STREAM VELOCITIES AND REAERATION COEFFICIENTS FOR THE SOUTH UMPQUA RIVER BETWEEN TILLER AND ROSEBURG, OREGON, 1991

By Antonius Laenen and Winston H. Woo

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CONVERSION FACTORS AND VERTICAL DATUM

To convert from	To	Multiply by
	Length	
foot (ft)	meter (m)	3.281
mile (mi)	kilometer (km)	0.6214
inch (in.)	millimeter (mm)	0.03937
	Area	
square foot (ft^2)	square meter (m^2)	10.76
square mile (mi^2)	square kilometer (km^2)	0.3861
acre	hectare (ha)	2.471
	Flow	
cubic foot per second (ft^3/s)	cubic meter per second (m^3/s)	35.31
	Volume	
acre-foot (acre-ft)	cubic meter (m^3)	0.0008107
	Temperature	
degree Fahrenheit (°F)	degree Celsius (°C)	°F = 1.8(°C)+32 °C = 5.9(°F-32)
	Velocity	
mile per hour (mi/h)	meter per second (m/s)	2.237

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

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ABSTRACT

Dye-tracer and gas-tracer studies were done in July and September, 1991, during low flows on four reaches of the South Umpqua River between Tiller and Roseburg, Oregon. For a streamflow of 435 ft^3/s (cubic feet per second) at the Brockway streamflow monitoring site (14312000) at river mile 132.7, the average stream velocity between Tiller and Myrtle Creek is estimated at 0.88 ft/s (feet per second), and between Myrtle Creek and Roseburg is estimated at 0.64 ft/s. For a streamflow of 129 ft^3/s at the Brockway site, the average stream velocity between Tiller and Myrtle Creek is estimated at 0.34 ft/s, and between Myrtle Creek and Roseburg is estimated at 0.23 ft/s. For a streamflow of 129 ft^3/s at the Brockway site, the reaeration coefficients determined from gas-desorption data collected in the selected reaches for this study ranged from 1.03 to 8.35 per day. The reaeration coefficients determined for this study were approximately two times larger than values derived from a semiempirical formula that uses variables of mean velocity and slope, but confirmed a conceptual formula that uses variables of mean velocity and average depth. Average stream-reach velocity, width, depth, and slope data that were used to compute reaeration coefficients were collected during this study.

INTRODUCTION

Stream velocity and atmospheric reaeration are two important physical properties that affect productivity of a stream. Stream velocity controls mixing and time of residence in pools and riffles. Atmospheric reaeration is the physical absorption of oxygen from the atmosphere by a flowing stream. Along with biological production of oxygen by aquatic plants, atmospheric reaeration completes the primary processes by which a stream replenishes oxygen consumed by aquatic animals and biodegradation of organic wastes.

Data collected and interpreted from this time-of-travel and reaeration study are important in understanding biological productivity and hydrological flow processes. For example, these data are critical in identifying sources and sinks of dissolved oxygen from biological processes, evaluating responses to a toxic spill, and calibrating water-quality models.

This investigation, done by the U.S. Geological Survey in cooperation with Douglas County, is part of a larger study to identify the productivity and respiration of periphytic algae in the South Umpqua River. Excessive growth of periphytic algae in the river is a problem during summer low-flow periods. At times during summer low-flow periods, pH levels and dissolved oxygen concentrations do not comply with U.S. Environmental Protection Agency (1986) criteria and State of Oregon (1988) standards.

Purpose and Scope

The purpose of this report is to present the results of a study of the average time of travel and the atmospheric reaeration characteristics of various reaches of the South Umpqua River.

The study includes the results of dye-tracer and gas-tracer studies made in July and September 1991 during low flows on four reaches of the South Umpqua River between Days Creek and Roseburg, Oregon (fig. 1). Stream velocities computed during this study are compared with velocities computed from dye-tracer data collected at higher flows by Harris and Sanderson (1968). Reaeration coefficients computed from field measurements of gas-desorption coefficients are compared with conceptual and semiempirical equations, and new equations were developed for the South Umpqua River between Tiller and Roseburg, Oregon.

HYDROLOGY

The South Umpqua River Basin (fig. 1) drains 1,760 mi^2 (square mile) of relatively impermeable bedrock and low-yield aquifers in southwestern Oregon (McFarland, 1983). The basin normally has dry summers and wet winters; precipitation ranges from 40 to 80 inches annually, and most precipitation falls as rain. Ninety-seven percent of the basin lies below 5,000 ft (feet). The uplands consist of parts of the foothills of the Cascade Range and the Coast Range. The combination of dry summers, minimal snow pack, low-yield headwater aquifers, and surface-water withdrawals for irrigation of about 13,000 acres results in extremely low flows in the summer (Rinella, 1986). Streamflows between July and September commonly are less than 100 ft^3/s near Roseburg (Friday and Miller, 1984) and provide minimal dilution of point-source inputs from sewage treatment plants (Rinella, 1986).

Between Days Creek and the mouth (fig. 1), the South Umpqua River is characterized by riffles and pools 5-15 ft deep. The river width ranges from approximately 50 to 200 ft, the stream gradient averages 7 ft/mi, and summer velocities range from near 0 to 2 ft/s. Streambed material differs among river reaches, generally ranging from bedrock and cobbles to gravel, sand, and fines.

EQUIPMENT AND FIELD TECHNIQUES

Dye-tracer Study

The dye tracer used in the South Umpqua River was rhodamine WT, a nontoxic fluorescent red chemical dye with a specific gravity of 1.19. The basic procedure is to introduce a measured quantity of dye solution into the stream and measure concentration at different times at selected downstream sampling points. Velocity and dispersion in the reach can be calculated on the basis of these measurements (Kilpatrick and Wilson, 1989).

Dye tracers were injected into the South Umpqua River at two different flow regimes; a medium-low flow (flow exceeded 62 percent of the time) in July, and a low flow (flow exceeded 92 percent of the time) in September. Predetermined quantities of rhodamine WT, at 20 percent solution, were slug-injected into the stream at mid-channel from a boat or by wading at the head of each of four reaches (fig. 1). The most downstream reach was injected first, with upstream reaches following in sequence. The quantity of dye introduced was determined by techniques established by Hubbard and others (1982), and is a function of the

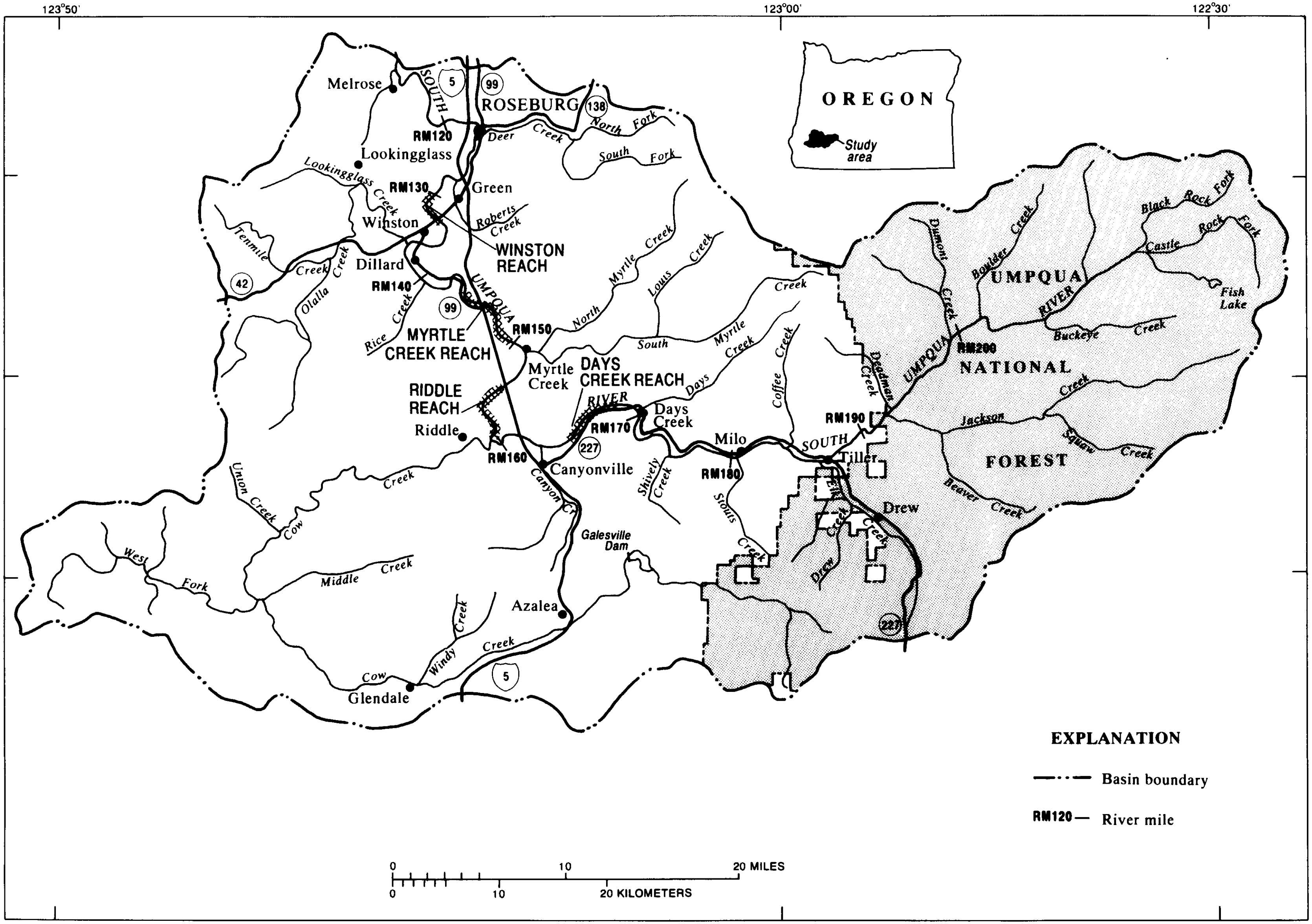


Figure 1. South Umpqua River study area.

stream discharge, mean velocity, and distance to the most downstream sampling point. Concentrations of dye were kept to a minimum (peak concentrations of less than 1 μg/L (microgram per liter) at the most downstream sampling point) to eliminate any possibility of effects on water users. The stream was divided into four study reaches of about 5 mi each because long travel times and sampling logistics prevented sampling the entire 60 miles of river between Tiller and Roseburg.

Water samples for dye were collected at selected downstream locations within each reach. The reaches are shown in figure 1, and exact measurement locations are more specifically identified by river mile in the text, figures, and tables. At measurement locations in each reach, a series of samples were collected by dipping a 40 mL (milliliter) bottle into moving water near midstream at selected intervals to define the passing dye cloud. Typical time-concentration curves depicting the passage of the dye cloud downstream are shown in figure 2. Concentrations of dye were determined by measuring the fluorescence of the water samples in the field with calibrated fluorometers and corrected for temperature. Dye concentrations of less than 0.01 μg/L can be measured with errors of less than ±1 percent (Replogle and others, 1966).

