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STREAM SURVEYS OF THE SHEEPSCOT AND DUCKTRAP RIVER SYSTEMS IN MAINE

By

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ABSTRACT

As part of a cooperative program to restore Atlantic salmon in Maine, the Fish and Wildlife Service and the Maine Sea Run Salmon Commission made stream surveys to collect information on obstructions to fish, pollution, water temperature, stream flow, and extent of spawning and rearing areas.

In the Sheepscot River system it was found that 14 out of 52 tributaries were seriously obstructed, and 20 had insufficient flows for salmon. Only 3 tributaries were considered to be of any value as salmon spawning and rearing areas. In addition to a very small number of salmon, a few shad, striped bass and alewives are found in the watershed. The abatement of pollution and the creation of adequate flows and passages for fish migration is recommended.

The Ducktrap River was found to have limited potentialities for salmon, the most inimical feature being low stream flows. Out of 19 tributaries, 4 were obstructed and 16 had flows too small for salmon. Only 2 were considered to have any value for salmon spawning and rearing. Provision of adequate passage facilities and the augmentation of flows is recommended.

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STREAM SURVEYS OF THE SHEEPSCOT AND DUCKTRAP RIVER SYSTEM IN MAINE

The U. S. Fish and Wildlife Service and the Atlantic Sea Run Salmon Commission conducted a cooperative investigation to determine methods for rehabilitating the Atlantic salmon in State of Maine waters. One phase of the program was concerned with stream surveys to collect information on obstructions to fish migration, pollution, water temperatures, and stream discharges. A further objective was to locate and to estimate the amount of spawning and rearing area that could be of use to salmon in each watershed.

This report summarizes the findings for the Sheepscot and Ducktrap Rivers.

John V. Mahoney helped collect data for this paper; J. E. Mason prepared the maps and revised the manuscript. Alden P. Stickney supplied information to make the description of the Sheepscot River and its obstructions correct as of 1956 and provided Figure 2. Acknowledgment is made of the information given and assistance rendered by members of the Lincoln County Fish and Game Association, and in particular to J. White Nichols and Clarence Race for their fact furnishing on the Sheepscot River. Mr. and Mrs. Arthur Oxton and Mr. Mark Wardsworth of Lincolnville Beach, gave much of their time assisting in the Ducktrap River area.

Methods

The procedures followed in these surveys were described in some detail in "A Survey of the Narraguagus River and Its Tributaries" by Floyd G. Bryant (Research Report No. 2, Atlantic Sea Run Salmon Commission). The first step was to classify a river section as either a pool or a riffle. The length and width of this area was then measured or otherwise determined and an estimate made of the percentage of the wetted river bottom covered by gravel classified as boulder rubble (stones larger than 18" in diameter), large rubbe rubble (stones 6-18" in diameter), medium rubble (stones 3-6" in diameter), small rubble (stones 1/4-3" in diameter), and mud and sand (stones or particles less than 1/4" in diameter). The localities of these data were recorded in miles above a designated landmark at or near the mouth of the river. This procedure made it possible to estimate the portions of the stream that were made up of pools or riffles and to estimate the square yards of spawning and/or nursery area in the different stream sections.

Concurrent with the observations on bottom composition, data were recorded on water depth, obstructions, water stage, water temperatures, gradient, pollution, predators, species of fish observed, and such other information as appeared pertinent.

The data relative to bottom composition are subject to errors of measurement, and to errors due to differences between observers and to differences in river discharge volumes on successive survey days. It is believed that these errors were minimized by observer training and that the net result is not of such magnitude as to prevent gross comparison of watersheds. A further limiting factor was that the survey year was the third of three successive years of low precipitation. As a result, the stream bottom normally wet is somewhat larger than indicated by the survey data.

Sheepscot River

General description

The Sheepscot River watershed was surveyed between June 13 and July 17, 1950. The survey started at the Alna (Public Dock) Bridge, defined as the mouth, and proceeded upstream to cover 24.5 miles of flowing water. Inspections of the stream were made at intervals in the succeeding 5.5 miles. The flow in the remaining approximately 9 miles to the source was considered too small and the channel too inaccessible to warrant the time and expense of a survey. No attempt was made to survey Sheepscot and Long Ponds on the main river, or the many small ponds on the tributaries.

The Sheepscot and its tributaries drain an area of about 228 square miles as shown in figure 1. The main river rises in small springs on Whitten Hill near West Montville at an elevation of about 620 feet. The river flows about 39 miles in a general southwesterly direction to Alna Bridge and then enters a long estuary above the town of Wiscasset in Lincoln County. The water is fresh at Alna Bridge although the effects of high tide were noted about 300 yards above the mouth of Trout Brook about 1.2 miles upstream.

In the lower 15 miles to Coopers Mill, the valley is one-fourth to 2 miles wide with bordering hills that gently slope to the river. The valley widens in the next 5 miles to a width ranging from 3 to 5 miles in the Long Pond and Sheepscot Pond area. Above Long Pond the valley narrows until it is generally from 100 to 300 yards wide from 29 to 35 miles above the mouth of the river. The upper 4 miles are in fairly steep hills with the main stem of the river little more than a spring-fed brook.

Along most of the stream there is a marginal band of thick brush, consisting mostly of alders, willows, poplar, and maple, with some conifers. The streambanks are typically earth and/or gravel. There are exceptions in the swampy areas near the larger ponds and in the sand-bank and ledge-rock outcrops near Head Tide, Whitefield, and Coopers Mills.

The area was once intensively farmed, and many grist and sawmills served the area. These are no longer operating, and many of the farms have been abandoned. Extensive areas are reverting to brush and woodland.

Width and depth

In the 21 miles below the Palermo Fish Hatchery the riffles were generally 20 to 60 feet wide and 2 inches to 1 foot deep. The deadwater sections and longer pools ranged from 30 to 80 feet wide and 2 to 5 feet deep with occasional holes 6 to 12 feet deep. With the exception of Coopers Mill Pond, Long Pond, and Sheepscot Pond, the stream decreased to a width ranging between 6 and 10 feet in the 14 miles above the Palermo Hatchery. The riffle areas ranged from 2 to 6 inches in depth and the pools ranged from 2 to 4 feet in depth with occasional holes up to 10 feet in depth. In the upper 4 miles of the stream the width and depth decreased until the stream was a series of small pocketlike pools and riffles. In the upper mile there was a series of small cascades.

Bottom composition

Table 1 presents a summary of the bottom composition in the pools and riffles in the surveyed sections of the Sheepscot watershed. The areas surveyed for bottom composition were on the main stem of the river and the West Branch only. While the sum of the flows of the numerous small tributaries made up the bulk of the discharge of the system, the individual streams were typically of such limited physical dimensions that they had little or no apparent use as past or potential producers of Atlantic salmon; hence they were not surveyed in detail. Table 2 presents a summary of the small tributaries, along with the factors, i.e. obstructions, total discharge, etc., affecting the stream as a salmon producer.

Stream flow

The survey crew measured the flow of the main river at North Whitefield on June 20, 1950, at 48.4 c.f.s. At this time the West Branch was flowing 17 c.f.s. or about 35 percent of the total river volume.

The records of the North Whitefield gauging station of the U. S. Geological Survey station show that the river discharge has ranged from a maximum of 5,260 second-feet to a minimum of 5 second-feet, with a mean of 206. The peak runoffs are typically in March and April following the spring thaws. The minimum flows

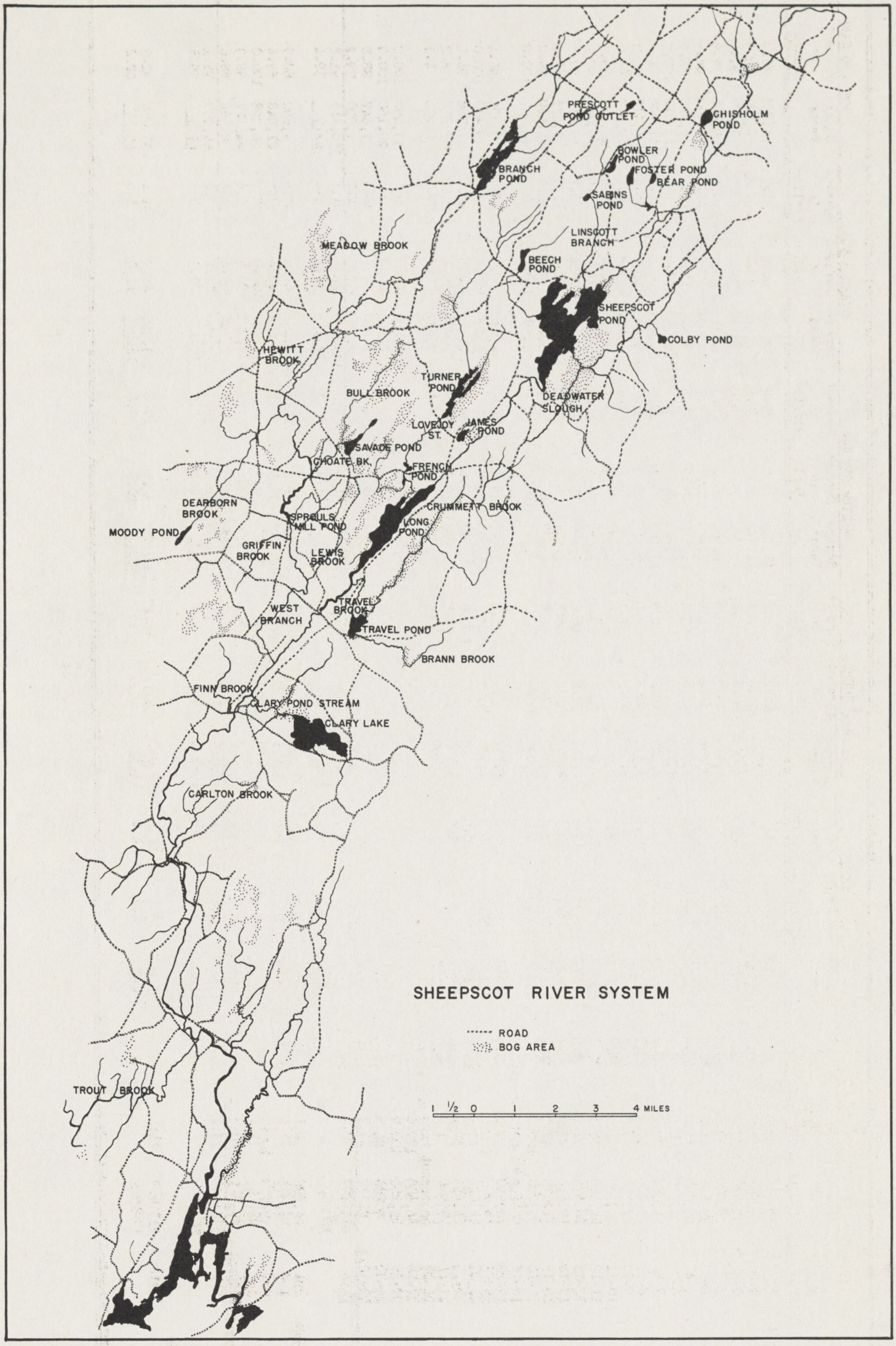

Figure 1.--Map of Sheepscot River

Table 1.- Summary of bottom composition of parts of the Sheepscot River and its principal tributary, the West Branch.

	Miles Above Mouth	TOTAL BOTTOM AREA			BOULDER RUBBLE			LARGE RUBBLE			MEDIUM RUBBLE			SMALL RUBBLE			MUD AND SAND		
		Square Yards	Percent in Pools	Percent in Riffles	Square Yards	Percent in Pools	Percent in Riffles	Square Yards	Percent in Pools	Percent in Riffles	Square Yards	Percent in Pools	Percent in Riffles	Square Yards	Percent in Pools	Percent in Riffles	Square Yards	Percent in Pools	Percent in Riffles
Main River	0-1	47,375	73.9	26.1	88	100.0	0	5,427	66.2	33.8	12,749	71.0	29.0	12,208	64.9	35.1	16,903	85.0	15.0
	1-2	33,955	30.1	69.9	1,921	36.3	63.7	6,889	25.6	74.4	14,584	25.4	74.6	4,440	32.4	67.6	6,121	42.9	57.1
	2-3	32,910	27.3	72.7	3,891	15.1	84.9	4,767	20.6	79.4	9,705	25.6	74.4	7,540	31.1	68.9	7,007	37.2	62.8
	3-4	28,270	36.6	63.4	5,045	10.2	89.8	5,343	9.7	90.3	6,964	29.7	70.3	4,312	48.0	52.0	6,606	78.3	21.7
	4-5	37,610	61.2	38.8	2,135	53.9	46.1	3,234	35.6	64.4	11,316	40.7	59.3	7,992	57.6	42.4	12,933	88.9	11.1
	5-6	43,890	39.0	61.0	7,290	53.6	46.4	7,975	36.6	63.4	15,610	26.9	73.1	7,575	40.8	59.2	5,440	55.0	45.0
	6-7	37,530	100.0	0	0			3,753			7,506	100.0	0	11,259	100.0	0	15,012	100.0	0
	7-8	51,385	79.2	20.8	6,200	67.0	33.0	8,449	58.0	42.0	12,182	79.1	20.9	13,345	85.3	14.7	11,209	94.9	5.1
	8-9	25,200	50.8	49.2	3,160	21.5	78.5	3,370	38.0	62.0	6,570	49.3	50.7	5,190	60.9	39.1	6,910	64.3	35.7
	9-10	27,660	83.7	16.3	905		100.0	3,919	67.9	32.1	6,192	76.6	23.4	7,281	93.8	6.2	9,363	95.2	4.8
	10-11	44,127	61.2	38.8	3,014	15.0	85.0	5,792	33.3	66.7	9,994	43.3	56.7	9,515	64.4	35.6	15,812	89.6	10.4
	11-12	41,400	79.1	20.9	3,319	47.8	52.2	7,072	70.7	29.3	7,534	53.4	46.6	3,626	77.1	23.9	19,849	97.6	2.4
	12-13	28,675	91.0	9.0	572	34.1	65.9	2,041	59.6	40.4	3,699	78.8	21.2	6,548	97.1	2.9	15,815	97.5	2.5
	13-14	19,410	49.3	50.7	424	76.9	23.1	4,547	51.9	48.1	7,544	38.2	61.8	3,460	48.7	51.3	3,435	67.1	32.9
	14-15	31,070	47.1	52.9	7,855	24.6	75.4	6,183	32.2	67.8	8,002	45.1	54.9	4,090	58.8	41.2	4,940	95.2	4.8
	15-16	53,950	100.0	0	5,395	100.0	0	2,898	100.0	0	5,395	100.0	0	5,795	100.0	0	34,467	100.0	0
	16-18	Long pond not surveyed.																	
	19-20	14,250	70.7	29.3	360	0	100.0	1,168	4.5	95.5	2,293	19.4	80.6	1,033	50.3	49.7	9,396	96.4	3.6
	20-21	59,300	100.0	0	1,190	100.0	0	2,380	100.0	0	3,220	100.0	0	2,680	100.0	0	49,830	100.0	0
	21-22	16,025	83.3	16.7	100	0	100.0	28	0	100.0	1,600	39.8	60.2	2,529	52.6	47.4	11,768	96.7	3.3
	22-23	14,595	17.0	83.0	1,889	5.2	94.8	3,197	6.5	93.5	4,966	18.1	81.9	2,285	18.1	81.9	2,258	38.2	61.8
	23-24	17,990	1.0	99.0	2,384			5,160	0.5	99.5	4,580	0.6	99.4	3,632	0.8	99.2	2,234	4.3	95.7
	24-27	Sheepscot pond not surveyed.																	
	27-28	66,600	100.0	0	0			0			6,660	100.0	0	6,660	100.0	0	53,280	100.0	0
	28-29	25,200	100.0	0	0			0			2,520	100.0	0	2,520	100.0	0	20,160	100.0	0
	29-30	9,986	84.0	16.0	125	100.0	0	125	100.0	0	509	68.8	31.2	1,580	63.5	36.5	7,647	88.8	11.2
	30-30.5	8,539	47.7	52.3	456	36.8	63.2	1,331	29.0	71.0	2,651	36.5	63.5	2,180	47.3	52.7	1,920	79.2	20.8
Total	24.5	816,902	70.1	29.9	57,718	40.3	59.7	95,048	44.3	55.7	174,545	51.6	48.4	139,276	68.5	31.5	350,315	91.8	8.2
Percent		100.0			7.1	2.8	4.2	11.7	5.2	6.5	21.3	11.0	10.3	17.1	11.7	5.4	42.9	39.4	3.5
West Branch	0-1	24,800	50.1	49.9	3,994	28.9	71.1	7,030	22.4	77.6	5,633	58.4	41.6	3,451	64.4	35.6	4,692	88.9	11.1
	1-2	27,975	75.4	24.6	589	0	100.0	1,636	7.0	93.0	2,207	32.5	67.5	1,695	42.4	57.6	21,848	89.4	10.6
	2-3	30,220	100.0	0	0	0	0	338	100.0	0	1,827	100.0	0	1,827	100.0	0	26,228	100.0	0
	3-4	29,465	94.0	6.4	330	47.3	52.7	764	44.5	55.5	972	52.5	47.5	3,272	90.4	9.6	24,127	98.3	1.7
	4-5.1	26,261	70.9	29.1	970	49.2	50.8	5,281	60.4	39.6	7,801	64.0	36.0	3,745	65.6	34.4	8,464	88.6	11.4
Total	5.1	138,721	79.3	20.7	5,883	30.4	69.6	15,049	36.9	63.1	18,440	61.5	38.5	13,990	72.8	27.2	85,359	95.1	4.9
Percent		100.0			4.2	1.3	3.0	10.8	4.0	6.8	13.3	8.2	5.1	10.1	7.3	2.7	61.5	58.5	3.0
Watershed Total	29.6	955,623	71.4	28.6	63,601	39.4	60.6	110,097	43.3	56.7	192,985	52.6	47.4	153,266	68.9	31.1	435,674	92.5	7.5
Percent		100.0			6.7	2.6	4.0	11.5	5.0	6.5	20.2	10.6	9.6	16.0	11.0	5.0	45.6	42.2	3.4

Table 2.--A summary of conditions limiting Atlantic salmon production in tributaries of the Sheepscot River.

Name of Tributary	Miles Above Mouth	Obstructed by Man-made Structure	Insufficient Flow for Salmon Migration	Estimated Discharge c.f.s.	Of Little or No Value to Salmon
Trout Brook	0.8		x	1.0	x
Unnamed Tributary	1.7	x	x	1.0	x
Five Unnamed Tributaries	1.7-6.3		x	1.0	x
Carlton Brook	6.7		x	1.5	x
Three Unnamed Tributaries	9.4-10.2		x	1.0	x
Finn Brook	11.0		x	1.0	x
Clary Pond Stream	11.4	x		---	x
Clary Pond				---	x
West Branch of Sheepscot	12.6	x		28	
Lewis Brook	3.5			1.0	x
Griffin Brook	4.7	x	x	3.0	x
Sprouls Mill Pond	5.2	x			x
Choate Brook	6.8			2.0	x
Bull Brook			x		x
Savade Pond			x		x
Dearborn Brook	9.3				x
Moody Pond					x
Hewitt Brook	10.5				x
Unnamed Tributary			x		x
Meadow Brook	12.8			1.0	x
Branch Pond	18.4	x			x
Prescott Pond Outlet	22.4	x		1.0	x
Travel Brook	15.8				x
Travel Pond					x
Black Brook					x
Crummett Brook					x
Brann Brook					x
Long Pond	16.0				?
Lovejoy Stream	18.4		x	5.0	x
Dodge Pond		x			x
French Pond		x	x		x
Turner Pond		x	x		x
James Pond Outlet	20.7				x
James Pond					x
Unnamed Tributary	22.2				x
Sheepscot Pond	24.0			20.0	?
Colby Brook	25.6				x
Deadwater Slough				3.0	x
Beech Pond Outlet	26.1		x		x
Beech Pond					x
Linscott Branch	26.7		x	2.0	x
Sabins Pond		x			x
Bowler Pond Outlet			x		x
Bowler Pond		x			x
Tobey Brook	29.9		x	1.0	x
Jump Pond Outlet					x
Foster Pond		x			x
Bear Pond		x			x
Chisholm Pond Outlet	32.0		x	1.0	x
Chisholm Pond					x
Unnamed Tributary	34.8		x		x
Unnamed Tributary	36.6		x		x

usually occur in September and October after prolonged dry periods. Figure 2 shows the seasonal trend for 1956.

Temperatures

Observed water temperatures of the main river ranged from 62° F. to 75° F. during the period of survey. These observations have been supplemented by a more extensive series of thermal data recorded on a thermograph. The daily water temperatures for part of a single year are shown in figure 2. Other thermograph records have been made in various sections of the river at other times. Temperatures seldom exceed 80° F. except in the quiet sections of the river, particularly the tidal portion. The highest recorded temperature was 88° F., an extreme of only a few hours' duration.

Obstructions

Table 3 presents a summary of past and present obstructions to fish migration, their location, description, possible effects, and recommendations for treatment. There are 11 such sites on the main river, 4 on the West Branch, and 9 on the other tributaries. Seventeen of the 24 obstructions to fish migration were man-made.

Diversions

There are no diversions that remove water from the watershed. There have been mills where the water has been bypassed through turbines for power production only to be returned to the river. At present the Palermo Hatchery withdraws some 2,000 g.p.m., of cool water from below the surface of Sheepscot Pond. This water is returned to the river after passing through the hatchery.

Pollution

Garbage dumps were found along the stream about 950 yards above Alna Bridge and at Whitefield and Coopers Mill. Below Sprouls Mill Dam on the West Branch some of the riffles were cluttered with tin cans and other debris.

Sawdust was observed along the banks at 9.1, 11.3, and 13.3 miles above the mouth; that at 11.3 miles apparently was carried in from Chases Mill on Clary Stream in past years.

Predators

The only salmon predators, other than fish, observed in the watershed were American mergansers. The Sheepscot serves not only as a feeding area but as a breeding area of these birds.

Fish present

The various species of fish seen during the survey are shown in table 4, along with the stream sections where they were observed. Relatively few salmonoids or warm-water game fish other than pickerel were seen. Chub, dace, shiners, and minnows seemed particularly abundant in some areas.

A few shad (Alosa sapidissima), striped bass (Roccus saxatilus), and Atlantic salmon are taken in sport or commercial fisheries in the Sheepscot or its estuary. The reported numbers vary from none to six or so for each species per year.

The earlier records indicate that the Sheepscot was probably the best producer of Atlantic salmon of the many small streams found between the Kennebec and Penobscot Rivers. The highest recorded catch before 1948 was that of 1872 when "12 to 15 salmon" were caught. Since then the numbers on record have varied from none to four per year. Since 1948, the river has been stocked annually with from 10 to 30 thousand young salmon. The returns have been rather small and erratic; although about 12 were caught on hook and line in 1954 and at least as many more ascended the river to spawn. Some of the latter were caught the following spring as kelts. A counting weir has recently been constructed by the U. S. Fish and Wildlife Service to obtain information on the migration and survival of salmon.

