	9.9	0300	3.2	1300	4.3
	1130	9.9	0330	3.7	1330	4.2
	1200	10	0400	4.3	1400	4.4
	1230	9.1	0430	4.7	1430	4.4
	1300	8.5	0500	5.3	1500	4.4
	1330	7.7	0530	5.4	1530	3.4
	1400	6.8	0600	5.7	1630	3.4
	1430	6.7	0630	5.8	1730	3.0
	1500	4.6	0700	5.7	1830	2.8
	1600	3.4	0730	5.7	1930	2.4
	1700	2.8	0800	5.3	2030	2.0
	1800	2.0	0830	5.2	2130	1.7
	1900	1.3	0900	4.9	2230	1.5
	2000	.9	0930	4.5	2330	1.2
	2100	.8	1000	3.4	0030	1.0
	2200	.6	1100	2.9	0130	.9
	2300	.4	1200	2.5	0230	.8
	2400	.3	1300	1.9	0330	.6
	0100	.2	1400	1.7	0430	.5
			1500	1.3	1500	.1
			1600	1.1		
			1700	.9		
			1800	.7		
			1900	.6		
			2000	.5		
			2100	.4		
			2200	.3		
			2300	.3		
			2400	.3		
			0100	.2		

Table 17. Dye-concentration data from traveltime study on Truckee River and Truckee Canal between Reno–Sparks sewage-treatment plant outfall near Reno, Nev., and U.S. Highway 95A near Fernley, Nev., May 29–30, 1979

[Modified from La Camera and others (1985, table 21). See table 2 for detailed information about sites and current road designations]

Injection site: Reno–Sparks sewage-treatment plant outfall near Reno, Nev. (site number 7)
Date and time of injection: May 29, 1979, at 1158
Volume of injected dye, in liters: 12.0

Sampling site:	
Name	Truckee Canal at U.S. 95A near Fernley, Nev.
Number	27
Distance downstream from injection site, in river miles.	31.94
Estimated streamflow during sampling period, in cubic feet per second.	630
Date	May 30, 1979

Rhodamine WT dye, in micrograms per liter	
Time of day	Concentration
0750	0.0
0800	.2
0810	.5
0820	1.2
0830	2.2
0840	3.1
0850	4.3
0900	5.6
0910	7.0
0920	7.7
0930	8.7
0940	9.5
0950	10
1000	10
1010	9.5
1020	7.5
1030	6.6
1050	4.9
1113	3.5
1130	2.4
1150	1.6
1213	.8
1233	.4
1250	.3

Table 18. Dye-concentration data from traveltime study on Truckee Canal between Derby Dam near Wadsworth, Nev., and U.S. Highway 50 above Lahontan Reservoir near Fallon, Nev., September 4–6, 1979

[Modified from La Camera and others (1985, table 22). See table 2 for detailed information about sites and current road designations]

Injection site: Truckee Canal at Derby Dam near Wadsworth, Nev. (site number 24)
Date and time of injection: September 4, 1979, at 1119
Volume of injected dye, in liters: 7.5

Sampling site:	
Name	Truckee Canal at U.S. Highway 50 above Lahontan Reservoir
Number	32
Distance downstream from injection site, in river miles.	30.98
Estimated streamflow during sampling period, in cubic feet per second.	140
Date	September 6, 1979

Rhodamine WT dye, in micrograms per liter	
Time of day	Concentration
1130	0.0
1200	.2
1230	.6
1300	4.6
1330	12
1400	18
1430	19
1500	14
1530	7.9
1600	3.9
1630	1.5
1700	.6
1730	.1

Table 19. Dye-concentration data from traveltime study on Truckee Canal between Derby Dam near Wadsworth, Nev., and U.S. Highway 50 above Lahontan Reservoir near Fallon, Nev., May 12–15, 1980

[Modified from La Camera and others (1985, table 23). See table 2 for detailed information about sites and current road designations]

Injection site: Truckee Canal at Derby Dam near Wadsworth, Nev. (site number 24)
Date and time of injection: May 12, 1980, at 2315
Volume of injected dye, in liters: 8.0

Sampling site: Name	Truckee Canal at U.S. 95A near Fernley, Nev.	Truckee Canal at Anderson Check Dam near Fernley, Nev.	Truckee Canal at Allendale Check Dam near Hazen, Nev.	Truckee Canal at Mason Check Dam near Hazen, Nev.	Truckee Canal at Bango Check Dam near Hazen, Nev.	Truckee Canal at U.S. Highway 50 above Lahontan Reservoir
Number	27	28	29	30	31	32
Distance downstream from injection site, in river miles.	13.19	16.35	20.35	25.03	28.17	30.98
Estimated streamflow during sampling period, in cubic feet per second.	170	140	120	120	110	110