For a specific time, water samples were collected at mid- and quarter-points in the cross section (by stream width) of the first downstream sampling location to determine if the dye was mixed laterally. At these locations, the average of the three samples was used to define the concentration for the specified interval. Distances from the point of injection to the first downstream sampling section were determined by methods described by Kilpatrick and Wilson (1989) to obtain 95-

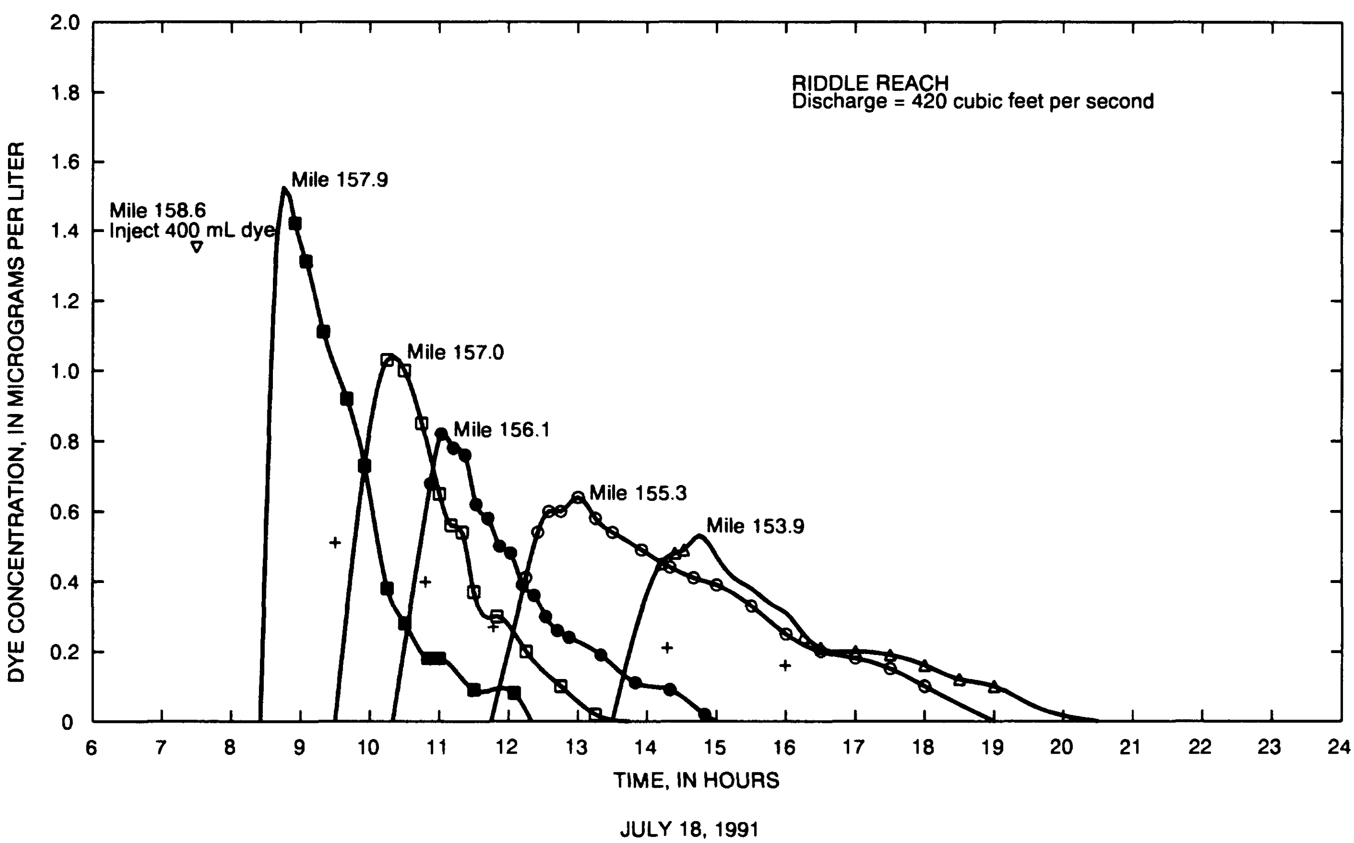


Figure 2. Time-concentration curves of dispersed dye in the South Umpqua River. The '+' is curve centroid.

percent mixing. Mixing at all reaches was not less than 75-percent complete at the first downstream sampling section. The length of channel required to obtain 95-percent mixing is dependent on stream velocity, width, depth, and slope; these data were collected during the preliminary survey.

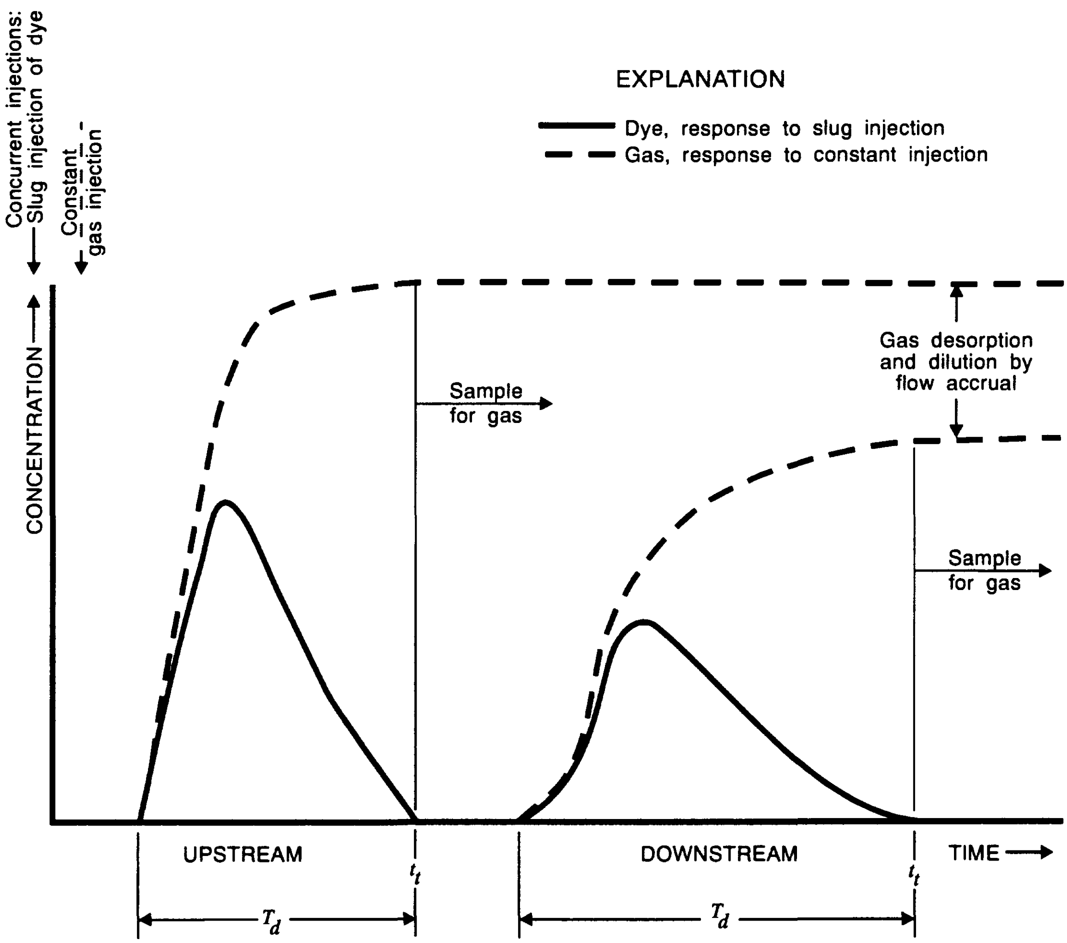
Quality control was assured by checking dye-calibration curves in the laboratory before and after field measurements, and in the field by reading standards, collecting background samples to identify natural fluorescence, and adding known quantities of dye to native water samples. Dye-calibration curves were defined by making dilutions of the dye lot used with distilled water and reading the dilutions on the fluorometers to be used in the field (Wilson, Cobb, and Kilpatrick; 1986). In the field, a 100 μg/L dye sample made with distilled water and a distilled water sample were measured each day by the two fluorometers. Measured quantities of dye were added to measured quantities of distilled water and native water to obtain a "spiked" sample that would define absorbtion of the dye to suspended particles in the native water. Comparison readings between the standard made with distilled water and the "spiked" sample made with native water indicated the "spiked" sample was consistently lower. Aliquots of dye samples were brought back to the laboratory and measured; laboratory results substantiated field measurements. Temperature corrections to the field fluorometer readings were not necessary because water temperatures used in the laboratory to develop curves were nearly the same as water temperatures measured in the field (all within 1.5 degrees Celsius). All laboratory results substantiated field measurements.

Gas-tracer Study

Propane gas was used as a tracer in the South Umpqua River. Laboratory studies have identified the relation between propane desorption and reaeration (Kilpatrick and others, 1989). The basic procedure for making a constant rate injection (CRI) gas-tracer study is to introduce the gas at an upstream location and collect samples at downstream locations when the level of the gas is constant (at a plateau). The dye tracer, which is treated as conservative, is used to determine when the gas (a non-conservative tracer) will reach the plateau. The dye cloud from a slug injection must be completely past a given location before the gas plateau occurs. Dye sampling used to determine the time for gas sampling is shown schematically in figure 3 (Kilpatrick and others, 1989). Successful results were obtained using gas tracers for only one flow regime--the low flow in September.

The rate and length of time that gas was injected were determined by techniques established by Kilpatrick and others (1989). Injection rate is a function of stream discharge, velocity, and depth; travel time to the most downstream sampling point; and the efficiency of absorption of the gas. Four ceramic diffusers (total surface area of 400 square inches) were used to inject propane into the flow. Diffusers were placed in flowing water at depths ranging from 4 to 7 ft. The flow rate at each injection site was approximately 2 pounds per hour; 40-pound propane tanks were used. The tanks were weighed at intervals to check consumption of gas; flow-rate meter adjustments were small and seldom necessary.

Water samples for gas were collected at the same downstream locations as dye sampling (fig. 1). At each location, a series of six samples were collected to define the gas plateau by dipping 40 mL bottles into moving water near midstream at intervals of one-half hour to 1 hour. Each 40-mL sample of water was injected with 1 mL of 37-percent formalin solution for preservation prior to capping.



NOTE: T_d is minimum duration of constant gas injection to just produce a plateau at the down stream samping section at the point of observation of the dye response curve.
t_t is earliest time at which gas sampling should begin.

Figure 3. Definition sketch of constant-rate-injection type of reaeration measurement. (Modified from Kilpatrick and others, 1989.

Bottles were capped underwater to prevent the capture of air bubbles which could affect the analysis of the sample. Samples were analyzed for propane at the U.S. Geological Survey Water Quality Laboratory in Ocala, Florida, by gas chromatographic techniques (Shultz and others, 1976) within 10 days of sampling. Propane concentrations of as low as 0.05 μg/L can be measured with errors of less than $\pm$4 percent (Wershaw and others, 1983).

Quality control was assured by sending duplicate samples to the laboratory for analysis. Quality control also was assured by checking the propane injection rates against tank weight differences in the field. Tank weights were measured to substantiate gas injection rates within 3 percent.

Discharge Measurements

Discharge measurements were made in each study reach the day of the injections. The measurement site/point within the approximate 5-mi long reach was selected by locating the hydraulic cross section that would permit the most accurate discharge measurement. None of the study reaches had any substantial tributary, irrigation diversion, or irrigation return flow. Ground-water contributions in each of the study reaches were assumed to be negligible. Only one measurement was made per reach for each flow period studied. Discharge measurement accuracy for all measurements is considered to be within $\pm$ 5 percent.