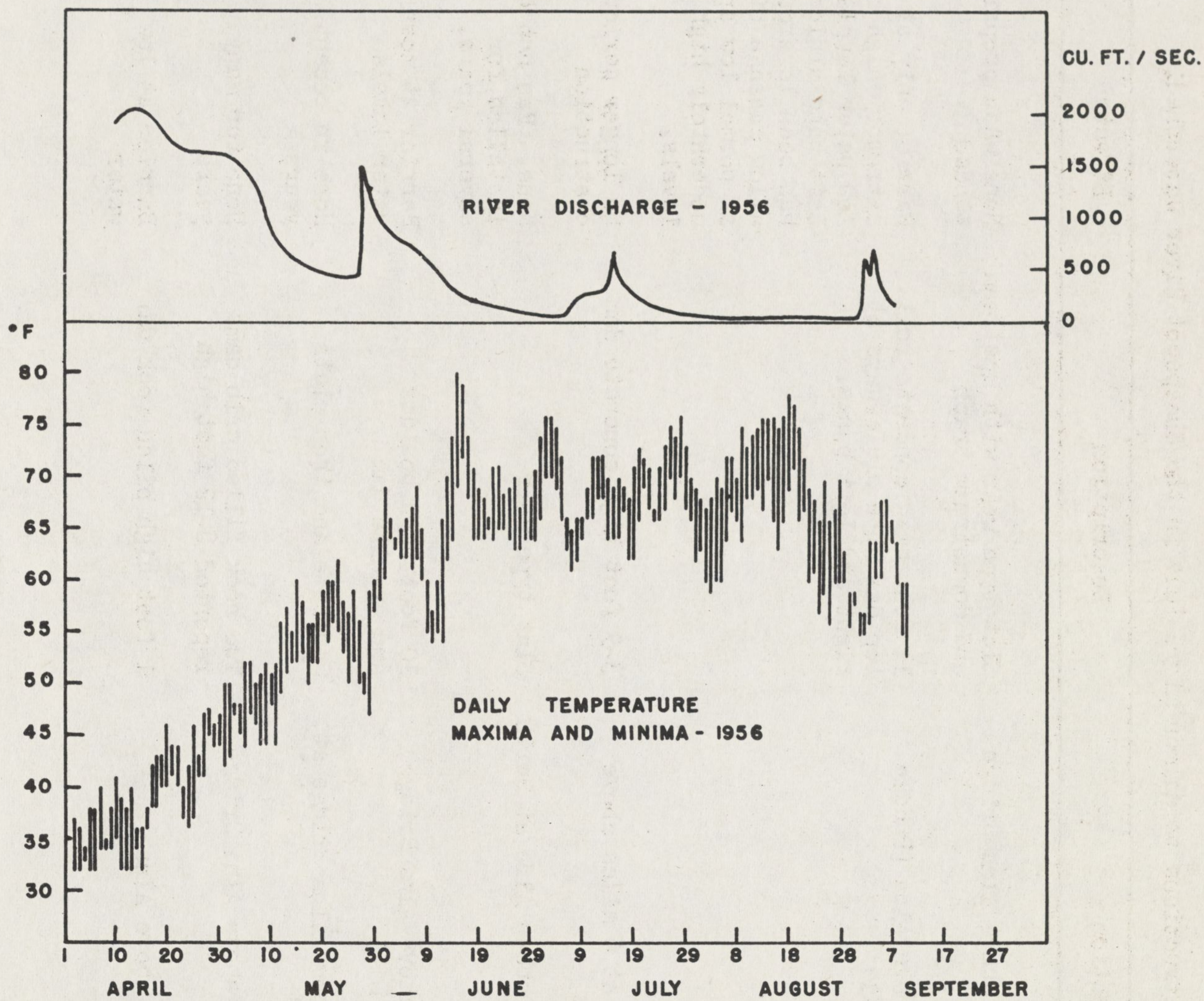

Figure 2.--Daily water temperatures and discharge volume of the Sheepscot River for the spring and summer of 1956.

Temperatures recorded at Whitefield, Maine.
Discharge recorded at Alna, Maine.

Table 3.--Past and present obstructions to salmon migrations in the Sheepscot River watershed.

Name or Type	Location	Description	Effects	Recommendations
MAIN RIVER				
Counting weir	0.7 Miles above Alna Bridge	Slat-type weir with upstream and downstream traps	None when properly tended	None
Head Tide Dam	2 Miles above Alna (Puddle Dock) Bridge	11 foot high concrete roll top dam with sluiceways at right and left banks.	Barrier only at extremely high or low water levels. Left hand sluiceway has been lowered to allow passage of fish at normal low and moderately high water levels.	Keep passages free of debris. Fishway desirable but not necessary.
Kings Mill Dam	Whitefield at 6 miles above Alna Bridge	3-9 foot high concrete dam	No longer serious obstruction	None
Eel Weir	10.9 Miles above Alna at North Whitefield	Slat type weir	None. Has not been installed for several years.	None
Coopers Mill	14½ Miles above Alna Bridge at Coopers Mill	10 foot high boulder and granite dam	Barrier at most water levels	Fishway improvement
Fish Screen	15 Miles above Alna Bridge at the "Basin"	Concrete and iron slats	None in recent years	None
Mill Dams	19.7 Miles above Alna Bridge	Two rock filled crib dams reported 8-12 feet high	None for many years	None
Rock Dam	20.0 Miles above Alna	1 foot high piled rock dam	Barrier at low water	Open a channel through

Table 3.--(Continued)

Name or Type	Location	Description	Effects	Recommendations
Shallow Channel	20.7 Miles above Alna Bridge	Broad flat weed choked channel	Difficult passage	Open a channel and maintain
Two Beaver Dams	21.1 Miles above Alna Bridge	8" and 2½' high active Beaver Dams	Barrier at low water levels	Further study
Hatchery Dam	23.8 Miles above Alna Bridge at Palermo Hatchery	51" high roll top concrete dam	None when fishway regulated	Regulate fishway
Mill Dams	Two, formerly located 30½ miles up	Piled rock	None for many years	None
<u>WEST BRANCH</u>				
Ledge Rock Rapids	235-460 Yards above mouth	Cascades and falls over ledge rock	Difficult passage at low water	Channelization
Sprouls Mill Dam	5.2 Miles above mouth of West Branch	8½-9 foot stone dam	None. H as been breached. A small, home-made, stone and log dam just below it may provide a barrier at low water.	Remove small dam
Weeks Mill Dam	12.2 Miles up	Stone dam reported 6 feet high, now breached	Difficult passage at low water	Deepen channel
Branch Mill (Dinsmore Mill)	18.4 Miles up at outlet of Branch Pond	8-10 foot high stone dam	Barrier	Remove, or install fishway

Table 3.--(Continued)

Name or Type	Location	Description	Effects	Recommendations
TRIBUTARY STREAMS				
Unnamed Tributary	1.7 Miles up main river	Natural falls at mouth of stream	Barrier	Further study
Clary Pond Stream	11.4 Miles up main river	6' dam at Chases sawmill 200 yds. above mouth of stream	Barrier	Further study
Clary Pond Stream	Above Chases sawmill	6-8 foot high water storage dam	Barrier	Further study
Griffin Brook	4.7 Miles up West Branch	Natural falls ½ mile above mouth	Barrier at low water	Further study
Lovejoy Stream	18.4 Miles up main river	Dodges Shingle Mill Dam 3/4 mile above mouth 8' high	Barrier	Further study
Lovejoy Stream	Frenches Mill Dam 1.2 miles up Lovejoy Stream	8-10 foot high stone dam	Barrier at least at low water levels	Further study
Lovejoy Stream	Colby's Mill Dam 2.7 miles up Lovejoy Stream	11 feet high	Barrier	Further study
Linscott Brook	26.7 Miles up main river	Cascade area about 1 mile above mouth	Barrier at low water	Further study
Outlet Stream from Foster Pond	Enters Tobey Brook 24.9 miles up main river	Natural falls	Barrier	Further study

Table 4.—Fish observed and their location during the survey of the Sheepscot River Watershed.

Name	Sheepscot R.	Trout Brook	West Br.	Lewis Brook	Savade Pond	Prescott Pond	Sheepscot Pond	Bowler Pond	Chisholm Pond
Alewife (Pomolobus pseudo harengus)	x								
Bass, Small Mouth (Micropterus dolomieu)	x						x	x	
Blueback (Pomolobus aestivalis)	x								
Bullhead, Brown (Ameiurus nebulosus)	x								
Chub, Creek (Semotilus atromaculatus)	x		x		x				
Dace (Cyprinidae)	x								
Eel (Anguilla bostoniensis)	x								
Killifish (Fundulus)	x		x						
Lamprey (Petromyzon marinus)	x								
Perch, Yellow (Perca flavescens)	x								x
Perch, White (Morone americana)	x								x
Pickerel, Chain (Esox niger)	x		x		x				x
Salmon, Atlantic (Salmo salar salar)	x								
Salmon, Landlocked (Salmo salar sebago)	x								
Shiners (Cyprinidae)	x		x			x			
Suckers, White (Catostomus commersonnii)	x								
Sunfish (Lepomis sp.)									x
Trout, Brown (Salmo trutta)	x	x	x	x					
Trout, Eastern Brook (Salvelinus fontinalis)	x		x		x				

Summary

From tables 1 and 2 it may be seen that of the 52 tributaries of the main river, 14 are listed as having obstructions to fish migration at or near the mouth of the stream, 20 of the 52 had insufficient flow for salmon migration, 49 of the streams were deemed of little or no value as spawning or rearing areas, while an additional two were of questionable value. Only the West Branch in addition to the main river was thought to have material value as a possible salmon producing area.

Reference to table 3 will show that there are 20 locations where fish migration is either obstructed or questionable. Seven of these locations are on the main river; the most severe are Head Tide Dam, Kings Mill Dam, and Coopers Mill Dam.

From the above information it is apparent that the Sheepscot River has a fairly small watershed with comparatively small discharges other than during the peak-run-off periods. The low flows that prevail during the period when adult salmon may be migrating upstream make the obstructions even more hazardous and extensive. While these obstructions do aid in supplementing minimum flows from the reservoir effect of stored water, it is apparent that this contribution is negligible in those areas which may presently be considered accessible to salmon on even rare occasions.

The available history indicates that a few shad, striped bass, and alewives, as well as Atlantic salmon, may be found in the watershed. It is not now possible to state whether all of these anadromous species were native to the area or were strays into the area. The presence of the alewife may be of importance in view of their role in the economy of other sections of Maine. The rather extensive pond and lake areas indicate the possibility of developing a local alewife fishery that may become of value. This possible extension of the alewife as well as other anadromous runs of fish cannot be made in the face of existing barriers to fish migration.

Recommendations

The following recommendations are made as a result of the survey:

1. That adequate fish-passage facilities be provided at Head Tide Dam and at other obstructions in the river as needed for possible extension of the anadromous fishery resources of the watershed.

2. That creation or extension of water impoundments be investigated as a means of supplementing normal stream flows during low-water seasons.

3. That fish-passage facilities and other improvements be developed as multiple-purpose projects particularly with the thought of creating a commercial alewife fishery as well as improving the status of Atlantic salmon and other anadromous species.

4. That the dumping of garbage and sawdust into the river and its tributaries be stopped.

The Ducktrap River

The Ducktrap River and its tributaries were surveyed on July 10 to 13, 1950, by Floyd G. Bryant and John V. Mahoney. The survey extended from the mouth where U. S. Route 1 crossed the river near Lincolnville to the site of an old mill 6.7 miles above the mouth. Above this area the prolonged drought had reduced the stream flow to a point where it was impossible to determine normal stream characteristics. Areas below Tilden Pond were inspected, as were parts of tributaries where the flow was insufficient to justify the time and expense of a survey.

General description

The Ducktrap River as shown in figure 3, runs from its source in Tilden Pond for about 10 miles in a southeasterly direction to empty into Penobscot Bay near Lincolnville. The watershed drains an area of about 36 square miles.

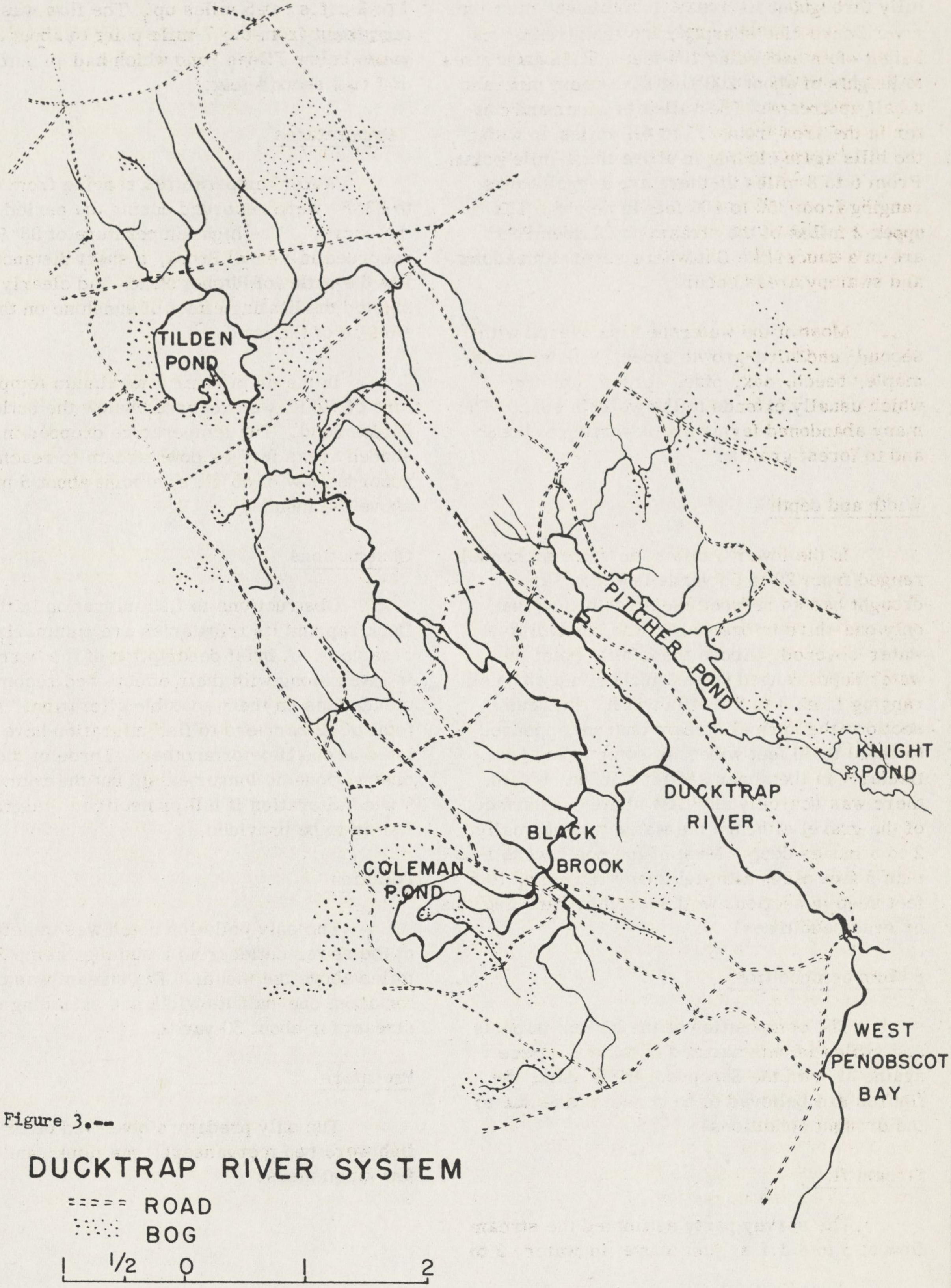

Figure 3.--

DUCKTRAP RIVER SYSTEM

The watershed is generally rugged and hilly throughout its area. In the lower mile the river banks rise sharply from the stream to a height often exceeding 100 feet. The banks rise to heights of about 200 feet in the next mile and a half upstream. The valley is wider and flatter in the area from 2.5 to 4.0 miles up with the hills again closing in above the 4-mile point. From 6 to 8 miles up there are rugged banks ranging from 350 to 600 feet in height. The upper 2 miles of the stream and Tilden Pond are in a saucerlike flat where several meadows and swampy areas occur.

Most of the watershed is covered with second- and third-growth alder, willow, birch, maple, beech, oak, pine, spruce, and fir, which usually extends to the water's edge. The many abandoned farms are reverting to brush and to forest growth.

Width and depth

In the lower 3 miles the stream channel ranged from 20 to 50 yards in width, but drought had so reduced the stream flow that only one-third to one-half of the channel was water-covered. Above the 3-mile point the water depth ranged up to 3 inches in a channel ranging from 3 to 5 feet in width. In these sections the normal stream channel appeared to be 10 to 30 feet wide. In some areas, particularly in the upper sections of the stream, there was scarcely any flow above the surface of the gravel although the water was normally 2 to 5 inches deep. Most of the pools were less than 3 feet deep, although many ranged up to 6 feet deep in sections well shaded by bank growths or brush and trees.

Bottom composition

The composition of the bottom in pools and riffles is summarized in table 5. Here again, as with the Sheepscot River data, the figures are believed to be conservative due to the drought conditions.

Stream flow

The survey party estimated the stream flow at 5 to 8 c.f.s. just above tidewater, 2 to 3 c.f.s. at a point 3 miles above the mouth and 1 to 2 c.f.s. at 5 miles up. The flow was intermittent from the 7-mile point to about 300 yards below Tilden Pond which had an outflow of 1 to 2 second-feet.

Temperatures

Water temperatures ranging from 65° F. to 83° F. were recorded during the period of the survey. The high temperature of 83° F. was recorded in Kendal Brook, a short distance below the outlet of Pitcher Pond, and clearly showed the heating effect of sunshine on the surface of the pond.

In the main river a maximum temperature of 79° F. was recorded below the outlet of Tilden Pond. The temperature dropped in the shaded areas further downstream to reach a recorded low of 65° F. at a point about 5 miles above the mouth.

Obstructions

Obstructions to fish migration in the Ducktrap and its tributaries are summarized in table 6. A brief description of the barriers is given along with their effects and recommendations on their possible alteration. A total of 12 barriers to fish migration have existed at one time or another. Three of the obstructions no longer exist, but the remaining 9 need alteration if full protection to migrating fish is to be provided.

Pollution

The only pollution noted was the effluent of the sewer outlet from a summer camp 2.8 miles above the mouth. The stream was clouded for about one-half its width and extending downstream for about 50 yards.

Predators

The only predators observed other than fish were two mergansers, one mink, and a few kingfishers.

Table 5.--A summary of the bottom composition of surveyed stream sections in the Duck Trap River watershed.

	Miles Above Mouth	TOTAL BOTTOM AREA Square Yards	Percent in Pools	Percent in Riffles	BOULDER RUBBLE Square Yards	Percent in Pools	Percent in Riffles	LARGE RUBBLE Square Yards	Percent in Pools	Percent in Riffles	MEDIUM RUBBLE Square Yards	Percent in Pools	Percent in Riffles	SMALL RUBBLE Square Yards	Percent in Pools	Percent in Riffles	MUD AND SAND Square Yards	Percent in Pools	Percent in Riffles
Main River	0-1	44,440	32.6	67.4	9,682	15.0	85.0	13,332	32.6	67.4	13,332	32.6	67.4	4,772	60.8	39.2	3,322	43.6	56.4
	1-2	20,810	6.4	93.6	7,867	6.9	93.1	5,657	5.9	94.1	3,739	5.8	94.2	2,370	4.7	95.3	1,177	10.7	89.3
	2-3	23,585	67.7	32.3	2,563	22.2	77.8	1,560	31.0	69.0	2,314	45.2	54.8	2,757	68.8	31.2	14,391	83.2	16.8
	3-4	15,130	71.4	28.6	36	100.0	-	1,196	91.3	8.7	648	19.8	80.2	1,721	62.8	37.2	11,529	73.4	26.6
	4-5	9,180	36.8	63.2	617	1.3	98.7	521	7.1	92.9	1,787	28.2	71.8	2,065	50.5	49.5	4,190	42.6	57.4
	5-6	9,660	16.6	83.4	1,232	13.1	86.9	2,127	14.1	85.9	4,321	16.1	83.9	1,404	18.4	81.6	576	31.8	68.2
	6-6.7	5,955	75.7	24.3	145	100.0	-	538	40.5	59.5	974	41.9	58.1	1,134	66.1	33.9	3,164	94.3	5.7
Total	6.7	128,760	40.5	59.5	22,142	13.2	86.8	24,931	27.3	72.7	27,115	27.1	72.9	16,223	49.6	50.4	38,349	70.3	29.7
Percent		100.0			17.2	2.3	14.9	19.4	5.3	14.1	21.1	5.7	15.4	12.6	6.2	6.4	29.8	20.9	8.8
Kendal	0-1	7,425	1.6	98.4	2,408	0.5	99.5	2,026	1.2	98.8	1,717	2.8	97.2	908	1.3	98.7	366	6.6	93.4
Stream	1-2	4,820	73.4	26.6	158	0	100.0	313	8.6	91.4	489	27.6	72.4	712	61.1	38.9	3,148	93.5	6.5
Total	2.0	12,245	29.9	70.1	2,566	0.5	99.5	2,339	2.2	97.8	2,206	8.3	91.7	1,620	27.6	72.4	3,514	84.4	15.6
Percent		100.0			21.0	0.1	20.9	19.1	0.4	18.7				13.2	3.7	9.6	28.7	24.2	4.5
Watershed Total	8.7	141,005	39.5	60.5	24,708	11.8	88.2	27,270	25.2	74.8	29,321	25.7	74.3	17,843	47.6	52.4	41,863	71.5	28.5
Percent		100.0			17.5	2.1	15.4	19.3	4.9	14.5	20.8	5.3	15.5	12.7	6.0	6.6	29.7	21.2	8.5

TABLE 6. PAST AND PRESENT OBSTRUCTIONS ON THE DUCKTRAP RIVER AND ITS TRIBUTARIES

Name or Type	Location	Description	Affects	Recommedations
Fish weir	About 250 yds. up from mouth	Wire and net alewife weir	Barrier when in operation	Provide salmon passage
Ledge Chute	1.2 Miles up	Ledge outcrop drops 4 feet in 30 feet	Barrier at low water levels	Channelization
Turner Falls	2.0 Miles up	Ledge rock area 270 yds. long	Barrier at low water levels, Nearly all spawning area locaed above	Channelization
Log and Debris	4.0 Miles up	Log and debris jam	Barrier at low water levels	Removal
Former Dam	6.1 Miles up	Unknown	Past Barrier Presently a barrier at low water levels	Channelization
Former Mill Dam	6.2 Miles up	Granite dam over 6 feet high	Former barrier	None

TABLE 6 (Cont.) PAST AND PRESENT OBSTRUCTIONS ON THE DUCKTRAP RIVER AND ITS TRIBUTARIES

Name of Type	Location	Description	Affects	Recommendations
Former Mill Dam	6.7 Miles up	Granite blocks	Former Barrier	None
Morses (Dickey Mill Dam)	9.4 Miles up	6' - 8' high stone dam	Former Barrier	None
Riffles & Bars	Upper three miles	Nearly dry stream section	Low water migration barrier	Improve flow
Kendal Brook cascade area	½-1 mile above mouth of Brook	Rock and ledge area cascades	Barrier at low water levels	Improve flow
Dam	Outlet of Pitcher Pond	8 foot high rock dam	Former barrier presently a low water barrier	Clean out debris & improve flow
Coleman Pond Dam	Outlet of Coleman Pond	3 foot high rock dam	Barrier	Install fishway

Fish present

A run of alewives usually occurs in Tilden and Pitcher Ponds in the spring of the year. Many of the resultant young are land-locked in the pond areas during drought periods.

Schools of small shiners, chub, dace, and suckers were seen from 2 to 7 miles above the mouth in the deeper pool areas. An occasional smallmouth bass was noted, as were small brook trout.

The available history shows that the Ducktrap supported a run of Atlantic salmon at one time. So far as can be determined, there have been no runs of any magnitude or of any consistency for more than a decade. None were caught in a weir operated about 3 miles above the mouth of the river in either 1949 or 1950.

Efforts have been made in recent years to establish a run of silver salmon (Oncorhynchus kisutch) in the watershed by means of hatchery plants of fingerlings. (In November 1952, two Atlantic salmon females and 21 silver salmon were seined from the mouth and liberated upstream where the flow was sufficient to allow fish to swim. There is no indication to date that the runs are firmly established).

Summary

The Ducktrap River has a small watershed with a limited potential for producing Atlantic salmon as compared with other, larger streams in the State of Maine. It is apparent from the above data that the stream flows, even in favorable precipitation years are one of the features most inimical to salmon production.

Table 7 is a summary of observations on the tributaries to the main river. The table shows that of the 19 tributaries 4 were blocked by man-made obstruction, 16 were considered to have too small a flow to provide adequate navigation water for salmon, and 17 were considered to be of little or no value to salmon production in the form of spawning or nursery area. One of the streams was of questionable value and one was considered of some value.

Table 6 lists 12 past or present obstructions to fish migration, of which 7 would require alteration to provide an adequate migration route. It was apparent that the low discharges enhanced the effectiveness of the obstructions.

The observed water temperatures in the portions of the main river where there was an appreciable water flow appeared favorable for production of salmon. In addition, many portions of the main river appeared favorable not only for spawning but as nursery areas for salmon, providing they were made more accessible.