Date	May 13, 1980		May 13–14, 1980		May 14, 1980		May 14–15, 1980		May 14–15, 1980		May 15, 1980		May 15, 1980	
	Rhodamine WT dye, in micrograms per liter													
	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
	1400	0.0	2200	0.0	0701	0.0	1532	0.0	2155	0.0	0043	0.0	1215	0.2
	1440	[a].0	2230	[a].0	0716	[a].0	1547	[a].0	2210	[a].0	0058	[a].0	1230	.2
	1450	.1	2240	[a].0	0731	.2	1602	.1	2225	[a].0	0113	.1	1245	.2
	1500	.3	2255	.2	0746	.6	1617	.1	2240	.1	0128	.1	1300	.2
	1510	1.0	2310	1.1	0801	1.9	1632	.5	2255	.1	0143	.2	1315	.1
	1520	2.6	2325	2.9	0816	4.0	1647	1.0	2310	.2	0258	.5	1330	.1
	1530	5.1	2340	6.5	0831	6.8	1702	1.8	2325	.5	0313	.8	1345	.1
	1540	8.2	2355	10	0846	10	1717	3.1	2340	.9	0328	1.3	1400	.1
	1550	12	0010	14	0901	13	1732	5.0	2355	1.5	0343	2.0	1415	.1
	1600	15	0025	14	0916	13	1747	6.6	0010	2.1	0358	2.8	1430	.1
	1610	17	0040	14	0931	11	1802	8.0	0025	3.1	0413	3.8		
	1620	17	0055	12	0946	9.1	1817	9.2	0040	4.3	0428	5.0		
	1630	16	0130	5.6	1001	6.8	1832	11	0055	5.6	0443	6.0		
	1640	14	0200	2.4	1033	5.3	1847	12	0110	6.6	0458	7.0		
	1700	4.5	0230	.9	1045	3.6	1902	12	0125	7.3	0513	7.9		
	1720	4.3	0300	.3	1100	2.4	1917	11	0210	9.3	0528	8.8		
	1740	1.6			1115	1.6	1932	9.9	0225	9.9	0543	8.8		
	1800	.7			1145	.9	1945	8.9	0240	9.9	0558	9.2		
	1820	.4			1200	.6	2000	8.0	0255	9.3	0613	9.2		
	1840	.2			1215	.4	2015	6.6	0310	8.6	0628	8.5		
	1900	.1			1230	.3	2030	5.8	0325	7.6	0643	8.5		
							2045	4.6	0340	6.9	0658	7.6		
							2100	3.9	0355	6.1	0713	7.0		
							2115	3.1	0410	5.0	0728	6.1		
							2130	2.4	0440	3.4	0743	5.0		
							2145	2.0	0455	2.9	0800	4.0		
							2200	1.5	0510	2.1	0815	3.4		
							2215	1.2	0525	1.7	0830	2.8		
							2230	.9	0540	1.4	0845	2.3		
							2245	.7	0555	1.0	0900	2.0		
							2300	.5	0610	.8	0915	1.6		
							2315	.4	0625	.7	0930	1.3		
							2330	.4	0640	.5	0945	1.1		
							2345	.4	0655	.4	1000	.9		
							2400	.3	0710	.3	1015	.8		
							0015	.3	0725	.3	1030	.6		
							0045	.2	0740	.3	1045	.5		
							0100	.2	0755	.2	1100	.4		
							0115	.2	0810	.2	1115	.4		
									0825	.2	1130	.3		
									0840	.1	1145	.2		
									0855	.1	1200	.2		

[a] Trace (less than 0.05 micrograms per liter) was present in this sample.

Table 20. Summary of traveltime data for Truckee River between Truckee, Calif., and Vista, Nev., 1979 and 1980

[Modified from La Camera and others (1985, table 29). See table 2 for detailed information about sites and current road designations. —, no data or not applicable]

Site		Distance down-stream from injection point	Date	Streamflow (cubic feet per second)	Traveltime of dye plume since injection (hours)				Mean velocity of centroid between sites (miles per	Duration of dye plume at site (hours)	Recovered mass of dye (kilograms)
Number	Name				Leading	Peak	Centroid	Trailing			
May–June 1979 (injection at site 1)											
1	Truckee River at State Highway 267 at Truckee, Calif.	0.0	May 31	—	—	—	0.0	—	—	0.0	[a]1.63
2	Truckee River at old U.S. 40 bridge below Truckee, Calif.	4.69	May 31	440	2.3	2.9	3.0	4.0	1.6	1.7	1.59
3	Truckee River at Boca Bridge near Truckee, Calif.	9.62	May 31	520	4.9	5.8	6.0	8.5	1.6	3.6	1.45
4	Truckee River below Farad power-plant near Floriston, Calif.	19.77	May 31	680	10.3	11.5	11.9	14.8	1.7	4.5	1.34
5	Truckee River at Mayberry Drive below Lawton, Nev.	35.16	June 1	510	18.3	20.8	21.4	25.4	1.4	7.1	.83
9	Truckee River at Vista, Nev.	48.63	June 1	450	27.8	31.2	32.3	39.1	1.5	11.4	.50
May 1980 (injection at site 1)											
1	Truckee River at State Highway 267 at Truckee, Calif.	0.0	May 21	640	—	—	0.0	—	—	0.0	[a]3.50
2	Truckee River at old U.S. 40 bridge below Truckee, Calif.	4.69	May 21	740	1.7	2.1	2.1	3.1	2.2	1.4	—
3	Truckee River at Boca Bridge near Truckee, Calif.	9.62	May 21	1,700	3.4	4.0	4.1	6.0	2.5	2.6	—
4	Truckee River below Farad power-plant near Floriston, Calif.	19.58	May 21	2,300	6.2	7.1	7.2	9.1	3.2	2.9	2.72
5	Truckee River at Mayberry Drive below Lawton, Nev.	35.16	May 21	2,300	10.3	11.9	12.1	14.2	3.2	3.9	2.34
9	Truckee River at Vista, Nev.	48.63	May 21–22	2,400	15.3	16.6	16.9	20.6	2.8	5.3	2.06
October 1980 (injection at site 1)											
1	Truckee River at State Highway 267 at Truckee, Calif.	0.0	Oct. 14	32	—	—	0.0	—	—	0.0	[a]2.04
2	Truckee River at old U.S. 40 bridge below Truckee, Calif.	4.69	Oct. 14	40	7.2	9.2	9.7	14.3	0.48	7.1	—
3	Truckee River at Boca Bridge near Truckee, Calif.	9.62	Oct. 14–15	310	14.5	17.1	17.5	22.0	.63	7.5	—
4	Truckee River below Farad power-plant near Floriston, Calif.	19.58	Oct. 15	380	22.1	24.7	25.7	33.1	1.2	11.0	1.22
5	Truckee River at Mayberry Drive below Lawton, Nev.	35.16	Oct. 15–16	240	32.5	36.4	38.3	48.3	1.2	15.8	.59
6	Truckee River near Sparks, Nev.	44.71	Oct. 16	240	42.1	46.8	48.9	60.6	.90	18.7	.55
9	Truckee River at Vista, Nev.	48.63	Oct. 16	420	47.3	51.3	53.7	69.0	.81	21.7	.49

[a] Injected dye mass.