STREAM VELOCITY

Preliminary reach investigations were done to obtain river geometry and velocity data that could be used to: (1) establish the scope of the investigation (narrow the field study to manageable reach lengths); (2) extrapolate geometry and velocity to low flows to develop reasonable estimates for dye and gas injection quantities; and (3) locate accessible sampling sites.

Velocities were determined for four reaches of the South Umpqua River during two low-flow discharges. Each of the four reaches used for time-of-travel studies was approximately 5 to 8 mi in length. The entire river from Tiller to Roseburg was not studied because the time, manpower, and quantity of dye required would have been excessive. The reaches were selected because they were good representations of the river channel and encompassed biological sections critical for the periphytic algae study as discussed in the Introduction.

Preliminary Reach Investigations

Surveys were made by canoe to obtain information about stream velocity, depth, width, bed material, configuration (pool, riffle, or run), and biology (table 1). At various locations, velocity was measured at mid-stream and mid-depth by velocity meter; depth was sounded by weight; width was estimated by range finder; bed material type was estimated by eye; and various biological information was recorded. River miles (RM) indicate the approximate location for each observation and can be located on figure 1. For preliminary surveys, the Winston reach is between RM 130 to 135; Myrtle Creek reach is between RM 144 to 151; Riddle reach is between RM 152 to 160; and Days Creek reach is between RM 162 to 170.

Velocity data collected in the preliminary survey, when compared with results of the subsequent time-of-travel studies, yielded mean velocity estimates for projected low flows that were reasonable for the Riddle and Days Creek reaches, but were double those for the Winston and Myrtle Creek reaches.

Time-of-Travel Investigations

Velocities were determined for four reaches of the South Umpqua River for two low-flow discharges. For the July 16-20, 1991 investigation, the flow at Brockway (14312000) ranged from 309-536 ft^3/s, and at Tiller (14308000) from

Table 1.--Results of preliminary survey of depth, velocity, width, bed material, and other miscellaneous data for selected locations on the Umpqua River from river mile 135.0 to 170.0, June 24-27, 1991

[LB = left bank, RB = right bank, DS = downstream, US = upstream, " = inch, est = estimate, XX" line = irrigation pipe, xx" in diameter, ft^3/s = cubic feet per second]

Site number	River mile	Time	Depth (feet)	Velocity feet per second	Width (feet)	Bed material	Biology	Location	Remarks
							WINSTON REACH		
	135.0								Launched boat
1	135.1	1426	10.0	0.25	180	Gravel,		Pool	
		1428				Rocks,	Caddis fly	Riffle	
						Bedrock	larvae		
		1430							LB 3" line, pump not running
		1432							LB 2" line, pump not running
2	134.6	1435	4.0	.60	210	Fine		Pool	
		1443				gravel	Cladophera	Pool	End of long, wide pool
								Riffle	2 ft drop
		1446							LB 2" line, pump not running
3	133.5	1452	6.0	.84	210	Fines		Pool	
		1459						Riffle	End of long pool
		1502					Cladophera	Pool	End of moderately long riffle
									Cladophera still not abundant,
									no streamers
									Tree debris in water
		1504	12.0		250			Pool	
		1509							USGS gage at Brockway
4	132.7		4.5	.83	275	Fines,			
		1513				Bedrock		Riffle	Winston Sewage Treatment Plant
									Fishermen catching bass
		1517						Pool	End of riffle area
									LB 4" line, pump not running
5	132.1	1521	8.0	1.18	235	Fines	Cladophera	Pool	No long streamers of Cladophera
									yet. RB 6" line, pump not running
		1526						Riffle	End of Class II rapids, drop 5 feet
		1531	1.0			Cobbles,		Pool	Moving fast
		1533				gravel		Pool	LB Tributary, no flow
									Safari Campground, LB line, pumping
6	131.5	1537	2.0	1.26	300	Fine	Cladophera	Pool	Cladophera beginning to grow on rocks
						Gravel			again. Strands 1-2 feet long
		1543	1-2		broad			Pool	Broad, shallow area
		1546						Pool	End of shallow area
7	130.9	1548	4.5	1.11	250	Fines			
		1551	15.0		200			Pool	RB 6" line, pumping
		1558	Deep			Bedrock	Macrophytes		Cladophera thicker but not long yet
									RB 4" line, pumping
8	130.3	1602	13.0	.40	210	Fines,		Pool	Bedrock humpbacks
		1606				bedrock	Osprey		LB 4" line, pump not running
9	129.9		10.0	.15	300	Silt,		Pool	Green Bridge
		1615				gravel	Macrophytes		Boat ramp, access. Lots of
									vegetation in water
		1617					Cladophera	Pool	Beds of macro's and long strings
									of clad.
								Riffle	Channel dug out with dozer
		1621					Canada Geese	Riffle	End of riffle area
10	129.2	1627	5.0	.93	315	Cobble,	Cladophera	Pool	Not long strands of clad.
						fines			LB Marsters Creek, 1.0 ft^3/s
									LB 2" line, not pumping
		1630	.5			Wide		Riffle	very long, very wide section
	129.7	1642				Bedrock		Riffle	Pulled out of water
							MYRTLE CREEK REACH		
		0955							Launched boat
1	151.1	0955	13.0	.49	132	Bedrock,	Cladophera	Pool	Below railroad bridge. Cladophera
		1000				gravel		Riffle	up to 6" long strands on bedrock
		1002				Bedrock			Myrtle Creek
2	150.5	1005	10.0	2.80	92	Bedrock	Otter	Shute	No algae
		1010				Bedrock		Riffle	3 feet drop
3	150.4	1014	8.0	1.76	130	Bedrock	Cladophera,	Pool	Below bridge
							Diatoms,		Small amounts of Cladophera
							Ducks		
		1017				Bedrock		Riffle	2 feet drop

Table 1.--Results of preliminary survey of depth, velocity, width, bed material, and other miscellaneous data for selected locations on the Umpqua River from river mile 135.0 to 170.0, June 24-27, 1991--Continued

Site number	River mile	Time	Depth (feet)	Velocity feet per second	Width (feet)	Bed material	Biology	Location	Remarks
						MYRTLE CREEK REACH--Continued			
4	150.1	1021	16.0	.32	235	Boulders, fines		Pool	Long, wide, deep pool
		1028				Bedrock		Riffle	Island
		1031				Bedrock, cobbles		Riffle	End of riffle
		1036				Gravel, Cobbles			Got out to look at riffle Possible road access
		1040							Start travel downstream again
5	150.5	1043	13.0	.38	109	Bedrock, gravel		Pool	Just above riffle
		1045				Rocks		Riffle	
		1049						Riffle	Long shute with interspersed riffles
6	149.5	1051	7.5	1.51	89	Bedrock, fines	Cladophera	Pool	Cladophera starting to grow
						Rip-rap			Getting slower and deeper
7	148.8	1101	7.0	.93	177	Rocks			
		1108					Cladophera		On downstream side of rocks, not abundant yet
		1109				Bedrock		Riffle	
		1113							LB Tributary, 1.5 ft^3/s
8	148.3		8.0	.39	195	Silt, gravel,			
		1117				bedrock		Riffle	Short
9	147.9	1121	4.5	1.54	139	Gravel, rocks		Pool	In pool getting shallow
		1125				Rock		Riffle	3 ft drop
		1127						Riffle	End of riffle area
10	147.5	1130	7.0	.75	180	Rocks, fines		Pool	LB 2" line, pump not running
						Gravel			Fishing hole, cleaned up trash
		1138				Bedrock		Riffle	
		1140							RB Tributary, 1.5 ft^3/s
11	147.1	1144	6.5	1.01	184	Fines, gravel		Pool	Grass growing near banks
		1149	.5		Broad			Riffle	Wadeable
	146.9	1155							RB 6" line, pump not running
12	146.4	1157	3.0	2.50	190	Gravel		Pool	More grass growing in river
		1201							RB Tributary, <0.5 ft^3/s
		1204	Deep				Cladophera		Pump house pumping, deep pools
		1205						Riffle	Under freeway
		1208					Osprey nest		
13	145.7		3.0	1.18	262	Gravel	Cladophera		1 feet long bunches of Cladophera just before riffle
		1214			Broad			Riffle	Broad and flat
									LB 4" line, not pumping, RB 6" line, pumping
		1210							Begin lunch, free-float
		1232	Deep						End of lunch break
14	145.2	1233	4.5	1.26	239	Silt	Cladophera	Pool	Lots of water vegetation
						Gravel	Macrophytes		5 feet long strands of Cladophera
			3.0	.58		Bedrock	Herons, blue and green		Bedrock humpbacks
		1243					Vultures		
			4-5		Wide		Small mouth bass		Heavy growths of macrophytes
15	144.6	1250	9.5	0.38	226	Gravel		Pool	Deep and wide
		1255			Broad	Gravel		Riffle	Power lines, access
		1258						Riffle	End of riffles
16	143.9	1302	4.0	1.32	185	Gravel	Grass, Macros Cladophera		
		1305	.5					Riffle	
17	143.6	1310	5.0	4.59	120	Bedrock		Pool	Under bridge, take-out point

Table 1.--Results of preliminary survey of depth, velocity, width, bed material, and other miscellaneous data for selected locations on the Umpqua River from river mile 135.0 to 170.0, June 24-27, 1991--Continued

Site number	River mile	Time	Depth (feet)	Velocity feet per second	Width (feet)	Bed material	Biology	Location	Remarks
							RIDDLE REACH		
1	159.9	1836	3.0	.86	193	Bedrock, cobble	Cladophera		Launch spot, freeway bridge
						Gravel	>1 ft		
		1840						Riffle	6" line LB
		1842						Riffle	Beginning of pool
		1845	20.0				Cladophera	Pool	Deep
		1851					heavy	Riffle	Two 4" lines RB
		1854						Pool	Two 2" lines RB with access at Gazely
2	158.7	1907	7.0	.49	143	Gravel, fines		Pool	Confluence of Cow Creek
3	158.6	1915	5.0	1.41	129	All	Cladophera,	Pool	4" line
		1917					snails	Pool	Slow
4	157.9	1922	.5					Run	Shallow, swift
5	157.8	1926	4-5	.83	140	Gravel	Thin films	Run	
		1936	1.5					Riffle	Power lines
		1937						Pool	
6	157.2	1938	7.5	.38	220	All		Pool	LB, Sluice mining, livestock smell
		1940	.5						Class II rapid
7	157.0	1952	8.0	1.11	77	Bedrock, cobble			
		1954	1.5					Riffle	RB, farm with cattle in river, 6" line
8	156.6	1959	3.0	.57	205	Bedrock	Cladophera		After riffle, long shallow run
		2003	1.5					Riffle	8" line RB, cattle
		2006						Riffle	Broad, before Missouri Bottom bridge
9	155.7	2013	5.5	.97	170	Gravel			After bridge, 4" line RB
		2017	12.0					Riffle	Pool after riffle, long run
		2020	3.6		150		Snails	Run	Swift, shallow
10	154.7	2030	3.5	.80	180	Gravel, fines			LB tributary, 0.5 ft^3/s, 8" line RB cattle access, smells
		2041							4" line LB, near railroad tracks
11	153.9	2045	4.0	.65	177	Gravel, cobble			I-5 bridge, campground at LB, 4" line
		2047							4" line RB at I-5 bridge
		2051	0.5-2		200			Run	Swift, 4" line LB
		2057							6" line LB, 4" line RB
		2101							4" line RB
12	152.9	2103	4.5	.65	250	Gravel			Swift, very dark, some access
13	151.7	2115	0.5-1	1.41	275	Gravel			6" line LB
		2120							6" line LB
		2121							4" line RB
		2123							Pulled out of water
							DAYS CREEK REACH		
		1330							Flow at Days Creek gage
1	169.7	1500	7.0	.30	95	Fines		Bridge	is 364 ft^3/s
	169.6		25.0					Pool	Riffle below pool 1.5 feet deep
2	169.5		3.5	1.00	95	Cobbles	Thin diatoms	Pool	LB 4" line, pump not running
3	169.4		7.0	1.26	93	Fines, Cobbles		Pool	Long straight pool
									LB 2", 6" lines, pumping
	168.6		1.5			Bedrock		Riffle	Long riffle
4	168.5	1523						Pool	Beginning of long pool
5	168.2	1527	5.0	1.20	141	Cobbles	Conical snails	Pool	
		1530	.5			Broad Cobbles		Riffle	Old abandoned pump site
		1532	2.5	1.50	140			Riffle	More riffle
		1533	2.0 est	3.00		Cobbles		Riffle	Very long riffle
		1537	4.0			Bedrock, Cobble	Bass fish	Pool	
6	167.6		4.5	1.80	109	Cobbles	Encased caddis	Pool	LB 4"line, pumping
							fly larva	Riffle	Short riffle