Recommendations

The survey of the Ducktrap River has shown that low stream flows and obstructions are the most inimical features to production of Atlantic salmon.

It may be possible to develop Tilden, Pitcher, Knight, and Coleman Ponds as water-storage areas for augmenting the normal stream flow during low-flow or drought seasons.

Some of the ponded areas presently have a small run of alewives which may possibly be materially increased if the areas were made accessible.

The following recommendations are made with the belief that any conservation measure undertaken should be of a type that would provide for multiple species development of the fishery resources of the watershed:

1. Provide adequate fish-passage facilities at obstructions.

2. Investigate the possibility of developing the ponded sections of the watershed as reservoirs to augment the normal stream flow during low-flow periods.

Table 7. **A summary of certain observations on tributaries of the Ducktrap River.**

Name of Tributary	Miles Above Mouth	Obstructed by Man-Made Structure	Insufficient Flow for Salmon Migration	Estimated Discharge c.f.s.	Of Little or No Value to Salmon
Kendal Brook	2.4	x		2	
S. W. outlet of Pitcher Pond	0.3	X	x	0	x
Unnamed Tributary	1.9		x	0 +	x
Pitcher Pond	2.0	x	x	2	?
Knight Pond thoroughfare	4.6		x	0	x
Knight Pond			x	0	x
Unnamed Tributary	3.0		x	0 +	x
Black Brook	3.5			2	x
Coleman Pond Outlet	0.9		x	1	x
Coleman Pond	1.0	x	x	1	x
Unnamed Tributary	3.8		x	0 +	x
Unnamed Tributary	5.3		x	0 +	x
Tucker Brook	6.8		x	1.0	x
Unnamed Tributary	8.2		x	0 +	x
Unnamed Tributary	8.5		x	0 +	x
Unnamed Tributary	8.6		x	1	x
Tilden Pond	9.0			1	x
Unnamed Tributary			x		x
Unnamed Tributary			x		x

Stream Channelization: Conflict between Ditchers, Conservationists

Stream channel alteration under the banner of "improvement" is undoubtedly one of the most destructive water management practices . . . the aquatic version of the dust-bowl disaster.—NATHANIEL P. REED, *Assistant Secretary of Interior for Fish, Wildlife, and Parks*

American agriculture couldn't survive without it.—EUGENE C. BUIE, *Assistant Deputy Administrator, Soil Conservation Service*

American agriculture and the nation's environmental movement, already locked in battle over the use of persistent pesticides, are moving toward a new collision on an issue no less emotionally charged. The conflict centers on several venerable programs of federal assistance to farmers for "improving" or rechanneling streams and small rivers. Despite the best efforts of the President's Council on Environmental Quality (CEQ) to mediate an escalating dispute over the propriety of stream channelization, the issue has already divided and polarized government agencies against each other, and it seems sure to bring an increasing number of lawsuits from conservation groups that doubtless will prove as infuriating to the agricultural community as the current barrage of legal actions aimed at DDT and other "hard" insecticides.

The federal government has been rechanneling rivers since the 1870's, when the Army Corps of Engineers began working along the Mississippi River Valley. But it was not until the mid-1950's, shortly after Congress passed the Watershed Protection and Flood Prevention Act of 1954 (Public Law 556), that alteration of the nation's small waterways for agricultural purposes got under way in earnest.

Through this program, the Department of Agriculture's Soil Conservation Service (SCS) has helped farmers widen and deepen and "straighten" more than 8000 miles of streams and rivers in every state. During the same time, the Corps has improved on nature along another 1500 miles of waterway.

The underlying rationale for reaming and rebuilding these thousands of miles of streambed, and for thereby altering the drainage patterns of more than 10 million acres of land, was, and still is, fundamentally economic: To protect the land from floods, improve navigation, and to help private landowners drain tracts of marsh and swamp and the rich, wet hardwood forest that thrived along the floodplains of the southeastern United States so that new land might be opened to cultivation.

Without question, stream rechanneling has benefited agriculture and the country as a whole. The Corps and the SCS have earned the sincere gratitude of the farmers and the communities they have served. Now, however, a number of state conservation agencies, federal agencies like the Department of the Interior, and a host of local and national conservation groups have begun to argue that, in the vast majority of cases, the biological damage which channel work inflicts on a shrinking supply of wetlands, and on the streams themselves, overwhelmingly negates any economic benefits that might be claimed.

An Outmoded Practice

Criticism of this practice is not based on environmental issues alone. For one thing, stream channelization would seem to provide an almost classic example of the ways in which government contrives to work at cross-purposes with itself. While the Department of Agriculture drains wetlands, the Interior Department tries to preserve them. While the Soil Conservation Service helps farmers drain their land to intensify their production of tobacco and soybeans, another part of the Department of Agriculture tries to prevent surpluses of the same crops. And broader questions of national priorities are involved as well: In an era of corporate farming and concentration of economic power, does agriculture still need all the public help it is getting to keep water off the land? To a growing number of environmentalists, both within government and outside it, the question is rhetorical; stream channelization, under all but a few special circumstances, has outlived its old rationale.

One of stream channelization's severest critics in government is Nathaniel P. Reed, Assistant Secretary of Interior. Last June, in an impassioned presentation to the House Committee on Government Operations, Reed said that his agency had compiled reports from Montana, Missouri, Florida, North Carolina, Mississippi, and elsewhere indicating that reconstruction of stream channels reduced local populations of fish, plant life, and ducks by 80 to 99 percent, and that contrary to SCS assertions, the loss was often permanent. Reed went on to charge that, if all 1119 watershed projects then on the SCS's drawing board for Southeastern states alone were actually completed, then 25,000 to 60,000 acres of stream habitat would be adversely affected and somewhere between 120,000 and 300,000 acres of forested wildlife habitat would be "damaged or destroyed by these alterations." The environmental effects of stream rechanneling have never been studied closely, Reed said, but he added that "I think we are kidding ourselves if we do not admit that the vast majority of stream channelization [projects] have had a devastating effect on our nation's waterways."

Officials of the SCS are inclined to regard such accusations as "nonsense," as one of them put it in a recent interview. In truth, the Agriculture Department has no clearer idea of the collective impact of 20 years of reaming streams than the Interior Department has. Intuitively at least, the SCS thinks that streams recover quickly, an opinion seemingly drawn largely from the fact that brush tends to grow back quickly along banks skinned bare of vegetation.

Eugene C. Buie, who is in charge of watershed planning for the SCS, insists that his agency is bending with the times. More and more, Buie says, channel work plans are incorporating damage-mitigating features such as water inlets for the cutoff meanders of newly straightened streams. In theory, the inlets help sustain vegetation, fish, and wildlife along the oxbows. And Buie says the SCS has recently "designed out" several hundred miles of

1) There are many areas of research and scholarship that are now of little interest to the government and for which few funds are available. This is particularly true in the humanities and social sciences, which may well hold the key to how men and nations can live together in harmony and happiness.

2) Even in science and engineering, where substantial funds are available, research considered a long shot and proposals involving radically new concepts suffer in comparison with more pedestrian proposals. The gauntlet of complex reviewing panels, committees, and criteria that government agencies have established almost automatically makes this so. The proposals on specific research topics that some agencies request before letting contracts cannot take into consideration the idea that might lead to a breakthrough of major importance. Independent research funds controlled by the universities and colleges are the only answer.

3) One of the criteria that government agencies are almost forced to apply in judging the merits of a research proposal is the stature and past achievements of the individual who will lead the work. Young men and women who have not yet had the opportunity to prove their abilities must, by and large, rely on research funds from their own university or college, or submerge their own ideas as assistants to more distinguished colleagues.

4) Many promising explorations of new concepts can be carried out with a very modest expenditure of funds. The cost and time involved in preparing and submitting a formal proposal to a prospective sponsoring agency are hardly justified; moreover, a small budget engenders the feeling that the work is of little importance—it is frequently and truly said that the $100,000 proposal is easier to sell then the $1,000 proposal.

5) When the idea for a new research project is first conceived, those individuals involved are full of enthusiasm and drive. The 6 months or more usually required for the preparation and submission of a formal proposal, which must then be reviewed and acted upon, dampen both the enthusiasm and the drive. Furthermore, preliminary research is often necessary to obtain the data and information necessary for preparing a convincing proposal. As a result, institutions must have independent research funds, even for those projects that may ultimately be of great interest to the government.

6) Finally, the people of this nation and, in response to their desires, the Congress and the executive agencies are emphasizing the direct expenditure of tax dollars for research projects that may help meet society's immediate needs (*12*). A scientist's motivation to search for truth, wherever that truth may lie, is little understood and even less appreciated in terms of federal expenditures for the direct costs of research projects.

The government's fiscal policies and practices for research contracts and grants to colleges and universities are a hindrance rather than a help. When institutions must share the costs of government-sponsored research, they have less money available for independent work. If they do manage to reserve some dollars for research of their own choosing, that research must bear indirect costs at a substantially higher rate than government-sponsored research. On the other hand, for industry, which is generally reimbursed full costs plus a profit for government work, Defense Department regulations provide for actual reimbursement of the costs of independent research as part of the overhead paid on government contracts. Why should universities and colleges not receive similar treatment? One of the best ways would be to provide an educational allowance in addition to reimbursement of all allowable costs. This could be particularly helpful in interdisciplinary research, as a means by which several participating departments could receive some funds as an incentive for cooperating in an interdisciplinary project.

In conclusion, then, the government's professed interest in research at universities and colleges and in the welfare of the institutions themselves are accompanied by fiscal policies for sponsored research that act to the detriment of these interests. Requirements and pressures for institutions to share the costs of government-sponsored research, inadequate compensation for indirect expenses associated with this research, provisions that discourage investment in buildings and equipment, and handicaps rather than assistance to independent research are all evidence to this effect. It seems time for a change.

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[1981]

Effects of Streamflow and Upwelling on Yield of Wild Coho Salmon (*Oncorhynchus kisutch*) in Oregon

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SCARNECCHIA, D. L. 1981. Effects of streamflow and upwelling on yield of wild coho salmon (*Oncorhynchus kisutch*) in Oregon. Can. J. Fish. Aquat. Sci. 38: 471–475.

To investigate the dependence of coho salmon (*Oncorhynchus kisutch*) yield on streamflow and oceanic upwelling, I regressed catch by the Oregon commercial troll fishery from 1942 to 1962 against indices of offshore upwelling the previous spring and measurements of streamflow from five Oregon coastal rivers during the freshwater rearing phase. A highly significant positive relation was found between total streamflows during the freshwater residency of the fish for the five rivers combined and the weight of the annual catch of coho salmon from 1942 to 1962. There was also a significant positive relation between total combined annual (January–December) flows for these rivers and the catch 2 yr later. Conversely, I found no significant relation between the 60 consecutive days of lowest flow during summer and catch 2 yr later. High flows during freshwater rearing probably provide more habitat and better conditions for growth and survival. I also found a significant positive relation between April through June upwelling at two stations and catch of coho salmon the following year from 1947 to 1962. Fifty-six percent of the variation in catch from 1947 to 1962 was explained by the total flows during freshwater residency, 60 consecutive days of lowest flow, plus combined April through June upwelling at both stations. It is suggested that some stocks of coho salmon smolts may move southward or remain in local offshore waters after they enter the ocean to take advantage of the production of invertebrates resulting from upwelling.

Key words: streamflow, upwelling, coho salmon, Oregon coast

SCARNECCHIA, D. L. 1981. Effects of streamflow and upwelling on yield of wild coho salmon (*Oncorhynchus kisutch*) in Oregon. Can. J. Fish. Aquat. Sci. 38: 471–475.

Dans l'étude décrite ci-dessous de la dépendance du rendement en saumons coho (*Oncorhynchus kisutch*) du débit des cours d'eau et de la remontée d'eaux profondes dans l'océan, nous avons calculé la régression des prises dans la pêche commerciale aux lignes traînantes de l'Orégon entre 1942 et 1962 contre les indices des remontées d'eaux profondes au large le printemps précédent et le débit de cinq rivières côtières de l'Orégon pendant la phase en eau douce des saumons. Il y a corrélation fortement positive entre le débit total des cours d'eau à l'époque où les poissons résident dans les cinq rivières combinées et le poids des prises annuelles de saumons coho entre 1942 et 1962. Il y a également une corrélation positive significative entre le débit annuel combiné total (janvier–décembre) de ces rivières et les prises 2 ans plus tard. Inversement, nous n'avons pas trouvé de relation significative entre les 60 jours suivant l'étiage estival et les prises 2 ans plus tard. De forts débits pendant la phase de croissance en eau douce fournissent probablement un habitat plus étendu et de meilleures conditions de croissance et de survie. Nous avons aussi trouvé une corrélation positive significative entre la remontée d'eaux profondes d'avril à juin, à deux stations et les prises l'année suivante, entre 1947 et 1962. Cinquante-six pour cent de la variation des prises de 1947 à 1962 s'explique par le débit total pendant la phase de résidence en eau douce, 60 jours après l'étiage, plus la remontée d'eaux profondes combinés entre avril et juin inclusivement aux deux stations. Il est possible que certains stocks de smolts de saumon coho se déplacent vers le sud ou demeurent dans les eaux du large locales une fois descendus à la

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mer de façon à tirer profit de la production d'invertébrés résultant de la remontée d'eaux profondes.

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YEARLY abundance and yield of coho salmon (*Oncorhynchus kisutch*) have historically fluctuated widely. Ability to predict coho salmon abundance before the fishing season enables fishermen to allocate time and money efficiently and allows biologists to recommend harvest rates that will prevent overfishing of stocks.

Inasmuch as catches of coho salmon on neighboring rivers tend to fluctuate together (McKernan et al. 1950; Tollefson 1959), biologists have searched for widespread environmental factors influencing abundance. One approach to predicting abundance before the fishing season is to correlate environmental variables with the catch of adult coho salmon by either terminal fisheries or troll fisheries. Neave (1949) reported a significant correlation between number of coho salmon caught per 100 hours of sport fishing in Cowichan Bay, British Columbia, and minimum summer streamflows 2 yr earlier.[3] Smoker (1955) found the combined annual runoff from 21 watersheds in western Washington to be highly correlated with total combined catch of coho salmon 2 yr later by the commercial fisheries of Puget Sound, Willapa Bay, and Gray's Harbor. Smoker also obtained significant correlations between summer flow, as well as lowest monthly flow, and catch 2 yr later. He concluded that these flows merely reflected annual flows. He was unable to show significant correlations between streamflow and catch for most individual rivers. The Washington Department of Fisheries now estimates the number of wild coho salmon returning to Puget Sound streams by using summer streamflows of western Washington 2 yr before the catch (Zillges 1977).

It has been assumed that available rearing area during low summer flows limits most coho salmon populations in Washington. However, Wood (1977) found poor correlations between low summer flows of western Washington coastal streams and the size of the ensuing runs.

Little is known about how variable oceanic factors affect survival of coho salmon from smoltification to maturity. Royal and Tully (1961) found that marine survival rates of sockeye salmon (*Oncorhynchus nerka*) ranged from 4 to 18%.

Upwelling is one oceanic factor which may affect survival of coho salmon. Upwelling occurs off Oregon primarily from April to September, and results from northerly winds blowing down the coast as they circulate clockwise around the large high-pressure system over the Pacific Ocean (Smith et al. 1966; Cushing 1971; Bakun 1973). During this time, cold, nutrient-rich, high-salinity water (Lynn 1967) is transported upward where nutrients support primary production. The lower temperatures and increase in primary production lead to an increase in the standing crop of zooplankton (Murphy 1961) which is consumed by many species of commercially important fish.

Upwelling affects the distribution and abundance of many species of fish. Sardines (*Sardinops sagax*) and anchovies (*Engraulis mordax*) utilize upwelled water for spawning and rearing (Ahlstrom 1966, 1967; Cushing 1971). Barton (1979) presented data indicating that upwelling may have influenced survival of Columbia River and Lemhi River spring chinook salmon (*Oncorhynchus tshawytscha*). Gunsolus (1978) found a positive relation between upwelling off Oregon and growth and survival of coho salmon from 1960 to 1975.

For coho salmon, I postulated that if upwelling affects survival, it would exert this effect primarily on smolts, and not on larger salmon, since Gunsolus' (1978) data indicate that survival of Oregon's hatchery-reared coho salmon during their final year in the ocean is fairly constant.

Upon reaching the ocean, the smolts have adjusted physiologically and behaviorally and begin feeding on pelagic invertebrates. Since coho salmon in Oregon emigrate from streams in April (Skeesick 1970) and May (Willis 1962), I postulated that spring and summer (April–September) was the critical period for marine survival of coho salmon smolts.

My objectives were (1) to determine if a correlation existed between coho salmon catch and annual streamflows, summer streamflows, and total streamflows during the freshwater rearing phase; (2) to determine if a correlation existed between both April–June and June–September upwelling and catch of coho salmon the following year; and (3) to relate the combined effects of streamflows and upwelling to subsequent catch of adult salmon by the commercial troll fishery.

Materials and methods — Streamflow records summarizing mean daily discharge for five coastal rivers — the Nehalem, Wilson, Siletz, Alsea, and Coquille — were obtained from U.S. Geological Survey reports for Oregon (1939–70; 1971–73). These five rivers were selected for study for three reasons: (1) data on daily streamflow were recorded on each river since 1939; (2) records of catch of coho salmon by the offshore fishery were recorded when corresponding data on streamflow were recorded; and (3) the rivers historically have supported substantial populations of coho salmon.

Low summer streamflows were measured as the sum of mean daily flows for the 60 consecutive days of lowest flows in each of the rivers. All other flows were expressed as sums of combined unweighted monthly discharges for the five rivers. All flows were expressed as $m^3 \cdot s^{-1}$. The period 1942–62 was chosen for analysis of catch and streamflow relations because streamflow data were unavailable before 1939 for two of the five rivers, and the period preceded the years of large returns of hatchery fish to the Columbia River (Korn 1977).

Upwelling data from 42°N, 125°W, off southern Oregon,

[3]Most coho salmon are age 1.1 where number left and right of the decimal indicate number of marine and freshwater annuli on their scales, respectively. If coho salmon are caught as age 1.1 adults in year *x*, they were fry in streams in year *x*-2 and yearlings in year *x*-1. Their parents probably spawned from about November, *x*-3, to January, *x*-2.

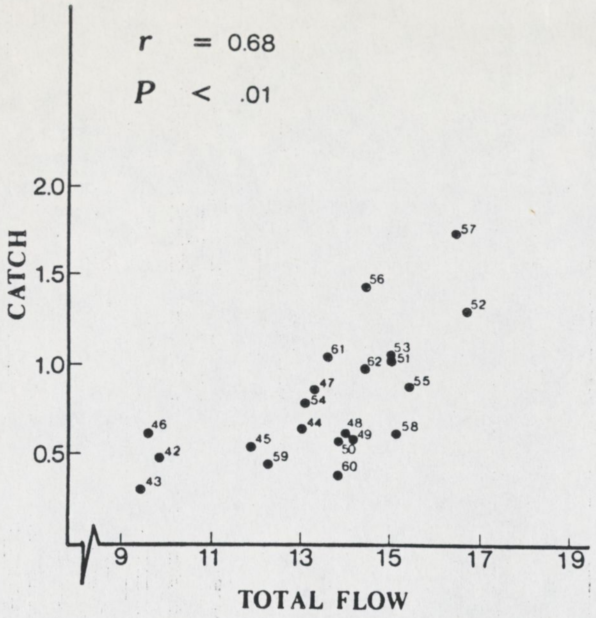

FIG. 1. Total November (x-3) through May (x-1) flows ($\times 10^9$ $m^3 \cdot s^{-1}$) for five coastal rivers combined versus weight (kg $\times 10^6$) of coho salmon caught in year x by the Oregon commercial troll fishery. Catch data extend from 1942 to 1962. Catch ($\times 10^{-3}$) = $-894.5236 + 0.1256$ (flow) ($\times 10^{-6}$).

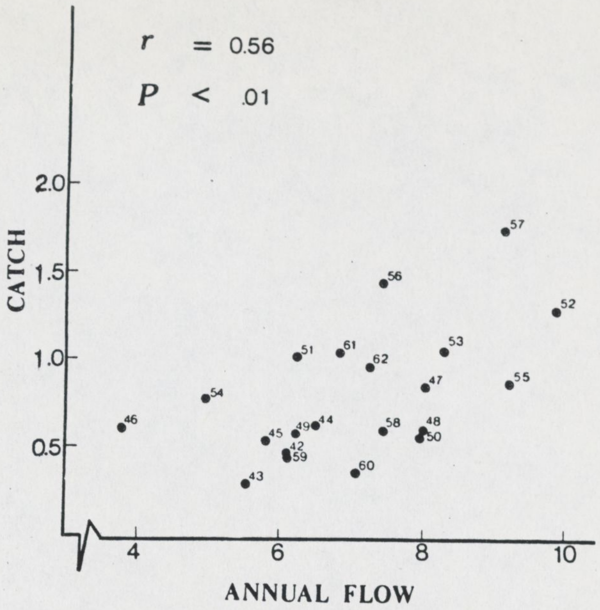

FIG. 2. Total annual flows ($\times 10^9$ $m^3 \cdot s^{-1}$) for five coastal rivers combined versus weight (kg $\times 10^6$) of coho salmon caught 2 yr later by the Oregon commercial troll fishery. Catch data extend from 1942 to 1962. Catch ($\times 10^{-3}$) = $-176.4991 + 0.1395$ (flow) ($\times 10^{-6}$).

and from 45°N, 125°W, off northern Oregon, were obtained from Bakun (1973). The indices are based on monthly means of atmospheric pressure fields from which winds and resultant upwelling were estimated. Upwelling is expressed as $kg \cdot s^{-1} \cdot 100\ m^{-1}$ of coastline. Data were unavailable from either station before 1946.

Yield was expressed as weight of the catch in kilograms rather than as numbers of fish caught because numbers of fish were not recorded before 1952. From 1952 to 1962, numbers and weight were closely correlated ($r = 0.98$).

I performed simple and multiple linear regression analyses on catch, flow, and upwelling data using the Statistical Interactive Programming System (SIPS) of the CDC 3300 computer at Oregon State University, Corvallis.

Results — A significant relation was found between total November (x-3) through May (x-1) streamflows for the five coastal rivers combined and weight of coho salmon caught by the Oregon commercial troll fishery in year x from 1942 to 1962 (Fig. 1). This 19-mo period of streamflow, from November to May 2 yr later, corresponds to the time from entrance of adult salmon into coastal rivers to the seaward migration of their progeny as smolts (Willis 1962; Moring and Lantz 1975). There was also a highly significant relation between total annual flow and catch 2 yr later (Fig. 2). The 60 consecutive days of lowest flow for the five rivers combined correlated poorly with annual flows ($r = 0.20$; $P > 0.05$) and with November (x-3) through May (x-1) flows ($r = 0.13$; $P > 0.05$). Though the relation between annual flows with catch 2 yr later was highly significant, the relation between the 60 consecutive days of lowest flow and catch 2 yr later was poor ($r = 0.28$; $P > 0.05$).

A significant relation was found between combined April (x-1) through June (x-1) upwelling at both stations and catch from 1947 to 1962 (Fig. 3). Similar significant relations were also found between catch and upwelling at each station separately ($r = 0.57$; $P < 0.05$ for 42°N, 125°W; $r = 0.54$; $P < 0.05$ for 45°N, 125°W). Midsummer upwelling (June–September) did not significantly relate to catch ($r = 0.34$; $P > 0.05$).

Since total November (x-3) through May (x-1) flows and 60 consecutive days of lowest flow were poorly correlated, I calculated a multiple regression of these flows and April (x-1) through June (x-1) upwelling at both stations versus catch from 1947 to 1962. Fifty-six percent of the variation in catch was explained (Fig. 4). The multiple regression equation was:

$$\text{Catch} (\times 10^{-3}) = -1853.0589 + 0.1499 \times 10^{-6} (\text{total flow}) + 0.3823 (\text{low flow}) + 0.00109 (\text{upwelling}).$$

Sixty-four percent of the variation in catch was explained when 1960, the year of lowest catch, was excluded from the analysis.