Table 21. Summary of traveltime data for Truckee River between Reno–Sparks sewage-treatment plant outfall near Reno, Nev., and Derby Dam near Wadsworth, Nev., 1979, 1980, and 1993

[1979 and 1980 data modified from La Camera and others (1985, table 30). See table 2 for detailed information about sites and current road designations. —, no data or not applicable]

Site		Distance down-stream from injection point (river miles)	Date	Streamflow (cubic feet per second)	Traveltime of dye plume since injection (hours)				Mean velocity of centroid between sites (miles per hour)	Duration of dye plume at site (hours)	Recovered mass of dye (kilograms)
Number	Name				Leading edge	Peak	Centroid	Trailing edge			
May 1979 (injection at site 7)											
7	Reno–Sparks sewage-treatment plant outfall near Reno, Nev.	0.0	May 29	[a]81	—	—	0.0	—	—	0.0	[b]1.95
9	Truckee River at Vista, Nev.	1.43	May 29	800	1.1	1.3	1.5	2.3	0.95	1.2	1.79
10	Truckee River at Lockwood, Nev.	3.61	May 29	780	2.3	2.8	3.1	4.7	1.4	2.4	1.90
11	Truckee River at Patrick, Nev.	8.74	May 29	770	4.9	5.9	6.1	8.2	1.7	3.3	1.68
12	Truckee River below Tracy, Nev.	13.04	May 29	770	7.8	8.9	9.2	11.5	1.4	3.7	1.59
14	Truckee River at Derby Dam	18.78	May 30	760	12.3	13.6	13.9	16.1	1.2	3.8	1.47
September 1979 (injection at site 7)											
7	Reno–Sparks sewage-treatment plant outfall near Reno, Nev.	0.0	Sept. 4	[a]78	—	—	0.0	—	—	0.0	[b]0.73
9	Truckee River at Vista, Nev.	1.43	Sept. 4	260	1.5	1.9	2.2	4.0	0.65	2.5	.63
10	Truckee River at Lockwood, Nev.	3.61	Sept. 4	240	4.3	5.3	5.7	8.2	.62	3.9	.57
11	Truckee River at Patrick, Nev.	8.74	Sept. 4–5	230	9.8	11.8	12.2	15.9	.79	6.1	.52
14	Truckee River at Derby Dam	18.78	Sept. 5	220	24.0	27.5	28.1	32.8	.59	8.8	.39
Jannary 1980 (injection at site 7)											
7	Reno–Sparks sewage-treatment plant outfall near Reno, Nev.	0.0	Jan. 18	[a,c]220	—	—	0.0	—	—	0.0	[b]2.60
9	Truckee River at Vista, Nev.	1.43	Jan. 18	2,900	0.7	0.9	1.0	1.7	1.4	1.0	2.06
10	Truckee River at Lockwood, Nev.	3.61	Jan. 18	2,900	1.3	1.8	1.8	2.8	2.7	1.5	1.77
11	Truckee River at Patrick, Nev.	8.74	Jan. 18	3,200	2.7	3.2	3.3	4.3	3.4	1.6	2.24
12	Truckee River below Tracy, Nev.	13.04	Jan. 18	3,200	4.0	4.7	4.8	6.7	2.9	2.7	2.16
14	Truckee River at Derby Dam	18.78	Jan. 18	3,300	6.0	6.9	7.0	8.5	2.6	2.5	2.17
November–December 1993 (injection at site 8)											
8	Steamboat Creek at mouth near Sparks, Nev.	0.0	Nov. 29	124	—	—	0.0	—	—	0.0	[b]0.51
9	Truckee River at Vista, Nev.	1.30	Nov. 29	134	2.0	2.8	3.1	6.9	0.42	4.9	.50
10	Truckee River at Lockwood, Nev.	3.43	Nov. 29	135	5.2	7.5	8.0	13.8	.43	8.6	.50
11	Truckee River at Patrick, Nev.	8.61	Nov. 30	154	14.0	17.5	17.8	24.8	.48	10.8	.51
12	Truckee River below Tracy, Nev.	12.91	Nov. 30	159	21.2	25.2	26.2	34.8	.49	13.6	.46
13	Truckee River at Clark, Nev.	14.97	Nov. 30–Dec. 1	159	23.8	29.5	30.4	38.5	.49	14.7	.50
14	Truckee River at Derby Dam	18.68	Nov. 30–Dec. 1	161	29.8	35.8	36.7	46.2	.51	16.4	.453

[a] Combined discharge of sewage-treatment plant and Steamboat Creek.
[b] Injected dye mass.
[c] Estimated.

Table 22. Summary of traveltime data for Truckee River between Derby Dam near Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., 1979, 1980, and 1993

[1979 and 1980 data modified from La Camera and others (1985, table 31). See table 2 for detailed information about sites and current road designations. —, no data or not applicable]

Site		Distance downstream from injection point (river miles)	Date	Streamflow (cubic feet per second)	Traveltime of dye plume since injection (hours)				Mean velocity of centroid between sites (miles per hour)	Duration of dye plume at site (hours)	Recovered mass of dye (kilograms)
Number	Name				Leading edge	Peak	Centroid	Trailing edge			
May 1979 (injection at site 14)											
14	Truckee River at Derby Dam	0.0	May 23	370	—	—	0.0	—	—	0.0	[a]2.44
15	Truckee River at Painted Rock Bridge.	4.91	May 23	370	3.0	3.5	3.7	5.4	1.3	2.4	2.34
16	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	11.19	May 23	370	6.9	8.0	8.3	10.2	1.4	3.3	2.02
19	Truckee River at Dead Ox Wash near Nixon, Nev.	21.70	May 24	310	14.0	16.1	16.4	20.8	1.3	6.8	1.79
21	Truckee River at State Highway 447 at Nixon, Nev.	31.66	May 24	270	22.9	26.7	27.0	33.4	.92	10.5	1.76
22	Truckee River at Marble Bluff Dam.	34.88	May 24–25	240	29.2	31.8	37.2	50.7	.32	21.5	1.27
23	Truckee River below Marble Bluff Dam.	34.93	May 24–25	240	29.4	32.7	37.3	51.2	[b].32	21.8	1.06
Angnst 1979 (injection at site 14)											
14	Truckee River at Derby Dam	0.0	Aug. 20	48	—	—	0.0	—	—	0.0	[a]0.33
15	Truckee River at Painted Rock Bridge.	4.90	Aug. 20–21	47	12.5	16.0	17.0	25.0	0.29	12.5	.15
16	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	11.19	Aug. 21–22	38	35.0	43.0	46.3	60.0	.21	25.0	.08
19	Truckee River at Dead Ox Wash near Nixon, Nev.	21.70	Aug. 23–24	36	73.3	82.3	83.7	96.0	.28	22.7	.02
January 1980 (injection at site 14)											
14	Truckee River at Derby Dam	0.0	Jan. 16	3,700	—	—	0.0	—	—	0.0	[a]3.26
15	Truckee River at Painted Rock Bridge.	4.91	Jan. 16	3,700	1.1	1.4	1.5	2.6	3.3	1.5	3.20
16	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	11.19	Jan. 16	3,700	2.6	3.0	3.2	4.1	3.7	1.5	3.10
17	Truckee River at S–Bar–S Ranch near Wadsworth, Nev.	17.06	Jan. 16	3,800	4.2	5.1	5.3	7.4	2.8	3.2	3.04
19	Truckee River at Dead Ox Wash near Nixon, Nev.	21.70	Jan. 16	3,800	5.7	6.7	6.9	9.3	2.9	3.6	2.91
21	Truckee River at State Highway 447 at Nixon, Nev.	31.66	Jan. 16	3,800	8.6	9.9	10.2	13.7	3.0	5.1	2.65
23	Truckee River below Marble Bluff Dam.	34.93	Jan. 16	3,800	10.1	11.5	11.9	15.0	1.9	4.9	2.17