Table 1.--Results of preliminary survey of depth, velocity, width, bed material, and other miscellaneous data for selected locations on the Umpqua River from river mile 135.0 to 170.0, June 24-27, 1991--Continued

Site number	River mile	Time	Depth (feet)	Velocity feet per second	Width (feet)	Bed material	Biology	Location	Remarks
				DAYS CREEK REACH--Continued					
7	167.5		3.0	1.51	107	Cobbles	Ducklings	Pool	LB old pump well, RB springs 0.2 ft^3/s
8	167.4	1556	7.0	1.16	94	Bedrock, Cobble		Pool	Bedrock forms steep banks
9	167.3	1600	10.0	.61	129	Bedrock		Pool	Steel truss bridge, LB 6" line, pumping
								Pool	1200 feet long
						Broad Cobbles		Riffle	
10	167.0	1609	3.0	1.58	132	Bedrock, Cobble		Pool	
						Bedrock		Riffle	Bedrock outcrop
			20.0			Bedrock, Fines		Pool	Sand beach
11	166.8	1617	5.5	1.47	132	Bedrock, Cobble		Pool	Power lines
			.5			Bedrock		Riffle	Class II rapids, wadeable below
12	166.2	1631	11.0	.97	59	Bedrock		Pool	
			23.0		40	Bedrock		Pool	
		1637	3.5		150	Cobbles		Pool	
						Bedrock		Riffle	Long riffle
13	165.5	1653	2.0	1.32	140	Gravel, Cobble		Pool	Power line, RB 8" line, pumping
			2.0			Bedrock		Riffle	LB pump, pump not running
14	165.3	1704	3.0	1.26	139	Cobble, Fines		Pool	New weigh station, good access
						Cobbles		Riffle	Long riffle, good drop, LB, RB pumps, not running
15	164.7	1706	5.0	1.96	106	Bedrock		Pool	
16	164.4	1715	2.5	1.18	157	Cobble, Gravel		Pool	In fast pool, photographs 1 and 2, upstream, downstream
		1722	1.5		Wide	Bedrock		Riffle	Long riffle, LB 4" line, pump not running
17	163.7	1730	5.0	1.35	116	Bedrock		Pool	Boat ramp at Canyonville County Park
		1736	.5			Bedrock, Cobble		Riffle	LB 4" line, pumping
		1738	4.0			Bedrock		Pool	
		1740	.5					Riffle	LB, many 2" lines from homes
		1745						Riffle	Class II drop, Camera got wet
18	162.8	1748	2.0	1.62	151	Cobble, Gravel		Pool	Sewage Treatment Plant Outfall
		1750	3.5		150			Pool	Canyon Creek
			.5					Riffle	LB, RB, 3", 4" lines, pumps not running
		1756							Canyonville Bridge
19	162.6	1800	3.5	1.47	110	Cobble, Gravel		Pool	LB 4" line, pump not running
		1803	9.0	slow	140			Pool	Stanton Park, LB 4" line, pumping
						Fast Narrow		Riffle	Wadeable
20	161.7	1810	2.5	2.25	50	Bedrock		Pool	Fast pool just before riffle
		1812				Bedrock	Cladophera	Riffle	Class II rapids, shallow, 5 feet drop
		1824							Bail-out break time some small indication of Cladophera
		1828						Pool	Begin again in bedrock pool drop
		1832	Fast					Riffle	Short and fast, LB, 4" line, pump not running
		1845							RB, 6" line, pumping
		1855							Finish, Freeway Bridge

168-298 ft^3/s. A storm occurred on July 16-17 that increased flows during the measurement. For the September 9-13, 1991, investigation, the flow at Brockway ranged from 113-129 ft^3/s, and at Tiller from 51-54 ft^3/s.

Stream velocity generally decreased in the downstream direction, except in the Riddle reach in both July and September investigations. The higher stream velocities in the Riddle reach are probably due to the increase of flow from Cow Creek (table 2). Time-concentration curves for July 16-20 measurements are shown in figure 4. Water discharges measured in the individual reaches at the time of sampling are listed for each graph. Time-concentration curves for September 9-13 measurements and measured discharges are shown in figure 5. Travel rates of peak-dye concentrations in each reach are listed in table 2 as stream velocities for specific river miles. For the July investigation, stream velocities representing each reach in a downstream direction were 0.68, 0.94, 0.56, and 0.35 ft/s. For the September investigation, stream velocities representing each reach in a downstream direction were 0.27, 0.35, 0.22, and 0.17 ft/s.

Velocities in the South Umpqua River from this study and results from a previous study by Harris and Sanderson (1968) are shown in figure 6. The velocities for the earlier high-flow study was controlled by channel friction (Harris and Sanderson, 1968). For a streamflow of 2,040 ft^3/s as defined by Harris and Sanderson (1968), the average velocity between Tiller and Roseburg was 1.83 ft/s and for a streamflow of 7,800 ft^3/s, the average velocity between Tiller and Roseburg was 3.45 ft/s. Only four 5-mile increments of the 70-mile reach between Tiller and Roseburg were measured in this study. Velocity data from these increments were used to estimate the velocity trends for the entire reach (see fig. 6). Velocities in the low-flow study was controlled by individual riffles. For a streamflow of 435 ft^3/s at the Brockway stream-gaging station at river mile 132.7, the average velocity between Tiller and Myrtle Creek is estimated at 0.88 ft/s, and between Myrtle Creek and Roseburg is estimated at 0.64 ft/s. For an streamflow of 129 ft^3/s at the Brockway stream-gaging station, the average velocity between Tiller and Myrtle Creek is estimated at 0.34 ft/s, and between Myrtle Creek and Roseburg is estimated at 0.23 ft/s.

REAERATION COEFFICIENTS

The following formula developed by Streeter and Phelps (1925) for oxygen deficit shows the relation between biochemical consumption of oxygen and atmospheric reaeration:

$$D(t) = \left[\frac{K_1}{K_2 - K_1}\right] \left(e^{-K_1 t} - e^{-K_2 t}\right) L + \left(e^{-K_2 t}\right) D \qquad (1)$$

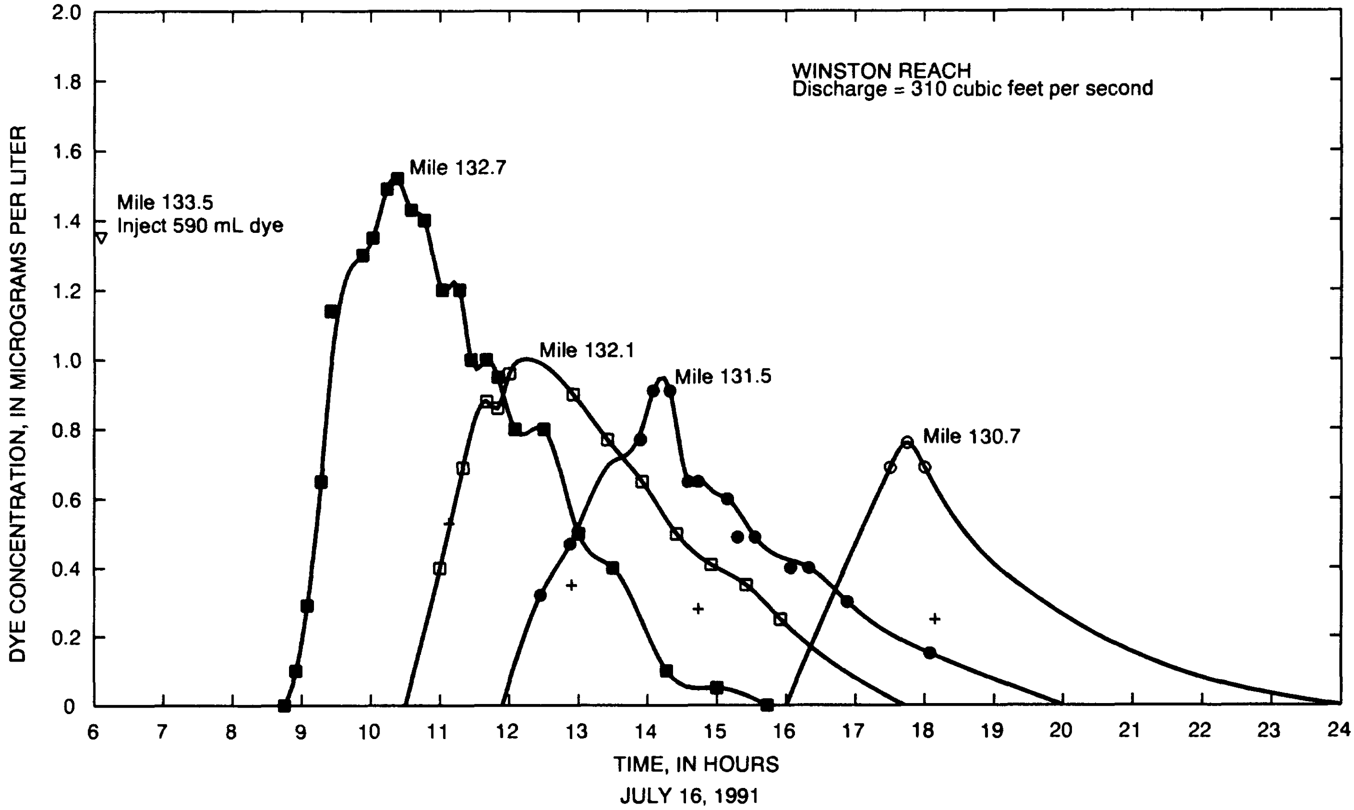
where,

$D(t)$ = the oxygen deficit at time t (mg/L),
K_1 = the biological-oxidation coefficient (per day),
K_2 = the atmospheric reaeration coefficient (per day),
L = the initial BOD (biochemical oxygen demand) concentration (mg/L), and
D = the initial oxygen deficit (mg/L).