Discussion — Although neither low summer flows nor upwelling entered significantly in the multiple regression analysis, both were included in the model. Low summer flows and low upwelling may decrease abundance of coho salmon, yet average summer flows and upwelling may not directly relate to abundance. In any year, I believe any of the three factors included in the model could limit abundance. Summer flows and upwelling together explained an additional 15% of

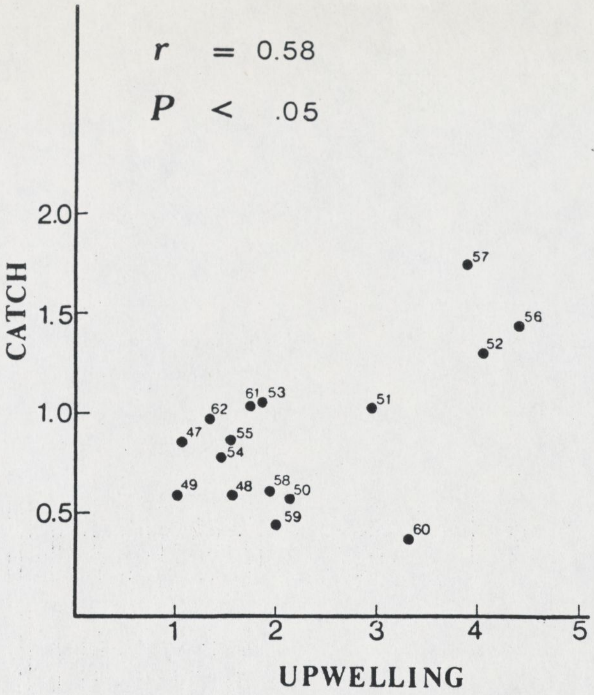

FIG. 3. Sum of total April through June upwelling indices at 42°N, 125°W, and 45°N, 125°W ($\times 10^6$ kg·s^{-1}·100 m^{-1} of coastline) off of Oregon versus weight (kg $\times 10^6$) of coho salmon caught 1 yr later by the Oregon commercial troll fishery. Catch data extend from 1947 to 1962. Catch ($\times 10^{-3}$) = 450.2993 + 0.00197 (upwelling).

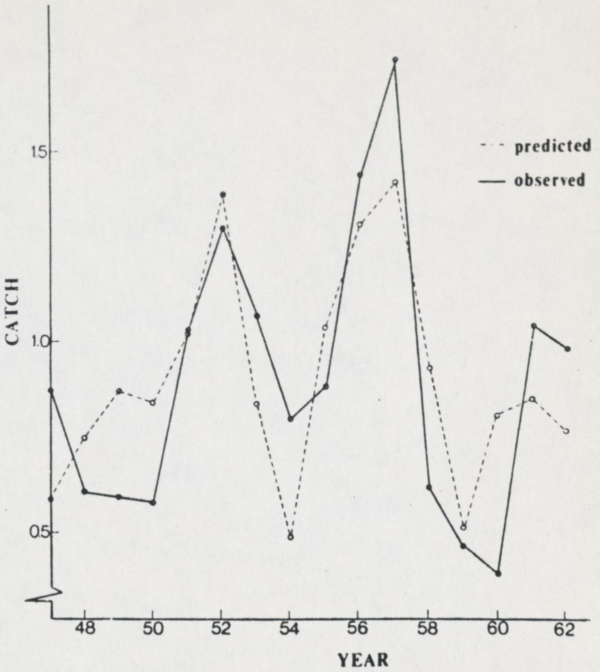

FIG. 4. Predicted and observed catch of coho salmon in kilograms by the Oregon commercial troll fishery from 1947 to 1962.

the variation in catch after the total flow variable entered the model.

The relation between total annual flows and catch of coho salmon 2 yr later is noteworthy, since Smoker (1955) found a similar relation between annual flows and catch of coho salmon in western Washington from 1935 to 1954, an overlapping but not identical time span. Before large numbers of smolts were released from hatcheries, a quantity of streamflow in coastal rivers influenced abundance and subsequent yield of coho salmon.

For Oregon coastal rivers, summer streamflows were not related to annual flows, although Smoker (1955) found a close relation between them in Washington. This difference between Oregon and Washington streams probably results from a difference in timing of runoff. The watersheds analyzed by Smoker were fed by melting snow and glaciers in summer, and high precipitation in winter often led to high streamflows the following summer, whereas the five Oregon rivers that I studied flow out of the Coast Range mountains, which receive nearly all precipitation in winter as rain. In these rivers, summer flows are mainly dependent on quantity of precipitation in summer.

High streamflows when adult spawners are entering rivers may allow access to upper spawning areas and may result in greater production of smolts in upper tributaries (Allen 1969). Higher flows may also increase the area of spawning beds. Of course, eggs spawned in gravel inundated by high flows may die if flows drop before fry emerge.

Higher flows and resultant higher velocities can cause individual Atlantic salmon to occupy smaller territories (Kalleberg 1958). Consequently, higher flows during time of emergence through the summer may lead to more space, more cover, and, in turn, to a higher density of young salmon in streams. The number of juveniles surviving low summer flows may depend on their initial numbers. In years when the number of fry is large before the period of low flow, more fish may survive the low flows, although the individuals may be smaller than in years of low numbers (L. S. Pearson, K. R. Conover, and R. E. Sams, Oregon Fish Commission, unpublished data).

From 1963 to 1972, the correlation between total annual flows and catch by the troll fishery was poor ($r = 0.24$; $P > 0.05$), as expected. During this period, hatchery fish were contributing significantly to the fishery, as indicated by returns of salmon to the Columbia River hatcheries (Korn 1977). Since hatchery fish are not reared in streams, other factors probably affect their return, e.g. oceanic factors, diseases, or the "quality" of smolts released (expressed as potential for growth and survival in the ocean).

Little is known about oceanic movements of coho salmon smolts. Loeffel and Forster (1970) corroborated the hypothesis of northward movement along the coast during summer. However, if upwelling affects survival of coho salmon, many smolts may move southward or remain nearby along the coast to use the available food.

Study is needed on oceanic feeding of coho salmon during their 1st year and the relation between food supply, upwelling, and survival of smolts. Upwelling may increase production of small invertebrates, and thereby increase growth and survival of larval fishes and large invertebrates, which may also serve as food for smolts. A causal link must be established between response of food organisms to upwelling and response of salmon to food organisms.

At present, I can only speculate about why upwelling may influence survival of year-classes of coho salmon. It seems unlikely that smolts would die of starvation in years of little upwelling. Perhaps in these years growth is reduced because food is scarcer. Smaller, slower-growing smolts may remain susceptible to predation longer than larger smolts. Larger, faster-growing fish with a greater supply of food may resist diseases better than poorly fed fish. Availability of abundant food may be crucial for growth and survival following the physiological adjustments coho salmon undergo during smoltification.

Although catch may poorly indicate abundance of adult fish, the troll fishery is the most reliable source of data on abundance available for comparisons with flow. Since this fishery gets the first opportunity to catch migrating coho salmon and has been virtually unregulated since its inception (Van Hyning 1951; Reed 1976), catch is probably more indicative of actual abundance than data from individual rivers.

I advise caution in using these findings predictively. Since the mid-1960s hatchery fish have made up a substantial percentage of coho salmon caught offshore (Korn 1977). Scarnecchia and Wagner (1980) estimated that ~75% of the coho salmon caught offshore in 1977 were reared in hatcheries. The unknown interaction between the wild and hatchery fish may alter the relationships presented. Other oceanographic factors may have changed since then. Present escapement of coho salmon may be inadequate because of heavy fishing pressure in recent years.

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Profitable Stream Positions for Salmonids:

Relating Specific Growth Rate to Net Energy Gain[1,2]

by

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Running head: Stream Salmonid Positions

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Abstract

A model is developed and tested relating the specific growth rates of three species of juvenile stream salmonids to the potential for net energy gain measured at stream positions of individual fish in a laboratory stream aquarium. The potential net energy gain, or potential profit, is calculated from characteristics of water velocity and invertebrate drift at fish positions, based on the energy available from the drift minus the cost of swimming to maintain the position.

In all experiments potential profit was a good predictor of specific growth rate, a relationship that was best described by the Michaelis-Menten or Monod model. Coho salmon (*Oncorhynchus kisutch*) always achieved higher specific growth rates than either brook trout (*Salvelinus fontinalis*) or brown trout (*Salmo trutta*) in concurrent experiments, and maintained growth to lower resource thresholds. In each experiment fish established intraspecific hierarchies, and dominant fish held optimal positions affording maximum potential profit. Potential profit was also used as an optimal foraging model to rank the positions of coho salmon by potential for net energy gain calculated from the pattern of flow and drift in the stream environment. This predicted ranking was nearly identical to that observed when fish were ranked by specific growth rate. The results of experiments confirm ideas of other investigators about the mechanisms of microhabitat selection by stream salmonids.

Key words: microhabitat selection, Michaelis-Menten model, fish growth model, optimal foraging model, Salmonidae, coho salmon, brook trout, brown trout.

Ten-year index key phrases: optimal microhabitat selection by stream salmonids
fish specific growth rate vs resources
Michaelis-Menten model to predict fish growth

Growth of stream salmonids, as in all fish, is related to net energy gain. To be successful, an organism must maintain a balance between the energy and materials it can get from its environment, and that required for metabolism, growth and reproduction (Warren 1971). This idea is the major tenet of bioenergetic (Ware 1980) and optimal foraging models (Werner and Mittelbach 1981).

For a stream salmonid, this energy balance can be viewed in terms of the position it maintains in the stream. These fish tend to hold relatively fixed positions, or focal points, from which they make short forays to feed on invertebrates drifting nearby (Kalleberg 1958). Drawing on work by Chapman and Bjornn (1969) and Everest and Chapman (1972), Fausch and White (1981) proposed that salmonids should choose focal points in areas of low water velocity to minimize the energy expended on swimming, yet close to swift currents to maximize access to invertebrate drift. Thus, the potential for net energy gain for a stream salmonid at a specific position can be defined in terms of the energy available from invertebrates drifting nearby, minus the metabolic cost of swimming to maintain the position. In terms of optimal foraging theory, optimal stream positions for salmonids are those that maximize the rate of net energy gain for the fish.

The potential for net energy gain, hereafter called <u>potential profit</u>, available at positions of stream salmonids should also be related to the specific growth rate of the fish in a predictable way. Recent efforts to define growth of algae (King 1980) and diatom (Tilman 1981) populations as a function of available resources, and to describe growth of individual fish as a function of rations (Brett 1979), indicate that the relationship between specific growth rate and resources is hyperbolic in both cases and fixed by two important points -- the resource threshold or maintenance level at which no growth occurs, and the maximum specific growth rate expressed at high resource levels. Thus, fish holding optimal stream positions that afford maximum net energy gain should also grow at maximum specific rates.

The purpose of this paper is first, to define a model of potential profit at positions of stream salmonids in terms of water velocity and drift characteristics that are measurable in streams. Secondly, I will relate the specific growth rates of three species of juvenile salmonids, coho salmon (*Oncorhynchus kisutch*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*), to potential profits measured at stream positions of individual fish over 9-18 day periods in a laboratory stream aquarium. The results of six experiments show that potential profit is a good predictor of specific growth rate, and provide an independent test of potential profit as a measure of optimal positions.

METHODS

Stream Aquarium

Experiments were conducted in a recirculating stream aquarium (Figure 1) described in Fausch and White (MS). The stream channel was constructed in two sine-generated curves, the pattern of meandering carved by natural streams (Leopold and Langbein 1966). This channel form permitted shaping natural riffles and pools in the stream bed, which simulated the diversity of depths and flow characteristics of lotic habitats that are important to juvenile salmonids more accurately than could be achieved with other channel shapes.

The channel shell, constructed of clear plexiglass, was 7.28 m long, 30 cm wide and deep, and had no slope. It was divided into two 3.64-m sections, each with a V-shaped trap for retaining migrants at its downstream end (Figure 1). The stream bed was formed of 2-3-cm diameter gravel. Pools were 15 cm maximum depth and riffles were 5 cm deep on average. During each experiment, flow was adjusted according to the swimming ability of the fish to prevent them from all trying to occupy the upstream riffle. Current velocities averaged 20-30 cm/second over the riffles and ranged from nearly zero to about 20 cm/second in the pools. Four larger rocks were spaced along each section to provide flow refuges for fish.

All experiments were conducted at 15 $\pm$ 0.5 C. Because stream flow was produced by air-lift pumping (cf. Fausch and White MS), dissolved oxygen was 100% of saturation throughout the stream. Chemical characteristics of the water were maintained at optimum levels by circulating water through a biofilter, built according to Spotte (1979). The following are ranges in ppm (except for pH) for chemical constituents measured at the beginning and end of each experiment: $CaCO_3$ alkalinity 100-128, pH 8.08-8.53, hardness 120-140, NH_3-N 0.01-0.02, NO_3-N 1.83-4.44.

The stream was lit by mercury vapor and incandescent lamps, the latter brightened and dimmed for about 30 minutes at the beginning and end of the 12-hour photoperiod. Light intensity measured at the water surface varied from 25-55 $\mu E/m^2$/sec, but was between 40 and 55 $\mu E/m^2$/sec for 90% of the stream area. Fish did not prefer areas of low light intensity. Curtains enclosed the stream channel to conceal the observer, who could watch fish through adjustable horizontal slits spaced 40-45 cm along the channel.

Acclimation and Experimental Design

I conducted six experiments (Table 1), three with coho salmon, two with brown trout and one with brook trout. Each experiment took place in one half of the stream aquarium (1.092 m^2) and another experiment using a different species was run simultaneously in the other half. I used groups of 13-22 fish (12-20 fish per m^2) averaging 33.7-54.1 mm FL and 0.26-1.59 g when experiments began (Table 1). Fish were selected to be as uniform in length and length distribution as possible.

All brook and brown trout were hatched from eggs of wild trout captured in Michigan streams, and coho salmon from eggs of adult salmon returning from Lake Michigan. After hatching in vertical-flow tray incubators, larvae were transferred to gravel beds in a stream holding tank and isolated from human disturbance to promote normal development and emergence. At the swim-up stage, fry were fed frozen Daphnia, then commercial trout pellets supplemented with frozen Daphnia and Artemia. Fish were maintained on a 12-hour photoperiod throughout, and were gradually acclimated to 15 C at least one week prior to the start of each experiment.

During each experiment, invertebrate drift was simulated with Daphnia introduced continuously in the riffle at the head of each section throughout the light cycle. Prior to experiments, fish were acclimated to the stream aquarium and to feeding on drifting Daphnia for periods ranging from 4-25.5 days (Table 1). During experiments 1 and 2, fish were acclimated to both food and the stream aquarium for 4 days before the 18-day experiments. During experiments 3 and 4, fish were acclimated for seven days to the food, the last five of these to the stream aquarium, and then grown for 10.5 days together in sympatry (10 coho and brook trout in each stream half) as part of an experiment to test competition between the two species, to be reported in another paper. Fish were then weighed, measured and isolated in allopatry in the downstream traps for two days under low light and flow conditions and fed a maintenance ration each day, a procedure designed to minimize the effects of prior residence on experiments. In total, fish were acclimated for 19.5 days to food and 17.5 days to the stream aquarium before the 10-day experiments.

Prior to experiments 5 and 6, fish were acclimated for 14 days to both stream aquarium and food, then grown for 9.5 days in sympatry and isolated for 2 days in the traps for a total of 25.5 days of acclimation prior to the 9-day experiments. Throughout experiments, fish appeared to acclimate to light and flow conditions in the stream aquarium after about four days, but physiological acclimation to feeding on drifting *Daphnia* probably took much longer.

To determine suitable fish density, during experiments 1 and 2 coho salmon and brown trout could migrate out of the sections into downstream traps. Migrants were returned to the head of the section three times before removal from the experiment. Of the original 25 fish of each species, 17 brown trout and 22 coho salmon remained in the channel throughout the experiments. In all other experiments traps were blocked to prevent fish from leaving the channel.

Fish in each experiment were individually marked prior to acclimation by excising fin tips in combinations of no more than four of the following five fins: dorsal (D), anal (A), adipose (X), top caudal lobe (T), and bottom caudal lobe (B). Most fish were given one to three finclips, but one fish in experiments 2 and 3 had no clips and one four-clip combination was used in experiment 2. Finclips did not appear to affect normal behavioral displays, and there was no difference in growth rates of fish receiving one, two, or three finclips by a Kruskal-Wallis test ($p>.30$ or greater for all experiments).

Fish were measured and weighed at the beginning and end of each experiment after being starved for 12 hours (2000 to 0800 EDT) to reach a standard level of gastric evacuation. Fish were individually anesthetized (MS222), measured ($\pm$ 0.5 mm), blotted lightly on a cloth towel, and weighed ($\pm$0.01 g) in a beaker of water previously tared on a balance. Fish weight was determined by subtraction, and all lengths were fork length due to the caudal fin clips. Specific growth rates for each fish were calculated from:

$$\mu = \frac{\ln W_t - \ln W_o}{t} \quad (1)$$

where: μ = specific growth rate (g/g/day)
W_t = final weight (g)
W_o = initial weight (g)
t = growth period to nearest 0.5 day.

Invertebrate Drift

The frozen Daphnia introduced at the upstream end of each section to simulate drifting invertebrates were thawed in a carboy of stream aquarium water and mixed with minimal bubbling from an airstone. The 27 liter mixture of Daphnia and water took about 3 hours to drain through a 1.5 mm orifice, so the carboy was refilled 4 times daily, and the mean residence time of Daphnia in the carboy was about 1.5 hours. Randomly chosen blocks of the frozen food were dried (24 hours at 105 C), ashed (3 hours at 550 C), and weighed to arrive at dry weights in Table 1. Mean percent ash was 8.26 (SEM 0.373) for all experiments.

Drift was measured at five cross sections located at 60 cm intervals along each section (Figure 1) using 0.3-mm mesh nets measuring 5-by-5 cm at the mouth with 18 cm long bags. During 20-minute drift samples at each cross section, two nets were positioned at least 50 mm apart to prevent flow disturbance of one net from affecting the other. Nets were fished at only one cross section at a time, and drift at each cross section was sampled five times during experiments 1 and 2, and eight times during the other four experiments. During experiments 1 and 2, drift was sampled using four or five nets in each cross section for 120-minute periods. In all experiments, fish became conditioned to disturbance of drift sampling and returned to their normal positions soon after drift nets were placed in the channel.

After the drift sample, I removed the nets and measured water velocities at points corresponding to the center and edges of each net along its horizontal midline, using a hot-bead anemometer modified from LaBarbera and Vogel (1976). Water velocity profiles measured around net frames with and without nets showed that the netting caused an 8.6% (SE 2.18) reduction in flow on average.

Daphnia were washed from drift nets into a gridded petri dish and counted under 15X magnification. The drift consisted of a mixture of sizes of whole and broken Daphnia, and during experiments 1 and 2 fish were observed to select those items larger than about 0.5 mm. Due to this size selectivity, after these first experiments I counted only Daphnia larger than 0.5 mm. In all experiments I set the largest Daphnia, which were about 2 mm, as the standard unit and equated three smaller whole or partial ones to one standard 2-mm Daphnia.

Because some Daphnia were broken, I suspected that thawing them, mixing them in water, and drifting them downstream may have ruptured their bodies and reduced their caloric content to fish. To convert drift counts to caloric value, I first counted and dried (24 hours at 105 C) 10 samples of Daphnia that had been thawed in stream water, mixed for 1.5 hours with an airstone to simulate treatment in the carboy, and strained in a drift net. The dry weight of these samples yielded results of 117 X 10^3 standard 2-mm Daphnia per gram dry weight

(SEM 5.4 X 10^3). Similarly, to convert dry weight of *Daphnia* to calories I circulated, strained and dried samples of *Daphnia* and combusted five replicates in a bomb calorimeter. Standard *Daphnia* yielded 5938 cal/g dry weight (SE 19.6), which is close to values reported by Cummins and Wuycheck (1971) and indicates that treatment of the *Daphnia* did not reduce their caloric content. Combining these data, a fish would have to capture 19.7 standard *Daphnia* from the drift to gain one calorie.

Potential Profit at Fish Positions

I estimated the potential profit for each fish on each day based on a measure of the *Daphnia* drifting within the feeding range of a fish's position, minus the cost of swimming to maintain the position. Thus:

$$P = D - S \qquad (2)$$

where: P = potential profit (cal/hour)
D = available drift energy (cal/hour)
S = swimming cost (cal/hour)

During all experiments most fish maintained the same position for many days so that a daily measurement of their position was adequate to estimate potential profit.

The cost of swimming (5) was calculated from the focal point water velocity measured at the fish's head, using the general metabolic equations developed by Stewart (1980) for coho salmon and rainbow trout. This estimate excluded the energy required for short forays to capture drifting food. I transformed Stewart's (1980) equations to calculate swimming cost in cal/hour given fish weight, water velocity and water temperature, yielding the following equations that are specific for a temperature of 15C:

Coho salmon: $$S = 0.9906\, W^{0.784}\, e^{0.0186 \cdot V} \qquad (3)$$

Rainbow trout: $$S = 0.7007\, W^{0.763}\, e^{0.0327 \cdot V} \qquad (4)$$

where: S = swimming cost (cal/hour)
W = fish weight (g)
V = focal point water velocity (cm/second)

To estimate the drift available to fish (D), I needed to determine: (1) the average foraging distance from their focal points, (2) the rate at which drift energy passed through the foraging area, and (3) the portion of drift energy to assign to each fish. During a pilot study, coho salmon and brown trout were observed to forage to a distance of about two body lengths (fork length), mainly in the area of maximum velocity within the quarter sphere above and in front on their focal point. In further tests, I placed a ruler beneath the foraging area of two different coho salmon positioned in pools, and measured only horizontal forays along the ruler. Feeding frequency of these fish dropped off sharply at distances further than two body lengths from the focal point. In addition, I observed that many fish chose positions in pools about two body lengths from the stream wall. Wankowski (1981) found that the area of capture upstream of positions held by juvenile Atlantic salmon was fan-shaped in the horizontal plane, and that capture distance varied seasonally from 1.9 to 9.9 body lengths. Although the area of drift capture for stream salmonids should be expected to vary with water velocity, particle size and abundance, hunger level and species, it appears that my "two-body-length" criterion may be a conservative estimate for the foraging distance of juvenile salmonids.

To determine the rate at which drift passed through the two-body-length foraging radius, I used the drift sample results presented below to map drift rates as a function of water velocity throughout the channel for each experiment. The amount of drifting Daphnia decreased downstream because fish ate it, and because some sank into the gravel and was rarely resuspended. Juvenile salmonids captured only moving particles, ignoring those that sank into interstices in the stream bed.

The final problem was to determine the portion of drift passing through the foraging area to assign to the fish. Because fish foraged mainly in one area of maximum velocity and highest drift rate within their feeding radius, I assigned each fish the drift energy passing through 1/4 of its semicircular feeding radius ($1/8\pi r^2$ envisioned in the vertical plane with the focal point at the center of the circle) at a rate dictated by the maximum velocity measured within the two-body-length radius above and in front of the focal point. Thus:

$$D = 1/8\pi r^2 \cdot E \qquad (5)$$

where: D = available drift energy (cal/hour)
r = two-body-length feeding radius (cm)
E = drift energy rate at maximum velocity ($cal/hour/cm^2$)

Relationships for E are developed below as functions of water velocity and distance from the upstream food source. The mean fork length of fish at the beginning of each experiment was used to calculate feeding radius.

In summary, calculating potential profit at fish positions using this model requires measuring drift energy rate and three position characteristics: focal point velocity, maximum velocity within the feeding radius, and distance of the fish position from the upstream end of the section. Water velocities were measured either with midget Bentzel speed tubes built according to Everest (1967) (3-30 cm/sec range) or with the hot-bead anemometer (0.1 - 3 cm/sec range), and distances were measured from a scale marked along the base of the stream wall.

In general, half of the fish in each experiment were chosen randomly for measurement of positions in the morning or afternoon on each day. To minimize disturbance for each group, all fish positions to be measured were first marked on the plexiglass stream wall with a wax pencil, and the stone directly beneath them on the stream bed recorded. Finally, the curtains were opened and characteristics of each position measured. Drift was most often measured in random order from 1100-1300 h each day, and fish positions were measured at other times between 0800 and 01700 h.