Table 22. Summary of traveltime data for Truckee River between Derby Dam near Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., 1979, 1980, and 1993—Continued

Site		Distance downstream from injection point (river miles)	Date	Streamflow (cubic feet per second)	Traveltime of dye plume since injection (hours)				Mean velocity of centroid between sites (miles per hour)	Duration of dye plume at site (hours)	Recovered mass of dye (kilograms)
Number	Name				Leading edge	Peak	Centroid	Trailing edge			
September 1980 (injection at site 16)											
16	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	0.0	Sept. 21	76	—	—	0.0	—	—	0.0	[a]1.63
19	Truckee River at Dead Ox Wash near Nixon, Nev.	10.51	Sept. 22–23	76	19.0	23.1	25.1	35.5	0.42	16.5	.89
20	Truckee River at Numana Dam near Nixon, Nev.	15.58	Sept. 23–24	80	35.7	41.9	44.0	56.7	.26	21.0	.82
21	Truckee River at State Highway 447 at Nixon, Nev.	20.47	Sept. 23–24	71	47.2	52.5	54.0	67.6	.50	20.4	.55
23	Truckee River below Marble Bluff Dam.	23.74	Sept. 24–26	71	[c]61.1	66.3	76.2	109	.15	47.9	.34
November 1993 (injection at site 14)											
14	Truckee River at Derby Dam	0.0	Nov. 15	8.7	—	—	0.0	—	—	0.0	[a]0.26
15	Truckee River at Painted Rock Bridge.	4.90	Nov. 16–18	12	34.9	45.9	48.5	78.9	0.10	44.0	.17
16	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	11.19	Nov. 19–23	14	98.6	132.9	133.7	184.9	.084	86.3	.14
November 1993 (injection at site 16)											
16	Truckee River at old U.S. 40 bridge at Wadsworth, Nev.	0.0	Nov. 8	20	—	—	0.0	—	—	0.0	[a]0.19
18	Truckee River below S–Bar–S Ranch near Wadsworth, Nev.	6.70	Nov. 9–10	29	28.2	36.2	36.8	52.7	0.18	24.5	.13
19	Truckee River at Dead Ox Wash near Nixon, Nev.	10.68	Nov. 10–11	32	40.2	49.2	50.0	71.2	.21	31.0	.13
November 1993 (injection at site 19)											
19	Truckee River at Dead Ox Wash near Nixon, Nev.	0.0	Nov. 4	45	—	—	0.0	—	—	0.0	[a]0.32
20	Truckee River at Numana Dam near Nixon, Nev.	4.89	Nov. 5–6	49	19.8	25.8	26.4	38.8	0.19	19.0	.32
21	Truckee River at State Highway 447 at Nixon, Nev.	9.81	Nov. 5–7	49	35.8	44.3	45.3	62.8	.22	27.0	.29
23	Truckee River below Marble Bluff Dam.	13.06	Nov. 6–7	50	42.8	52.3	53.3	76.8	.24	34.0	.25

[a] Injected dye mass.
[b] Velocity computed from State Route 447 bridge at Nixon, Nev.
[c] Estimated.

Table 23. Summary of traveltime data for Truckee Canal between Derby Dam near Wadsworth, Nev., and Lahontan Reservoir near Fallon, Nev., 1979, 1980, and 1981

[Modified from La Camera and others (1985, table 32). See table 2 for detailed information about sites and current road designations. —, no data or not applicable]