Table 2.--Stream velocities at peak concentrations of dye injections in July and September 1991, on selected river reaches of the South Umpqua River

Date	Reach name	Discharge (cubic feet per second)	River mile	Travel time (hours)	Stream velocity (feet per second)
July 16	Winston	310	133.5-132.7	4.2	0.28
			132.7-132.1	1.9	.46
			132.1-131.5	2.0	.44
			131.5-130.7	3.6	.33
			133.5-130.7	2/11.7	2/ .35
July 17	Myrtle Creek	1/373	149.2-147.8	2.8	.73
			147.8-146.6	2.8	.63
			146.6-145.9	2.1	.49
			145.9-145.2	2.9	.35
			145.2-144.3	2.2	.60
			149.2-144.3	2/12.8	2/ .56
July 18	Riddle	1/420	158.6-157.9	1.3	.79
			157.9-157.0	1.5	.88
			157.0-156.1	.7	1.89
			156.1-155.3	2.0	.59
			155.3-153.9	1.8	1.14
			158.6-153.9	2/7.3	2/ .94
July 19	Days Creek	187	168.0-167.3	1.1	.93
			167.3-166.6	1.6	.64
			166.6-166.3	.3	1.47
			166.3-165.5	1.7	.69
			165.5-164.7	2.4	.49
			168.0-164.7	2/7.1	2/ .68
September 9-11	Winston	129	133.5-132.9	9.3	.13
			132.9-131.9	4.0	.29
			131.9-131.5	2.0	.29
			131.5-130.7	8.7	.13
			133.5-130.7	2/24.0	2/ .17
September 10-12	Myrtle Creek	123	149.2-147.8	8.2	.25
			147.8-146.6	7.6	.23
			146.6-145.9	3.7	.28
			145.9-145.2	7.1	.14
			149.2-145.2	2/26.6	2/ .22
September 11-12	Riddle	110	158.6-157.9	2.6	0.39
			157.9-157.0	2.2	.60
			157.0-156.1	3.7	.36
			156.1-155.3	5.5	.21
			158.6-155.3	2/14.0	2/ .35
September 12-13	Days Creek	53	168.0-167.3	2.9	.35
			167.3-166.6	3.6	.28
			166.6-166.4	.5	.58
			166.4-165.5	5.9	.22
			165.5-164.7	5.1	.23
			168.0-164.7	2/18.0	2/ .27

1/ Increase in discharge is because of rain occurring July 16-17.
2/ Travel time and stream velocity is based on travel time for the river miles shown in this row.



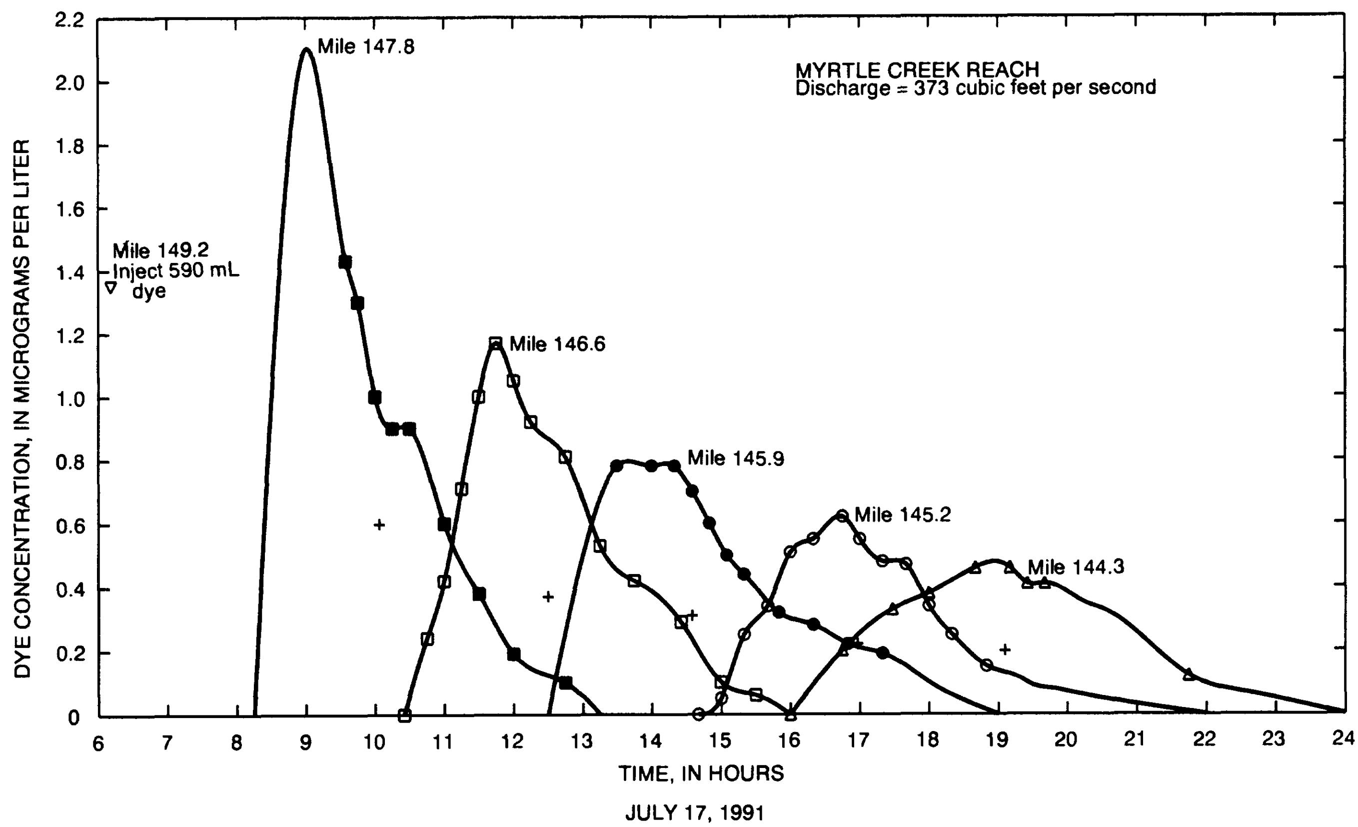
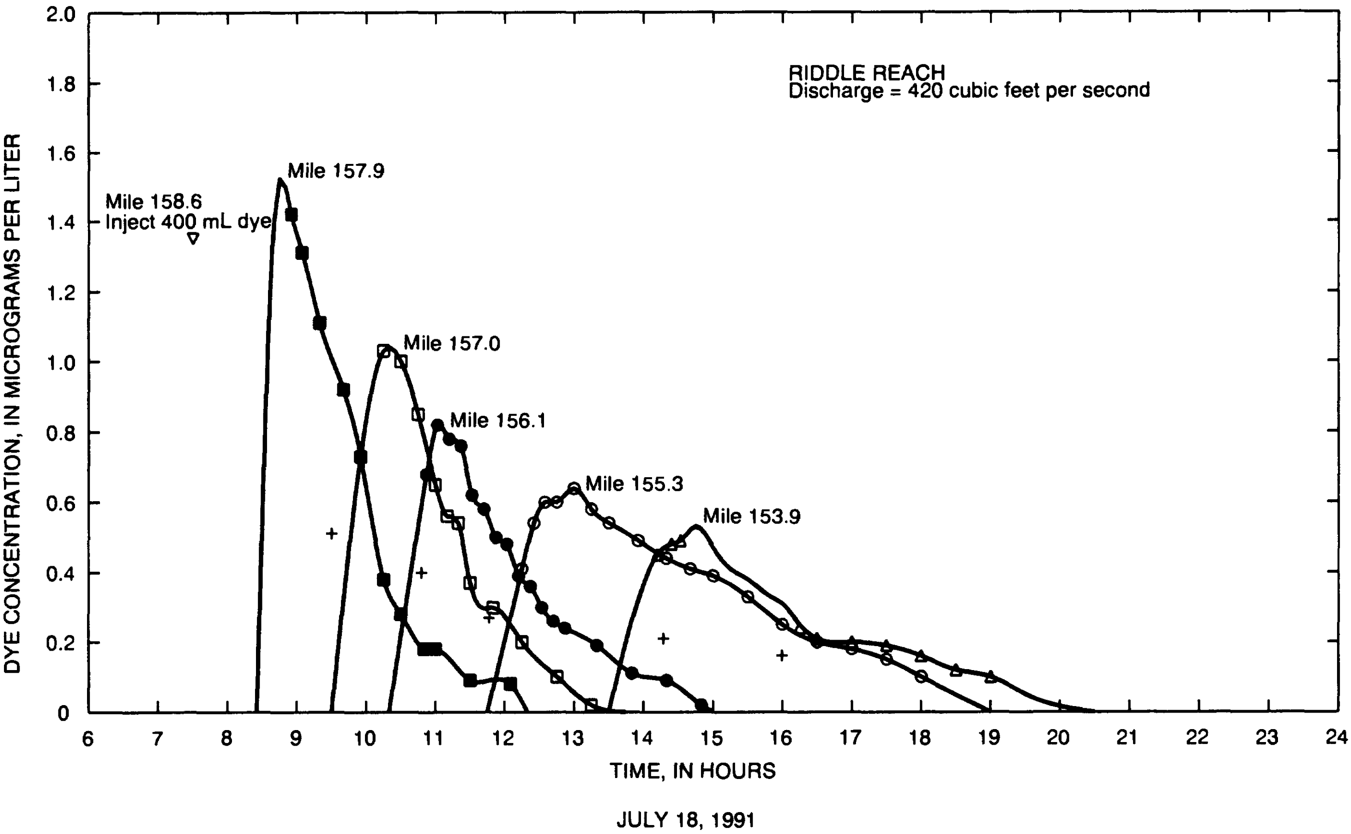
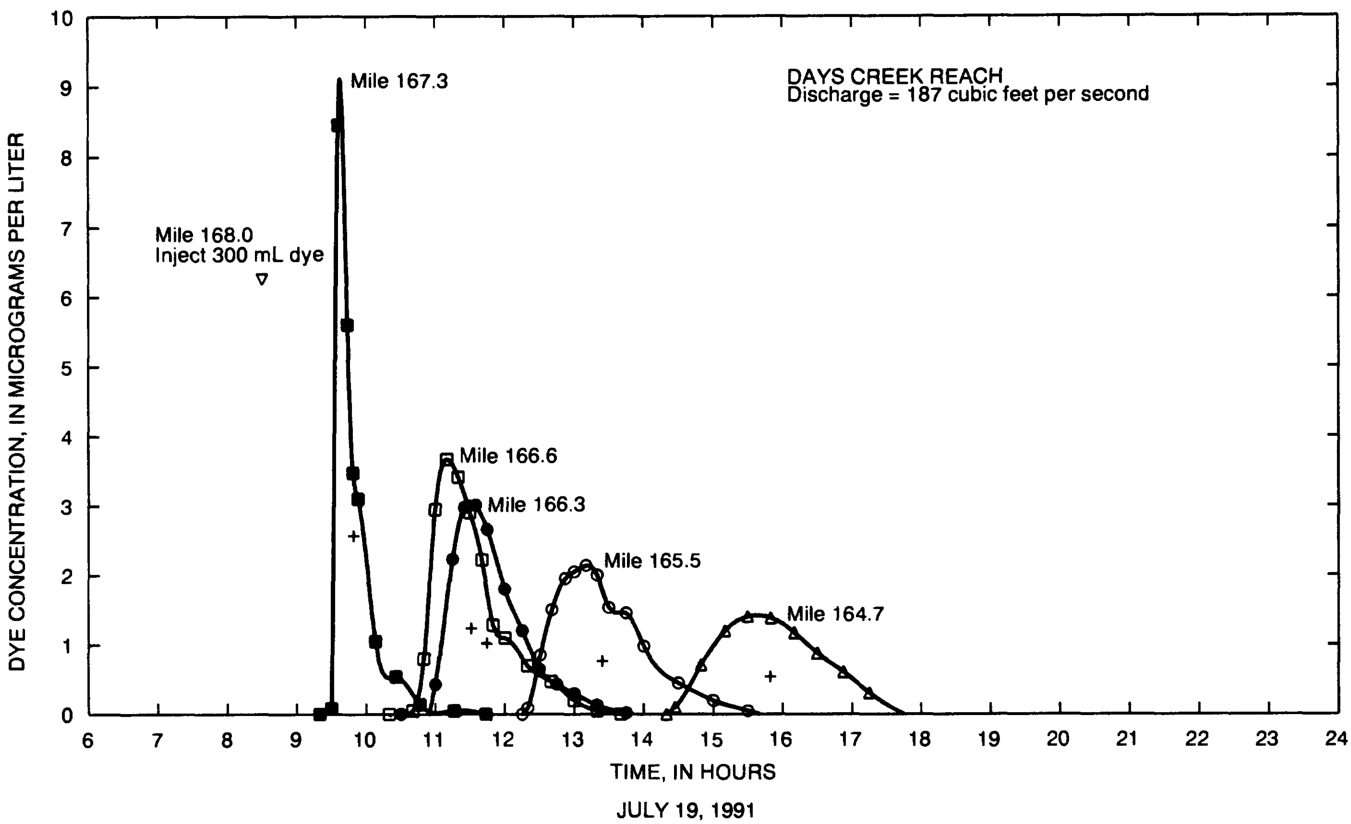