The relationships between specific growth rate of individual fish and potential profit were fit to Michaelis-Menten or Monod functions of the form:

$$\mu = \mu_{max} \frac{(R-T)}{(K_R-T) + (R-T)} \quad (6)$$

where: μ = specific growth rate (g/g/day)
μ_{max} = maximum specific growth rate (g/g/day)
R = potential profit (cal/hour) or resources
K_R = resource level at $\frac{1}{2}\mu_{max}$ (half-saturation constant in cal/hour)
T = resource threshold at which no growth occurs (cal/hour)

If the resource threshold is zero, the equation simplifies to the original Michaelis-Menten form which passes through the origin. In practice, I first estimated the threshold (T) using points close to the x-axis, then substracted this threshold value from all data to transform the equation to the simple form and used the best fit of the three reciprocal plots outlined in Dowd and Riggs (1965) to determine the equation.

RESULTS

Juvenile salmonids quickly established dominance hierarchies in the stream aquarium, and competed for an optimal position in the area of the stream that afforded maximum potential profit. The individual fish in each experiment that held this optimal position also showed the highest specific growth rate. In general, mean potential profit, calculated from characteristics of water velocity and drift patterns at fish positions, was a good predictor of specific growth rate for all three species of salmonids.

Drift Energy

In all experiments, the energy available to fish as drift was a linear function of water velocity for each of the five cross-sections (Figure 2A) so that:

$$E = m \cdot V \qquad (7)$$

where: E = drift energy (cal/hour/cm^2)
m = slope of drift-vs-velocity relationship
V = water velocity (cm/second)

These linear relationships were often better for the three pool cross-sections (120, 180 and 240 cm in Figure 1) than for the 60- and 300-cm ones in the riffles. At the 60-cm distance the drifting Daphnia were not evenly distributed across the channel in proportion to flow despite a small baffle positioned just downstream of the food input for this purpose. The best drift-vs-velocity relationships, shown in Figure 2A, were achieved during experiments 5 and 6 as the sampling and counting techniques were most refined then.

The decline in slopes of drift-vs-velocity relationships with distance downstream from the food source were fit to negative exponential equations shown in Figure 2B:

$$m = a\ e^{-bx} \qquad (8)$$

where: m = slope of drift-vs-velocity relationship
x = distance downstream from food source (cm)
a and b are constants

To determine the available drift energy (D) at a fish's position, equation (8) may be substituted into (7), and the result into equation (5), yielding:

$$E = a\ e^{-bx} \cdot V \qquad (9)$$

$$D = 1/8\ \pi r^2 \cdot ae^{-bx} \cdot V \qquad (10)$$

so that the available drift energy is a function of fish body length (½r), distance downstream from the food source (x), and water velocity (V), the last being the maximum velocity within the two-body-length radius. The drift equations (9) for each experiment are presented in Table 2.

Specific Growth Rate vs Potential Profit

In experiments 1 and 2, few fish grew because food levels were low (Figure 3). Despite this constraint, the specific growth rates of coho salmon were a hyperbolic function of mean potential profit at their stream positions, which fit the Michaelis-Menten model well. Of the 22 coho in experiment 1, 19 lost weight, and 18 of these held positions requiring a net energy expenditure as shown by the negative mean potential profit. The 95 percent confidence intervals for mean potential profit are shown in Figure 3 and subsequent figures, but only for fish with confidence intervals of 1.0 or greater. The narrow confidence intervals in Figures 3A and 3B indicate that coho salmon and brown trout often used the same positions or ones with similar characteristics throughout the 18-day experiments.

It did not matter much whether equations for coho salmon (3) or rainbow trout (4) were used to calculate the cost of swimming, as shown by the small difference between the two for coho salmon in experiment 1 (Figure 3A). The resource threshold at which no growth occurred for coho salmon (T in equation 6) was 0.0 cal/hr for coho metabolism and -0.5 cal/hr for rainbow metabolism. Resource thresholds were accurately determined for most experiments because points fell close to this threshold on both sides of the x-axis.

The Michaelis-Menten relationship based on the metabolic equation for coho salmon (3) happens to pass directly through the origin, but this may just be fortuitous, since mean potential profit does not measure additional energy costs such as metabolism at night and aggressive displays. I expect resource thresholds to vary slightly with changes in fish size and drift measurement, so that results are most comparable between experiments run concurrently (1 vs 2, etc., see Table 1), because fish size, food level and drift measurement are nearly identical.

The data for brown trout from experiment 2 (Figure 3B) are not adequate to fit the Michaelis-Menten model, but the resource threshold was estimated to be 2.15 cal/hour by linear regression. Of the 17 fish that remained in the experiment, only 2 grew, and one of these was excluded as an outlier because its position was characterized by highly variable potential profits indicated by the large confidence interval in Figure 3B. This fish held a focal point in a crevasse on the upper riffle for most of the experiment, but was able to capture only a small proportion of the drift passing by due to the high water velocities overhead, and was therefore not able to garner the same proportion of potential profit that other fish did.

In all experiments, individual fish occasionally swam to other parts of the stream for short periods to use atypical positions. These positions were detected from abnormally high or low potential profit values relative to other days, and were excluded as outliers by the method of Grubbs and Beck (1972). Mean potential profit was then recalculated using the remaining measurements.

The behavior of juvenile brook and brown trout with regard to holding positions tended to differ from that of coho salmon in two ways throughout experiments. First, trout that were forced into positions in fast water often applied the leading edges of their pectoral fins to the stream bed to hold themselves on the bottom with little energy expenditure. Brook trout also did this occasionally, and Gibson (1981) and Kalleberg (1958) report that Atlantic salmon used this technique. Coho salmon never rested on the bottom. Whenever trout were observed resting on the bottom in experiments 2 and 4, they were assigned a focal point velocity and maximum velocity of 0.0 cm/second, because I assumed that they required only their standard metabolic rate to maintain the position, and did not forage. During experiment 6, brown trout were assigned a focal point velocity of 0.0 and a maximum velocity measured only to the small distance from their focal point that they were observed to travel to capture drift.

A second distinguishing characteristic of trout was that subordinate fish tended to hide in the gravel, often lodging themselves next to the plexiglass stream wall. These fish were also assigned focal point and maximum velocities of 0.0 cm/second.

In experiment 3, coho salmon grew at much higher rates than in experiment 1, and only two fish lost weight (Figure 4A), probably because fish were acclimated longer and fed more than in the previous experiment (Table 1). The Michaelis-Menten function was difficult to fit to these data because no fish grew near the maximum specific growth rate, but the resource threshold required for maintenance was estimated to be 2.5 cal/hour. As in experiment 1, coho positions showed little variability in mean potential profit, as indicated by the small 95 percent confidence intervals in Figure 4A. One coho salmon disappeared into the gravel on the last day of the experiment and was never found.

In contrast, only three brook trout grew or maintained their weight in experiment 4 when fed at the same rate as coho salmon were in experiment 3 (Figure 4B). Brook trout grew at a lower specific rate for a given mean potential profit, required a higher resource threshold to maintain their weight (5.5 cal/hour), and occupied positions with more variable mean potential profit than did coho salmon. Experiment 4 was begun with 20 brook trout, but 2 fish died by the 4th day of the experiment and 8 fish burrowed into the gravel at the downstream end of the section and were never recovered. All of these fish were healthy, but all held unfavorable positions with negative mean potential profits for the days before they disappeared, indicating that they were probably losing weight rapidly.

In experiment 5, coho salmon grew similarly to those in experiment 3 and several fish had high specific growth rates, providing the most complete data set of any experiment for fitting the Michaelis-Menten function (Figure 5A). All coho salmon grew, although the 95 percent confidence intervals indicate that some fish held positions with more variable potential profit than during experiments 1 and 3. One coho salmon held a position in a crevasse on the upper riffle and was excluded as an outlier for the same reasons given for a similar fish in experiment 1. The resource threshold for coho salmon during this experiment was 1.1 cal/hour.

When I ranked fish in linear dominance hierarchies according to my observations of the aggressive behavior throughout each experiment, the ranking generally agreed well with their order along the specific growth rate vs potential profit curve. That is, the dominant or highest ranking individual defended an area with the highest resource level, and the hierarchy of subordinates held positions affording successively lower potential profits. This behavior produced the patterns seen in all experiments, especially 1, 2, 4 and 5, where one individual far exceeded others in mean potential profit and specific growth rate. This pattern produced by the dominance hierarchy, makes fitting the Michaelis-Menten equation using reciprocal plots difficult, because the variability inherent in measuring small potential profits and growth rates of the most subordinate fish (corresponding to points close to the threshold) is magnified when the reciprocal is calculated, and exerts a strong influence on the linear regression used to fit the equation (see Methods). Thus, these functions are easier to fit if more fish grow at higher rates and data are more evenly spaced. For example, even spacing can be achieved in aquaculture research when individual fish are grown separately on known rations.

Only five brown trout in experiment 6 grew or maintained their weight when fed at the same level as coho salmon in experiment 5 (Figure 5B). Brown trout grew at lower specific rates than coho at all levels of potential profit, required a higher resource threshold to maintain growth (4.0 cal/hour), and often held positions with more variable potential profits than coho did. This pattern is similar to that for brook trout and coho salmon in experiments 3 and 4 (Figures 4A and 4B). One fish that hid in the gravel throughout the experiment was not recovered.

DISCUSSION

Specific Growth Rate vs Resources: the Michaelis-Menten model

The results of these experiments (Figures 3 through 5) may be added to the growing body of evidence suggesting that the Michaelis-Menten or Monod equation describes the relationship between the specific growth rate and a critical resource for a wide range of organisms. This approach has most often been used to describe population growth of microorganisms (Monod 1949), algae (King 1980), and diatoms (Tilman 1981), but a brief search of the literature (D. King personal communication) revealed that more complex organisms show similar relationships. For instance, population specific growth rates of two species of zooplankton (Daphnia pulex and D. rosea) grazing on phytoplankton (Lampert and Schober 1980) and individual specific growth rates of pelagic juvenile sockeye salmon (O. nerka) as a function of zooplankton density in British Columbia lakes (Warren 1971, p. 260) follow the Michaelis-Menten form but equations were not fit to either of these relationships.

It is important here to make the distinction between specific growth rates of populations as opposed to specific growth rates of individual organisms. Rates for populations include births, deaths and costs of reproduction, whereas rates for individuals describe only body growth. Lampert and Schober (1980) make this distinction for individual and population specific growth rates of the zooplankton they studied.

The specific growth rates of fish fed known rations in feeding trials used in aquaculture research (cf. Brett 1979) also may be described by the Michaelis-Menten relationship. Stauffer (1973) fit various functions to data of this type from Brett et al. (1969), but favored a modified sine function over the Michaelis-Menten because it fit the data better. However, further inspection revealed three differences between Stauffer's (1973) methods and mine that affected how well the resulting equations fit the data. First and most importantly, Stauffer (1973) ignored data for fish that were fed to satiation or to excess and consequently grew at high specific rates. Fitting the Michaelis-Menten is difficult without an adequate number of points near the maximum specific growth rate, as I found for experiment 3 (Figure 4A). Secondly, Stauffer (1973) transformed the equation in a different manner to account for the maintenance ration or resource threshold. In effect, he transformed the axes to the point on the curve where R=0, i.e. a point corresponding to the negative specific growth rate achieved when fish were not fed. This technique also makes fitting the equation difficult because points other than μ_{max} and K_R must be estimated, a reason Stauffer (1973) used to reject the equation. The third problem is that Stauffer (1973) apparently estimated μ_{max} and K_R simply by inspection from curves fitted by eye by Brett et al. (1969). My preliminary analysis of the data in Brett et al. (1969) show that substantially better fits result when the Michaelis-Menten parameters are calculated using the best of three transformations outlined in Dowd and Riggs (1965).

Carline and Hall (1973) found hyperbolic relationships between the specific growth rates of coho salmon fed known amounts of fly larvae in an artificial stream and in aquaria. Quadratic equations they fit to their curvilinear relationships show that maximum specific growth rates ranged from 0.012 to 0.020 g/g/day for 45-78 mm fish, which was close to the range I observed for fish of similar size. Carline and Hall (1973) and Stauffer (1973) used the ingested ration as their measure of resources, whereas potential profit measures the availability of resources to fish. The general consensus among Warren (1971), Stauffer (1973) and Carline and Hall (1973) is that the specific growth rate vs ration curve falls off at high rations because net growth efficiency decreases linearly above the maintenance ration as a result of decreased assimilation efficiency as more food moves through the gut, increased specific dynamic action or increased activity. In this study, an additional factor contributing to the hyperbolic nature of the function is that higher ranking fish became satiated at positions of high potential profit, and captured a smaller proportion of the drift than subordinate fish did at positions with lower potential profit.

Describing growth using the approach outlined in this paper relies on the fundamental idea that populations and individuals grow exponentially according to:

$$Y_t = Y_o e^{\mu t} \quad (11)$$

where: Y_t = final number or weight of population or individual
Y_o = initial number or weight of population or individual
μ = specific growth rate
t = time interval.

But as a population or individual grows in a resource-limited environment, its specific growth rate declines as resources are depleted according to the Michaelis-Menten function (see equation 6). Not considered here are cases where more than one resource is in short supply. Young and King (1980) and Tilman (1981) use the Michaelis-Menten model to describe the interacting effects of multiple resource limits on algae and diatoms.

The strengths of the Michaelis-Menten equation in describing growth lie in four areas. First, the parameters are biologically meaningful. The resource threshold corresponds to the maintenance ration for the organism at which it neither gains or loses weight -- R_{maint} of the aquaculturists (Brett 1979), and the maximum specific growth rate (μ_{max}) is a genetically constrained maximum -- r_{max} of ecologists.

Second, the equation provides a clearer insight into the mechanism of population or individual growth, in contrast to density-dependent models of population growth, such as the Verhulst-Pearl logistic (Kingsland 1982), or the various empirical models of individual fish growth in relation to age, such as the von Bertalanffy (cf. Ricker 1979). Growth of individuals or populations is related to resources, such as food or space, and thus should be tractable in this form if the critical resources can be measured.

Third, the relationship appears to be a general one for organisms. It has thus far been used for organisms ranging from bacteria to fish, and should apply to others, requiring only that the population grow at some exponential rate subject to the constraints of resource levels.

Finally, the relationships between specific growth rate and resources are useful in comparing the resource use and predicting the competitive ability of different species (Healey 1980, Tilman 1981). Such relationships can be used to make *a priori* predictions about which species will grow faster in sympatry, and which will maintain growth to a lower resource level. Figure 6 shows the relationships for all experiments except number 2. In all cases, coho salmon maintained growth to lower resource thresholds than either brook or brown trout and, except for experiment 1, coho showed higher specific growth rates than trout. As mentioned above, comparisons of these curves are most appropriate for experiments run simultaneously. These results indicate that coho salmon would grow faster than either trout and grow at lower food levels. However, these relationships ignore the behavioral aspects of competitive interactions. Results of competitive experiments among the three species are the subject of a forthcoming paper.

Potential Profit as an Optimal Foraging Model

The major assumption of a large class of optimal foraging models is that organisms maximizing net energy gain also maximize fitness (Pyke et al. 1977). In this respect the model of potential profit is an optimal foraging construct, based on drift and flow characteristics at feeding positions of stream salmonids. Proponents of the theory argue that the strength of optimal foraging models lies in their ability to predict an animal's behavior when it is given an array of food or habitat resources from which to choose (Werner and Mittelbach 1981). Although variations of optional foraging models have proliferated, relatively few have been tested, especially in the field. A rigorous test of an optimal foraging model involves comparing the observed resource use of an organism to that predicted by the model from knowledge of the resource distribution in the environment.

This approach has been used successfully by Werner and Hall (1974) and Mittelbach (1981) for fish that compete exploitatively, but I modified it slightly to make predictions about optimal position choice by stream salmonids, which set up linear dominance hierarchies (Jenkins 1969). Within the short section of stream aquarium where all fish in an experiment could potentially interact, fish should compete for optimal positions that maximize potential profit. Moreover, because juvenile salmonids defend areas around their focal points, use of a position by one fish precludes use by all others of lower rank in the hierarchy. Therefore, corresponding to the decrease in rank along the linear dominance hierarchy should be a hierarchy of positions offering successively less potential profit.

To test potential profit as a measure of optimal positions, I chose to compare the positions held by juvenile coho salmon in the upstream half of the stream aquarium during experiment 5 with the pattern of potential profit in this section predicted by the model. To map potential profit, I first measured water velocity at identical points in the horizontal plane for three depths: 2.5, 7.5, and 12.5 cm. At each point of measurement the velocity closest to the stream bed was used as the focal point velocity, and the maximum velocity within two body lengths (83 mm for coho salmon in experiment 5) above and in front of the focal point was determined from the three-dimensional velocity profiles. Using the drift equation for experiment 5 (Table 2) and these velocity characteristics, potential profits for each focal point were determined using equations 2, 3 and 10, and mapped in Figure 7. Also shown in Figure 7 are typical positions for the coho salmon, designated by their finclip codes. Of the 16 fish positions shown, the 5 shown as squares in Figure 7 were atypical in relation to the map and deserve mention. Fish TA on the upper riffle was the outlier in Figure 5A, and did not grow according to its potential for the reasons described above. Four fish in the lower pool (TD, TBA, TAD and BD) usually held positions 7-14 cm above the stream bed and were not considered because the potential profit contours apply only to fish using focal points close to the substrate. The map provides conservative estimates for potential profit of the other 11 fish because most used small irregularities of the stream bed as refuges affording reduced swimming velocities, which would decrease swimming costs and increase potential profit.

I chose the ranking of specific growth rate as the closest correlate of the dominance hierarchy, because I did not measure the latter other than by observation during and records made at the end of each experiment. Without careful behavioral measurements the ranking among subordinates cannot be accurately elucidated, although my assessment of the dominance hierarchy generally coincided with the order of specific growth rates as stated in the Results section.

The coho were ranked by their specific growth rate, indicated by the number preceding the finclip code in Figure 7, and were similarly ranked according to the predicted potential profit at their positions based on the map, the number shown after the finclip code. The correlation between the two rankings is highly significant ($r = 0.963$, $p \ll .001$) by Pearson's nonparametric test (Conover 1980), which indicates that the predicted position choice based on potential profit fits closely that observed. In turn, this suggests that these salmonids choose stream positions with respect to constraints of food supply and flow.

In the terms of optimal foraging theory, drift-feeding stream salmonids are energy maximizers, at least as juveniles and in the absence of predators.

The relationships between specific growth rate and net energy gain for stream salmonids may help validate the assumption stated above that maximizing net energy gain is equivalent to maximizing fitness. A problem in linking the two is that net energy gain is measured on the short term in calories per second or hour, while fitness is a function of long-term reproductive success, requiring months or years to be expressed in most animals. Thus, optimal foraging models fail to account for the additional factors involved in optimization on an evolutionary time scale, a problem described but largely circumvented by Pyke et al. (1977).

Specific growth rate incorporates more of the factors that bear on fitness and is measured over a longer time scale than net energy gain usually is. Moreover, specific growth rate is expected to be closely correlated with fitness in fish, because fish that grow at the highest specific rates should have more energy to invest in reproduction and produce more offspring that survive. Therefore, the positive relationship between specific growth rate and potential profit of salmonids lends power to the argument that the dominant fish that gain maximum potential profit also maximize fitness.

Microhabitat Selection by Stream Salmonids

The results of these experiments confirm the ideas set forth by several investigators more than a decade ago about the mechanisms of microhabitat choice by stream salmonids. Everest and Chapman (1972) observed that juvenile chinook salmon (*O. tshawytscha*) and steelhead trout (*Salmo gairdneri*) consistently faced moderate current speeds yet were close to fast water, and proposed that such behavior should maximize the quantity of available drift while minimizing energy expenditure to remain at feeding stations. Everest and Chapman (1972) also showed that faster water delivered more drift per unit time in natural streams than slower water. Using these data (then unpublished) Chapman and Bjornn (1969) proposed that much of the reason juvenile salmonids move into faster and deeper water as they grow is to exploit the greater rate of food supply there.

In a study of social behavior of adult brown trout and rainbow trout, Jenkins (1969) found that groups of fish set up linear dominance hierarchies and that all fish preferred one most favorable position in each stream section. When the dominant fish was removed, the next fish in each hierarchy moved into the preferred position. Jenkins (1969) found that these preferred feeding positions were consistently located under principal surface drift patterns but were limited by subsurface velocities tolerable to the fish, which led him to propose that trout must be able to choose positions in the current which will maximize food intake while minimizing energy expenditure.

Fausch and White (1981), using these ideas of favorable positions for stream salmonids and drawing from the methods of fish position measurement used by Griffith (1972), developed a simple measure of trout position quality called "water velocity difference", for use in a study of competition between adult brook trout and brown trout. Water velocity difference was defined as the difference between the maximum velocity within 60 cm of an adult trout, and the focal point velocity, and thus incorporated the ideas of maximum net energy gain proposed by Jenkins (1969) and Everest and Chapman (1972).

The results of all experiments support the hypothesis that juvenile salmonids select focal points on the basis of water velocity characteristics and food supply to maximize net energy gain. In specific stream sections, selection of focal points is further constrained by the formation of intraspecific hierarchies in which dominant fish hold optimal positions and, in turn, achieve the highest specific growth rates. Moreover, the specific growth rates of all fish in the hierarchy are related to potential for net energy gain at their stream positions according to hyperbolic functions that are best described by the Michaelis-Menten model.

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Table 1. Design of experiments.

Experiment	Stream section[a]	Number of days: accli-mation	Number of days: experi-ment	Number of fish	Mean initial: length (mm)	Mean initial: weight (g)	Dry weight (g) *Daphnia* fed per day
1. Coho salmon	U	4	18	22	54.1 (50.5-57.5)[b]	1.59 (1.21-2.03)	0.280 (0.0124)[c]
2. Brown trout	D	4	18	17	52.4 (47.5-54.5)	1.40 (0.99-1.63)	0.172 (0.0172)
3. Coho salmon	D	17.5[d]	10	20	35.1 (32.0-38.0)	0.32 (0.20-0.49)	0.314 (0.0090)
4. Brook trout	U	17.5[d]	10	18	33.7 (30.0-37.0)	0.26 (0.15-0.45)	0.314 (0.0090)
5. Coho salmon	U	25.5	9	16	41.3 (39.0-43.5)	0.62 (0.46-0.87)	0.418 (0.0112)
6. Brown trout	D	25.5	9	13	41.0 (39.0-43.0)	0.50 (0.37-0.63)	0.418 (0.0112)

a. U=upstream, D=downstream section.
b. Ranges shown for initial length and weight.
c. SEM
d. Fish acclimated two additional days to food (see text).

Table 2. Relationships between slopes of drift-energy-vs-water-velocity regressions (m) and distance downstream from the food source (x).

Experiment	Drift equation[a]
1. Coho salmon	$m = 0.1002\ e^{-0.0236\ x}$
2. Brown trout	$m = 0.0546\ e^{-0.0207\ x}$
3. Coho salmon	$m = 0.0246\ e^{-0.00305\ x}$
4. Brook trout	$m = 0.0330\ e^{-0.000747\ x}$
5. Coho salmon	$m = 0.0330\ e^{-0.00410\ x}$
6. Brown trout	$m = 0.0154\ e^{-0.00100\ x}$

a. See equation 8 in text.

Figure 1. Plan view of the stream aquarium (after Fausch and White MS). Flow is pumped between head box and biofilter.

Figure 2. (A) Drift energy as a function of water velocity at five distances from the upstream end during experiment 5.

(B) Slope of the drift-vs-velocity relationship ($\pm$1 SE) as a function of distance from the upstream end during experiments 5 and 6.

Figure 3. Specific growth rates of (A) coho salmon (experiment 1) and (B) brown trout (experiment 2) as a function of mean potential profit.

Figure 4. Specific growth ratesof (A) coho salmon (experiment 3) and (B) brook trout (experiment 4) as a function of mean potential profit.

Figure 5. Specific growth rates of (A) coho salmon (experiment 5) and (B) brown trout (experiment 6) as a function of mean potential profit.

Figure 6. Specific-growth-rate-vs-mean-potential-profit curves for all experiments where Michaelis-Menten equations were fit. Numbers by curves refer to experiments.

Figure 7. Map of mean potential profit (cal/hr) in the upstream section during experiment 5. Hatched areas are rocks. See text for explanation of fish positions.