Site		Distance downstream from injection point (river miles)	Date	Flow (cubic feet per second)	Traveltime of dye plume since injection (hours)				Mean velocity of centroid between sites (miles per hour)	Duration of dye plume at site (hours)	Recovered mass of dye (kilograms)
Number	Name				Leading edge	Peak	Centroid	Trailing edge			
May 1979 (injection at site 7)											
24	Truckee Canal at Derby Dam near Wadsworth, Nev.	[a]18.78	May 30	700	12.3	13.6	13.9	16.1	—	3.8	1.47
27	Truckee Canal at U.S. 95A near Fernley, Nev.	[a]31.94	May 30	630	19.9	21.9	22.1	26.1	1.6	6.2	1.32
September 1979 (injection at site 24)											
24	Truckee Canal at Derby Dam near Wadsworth, Nev.	0.00	Sept. 4	200	—	—	0.0	—	—	0.0	[b]1.22
32	Truckee Canal at U.S. Highway 50 above Lahontan Reservoir	30.98	Sept. 6	140	49.0	51.1	51.2	56.6	0.61	7.6	.59
May 1980 (injection at site 24)											
24	Truckee Canal at Derby Dam near Wadsworth, Nev.	0.00	May 12	200	—	—	0.0	—	—	0.0	[b]1.30
27	Truckee Canal at U.S. 95A near Fernley, Nev.	13.19	May 13	170	15.3	17.0	17.2	20.1	0.77	4.8	.43
28	Truckee Canal at Anderson Check Dam near Fernley, Nev.	16.35	May 13–14	140	23.1	25.2	25.4	28.6	.39	5.5	.36
29	Truckee Canal at Allendale Check Dam near Hazen, Nev.	20.35	May 14	120	32.1	34.0	34.3	38.0	.45	5.9	.30
30	Truckee Canal at Mason Check Dam near Hazen, Nev.	25.03	May 14–15	120	40.5	43.7	44.2	50.8	.47	10.3	.42
31	Truckee Canal at Bango Check Dam near Hazen, Nev.	28.17	May 14–15	110	46.7	51.3	51.5	58.2	.43	11.5	.40
32	Truckee Canal at U.S. Highway 50 above Lahontan Reservoir	30.98	May 15	110	49.8	54.7	55.2	63.5	.76	13.7	.40
October 1981 (injection at site 24)											
24	Truckee Canal at Derby Dam near Wadsworth, Nev.	0.00	Oct. 20	655	—	—	0.0	—	—	0.0	—
25	Truckee Canal at Pyramid Check Dam near Wadsworth, Nev. [c]	6.04	Oct. 20	640	4.0	4.4	4.5	5.6	1.3	1.6	—
26	Truckee Canal near Wadsworth, Nev.[c]	8.88	Oct. 20	635	5.1	5.7	5.8	6.9	2.2	1.8	—
27	Truckee Canal at U.S. 95A near Fernley, Nev.[c, d]	13.40	Oct. 20	620	8.1	9.0	9.1	11.2	1.4	3.1	—
28	Truckee Canal at Anderson Check Dam near Fernley, Nev.[c]	16.35	Oct. 20	605	10.5	11.6	11.7	13.9	1.1	3.4	—
29	Truckee Canal at Allendale Check Dam near Hazen, Nev.[c]	20.35	Oct. 20–21	590	13.6	14.6	14.8	18.7	1.3	5.1	—
30	Truckee Canal at Mason Check Dam near Hazen, Nev.[c]	25.03	Oct. 21	570	16.8	18.4	18.5	21.4	1.3	4.6	—
October 1981 (injection at site 30)											
30	Truckee Canal at Mason Check Dam near Hazen, Nev.[c]	0.00	Oct. 21	570	—	—	0.0	—	—	0.0	—
31	Truckee Canal at Bango Check Dam near Hazen, Nev.[c]	3.14	Oct. 21	560	1.9	2.2	2.2	2.9	1.4	1.0	—
32	Truckee Canal at U.S. Highway 50 above Lahontan Reservoir	5.95	Oct. 21	550	3.4	3.8	3.9	4.9	1.6	1.5	—

[a] Continuation of record from injection at Reno–Sparks sewage-treatment plant outfall (on Truckee River) near Reno, Nev. (See table 21.)
[b] Injected dye mass.
[c] Cumulative traveltime, mean velocity, and duration of dye plume based on uncalibrated field-fluorometer readings rather than laboratory determinations of dye concentration.
[d] Data shown are for samples collected at Fernley Check Dam, which is 0.21 mile downstream from U.S. Highway 95A bridge.

Table 24. Index gaging stations used in traveltime studies

Station number	Site name	Period of record
10338000	Truckee River near Truckee, Calif.	December 1944–September 1961 June 1977–September 1982 October 1992–September 1995 October 1996–present
10346000	Truckee River at Farad[1]	January 1909–present
10350000	Truckee River at Vista, Nev.[2]	August 1899–December 1907 January 1932–December 1954 October 1958–present
10351600	Truckee River below Derby Dam[3]	January 1909–December 1910 January 1916–December 1916 January 1918–July 1958 October 1958–present
10351300	Truckee Canal near Wadsworth, Nev.	October 1966–present

[1]Near Floriston, Calif.

[2]See table 2 for detailed information about this site.

[3]Near Wadsworth, Nev.