Figure 4. Time-concentration curves for the July 16-19, 1991 injection of rhodamine WT dye in the South Umpqua River from





river mile 130.7 to 167.0. The '+' is curve centroid.

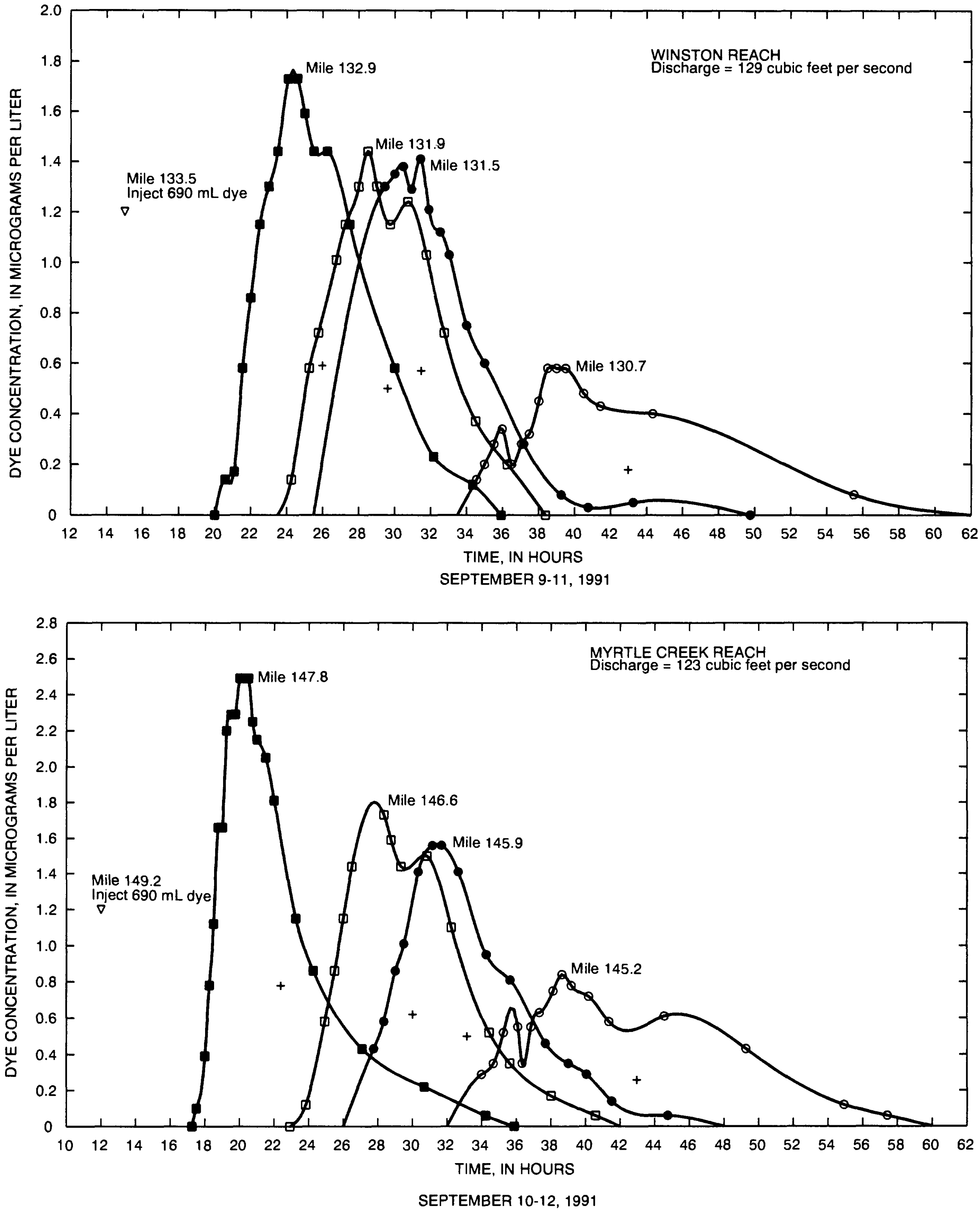
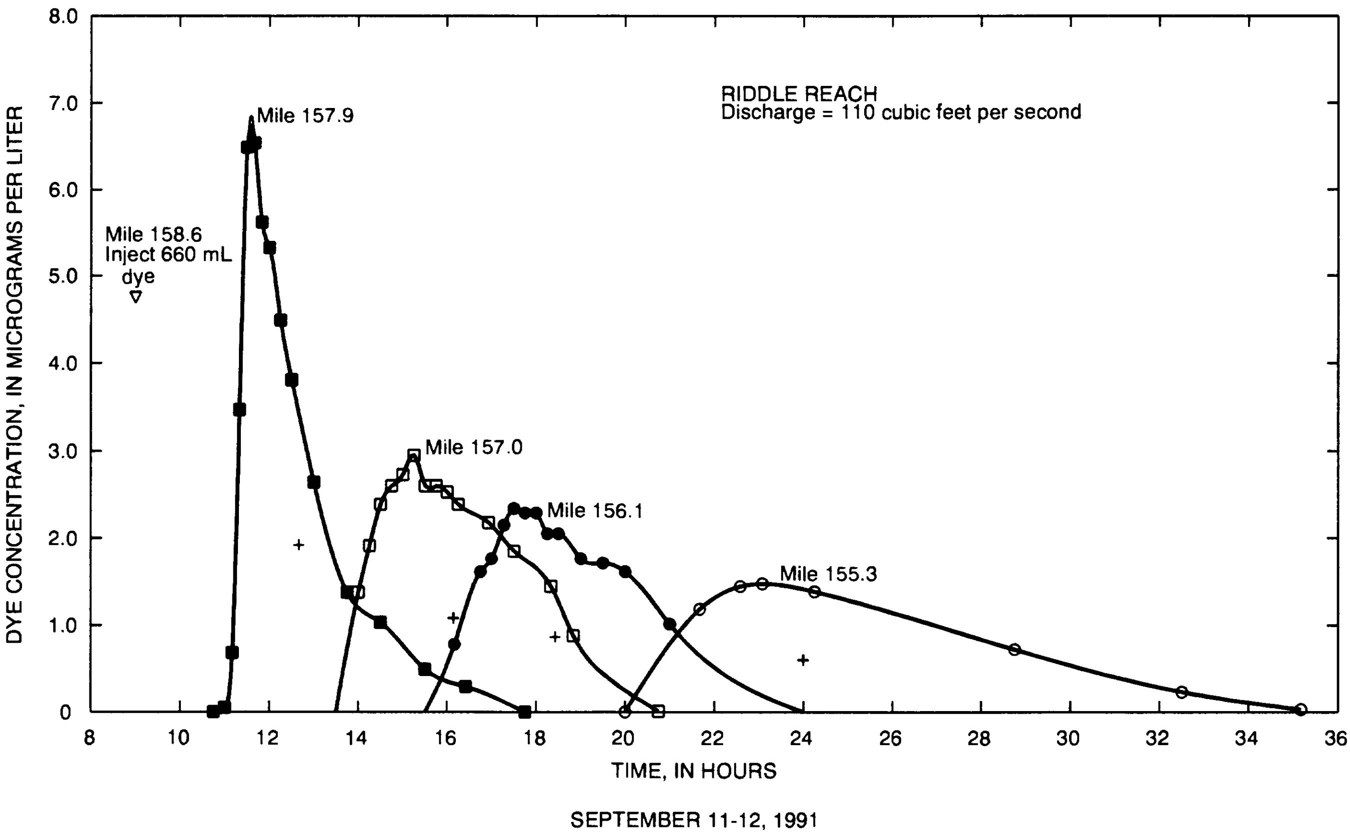
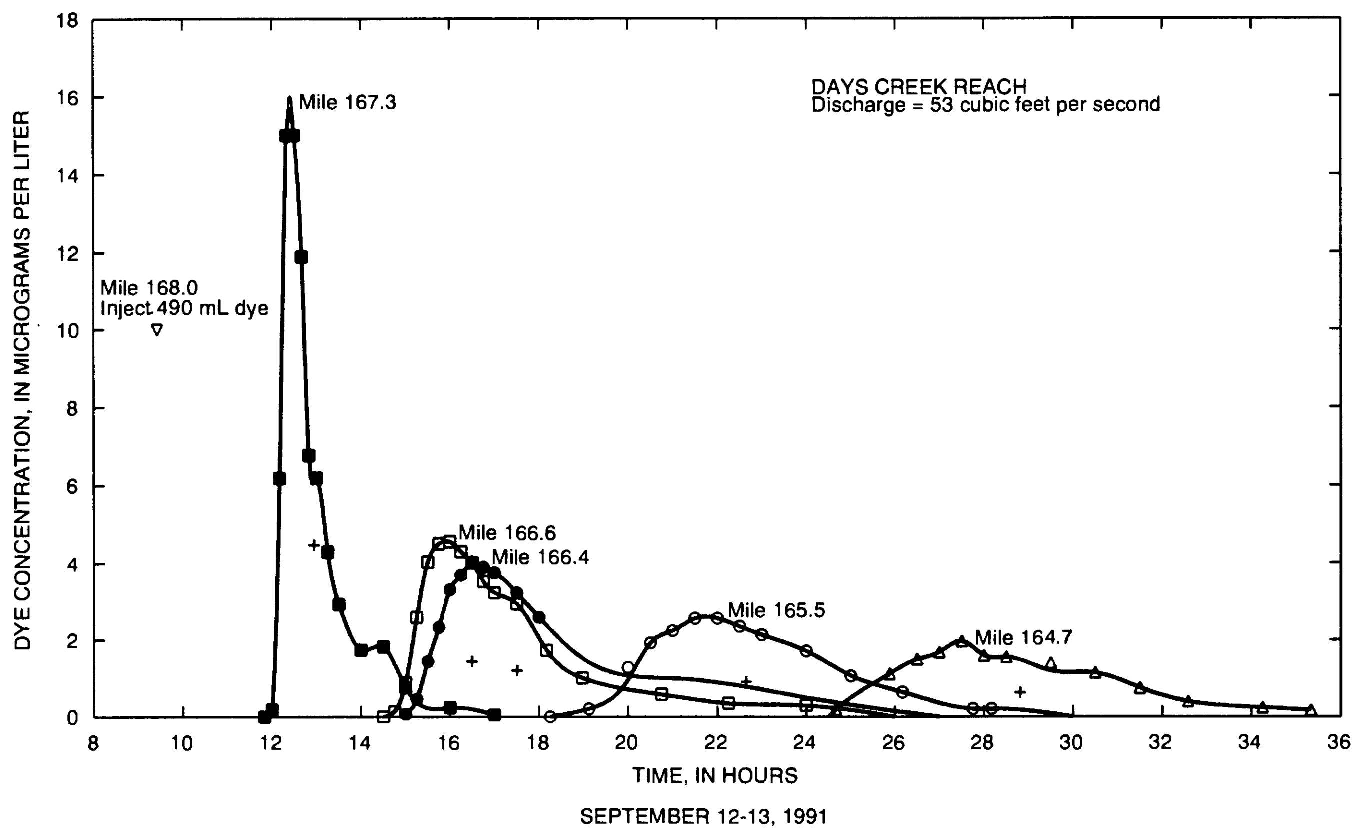