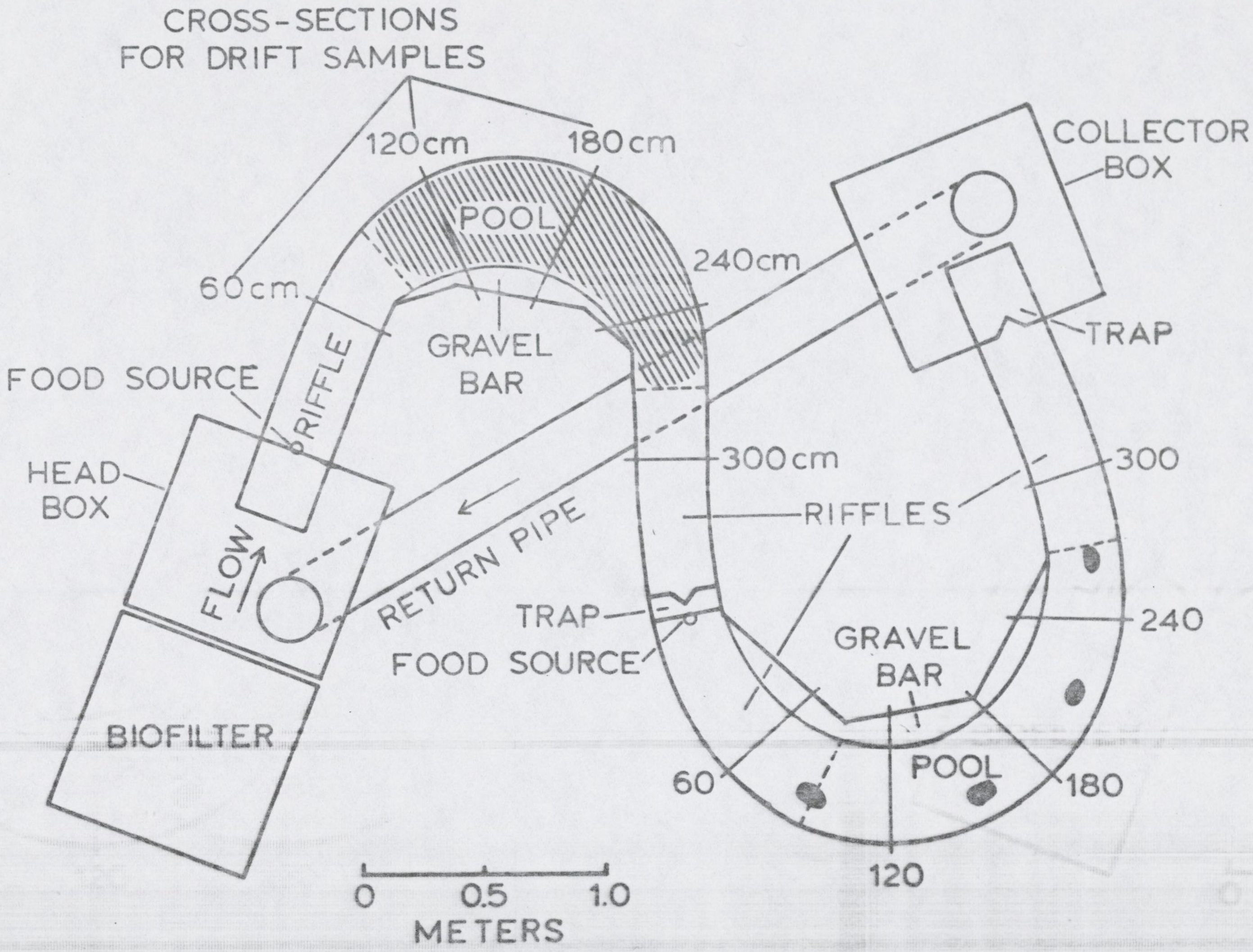

CROSS-SECTIONS
FOR DRIFT SAMPLES
120cm
180cm
60cm
240cm
POOL
GRAVEL
BAR
COLLECTOR
BOX
TRAP
FOOD SOURCE
RIFFLE
HEAD
BOX
300cm
RIFFLES
300
FLOW
RETURN PIPE
TRAP
FOOD SOURCE
240
GRAVEL
BAR
BIOFILTER
60
POOL
180
120
0
0.5
1.0
METERS

Figure 1

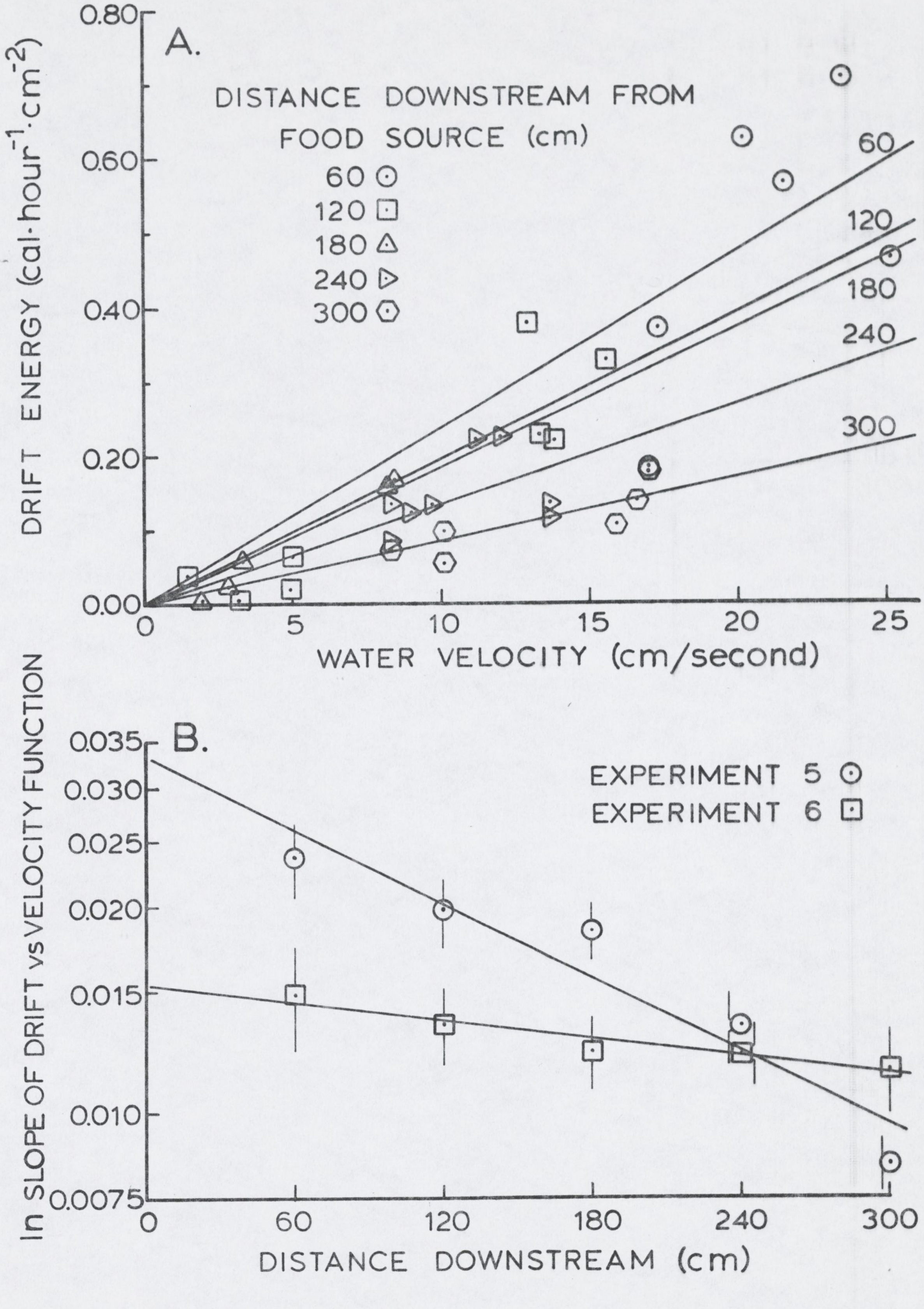

A.
DISTANCE DOWNSTREAM FROM FOOD SOURCE (cm)
60
120
180
240
300
DRIFT ENERGY (cal·hour-1·cm-2)
0.00
0.20
0.40
0.60
0.80
0
5
10
15
20
25
WATER VELOCITY (cm/second)
B.
EXPERIMENT 5
EXPERIMENT 6
ln SLOPE OF DRIFT vs VELOCITY FUNCTION
0.0075
0.010
0.015
0.020
0.025
0.030
0.035
0
60
120
180
240
300
DISTANCE DOWNSTREAM (cm)

Figure 2

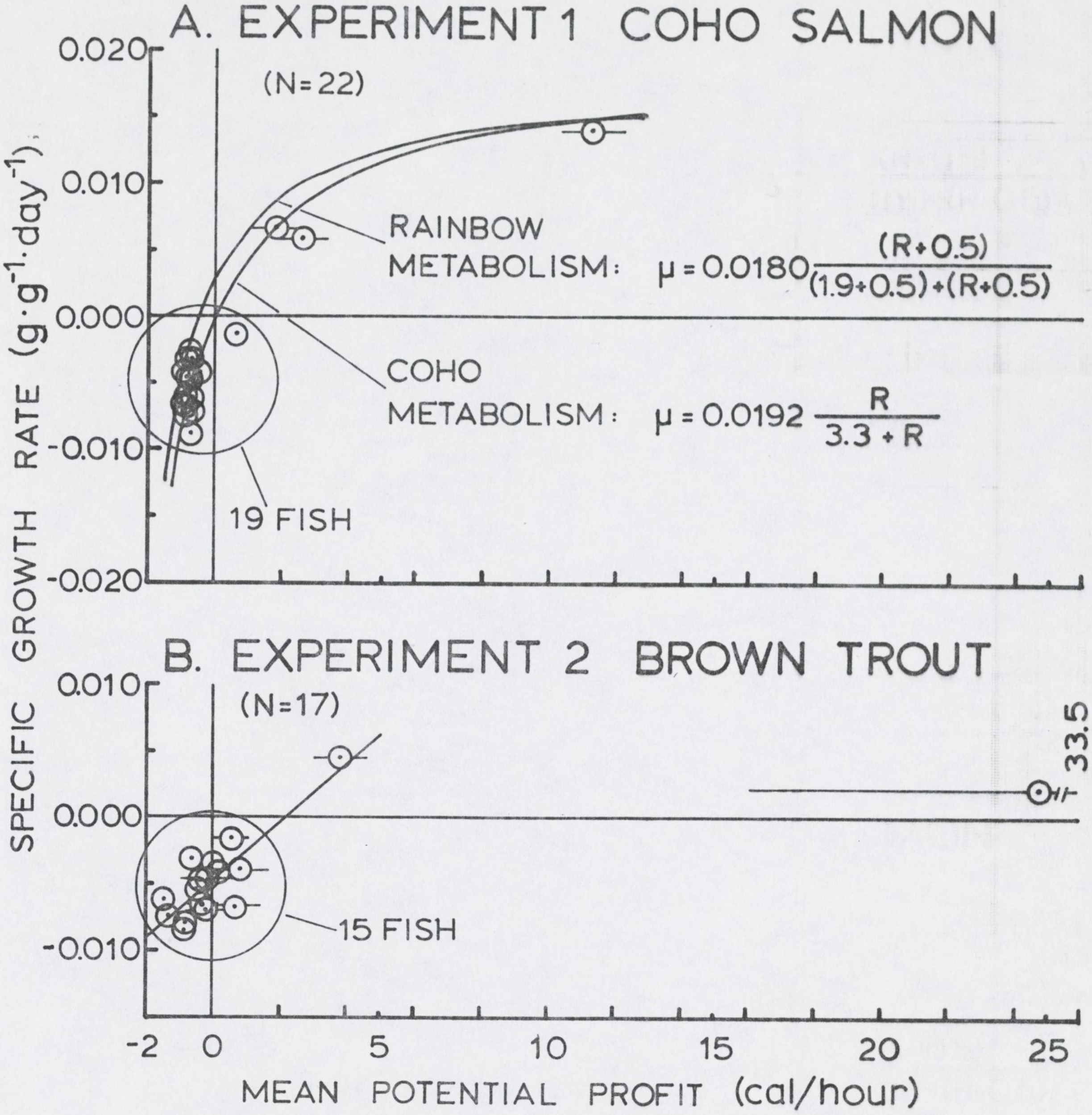

A. EXPERIMENT 1 COHO SALMON
(N=22)
RAINBOW
METABOLISM:
$\mu = 0.0180 \frac{(R+0.5)}{(1.9+0.5)+(R+0.5)}$
COHO
METABOLISM:
$\mu = 0.0192 \frac{R}{3.3+R}$
19 FISH
0.020
0.010
0.000
-0.010
-0.020
B. EXPERIMENT 2 BROWN TROUT
(N=17)
33.5
15 FISH
0.010
0.000
-0.010
-2
0
5
10
15
20
25
SPECIFIC GROWTH RATE $(g \cdot g^{-1} \cdot day^{-1})$
MEAN POTENTIAL PROFIT (cal/hour)

Figure 3

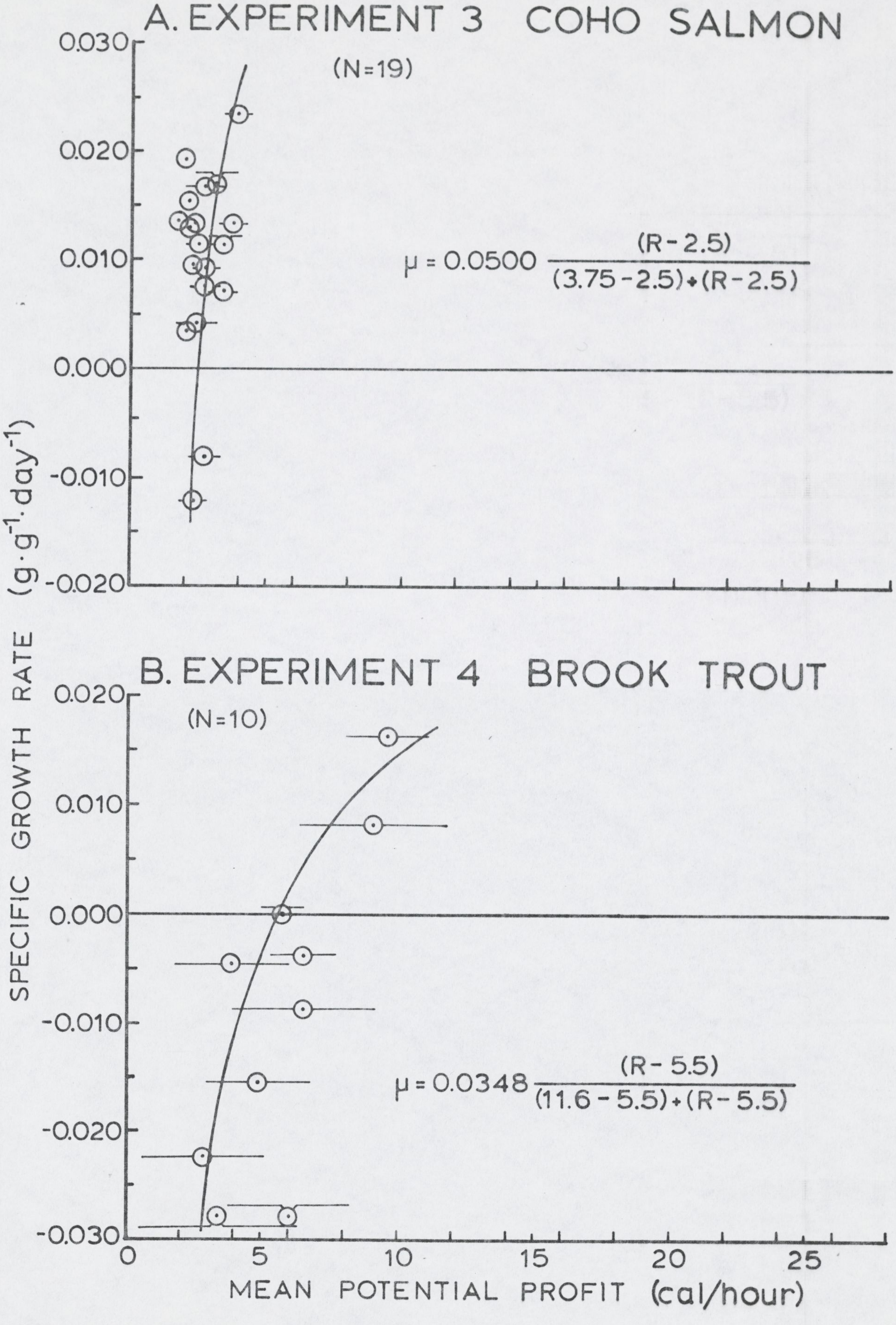
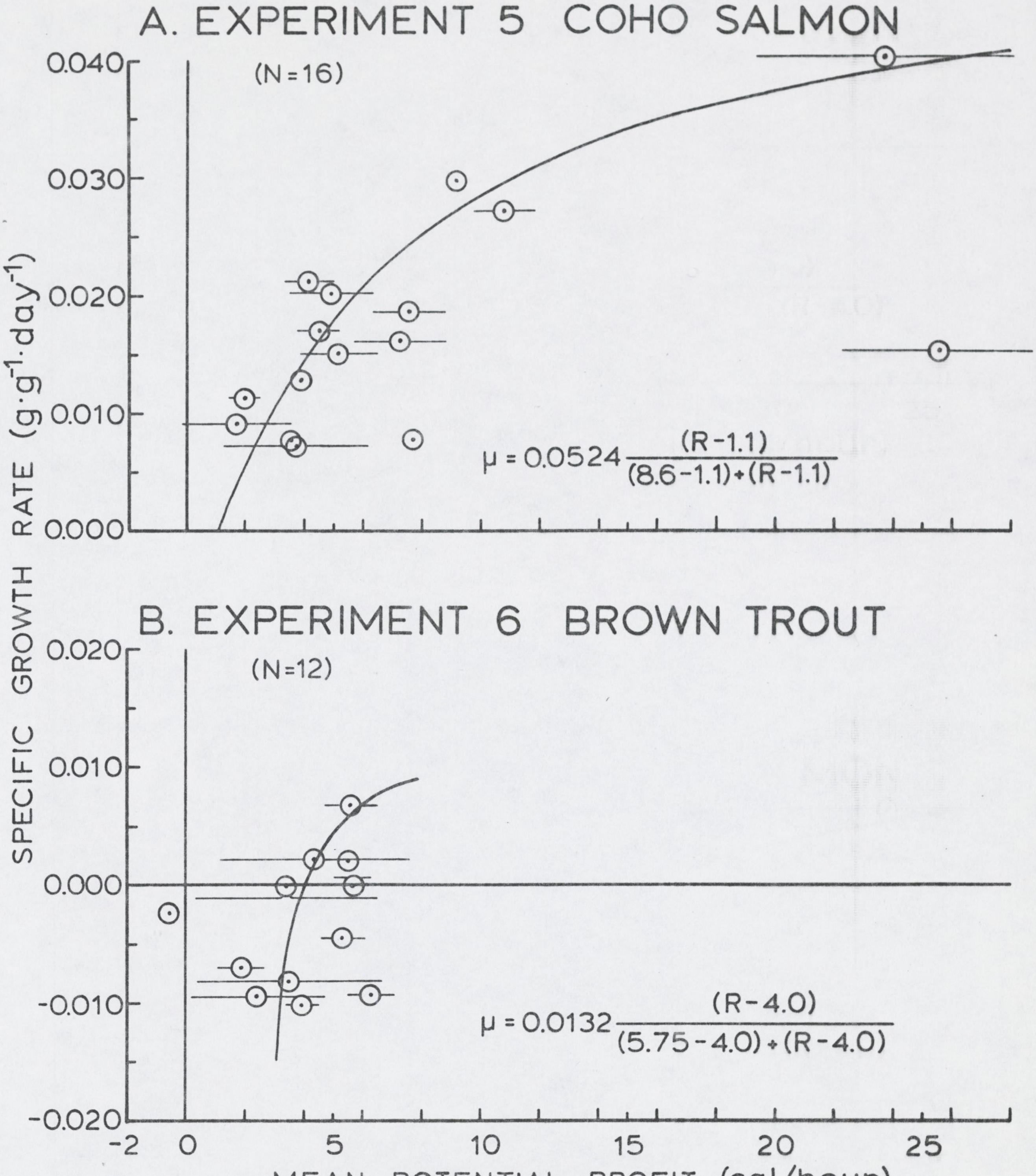
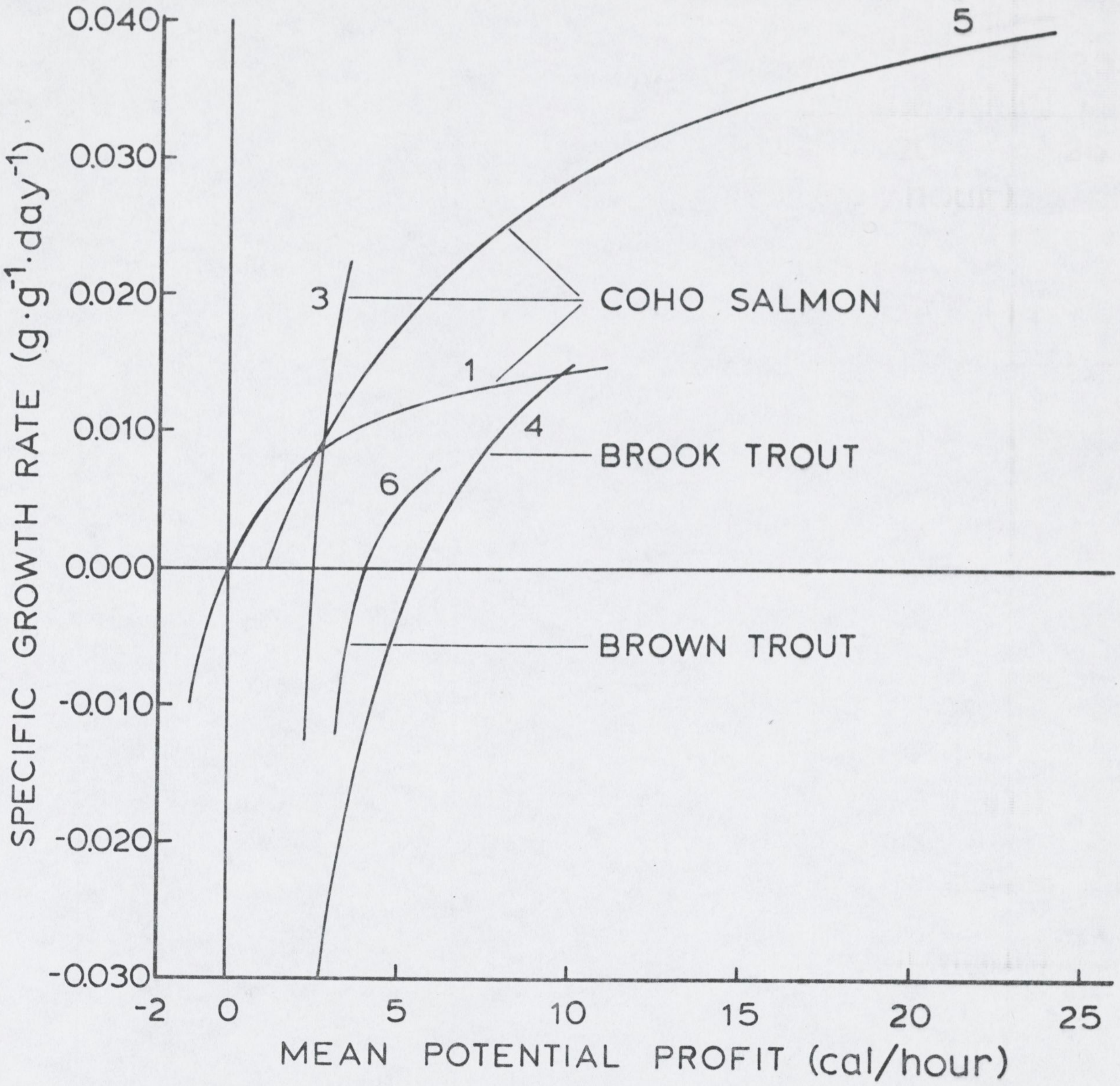