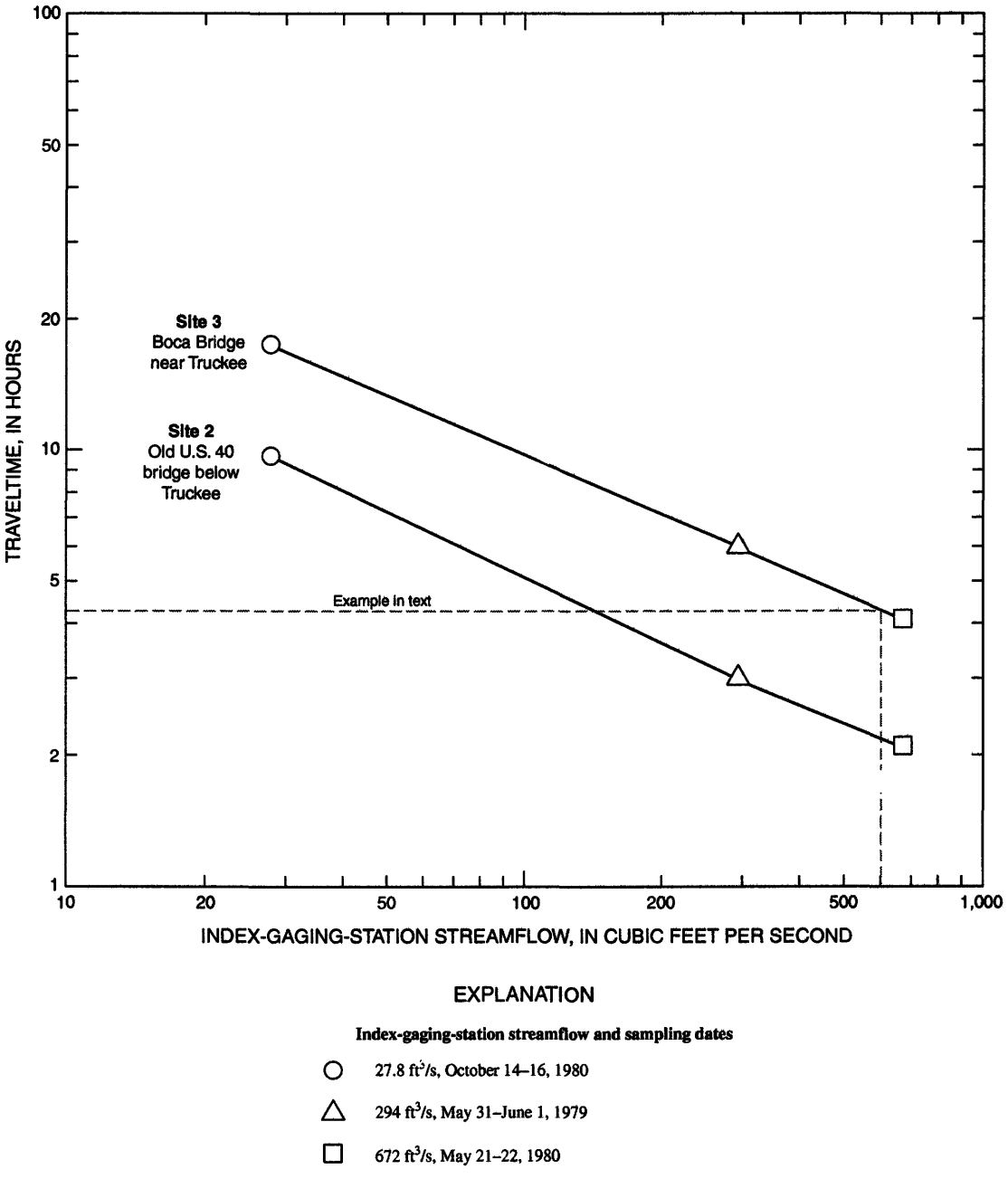

Figure 7. Traveltime for Truckee River between State Route 267 bridge at Truckee, Calif. (site 1), and Boca Bridge near Truckee (site 3) plotted against streamflow at index gaging station (no. 10338000) Truckee River near Truckee. Data from La Camera and others (1985, p. 178). See table 2 for full site names and alternate route names and table 24 for more information about index gaging stations.

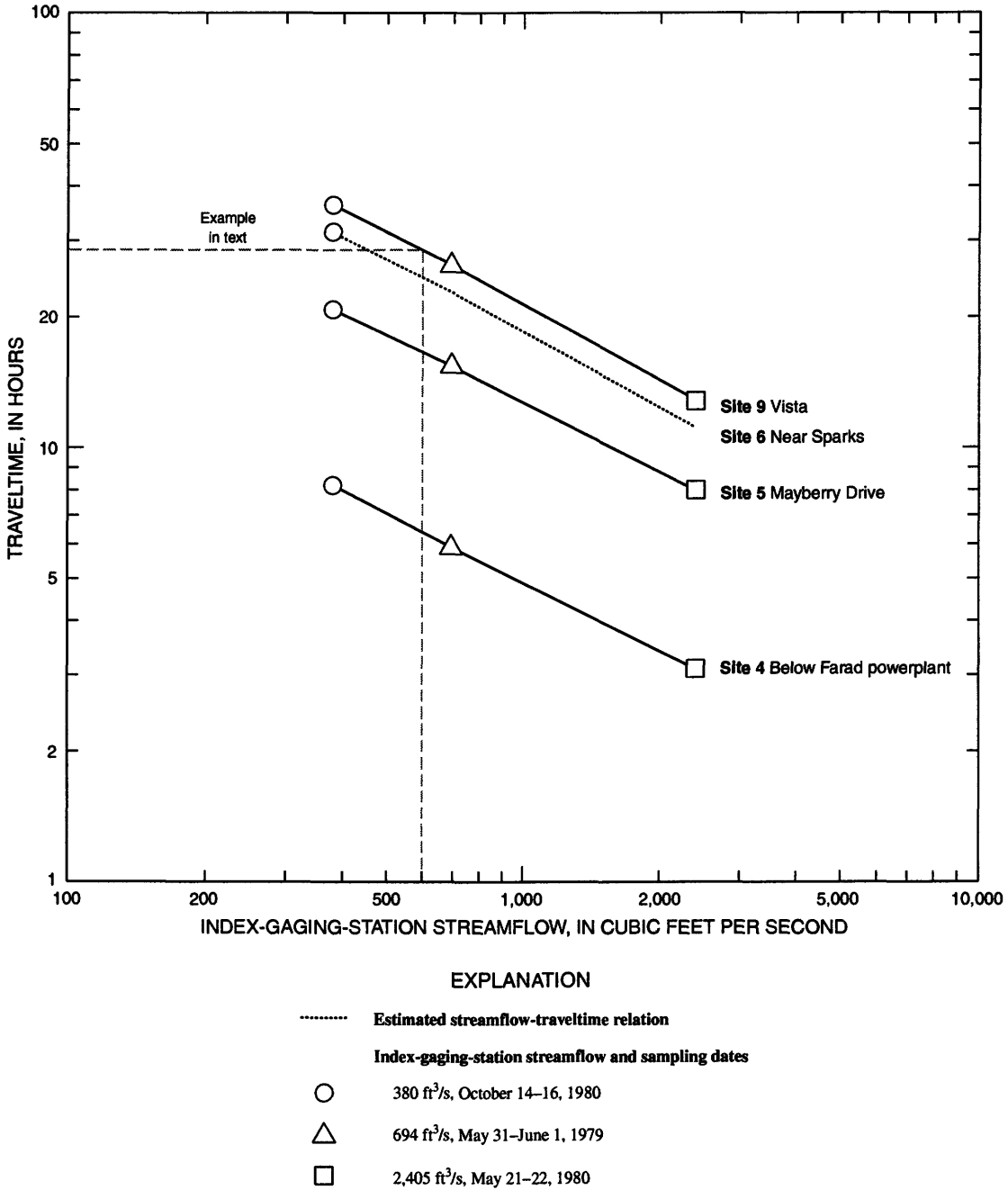

Figure 8. Traveltime for Truckee River between Boca Bridge near Truckee, Calif. (site 3), and index gaging station (no. 10350000) Truckee River at Vista, Nev. (site 9), plotted against streamflow at index gaging station (no. 10346000) Truckee River at Farad (near Floriston, Calif.). Data from La Camera and others (1985, p. 178). See table 2 for full site names and table 24 for more information about index gaging stations.