Figure 5. Time-concentration curves for the September 9-13, 1991 injection of rhodamine WT dye in the South Umpqua River





from river mile 130.7 to 167.0. The '+' is curve centroid.

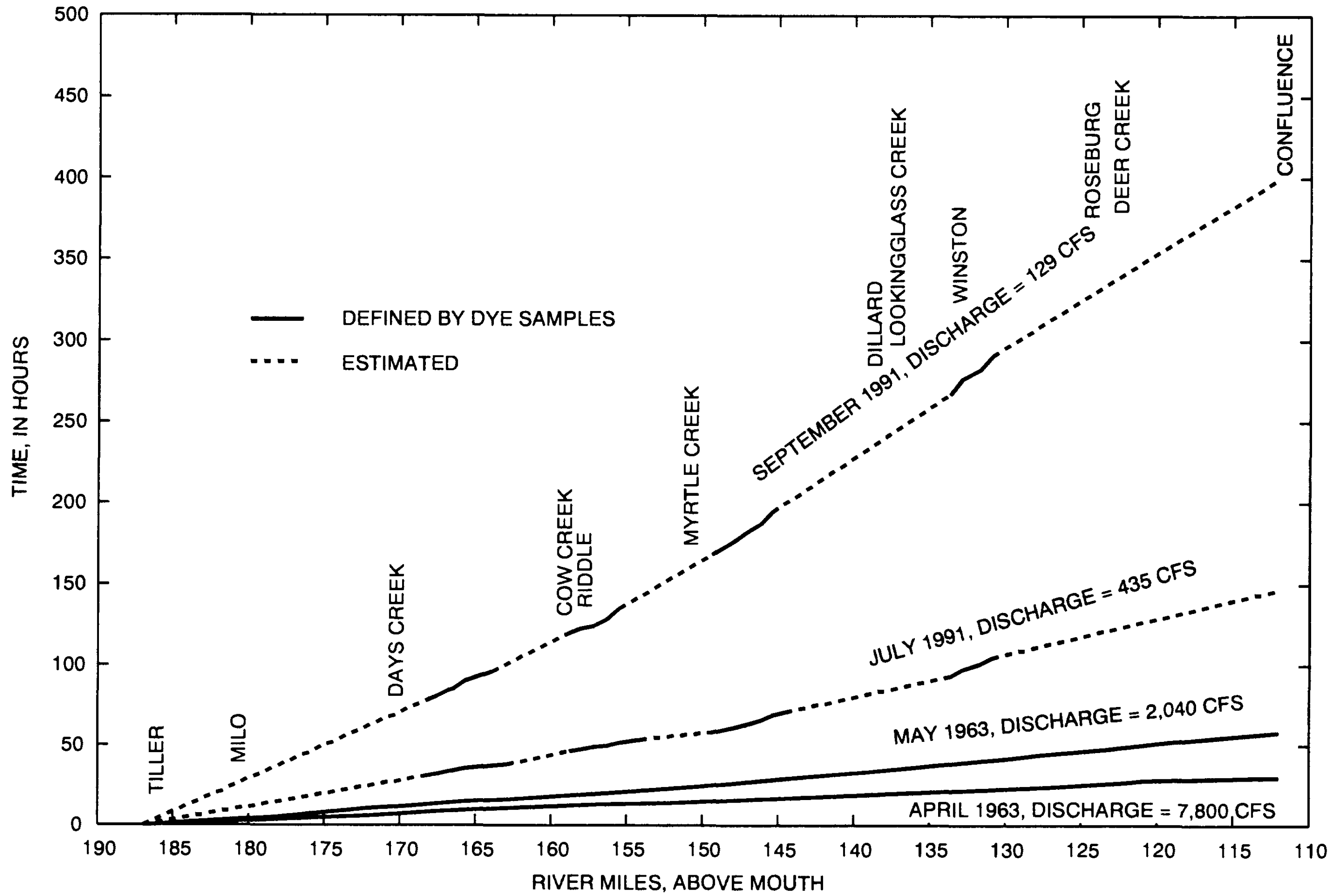


Figure 6. Time of travel of peak dye concentrations on the South Umpqua River from Tiller to the confluence with the North Umpqua River for selected discharges at the Brockway streamgage (14312000) at river mile 132.7.

Atmospheric-reaeration coefficients for specific reaches and discharges were determined from gas-desorption values obtained by field sampling for propane concentrations and analysis by gas chromatography. Generalized atmospheric-reaeration coefficients were then defined for the South Umpqua River for all reaches with respect to stream velocity, slope, and depth.

Atmospheric-reaeration coefficients (K_2) were determined for four reaches of the South Umpqua River for one low streamflow. Gas samples taken during the July 16-20, 1991, investigation were incomplete and could not be interpreted with any accuracy.

For the September 9-13, 1991, investigation, the average flow at Brockway was 129 ft^3/s, and at Tiller was 53 ft^3/s. Reaeration coefficients calculated from gas concentrations measured during the September investigation are listed in table 3. First, a propane coefficient (K_t) is calculated by the formula from Kilpatrick and others (1989):

$$K_t = \frac{1}{t_c} \ln \left(\frac{C_{gu} Q_u}{C_{gd} Q_d} \right) \qquad (2)$$

Table 3.--Reaeration coefficients calculated from propane concentrations sampled at selected reaches of the South Umpqua River, September 9-13, 1991

[μg/L = micrograms per liter; °C = degrees Celsius; Cr. = Creek]

Reach name	River mile	t_c 1/ (days)	C_{gu} 2/ (μg/L)	C_{gd} 3/ (μg/L)	K_t 4/ (per day)	Temperature (°C)	K_{t20} 5/ (per day)	$K_{2,20}$ 6/ (per day)
Winston	132.7-132.1	0.152	5.20	3.66	2.31	21.0	2.26	3.14
	132.1-131.5	.081	3.66	2.41	5.16	21.0	5.04	6.99
	131.5-130.7	.475	2.41	1.19	1.49	22.5	1.40	1.95
	132.7-130.7	.708	5.20	1.19	2.08	21.5	2.01	2.79
Myrtle Cr.	147.8-146.6	.319	5.10	3.09	1.57	20.5	1.55	2.15
	146.6-145.9	.129	3.09	2.55	1.49	20.0	1.49	2.07
	145.9-145.2	.410	2.55	1.54	1.23	19.0	1.26	1.75
	147.8-145.2	.858	5.10	1.54	1.40	20.0	1.40	1.95
Riddle	157.9-157.0	.146	12.10	4.87	6.23	21.5	6.01	8.35
	157.0-156.1	.096	4.87	2.96	5.19	21.5	5.01	6.96
	156.1-155.3	.231	2.96	2.48	.77	21.5	.74	1.03
	157.9-155.3	.473	12.10	2.48	3.35	21.5	3.23	4.49
Days Creek	167.3-166.6	.162	26.20	14.70	3.57	20.0	3.57	4.96
	166.6-166.4	.042	14.70	12.40	4.05	20.0	4.05	5.63
	166.4-165.5	.204	12.40	9.78	1.16	19.0	1.19	1.65
	165.5-164.7	.258	9.78	2.75	4.92	20.0	4.92	6.84
	167.3-164.7	0.661	26.20	2.75	3.41	20.0	3.41	4.74

1/ Time of travel between centroids from dye study.

2/ Upstream propane plateau concentration.

3/ Downstream propane plateau concentration.

4/ Gas desorption coefficient $K_t = 1/t_c[\ln(C_{gu}/C_{gd})]$.

5/ Gas desorption coefficient adjusted for temperature

$$K_{t20} = K_{ty}(1.0241)^{(20-y)}.$$

6/ Reaeration coefficient $K_{2,20} = 1.39\ K_{t20}$.

where,

K_t = the gas desorption coefficient (per day),
t_c = the time of travel between centroids of the dye cloud (days),
C_{gu} = the upstream measured plateau gas concentration at plateau ($\mu g/L$),
C_{gd} = the downstream measured plateau gas concentration at plateau ($\mu g/L$)
Q_u = the upstream measured discharge, and
Q_d = The downstream measured discharge.

Next, the gas desorption coefficient (K_t) is adjusted to a standard water temperature (20°C) value by the following formula (Kilpatrick and others, 1989):

$$K_{t20} = K_{ty} (1.0241)^{(20-y)} \qquad (3)$$

where,

K_{ty} = the gas desorption coefficient at field temperature y (per day), and

y = the field temperature (°C).

Finally, the gas desorption coefficient is converted to a reaeration coefficient by a relation developed in the laboratory between propane and air (Kilpatrick and others, 1989):

$$K_{2,20} = 1.39K_{t20} \qquad (4)$$

Calculated atmospheric-reaeration coefficients and associated stream parameters of velocity and depth are listed in table 4. The average atmospheric-reaeration coefficient for the Winston reach (RM 130.7 to 132.7) was 2.79/day, for the Myrtle Creek reach (RM 145.2 to 147.8) was 1.95/day, for the Riddle reach (RM 155.3 to 157.9) was 4.49/day, and for the Days Creek reach (RM 164.7 to 167.3) was 4.74/day. Individual subreach reaeration coefficients were plotted against a function of stream velocity and depth (see fig. 7) and compared to a conceptual formula by O'Connor and Dobbins (1958).