A. EXPERIMENT 3 COHO SALMON
(N=19)
μ = 0.0500 (R − 2.5) / ((3.75 − 2.5) + (R − 2.5))
0.030
0.020
0.010
0.000
-0.010
-0.020
SPECIFIC GROWTH RATE (g·g⁻¹·day⁻¹)
B. EXPERIMENT 4 BROOK TROUT
(N=10)
μ = 0.0348 (R − 5.5) / ((11.6 − 5.5) + (R − 5.5))
0.020
0.010
0.000
-0.010
-0.020
-0.030
0
5
10
15
20
25
MEAN POTENTIAL PROFIT (cal/hour)

Figure 4



A. EXPERIMENT 5 COHO SALMON
(N=16)
μ = 0.0524 (R-1.1) / ((8.6-1.1)+(R-1.1))
B. EXPERIMENT 6 BROWN TROUT
(N=12)
μ = 0.0132 (R-4.0) / ((5.75-4.0)+(R-4.0))
SPECIFIC GROWTH RATE (g·g⁻¹·day⁻¹)
0.040
0.030
0.020
0.010
0.000
0.020
0.010
0.000
-0.010
-0.020
-2
0
5
10
15
20
25
MEAN POTENTIAL PROFIT (cal/hour)

Figure 5



0.040
0.030
0.020
0.010
0.000
-0.010
-0.020
-0.030
SPECIFIC GROWTH RATE (g·g-1·day-1)
-2
0
5
10
15
20
25
MEAN POTENTIAL PROFIT (cal/hour)
5
3
1
4
6
COHO SALMON
BROOK TROUT
BROWN TROUT

Figure 6

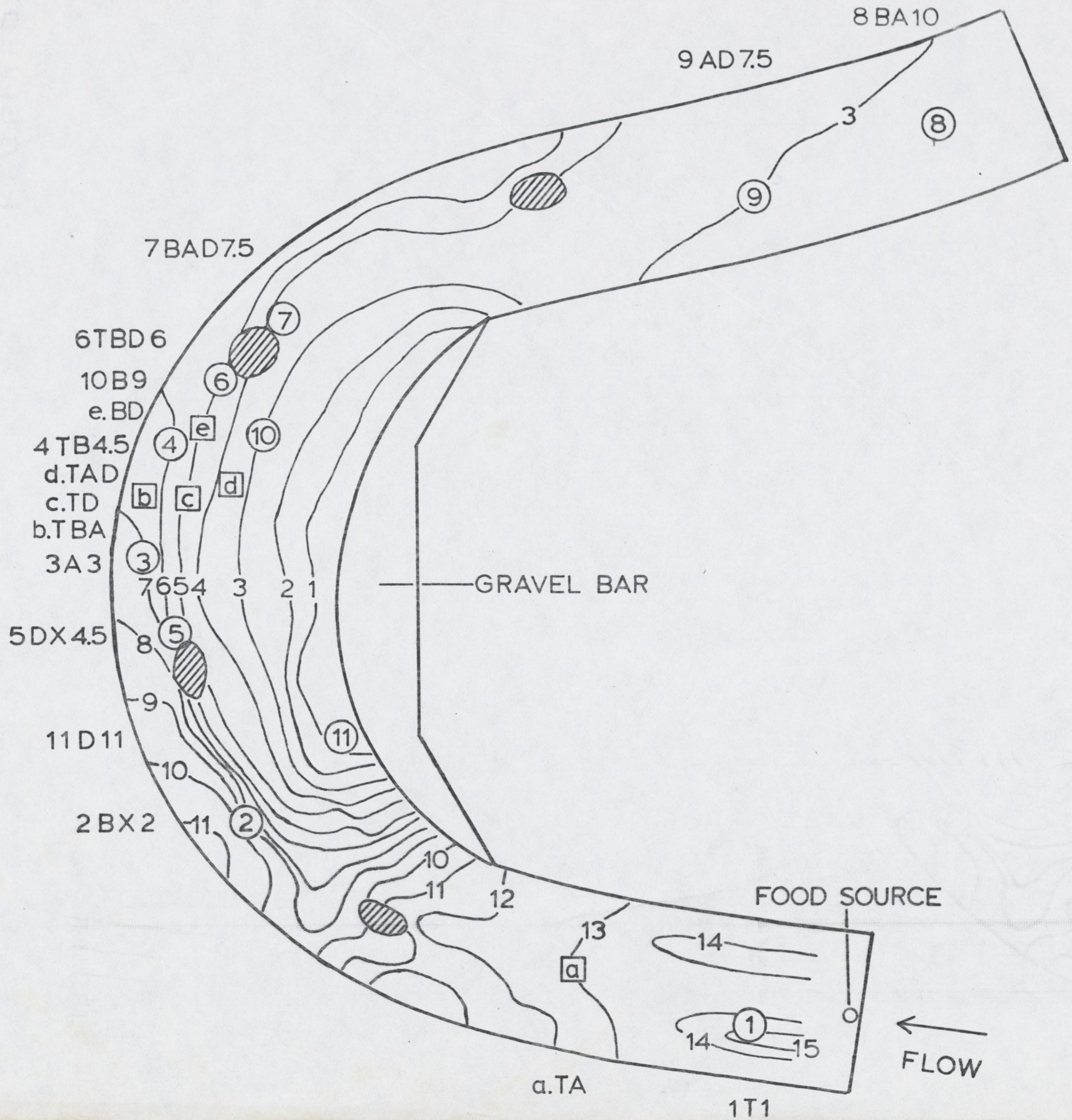

8 BA 10
9 AD 7.5
3
8
9
7 BAD 7.5
7
6 TBD 6
6
10 B 9
e. BD
e
10
4 TB 4.5
4
d. TAD
d
b
c
c. TD
b. TBA
3
3 A 3
7654 3 2 1
GRAVEL BAR
5 DX 4.5
5
8
9
11 D 11
11
10
2 BX 2
11
2
10
11
12
FOOD SOURCE
13
14
a
1
14
15
FLOW
a. TA
1 T 1

Figure 7.

RESEARCH NEWS

Colorado Division of Wildlife

Spring 1984

New system rates trout habitat

by Rick Anderson

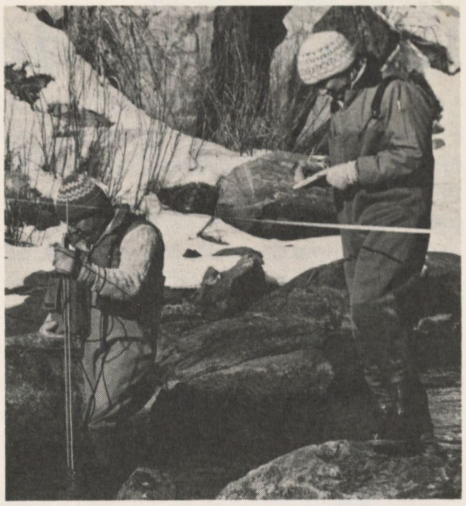
Trout habitat quality is primarily determined by the amount of water flowing in the stream. It has been difficult to accurately relate stream flow to the habitat available for trout. This problem is now being addressed by a computer program, PHABSIM (Physical Habitat Simulation System), developed by the U.S. Fish and Wildlife Service Western Energy and Land Use Team. PHABSIM will quantify the microhabitat available to the different ages and species of trout in relation to the amount of discharge from a dam. The result from the computer is a unit of microhabitat called Weighted Usable Area (WUA).

There are numerous applications for this information such as enhancing analysis studies on various Colorado water projects that will impact stream flow. The information generated by PHABSIM could influence minimal in-stream flow recommendations made to protect fish habitat. When incorporated into the water release pattern of a dam, PHABSIM could predict the flows that produce the best possible habitat for the tailwater (that part of a stream immediately below a dam) given the constraints and discharge demands of the reservoir. The carrying capacity of a stream for adult trout could also be defined based on the habitat availability.

For the last two years, Barry Nehring and I have been generating the PHABSIM data base necessary to validate this program. So far the results have been very encouraging. PHABSIM can identify the relative quality of habitat for trout and also predict which species are best suited for the habitat.

High correlations have been found between WUA and year class survival. Newly-hatched trout fry are not good swimmers and are found in the still, shallow water near the banks during their first month or so. Floods eliminate most suitable fry habitat. Brown trout fry are most vulnerable to floods in May and June while rainbow fry are most vulnerable in June and July. It is conceivable that year class survival of trout or other species could be manipulated below reservoirs by regulating flow, either promoting or depressing numbers depending on the stability of the adult population and the management goals.

Our primary concern is to produce a quality adult trout population. By using



STREAM CROSS SECTION INFORMATION, including water velocities, are being used in a new system designed to predict trout carrying capacities. Ann Hodgson, Division water projects coordinator, and biologist Bill Miller measure velocities in the South Platte.

habitat quality ratings generated by PHABSIM and adult mortality rates, we want to predict the flow necessary to maintain high adult survival over winter.

We have also found strong positive correlations between WUA and adult trout populations. This may allow us to predict the change in populations that could be expected if the stream were closed to fishing or if catch and release regulations were implemented. This has been tried for the new Gold Medal Area on the South Platte River at Deckers. Based on PHABSIM, the carrying capacity was predicted to be 281 kilograms of adult trout per 1000 feet of stream. Under the eight trout per day bag

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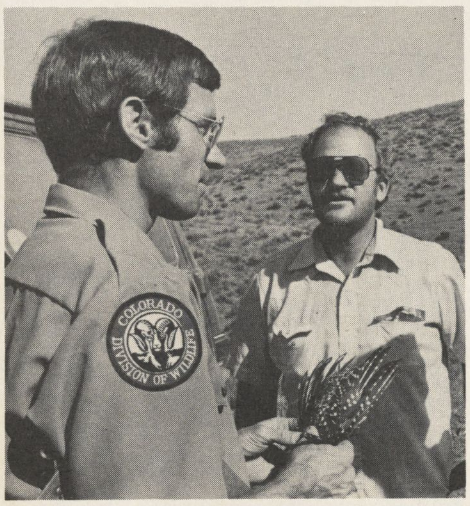

RESEARCHER KEN GIESEN examines a sharptail wing collected from hunters. His studies have indicated a surprising number of hunters were able to distinguish between sharptails and other grouse species.

Liberal sharptail season sought

by Ken Giesen

Longer seasons and more liberal bag limits are now being proposed as methods for increasing recreation opportunities for hunting sharp-tailed grouse in northwestern Colorado. Recent Division studies on blue grouse and sage grouse demonstrated that longer seasons had little impact on harvest rates but did distribute hunting pressure over a longer period. Because harvest surveys indicated that sharp-tailed grouse are underharvested in Colorado, several alternatives were investigated as a means of increasing recreation opportunity and harvest by sharp-tailed grouse hunters.

Historically sage and sharp-tailed grouse hunting seasons coincided and harvest regulations specified an aggregate bag limit. Presumably this was because wildlife managers believed that hunters could not differentiate between the two species. As part of an intensive research project on Columbian sharp-tailed grouse in Routt and Moffat counties, grouse harvest was measured and hunters were interviewed. Successful hunters were asked to identify the species of grouse they harvested. Nearly 300 hunters were contacted and only a few (6%) were unable to identify the grouse they bagged. Of 56 hunters having both sage and sharptail only one could not differentiate between the two species. Surprisingly, blue grouse were misidentified most often.

In 1982 grouse harvest regulations specified separate bag limits for each species of grouse. Nearly 95% of the hunters contacted in 1983 were aware of the regulation change and most reacted favorably to it. The opportunity to hunt for several species of grouse was appealing to most hunters, especially those from the Front Range.

High energy deer pellet facing critical field test

by Geoff Tischbein

"It's no miracle pellet. . .we're going to lose some deer," commented Wildlife Research Leader Bruce Gill about the food pellet now being used to feed thousands of deer throughout the state. Nevertheless, he and fellow researchers Dan Baker and Tom Hobbs are cautiously optimistic that the pellet will save the deer from a most certain starvation due to the abnormally deep snows and cold temperatures.

Gill's caution stems from the lack of experience in feeding the pellet to wild populations under winter stress conditions. "What we know is that in a pen situation it works great; but in the field we don't have the control over how much is being fed or how much they are getting. For example, the fawns probably won't do as well due to competition from the adults."

However, what is also known is that the pellet is the best substitute for a natural diet yet to be developed in Colorado. This, and the fact that the feeding program was started while the deer were still in good condition, should give them a better than average chance to survive the winter.

According to Baker, the advantage of the new pellet is its ability to provide a readily available supply of digestible energy. Previous pellets were successful in supplementing the diet of captive deer but were too rich for wild deer that were subsisting mainly on low quality winter grass and browse.

"It was like giving them M&M's," Baker said, "they'd melt in their mouths." But for animals not used to the sudden large burst of high energy, the result was severe gastrointestinal upset and in some cases even death. The super rich pellet would drastically alter the pH of the rumen (stomach) and eventually upset the chemical balance of the whole body.

One way to counter the high energy problem is to increase the fiber content of the pellet. However, a ration too high in undigestible fiber will not meet the energy requirements of starving deer, particularly in winter situations when high energy intake is critical. The key was to find a source of digestible energy which is exactly what happened. But the source was not an ingredient Colorado researchers were used to working with: cottonseed hulls! Nevertheless, experiments with captive deer have shown that cottonseed hulls closely resemble the fiber deer get in natural diets and have proven to be about 60 percent digestible.

Hobbs likens the results to the difference between eating a candy bar (M&M's) and a potato. "Both supply energy but with the candy bar it's a quick burst whereas with a potato it's more longterm." The new pellet not only gives the short burst without overpowering the digestive system, but also provides a longterm supply of fiber energy from the cottonseed hulls.

The reasons deer are more sensitive than elk to sudden changes in diet are their smaller digestive systems, more rapid food passage rates, and higher energy requirements per unit of body weight. They do not have the ability elk do to efficiently digest and utilize the nutrients in low quality diets such as hay.

Baker conducted a study this fall to determine if deer consuming a low quality diet could quickly adjust to the new pellet. After holding deer on the poor diet for several weeks he immediately allowed them to eat as many pellets as they wanted. The deer showed no ill effects from the switch leading him to be optimistic about the success of the pellet with wild deer this winter.

Since the pellet was originally developed to be a total nutritional package no other food sources are required. Unfortunately, the sudden need for the pellet this winter

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DEER FAWNS chow down on specially formulated deer pellets at a feeding area near Gunnison. At this point the pellets seem to be working well.

WILDLIFE RESEARCHER DAN BAKER holds a handful of the deer pellets he helped formulate at the Division's research facilities in Ft. Collins. The pellets were originally designed for captive deer, but Baker anticipated their use this winter and ran a test that indicated deer on low quality diets could be shifted to the pellets with no ill effects.

Feeding effort under evaluation

MEASURING SNOW DEPTHS at various feeding sites is part of the evaluation effort now being conducted by Bruce Gill (pictured), Len Carpenter, Tom Hobbs, and Dan Baker. (Photo by Len Carpenter)

No matter how you slice it, this winter's deer and elk feeding program is the biggest emergency operation ever attempted by the Division. Whether you look at tons of hay distributed, semi-trucks of pellets delivered, number of volunteers enlisted, hours logged by Division personnel, dollars donated by private citizens, or numbers of deer and elk reached, it has amounted to an enormous effort. But has it done any good?

That is the key question that Len Carpenter and Bruce Gill hope to be able to answer after they analyze the data they are currently collecting. "Right now we're just trying to observe what's going on so that in the end we can try to make some sense of it all," Carpenter recently commented. At this point no one would even hint the effort has been unnecessary or futile and by the time the two research leaders have looked at the evidence, they should have some concrete data to determine how beneficial the program was.

When the decision was made to begin a major feeding operation it was also decided that an evaluation of its effectiveness would be critical. Carpenter and Gill were given the task of designing a system to do just that. By mid-January they had developed a two-pronged approach which was immediately implemented.

The first phase is an intensive study in Middle Park. Researchers Tom Hobbs and Dan Baker are evaluating the results of various feeding rates in three areas. In one area the deer are being fed a moderate amount while in another they are given all they can eat. In the third, they are not being fed pellets at all. The objectives are to determine the mortality rates of the three groups, describe the overwinter changes in body condition, and finally to estimate what feeding rate maximizes deer survival per dollar invested.

Necropsies are also being performed on does to try to determine the specific cause of death and to estimate what effect the situation will have on reproduction this spring. "There could be other factors such as stress-induced pneumonia that caused the death," Gill said, "so we need to try to determine just what happened."

According to Carpenter, Middle Park was chosen because it has an unfed deer population in close proximity to the fed populations. "We also have an extensive existing data base on past deer population size, distribution, and mortality rates. These features will allow measurement of effects of feeding this winter as well as comparison of mortality of deer currently fed to mortality of past, unfed populations."

The second phase of the valuation is an "extensive" study of four major feeding areas: Middle Park, North Park, Craig, and Gunnison. Every two weeks Carpenter and Gill visit the four areas to classify the condition of the animals, check for signs of mortality, measure snow depths and snow compaction, take air temperature readings, and estimate total numbers of deer being fed. This data will permit comparisons of feeding effects among the four areas.

The final step of this phase will be mortality counts planned for late spring. People will walk the transects to get a total mortality estimate and to analyze it by age and sex. Once these figues are in, Carpenter and Gill feel they will be able to evaluate how beneficial the program was. This evaluation will become the cornerstone for developing plans to improve future supplemental feeding programs.

Field activities calendar — Mar, Apr, May

A. Anderson — trapping puma on Uncompahgre Plateau (Mar).
R. Anderson/Barry Nehring — electrofishing Blue and Arkansas rivers (Mar, Apr); spawn taking on Colorado River (Apr, May); invertebrate sampling on Colorado and Arkansas rivers (May).
Baker/Hobbs — intensive deer feeding evaluation in Middle Park (Mar).
Bartmann — deer trapping Piceance Basin (Mar).
Bear — radio tracking elk in North Park (Mar, Apr); capturing and marking elk calves in North Park (May).
Beck — den work on Black Mesa (Mar); radio tracking and trapping bear (May).
Braun — sage grouse counts, trapping and banding in North Park and Gunnison (Mar, Apr, May); sage grouse telemetry in Gunnison (Mar, Apr, May); ptarmigan surveys on Guanella Pass and in Rocky Mountain Park (Mar, Apr, May).
Carpenter/Gill — extensive deer feeding evaluations in North Park, Middle Park, Craig area, and Gunnison area (Mar).
Craig — peregrine falcon nest observations and manipulations (Apr, May).
Finnell — northern pike sampling at Eleven Mile Reservoir (May).
Freddy — deer cover study at Junction Butte (Mar).
Giesen — ptarmigan winter surveys on Guanella Pass, sharp-tailed grouse lek counts in Craig-Hayden area (Mar); sharp-tailed grouse lek counts, trapping and radio marking (Apr, May); ptarmigan breeding surveys in Rocky Mountain Park (May).
Goettl — sampling Horsetooth, Quincy, and North Sterling reservoirs (Apr); sampling Horsetooth, Quincy, North Sterling, and Rampart reservoirs, and Duck Creek and Pilkington ponds (May).
Haynes — setting up sampling station on Yampa River (Mar).
Hoffman — investigating wild turkey and determining time of breeding seasons in NE, SE, and SW regions (Mar, Apr, May).
Krieger — sampling Chatfield, Pueblo, and Brush Hollow reservoirs, and Prospect Park Ponds for bass (May).
Kufeld — monitoring deer in Lory State Park (Mar).
Lorentzson — duck breeding pair counts in San Luis Valley (May).
McAfee — fish sampling at Bear, Stillwater, Yamcola, Steamboat, and Pearl reservoirs (May).
Miller — greater prairie chicken pre-trapping investigations (Mar); trapping greater prairie chickens and relocating to Tamarack State Wildlife Area (Apr); radio tracking greater prairie chickens on Tamarack (May), evaluating impacts of controlled burning on Tamarack (May).
Reed — radio tracking mountain goat and mountain sheep on Mt. Evans and trapping mountain sheep (Mar, Apr); radio tracking goat and sheep (May).
Snyder — sampling and planting cottonwood stems on South Platte and Republican wildlife areas (Mar); sand sage and blue stem prairie study on South Tamarack (Mar, Apr); revegetation and renovation treatments on S. Tamarack (Mar, Apr, May); controlled burning of sand sage-blue stem areas on S. Tamarack (May).
Van Velson — McConaughy rainbow spawn taking at Juniata and Chico reservoirs (Mar); setting up spawning facilities at Joe Wright Reservoir (May).
Wiltzius — creel census at Granby Reservoir (May).

RESEARCH NEWS
Colorado Division of Wildlife
317 West Prospect
Fort Collins, CO 80526

Robert J. Behnke
Fishery and Wildlife Biology
15A Wagar
CSU

PHABSIM *Continued from page 1*

limit regulation (1979-82) the adult population has averaged only 106 kilograms per 1000 feet. But in the first year of catch and release fishing (1983) the adult population increased to 185 kilograms per 1000 feet. It appears the adult population will show a substantial increase this year since the population in 1983 had relatively few carry-over adults.

We are still in the initial stages of realizing the full potential of this new tool. With more data the predictive capability of this stream simulation model could be improved by adding a stream fertility variable. Other variables such as the size of a sucker or forage species population could also be added to the model to determine their effects on the trout population.

River habitat is constantly lost due to dam construction. Recreational use of Colorado's streams has dramatically increased over the last decade. It is now very important for biologists to maximize the potential of the stream habitat that remains. PHABSIM appears to give the biologist the information necessary to do this on tailwater fisheries.

THE NEW SMILING FACE at the switchboard in the Ft. Collins office is Judi Reeve who replaced Audrey Fischer after her retirement in January. Judi is a Colorado native and worked for CSU before coming over to the Division. She and her husband Stu live in Laporte.

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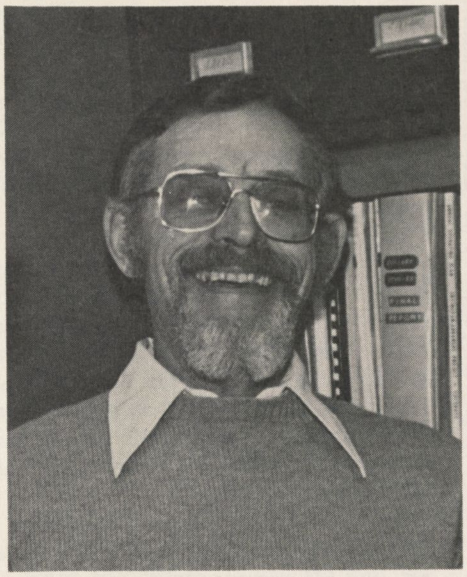
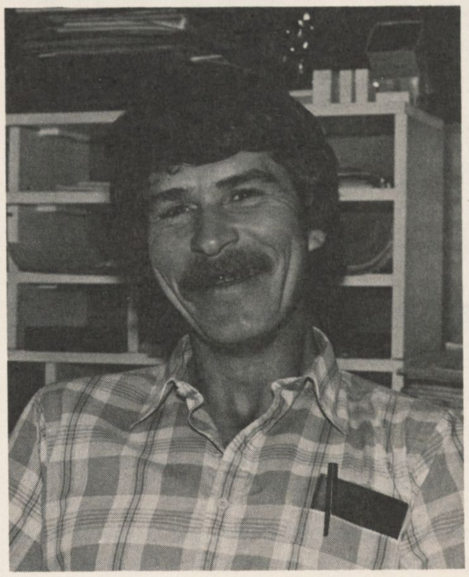


LARRY FINNELL, Wildlife Researcher. Larry is one of those rare breeds, a Ft. Collins native! He entered CSU (Colorado A&M at the time) in 1950 and was the only fish management student in his class. After he graduated he joined the Air Force. In 1957, he was hired by the Division to study the fisheries at Granby, Shadow Mountain, and Grand Lakes. During that study he developed the kokanee spawn-taking system which eventually led to the operation that currently supplies kokanee fry for the entire state. He returned to CSU to earn his M.S. degree in 1968 and then took over the Frying Pan-Arkansas project determining the impacts of trans-mountain water diversions. His study evaluating the effectiveness of various walleye stocking rates is now being handled by regions and he is currently conducting a northern pike study to learn more about its life history, the impacts of its predation on rough and game fish, and the impacts of fisherman harvest on pike populations. Larry and his wife Pat live in Ft. Collins. Their son Mark lives in Vail.