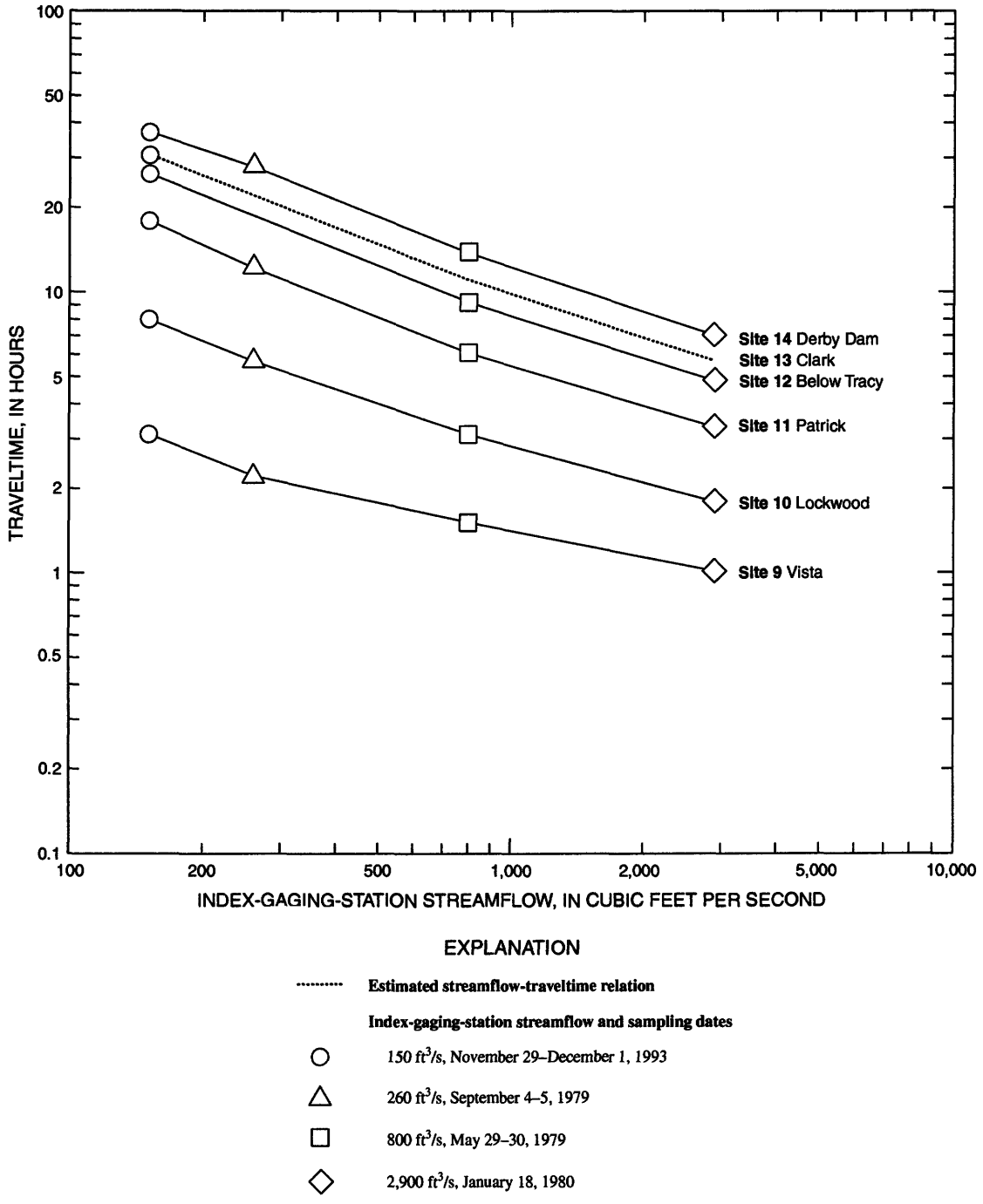

Figure 9. Traveltime for Truckee River between Steamboat Creek at mouth near Sparks, Nev. (site 8), and Derby Dam (site 14) near Wadsworth, Nev., plotted against streamflow at index gaging station (no. 10350000) Truckee River at Vista, Nev. Data for 1979–80 from La Camera and others (1985, p. 179). See table 2 for full site names and table 24 for more information about index gaging stations.