REAERATION COEFFICIENT MODELS

For selected reaches, table 4 shows the average velocity, depth, slope, reaeration coefficients determined from desorption data. Reaeration coefficients can be computed for two commonly used reaeration-coefficient equations. The first equation is a physically-based conceptual formula from O'Connor and Dobbins (1958):

$$K_2 = 13.82\, U^{0.5} H^{-1.5} \qquad (5)$$

Table 4.--Relation of reaeration coefficients determined from propane desorption data to mean velocities and average slope and depths of selected river reaches, South Umpqua River, September 9-13, 1991

Reach name	River mile	Reaeration coefficient (per day)	Mean velocity 1/ (feet per second)	Average depth 2/ (feet)	Slope3/ (feet per foot)	Channel configuration3/
Winston	132.7-132.1	3.14	0.29	1.7	0.0016	Mixed pool and
	132.1-131.5	6.99	.29	1.4	.0013	Falls and rapid
	131.5-130.7	1.95	.13	4.0	.0002	Long, deep pool
Myrtle Creek	147.8-146.6	2.15	.23	3.1	.0016	Mixed pool and
	146.6-145.9	2.07	.28	1.9	.0003	Mixed pool and
	145.9-145.2	1.75	.14	3.5	.0005	Mixed pool and
Riddle	157.9-157.0	8.35	.60	1.2	.0011	Run, riffle, ra
	157.0-156.1	6.96	.36	2.2	.0029	Riffles
	156.1-155.3	1.03	.21	3.3	.0017	Riffle, then de
Days Creek	167.3-166.6	4.96	.28	1.4	.0006	Mixed pool and
	166.6-166.4	5.63	.58	1.0	.0019	Falls and rapid
	166.4-165.5	1.65	.22	2.5	.0006	Deep pool
	165.5-164.7	6.84	.23	1.7	.0007	Shallow water

1/ Mean velocity from dye peak.
2/ Average depth for each reach using area computed from measured discharge and mean velocity, divided by widths measured in preliminary survey.
3/ Slope as determined from low water profile from Oster (1972).
4/ Channel configuration from preliminary survey.

where,

K_2 is the reaeration coefficient (per day),
U is the mean stream velocity (in ft/s), and
H is the average depth of flow (in feet).

The second equation is a semiempirical formula developed by Tsivoglou and Wallace (1972):

$$K_2 = 4656US \qquad (6)$$

where,

S is the average slope (in feet per foot).

The use of equations 5 and 6 with data collected in the field and averaged can produce variable results. Reaeration coefficients computed with these equations using average data compared with reaeration coefficients determined by field sampling are shown figures 7 and 8.

Use and accuracy of these equations and several other equations are discussed by Rathbun (1977). Reaeration coefficients determined by desorption data from this study confirmed the use of the conceptual formula (equation 5), but were approximately double the values derived from the semiempirical formula (equation 6) when applying average stream reach velocity, depth, and slope data. Generally, similar accuracy results were observed with the data used in Rathbun's study. Using these equations with available averaged stream parameter data results in error because the equations were developed for uniform reaches.

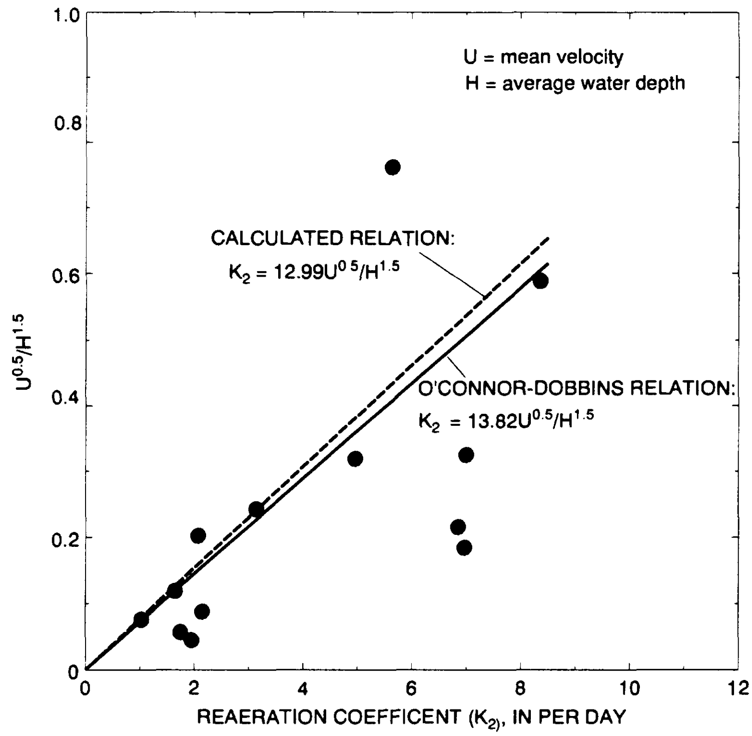


Figure 7. Reaeration coefficients (K_2) determined from desorption data compared to the O'Connor-Dobbins relation (1958).Mean velocity is defined by travel-time of dye, and average water depth is defined by taking the measured discharge divided by the product of the mean velocity times the average stream width. The calculated relation is defined by desorption data.

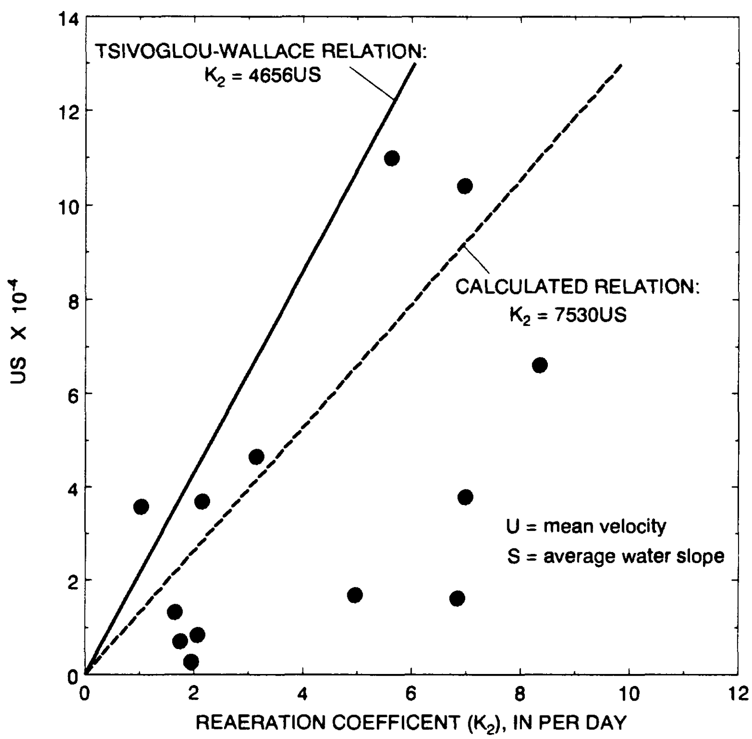


Figure 8. Reaeration coefficients (K_2) determined from desorption data compared to the Tsivoglou-Wallace relation (1972). Mean velocity is defined by travel-time of dye, and average water slope is defined by contours from 1:24,000 scale maps.The calculated relation is defined by desorption data.

A relation between mean velocity, slope and reaeration coefficient data (table 4) is shown in figure 8. Average slope (S) was determined from U.S. Geological Survey 1:24,000 scale topographic maps. The multiplier from this relation is 7,580, as compared with the multiplier of 4,656 of the Tsivoglou-Wallace formula. For the South Umpqua River between Roseburg and Tiller, a better formula than the Tsivoglou-Wallace formula would be:

$$K_2 = 7580US \qquad (7)$$

Reaeration occurs predominantly in riffle and shallow-water areas. If depth and velocity can be computed separately for these segments, and weighted as a percent of the time spent in each segment of the reach instead of using average reach values, reaeration coefficients computed by commonly-used formulas (equation 5) compare well with values derived from data collected during the reaeration study.

For example, the Days Creek reach between RM 166.6 and 166.4 is a series of 3 riffles and shallow pools in quick succession. The reach is nearly 50 percent riffle and 50 percent pool by length. The average velocity through the reach, as measured by the passage of dye through the reach on September 12, is 0.58 ft/s. If the mean velocity in the riffle section is estimated at 1.5 ft/s, the mean velocity in the pools is then estimated to be 0.36 ft/s. The average mid-channel depth of riffles in this reach is about 1.0 ft and about 3.0 ft in the pools. Considering depths were measured in mid-channel, a better estimate of mean depth would be 0.9 ft in riffle sections and 2.1 ft in pool sections because the riffle sections are rectangular and the pool sections are parabolic in shape. Respective reaeration coefficients can be computed, using the O'Connor-Dobbins equation, as 19.8/day in the riffle section and 2.93/day in the pool section. The time-weighted average for the computed reaeration coefficient in the pool and riffle sections is 6.03/day. This value is different than the reaeration coefficient of 10.5/day computed using equation 5 from stream reach mean velocity and average depth data found in table 4, and close to the coefficient of 5.63/day computed from gas-desorption data (table 4).

Riffles and their linear extent in a reach have a large influence on the magnitude of the reaeration coefficient. Using the example in the paragraph above as a case in point, the scatter shown in figure 7 can be explained. The one data point that falls far above the curve is computed with the average data of the example above. This reach had the greatest length of riffles of all reaches measured. Generally, those data points that fall on or near the curve had the most homogeneous depths throughout. Those data points below the curve had significant riffles, but they constituted only a small percentage of the overall reach length.

Limited desorption data, collected during higher flows in July at the time of the dye injection measurements, indicate that reaeration coefficients determined for July are approximately three to four times higher than those determined for the desorption data collected in September. Streamflows in July were about three times higher than flows in September, average stream velocities were about two times higher, and stream depths were only slightly greater. These data were not included because they were not complete.

SUMMARY

Rhodamine WT dye was injected in four reaches of the South Umpqua River between Tiller and Roseburg, Oregon, during July 16-20 and September 9-13, 1991. Study reaches were the Winston reach from river mile 130.7 to 133.5, the Myrtle Creek reach from river mile 144.4 to 149.2, the Riddle reach from river mile 153.9 to 158.6, and the Days Creek reach from river mile 164.7 to 168.0. Water samples were collected at selected locations and times within each reach and measured by fluorometer to determine dye concentrations and subsequent velocities.

For an average streamflow of 435 ft^3/s at the Brockway stream-gaging station (14312000) from July 16-19, 1991, stream velocities in the four selected reaches between Tiller (river mile 75.3) and Roseburg (river mile 12.0) were 0.68, 0.94, 0.56, and 0.35 ft/s, respectively. For an average streamflow of 129 ft^3/s at the Brockway gaging station at river mile 132.7 from September 9-13, 1991, stream velocities were 0.27, 0.35, 0.22, and 0.17 ft/s, respectively. Pool and riffle control dominated the flow throughout the study reach.

Propane gas was injected at a constant rate in each of the four study reaches and water samples were collected for gas chromatographic analysis. The resultant propane concentration data was used to calculate reaeration coefficients for the individual reaches.

Average reaeration coefficients determined from desorption data collected September 9-13, 1991, were found to be 2.79/day, 1.95/day, 4.49/day, and 4.74/day for the respective reaches. Reaeration coefficients determined from desorption data were approximately two times that of values derived from a semiempirical formula but generally confirmed a conceptual formula. Both formulas were developed for reaches of uniform geometry. Use of average values of slope, depth, and velocity, where channel geometry is nonuniform, can yield reaeration coefficients that can be considerably different than measured values. Average stream reach velocity, depth, and slope data from this study were used in both formulas.

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