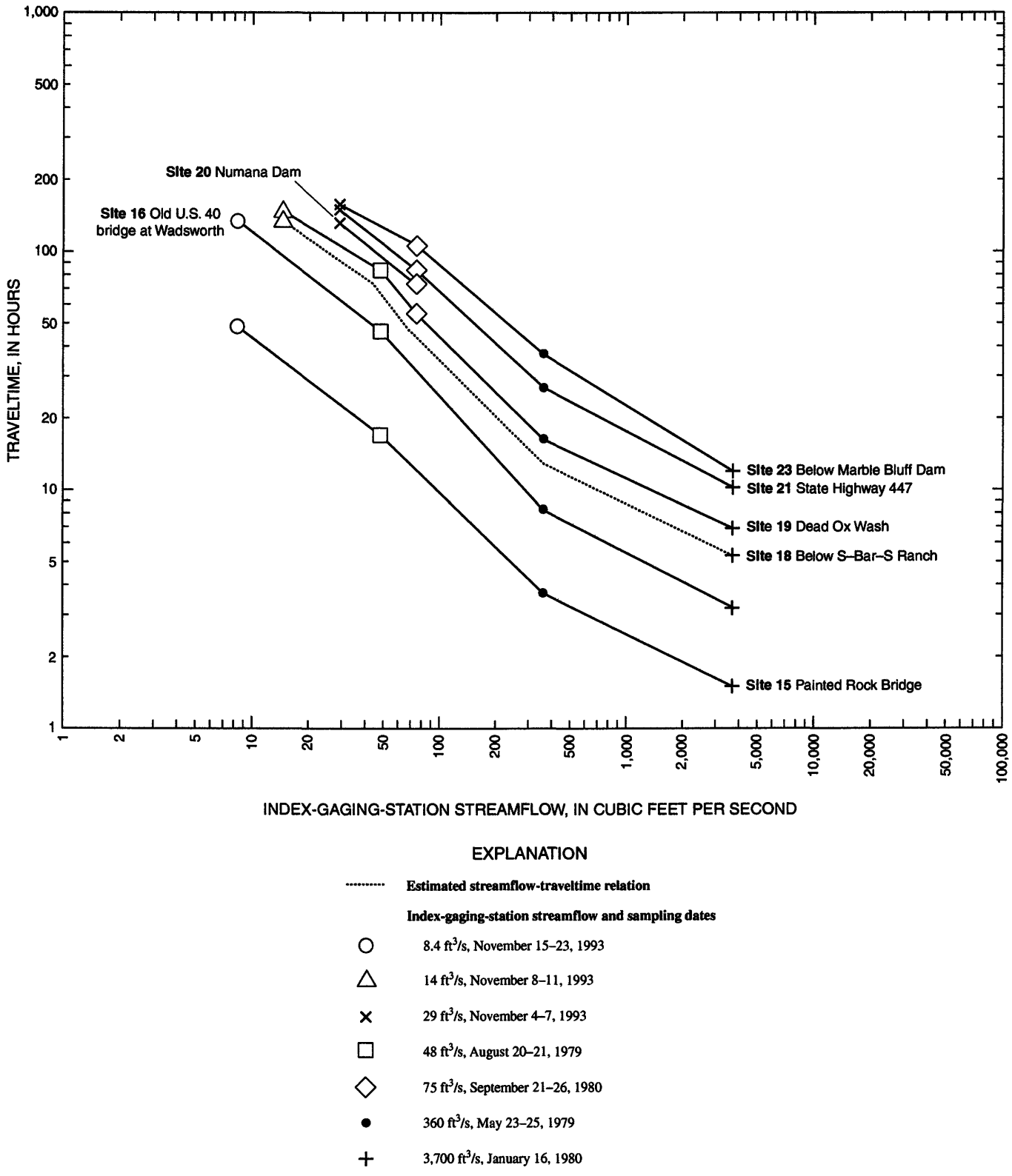

Figure 10. Traveltime for Truckee River between Derby Dam (site 14) near Wadsworth, Nev., and Marble Bluff Dam (site 22) near Nixon, Nev., plotted against streamflow at index gaging station (no. 10351600) Truckee River below Derby Dam. Data for 1979–80 from La Camera and others (1985, p. 180). See table 2 for full site names and alternate route names and table 24 for more information about index gaging stations.

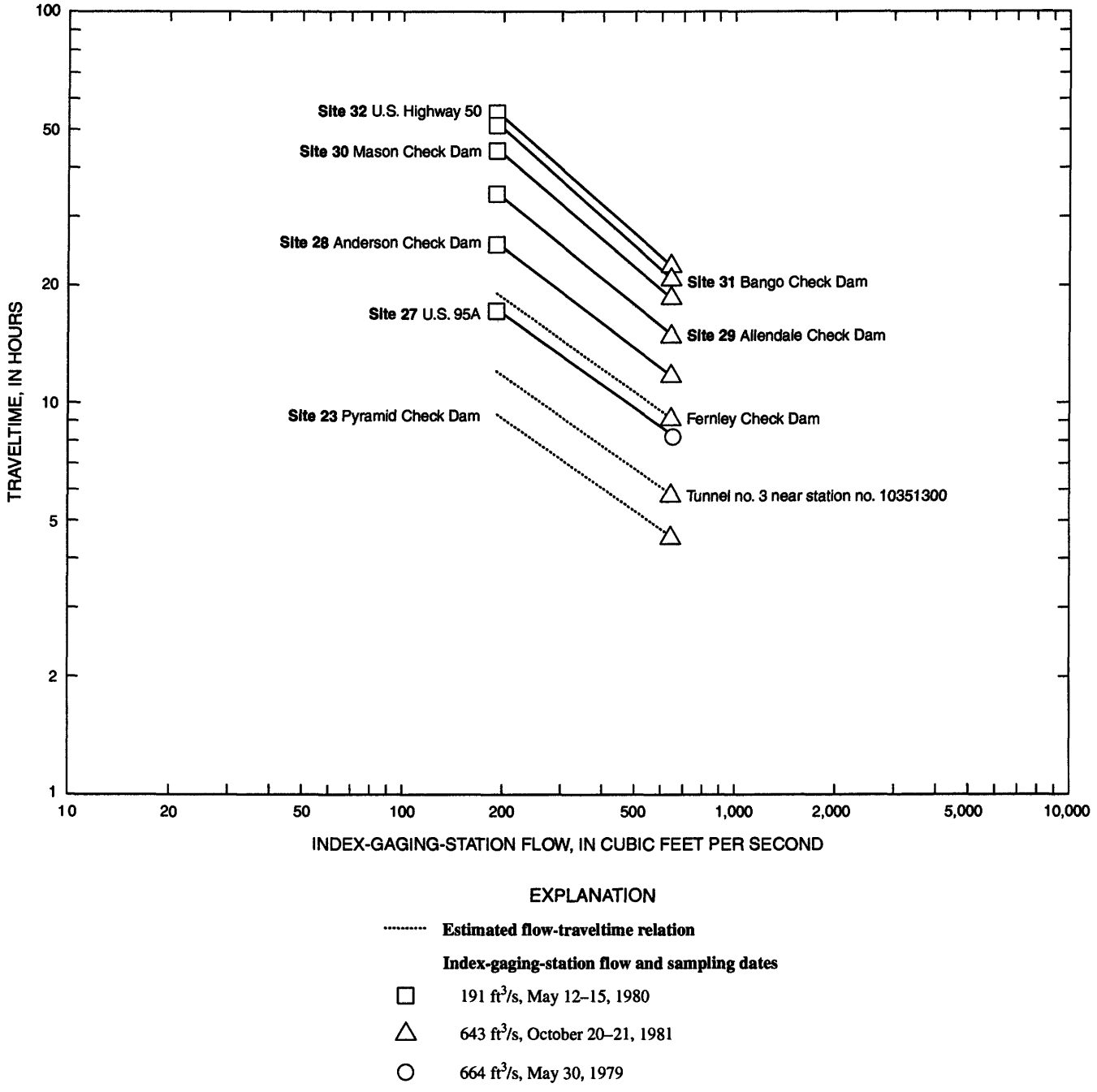

Figure 11. Traveltime for Truckee Canal between Derby Dam near Wadsworth, Nev. (site 24), and U.S. Highway 50 above Lahontan Reservoir (site 32) near Fallon, Nev., plotted against flow at index gaging station (no. 10351300) Truckee Canal near Wadsworth. Fernley Check Dam is 0.21 mile downstream from U.S. Highway 95A. Data from La Camera and others (1985, p. 181). See table 2 for full site names and alternate route names and table 24 for more information about index gaging stations.