RICK HOFFMAN, Wildlife Researcher. Rick came to Colorado in 1967 when he entered CSU as a wildlife biology student. He graduated in 1971 and continued on to study winter migration patterns of white-tailed ptarmigan which led to a Master's degree in 1974. He was designing a Ph.D. program on blue grouse when a position with the Division's small game research section became available. "I wanted a job more than a doctorate!" and he took that position in the winter of 1974. For the next nine years he studied the population dynamics and habitat relationships of blue grouse, which eventually led to the biological justification for more liberal seasons. He also established the use of wing barrels to collect grouse wings from hunters, which greatly increased the amount of information. He was involved with the ptarmigan introduction on Pike's Peak and is now starting a study on wild turkeys. He recently became president of the Colorado Chapter of the Wildlife Society. Rick, his wife Colleen, and daughter Amy live in Ft. Collins. His son Richy lives in Loveland.

Pellet *Continued from page 3*

precluded getting that information out. "The message that doesn't seem to be getting across is that we don't need to be feeding alfalfa with the pellets," Gill said. In fact, unless it is leafy third cutting alfalfa, it can do more harm than good since the deer's digestive system is not well suited for digesting poor quality hay.

Though the pellet is an improvement over previous supplemental feeds, it is not the final answer. It appears to be lacking in the proper balance of phosphorous and calcium, thus more testing is needed. Nevertheless, in terms of what is required in critical winter situations — a highly digestible source of energy that doesn't overwhelm the digestive systems of deer — it could prove to be the saving grace for thousands this winter.

What Is It?

The Wildlife and Fish Habitat Relationships (WFHR) System is the USDA Forest Service's set of habitat planning and analysis tools. The purpose of the WFHR System is to help National Forest managers provide habitats for full animal diversity and a sustained yield of wildlife and fish for diverse uses.

WFHR includes models and methods for describing fish and wildlife habitat needs, evaluating an areas's habitat capability, and projecting the outcomes of different actions on wildlife and fish.

Forest Service Research supports the WFHR System with basic biological studies and experiments to test the validity of WFHR models and concepts. Scientists also cooperate with management biologists in developing new WFHR tools.

What Are the Components?

Regional WFHR Coordinators maintain quality standards in four areas and provide state-of-the-art tools and methods to Forest and District biologists:

Resource Coordination

Resource coordination stresses an adaptive management philosophy. Management treatments are guided by an integrated plan, and monitoring is used to provide feedback on the validity of the plan. A bias for action and a willingness to find common solutions to management opportunities characterize the WFHR approach to resource coordination.

Habitat Evaluation Procedures

Part of an integrated plan is a statement of the expected benefits and effects of a specific course of action. Habitat evaluations provide the estimates of wildlife and fish benefits and effects.

The preeminent concern in habitat evaluations is the cumulative effects of a series of actions on wildlife and fish. The purpose of cumulative effects analysis is to evaluate the full array of benefits and costs of alternative management decisions over time and space.

Habitat and Species Information

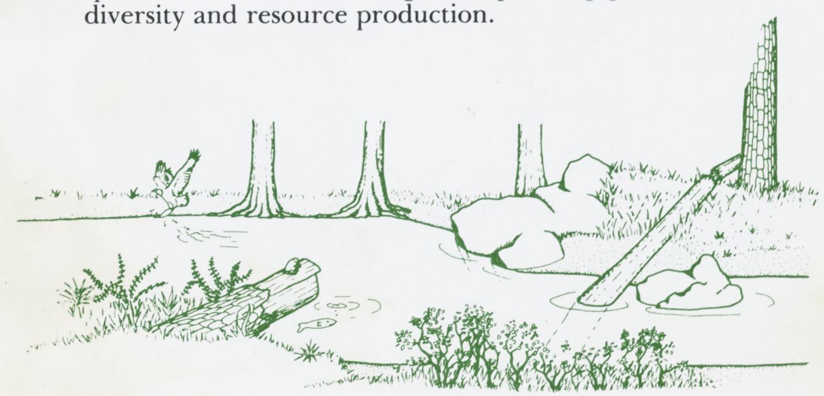
Habitat and species information is the foundation upon which planning models and methods are based. It includes: 1) Species Classification, 2) Habitat Classification, 3) Species Distribution, 4) Habitat and Species Inventories, 5) Species Life Histories and Habitat Needs, and 6) Data Management Systems.

Habitat Capability Models

Habitat Capability Models are the primary tools used in habitat evaluations. The models have a variety of forms, but they all have one thing in common; they allow resource managers to predict species population conditions from habitat conditions.

At the simplest this prediction is the list of species likely to be present on an area. Detailed models are also used in procedures that evaluate population viability or the sustained yield of recreational use opportunities from a species.

The set of WFHR models includes: 1) models for evaluating the quality of sites for a species' life needs, 2) models for evaluating the capability of an area composed of many sites to meet the seasonal habitat needs of a group of animals, 3) models for evaluating the ability of an entire National Forest to sustain populations year-round, and 4) models for evaluating the contribution of special habitats such as snags and spawning gravels to diversity and resource production.



What Are the Benefits?

The public benefits from Forest Service use of the WFHR System to improve wildlife and fish management.

WFHR helps managers shape land management on National Forests and Grasslands to meet the full array of fish and wildlife demands.

Coordination methods help managers integrate wildlife and fish habitat requirements into forest and rangeland management practices.

Quantitative habitat evaluations enable managers to chose the most effective course of actions.

WFHR tools give biologists the ability to quantify and predict the cumulative effects of management actions on fish and wildlife habitat diversity and productivity.

WFHR models provide for monitoring efficiency to support adaptive management.

Forest Service Research is efficiently focused on problems that derive from management needs.

USDA Forest Service Wildlife and Fish Ecology Unit 3825 E. Mulberry, Fort Collins, CO 80524

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WFHR

A Bias for Action

8

OFFICE MEMO

TO:

Date

FROM: Annear, T. C. and A. L. Conder. 1984. Relative bias

SUBJECT: of several fisheries instream flow methods. N. Am.

REMARKS: J. Fish. Mgt. 4 (4B): 531-39.

Tennant method most unbiased, but lacks biol. data for identifying trade-offs. PHABSIM IFG-4 biased - too high recommend. for small (20 ft.) streams, too low for large (700 ft.)

Problem w/ $\bar{x}$ column velocity (WUA) - small to microhabitat impt..

- Assumptions of PHABSIM: (WUA): Habitat quality (= goodness of fish. pop. determined (deterministic model) by depth, velocity. (i.e. these variables are most limiting) substrate - where true than PHABSIM works -

* Also - That these habitat variables are independent of each other

- But depth & velocity (at any point) & velocity directly influ. substrate

→ "Presents serious problems validity of these assumptions should not be routinely accepted as it may often be invalid".

Colorado State University

Instream Flow Chronicle

A Training Announcement

October, 1986 | Vol. III, No. 3 | Conference Services

Frequently Asked CIAP Questions

by
J. Mark Robinson
and
John Staples
Federal Energy Regulatory Commission

Rising interest in the development of our nation's hydropower potential, following the passage of the Public Utilities Regulatory Policies Act in 1978, has resulted in unprecedented concern by natural resource agencies for the potential cumulative impacts that may be associated with multiple hydropower development in specific river basins. Commonly occurring hydropower impacts that may have significance from a cumulative perspective include the loss of aquatic habitat from streamflow modification, the reduction of visual quality, and the disturbance of recreational patterns.

On April 24, 1985, the Federal Energy Regulatory Commission directed its staff to utilize a Cluster Impact Assessment Procedure (CIAP) to assess the potential for cumulative impacts in the Snohomish River, Owens River, and Salmon River basins in Washington, California, and Idaho, respectively. The CIAP (Figure 1) is a process for assessing this potential, developed by the Commission's staff, that includes first, the scoping or defining of the cumulative impact issue and the collection of pertinent information (the Geographic Phase and the Resource Sort Phase), followed by the analysis of impacts (the Multiple Project Assessment Phase), and finally the documentation of the entire process in accordance with the National Environmental Policy Act (the NEPA Document Phase).

Since the Commission's April 1985 directive, the staff has held more than 30 meetings and workshops in several western states and on Capitol Hill to expose the CIAP to as many individuals as possible. The rewards for this effort have been a tremendous stimulation of the critical review of the CIAP and some key enhancements of the CIAP process.

During these interactions, several questions have been asked so often as to be considered fundamental to an understanding of the CIAP. Some of the most frequently asked questions are answered below. For more information concerning the CIAP, please write to the following address: Federal Energy Regulatory Commission, Office of Hydropower Licensing, 825 North Capitol Street, Washington, D.C. 20426.

Question 1: Why is it necessary to perform a cumulative impact analysis?

Answer: An analysis of the cumulative impacts of multiple hydropower proposals within a river basin is necessary from a pragmatic as well as a legal viewpoint. From a pragmatic viewpoint, specific analyses of individual projects alone are inadequate to detect the additive or synergistic effects of several projects on a common resource. From a legal viewpoint, the consideration of cumulative impacts in determining the scope of an environmental impact statement (EIS) seems to be required in the National Environmental Policy Act (NEPA). The responsibility of agencies to address cumulative impacts have been reinforced by several legal decisions. For example, in Natural Resources Defense Council v. Callaway, the court ordered the Department of the Navy to prepare a supplemental EIS to address the cumulative effects of several dredging operations in the New London, Connecticut, area. In National Wildlife Federation v. United States Forest Service, because of potential effects to anadromous fish, the court required the Forest Service to assess the cumulative effects of all proposed timber harvests planned for the same geographic area in the Forest Service's Mapleton District in Oregon.

Question 2: How does the CIAP relate to cumulative impacts?

Answer: The main purpose of the CIAP is to assess the cumulative effects of multiple hydropower developments on environmental resources. The CIAP serves as a framework for cumulative impact studies and consists of scoping, analysis, and documentation.

Question 3: Does the CIAP evaluate only the cumulative impacts of projects "clustered" together in a small geographic area?

Answer: No, a "cluster" is the area where multiple project impacts could affect target resources. The definition of a cluster involves both the geographic location of projects and the geographic distribution of the target resources. The cluster area is determined in cooperation with the CIAP participants.

Question 4: How does the Commission determine which resources to designate as target resources for cumulative impact assessment?

Answer: Target resources are identified by the local resource professionals, other interested parties, and the staff as important resources that may be adversely affected by two or more proposed hydropower developments. Public input is provided during the scoping session of the Geographic Sort Phase of the CIAP. Following the workshop, the staff evaluates the information presented and the candidate resources discussed to determine the target resources in the CIAP.

Question 5: How could a project drop out of the CIAP?

Answer: The Geographic Sort and the Resource Sort Phases would determine which projects would be studied in the Multiple Project Assessment Phase. Projects that are determined through the Geographic Sort and the Resource Sort Phases to have no impact on a target resource would not be carried through the CIAP, but would be assessed on a case-by-case basis in individual NEPA documents.

Question 6: Will past actions be considered?

Answer: Yes, past development, the resulting impacts, and the history of the area all will be incorporated into the analysis and addressed in the NEPA document. For example, if past hydropower development, current logging practices, or other factors have severely stressed anadromous fish in an area, the CIAP would evaluate pending hydropower applications in relation to the existing condition of anadromous fish.

Question 7: In view of the restrictions on the staff's fish and wildlife analysis in exemption applications how does an application for exemption fit into the CIAP and how would fish and wildlife resources be protected?

Answer: Under the Commission's Olympus decision, which recognized the responsibilities of the fish and wildlife resources agencies, applications for exemption will be reviewed in the CIAP for all resource areas except fish and wildlife. It is the responsibility of the fish and wildlife agencies to set terms and conditions for exemptions that would avoid both site-specific and cumulative impacts to fish and wildlife resources.

Question 8: Why are preliminary permits not included in the CIAP?

Answer: Preliminary permits are not viewed collectively as reasonably foreseeable actions. The purpose of a preliminary permit is to allow a prospective developer to conduct necessary studies and tests on a site to determine the feasibility of hydroelectric development. The permit authorizes no construction.

Question 9: How often and at what times do interested parties have an opportunity to comment on the CIAP or to provide input?

Answer: The CIAP is a coordination-intensive process. Consultation with agencies, tribes, and developers is the most important aspect of the Geographic and Resource Sort Phases. This is why the scoping meetings are held near the beginnings of these phases and why the remainder of each phase is devoted to processing the results of the meetings. The Geographic and Resource Sort Phases may be considered as the first and second stages of the CIAP scoping process. Both phases produce an initial scoping document for review and comment and both involve a scoping workshop. Toward the end of both phases, the participants will receive a document detailing the workshop results. The third phase, the Multiple Project Assessment, also begins with a scoping document for review and comment. The staff conducts technical sessions halfway through the Multiple Project Assessment Phase to get the participants' comments on the draft impact matrix. The results are incorporated into the final matrix, which is used in the cumulative analysis. The staff reports these results, along with all of the supporting documentation, in the draft NEPA document, which affords a period of 45 days for public review and comment. The staff addresses and incorporates the comments into the final NEPA document, which is noticed in the Federal Register and made available to interested parties.

Including the draft and final NEPA document, then, there are five formal opportunities for consultation and comment built into the CIAP timeline. In addition to the formal opportunities provided, all parties with information or constructive comments are encouraged to consult informally at any time during the process.

Question 10: What is the purpose and function of the matrix approach to cumulative impact assessment?

Answer: The purpose of the matrix analysis is to simplify a large and incomprehensible volume of data to a meaningful level. A computerized matrix analysis can examine thousands of combinations of proposed projects for each target resource.

The Commission's CIAP Studies are gradually breaking the stalemate over hydropower development. The purpose of the CIAP is to provide a basic framework and a forum for the analysis and discussion of the potential cumulative impacts from multiple hydropower developments, relative to multiple-use concerns and pursuant to NEPA. The progress of the CIAP so far is largely due to the inherent flexibility of the procedure, to the interest and participation of the resource agencies, the developers and other interested parties, and to the work of the staff in tailoring the CIAP Studies to the individual river basins by analyzing and incorporating the suggestions of the participants. With this support, the CIAP will produce informed decision-making about multiple hydropower development.

Negotiating Instream Flows: Some Lessons

by
Berton L. Lamb
Administrative Analyst
Instream Flow Group

Staff members at the Instream Flow Group have been cataloging errors commonly made in instream flow negotiations. The staff has described two types of mistakes: cardinal errors (100 series) and miscellaneous gaffes (400 series). Consider the two mistakes listed below:

Error 105: "They understand our proposal completely." This is a very common error, but it may also be true. Many times the staff of the Instream Flow Group is asked to consult on negotiations after the parties have been working on the problem for months and even years. In such cases, the parties may completely understand one another yet they disagree. More often than not, however, this understanding is less than complete. In a recent case, for example, the animosities between the parties were so high that even long-term discussions did not yield complete understanding. In another case the parties' "belief systems" were so different that no amount of sharing seemed to bridge the difference in values. In these circumstances it might be profitable to engage a third party mediator. It is always important to remember that the other side may not see all the subtleties in your proposal.

Gaffe 405: "That is a stupid suggestion." There are many variations on this sort of put-down. It is hard to imagine when a personal attack would help a negotiation. Almost always a tactic designed to embarrass or belittle is counter-productive. These negative tactics are not always overt; such things as aggressive gestures, poor-taste jokes, and innuendos should be avoided.

IFG Training

Final Call For Papers
Species Criteria Workshop

The organization of the Species Criteria Workshop (formerly the IF 403 course) is beginning to take shape. This workshop will be held at Rockwell Hall on the Colorado State University campus, during the week of December 8-12, 1986. As of the end of September, 18 authors have expressed an interest in presenting one or more papers, with topics ranging from habitat-use guilds to the use of exponential polynomials. The workshop will consist of five sequential sessions, delineated by these general subject areas: (1) study planning and design considerations, (2) developing criteria by concensus (professional judgement) methods, (3) field methods for determining habitat utilization, (4) statistical methods for fitting functions to data, and (5) criteria verification and validation case studies. This is a general call for papers to any authors who feel they might have an interesting contribution to one of these sessions. Specifically, we could use a few more submissions in the first three sessions. Persons submitting papers should have experience in the criteria development and testing business, as this will be a workshop, not a class. If you would like to submit a paper, the deadline for abstracts (nothing fancy, but please use a title you intend to use on your paper) is November 14. For further details, contact Ken Bovee, Pat Nelson, or Clair Stalnaker at 303-226-9331.

IFG 300 Water Law Short Course
January 27-29, 1987 Clear Lake (Houston), Texas

This 24-hour course has been offered since 1977 as an introduction to the principles of water law. Taught by practicing attorneys, the course reviews legal terminology and summarizes the operating rules of the Riparian and Appropriation Doctrines of surface water allocation. Special attention in this Houston course is given to Texas water management and Federal Environmental Law as it impacts project development. The basic rules involved in groundwater law are also presented and national trends and developments are discussed. Materials provided include detailed readings and up-to-date summaries of state law applicable to instream uses. Because the law is dynamic in nature, it is recommended that professionals who wish to keep up-to-date enroll in this course periodically. This course is recommended for anyone concerned with water administration and the role of law in managing instream and out-of-stream uses of water. No prerequisites. Tuition: $275.

IFG 402 Hydraulics in PHABSIM
February 11-12, 1987 Fort Collins, Colorado

This 16 hour seminar provides advanced discussion and training in the use of hydraulics in the Physical Habitat Simulation System (PHABSIM) element of the Instream Flow Incremental Methodology (IFIM). This seminar is being offered for experienced PHABSIM users who want to discuss and gain experience in using the many options which have been described in the Technical Notes available from the Instream Flow Group. The course will cover the following topics: the use of IFG4 with one data set; the selection of the hydraulic simulation techniques most appropriate for various PHABSIM applications; use of IFG4 and WSP together; and the development of stage-discharge relationships. This course is recommended for persons actively involved in the use of PHABSIM. PREREQUISITES: Experience using the hydraulic simulation models in PHABSIM. Class size: 25 maximum. Tuition: $175.

IFG 400 Stream Network Temperature Model (SNTMP)
January 19-23, 1987 Fort Collins, Colorado

The Physical Habitat Simulation System (PHABSIM) portion of the Instream Flow Incremental Methodology (IFIM) focuses on quantification of micro-habitat at selected sites within a stream. One of the major macro-habitat variables of interest is the water temperature regime. This course provides instruction for persons who will be responsible for conducting analysis of instream temperature using SNTMP. Major topics covered include study organization, data sources, stream side data collection techniques, data synthesis, the physical principles underlying the model, execution of the model and anaysis of the various model outputs. Course participants have the opportunity to run the model and deal with a variety of what-if issues during the class. While there are no specific prerequisites for this course, experience in using computer simulation models is very helpful. Tuition: $450. For further information regarding the course, contact John Bartholow or Terry Waddle at IFG (303-226-9331 or FTS 323-5331).

IFG 403 Hydraulics in PHABSIM
February 13, 1987 Fort Collins, Colorado

This one day seminar supplements IFG 402. It provides a "hands on" opportunity using the program discussed in that course and includes discussion of the results obtained by the participants. Class limit: 15. Tuition: $75.

Training Calendar

IFG 200	October 27-31	1986	Sacramento, CA
IFG 210	November 3-7	1986	Fort Collins, CO
IFG 305	November 14	1986	Fort Collins, CO
IFG 215	November 17-21	1986	Fort Collins, CO
IFG 403*	December 8-12	1986	Fort Collins, CO
IFG 400	January 19-23	1987	Fort Collins, CO
IFG 300	January 26-30	1987	Clear Lake, TX
IFG 402	February 11-12	1987	Fort Collins, CO
IFG 403	February 13	1987	Fort Collins, CO
IFG 200	February 16-20	1987	Albuquerque, NM
IFG 210	March 23-27	1987	Fort Collins, CO
IFG 215	March 30-April 3	1987	Fort Collins, CO
IFG 200	May 11-15	1987	Richmond, VA
IFG 205	August 10-14	1987	Fort Collins, CO
IFG 205	Aug 31-September 4	1987	Leetown, WV
IFG 215	November 2-6	1987	Fort Collins, CO
IFG 300	November 10-12	1987	Fort Collins, CO
IFG 305	November 13	1987	Fort Collins, CO
IFG 310	January 25-29	1988	Fort Collins, CO
IFG 402	February 17-18	1988	Fort Collins, CO
IFG 403	February 19	1988	Fort Collins, CO
IFG 210	February 22-26	1988	Fort Collins, CO

*See new course description

To register for courses contact:
Henrietta Cullinane
Office of Conference Services
Rockwell Hall
Colorado State University
Fort Collins, CO 80523
(303) 491-6222

Through these quarterly training announcements we attempt to provide three kinds of information: highlights of upcoming courses, a 2-year training calendar, notes and articles by course graduates on their experiences using IFIM, and suggestions or examples of specific component parts such as PHABSIM and LIAM.

To submit an article, please contact Pete Pedersen, Editor, CSU, Office of Conference Services, Rockwell Hall, Fort Collins, CO 80523.

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HAIG

CRITIQUE OF INSTREAM FLOW METHODOLOGIES

Robert J. Behnke Area code 303/491-5320

May, 1986

ABSTRACT

During the past 30 years numerous methodologies have been developed to assess instream flow needs of fishes. A basic problem is that no methodology is likely to have success, on a broad scale, to accurately predict changes in abundance or biomass of a species with changes in flow. This is due to limitations for making predictions based on variable biological systems and the failure of any model to accurately take into account all of the subtle interacting factors that determine the well-being of a species in a particular environment in addition to physical habitat limitations. The IFIM of the US Fish and Wildlife Service is a widely used standard model that offers the advantage of comparing habitat changes (expressed as weighted useable area or WUA) for different life history stages of a species throughout an annual cycle. The problem with WUA, however, is into what biologically meaningful terms can it be translated? It cannot accurately predict changes in numbers or biomass because the IFIM model is faced with the same problems that limit any predictive habitat model.

Dr. Behnke

Could you please tell me the purpose of this report and in what forum you intended to use it? I have called you several times but no answer to your telephone. Thanks

Cole Shrivell

WATER RESOURCES BULLETIN
VOL. 22, NO. 5 AMERICAN WATER RESOURCES ASSOCIATION OCTOBER 1986

QUANTIFICATION OF INSTREAM FLOW NEEDS OF A WILD AND SCENIC RIVER FOR WATER RIGHTS LITIGATION[1]

Herbert S. Garn[2]

ABSTRACT: The lower 4 miles of the Red River, a tributary of the Rio Grande in northern New Mexico, was designated as one of the "instant" components of the National Wild and Scenic River System in 1968. The Bureau of Land Management (BLM), as the managing agency of the wild and scenic river, was a participant in a general water rights adjudication of the Red River stream system. The BLM sought a federal reserved water right and asserted a claim to the instream flows necessary to protect and maintain the values of the river. Instream flows are not recognized under New Mexico water law.

Instream flow requirements were determined by several methods to quantify the claims made by the United States for a federal reserved water right under the Wild and Scenic Rivers Act. The scenic (aesthetic), recreational, and fish and wildlife values are the purposes for which instream flow requirements were claimed. Since water quality is related to these values, instream flows for waste transport and protection of water quality were also included in the claim. The U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology was used to quantify the relationship between various flow regimes and fish habitat.

Experience in this litigation indicates the importance of using state-of-the-art methodologies in quantifying instream flow claims. The incremental methodology held up well under technical and legal scrutiny and is an example of the latest methodology that was applied successfully in an adjudication. On February 23, 1984, the parties involved in the adjudication entered a precedential stipulation recognizing a federal reserved right to instream flows for the Red River component of the National Wild and Scenic River System.

(KEY TERMS: instream flow; federal reserved water rights; water rights; wild and scenic rivers.)

INTRODUCTION

The lower 4 miles of the Red River in New Mexico as well as 48 miles of the Rio Grande downstream from the Colorado State line were designated as one of the "instant" components of the National Wild and Scenic River System by the Wild and Scenic Rivers Act of 1968. The Wild and Scenic Rivers Act states that it is "the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." The Bureau of Land Management (BLM), as the managing agency of the wild and scenic river, was a participant in a general water rights adjudication of the Red River stream system.

The Red River stream system adjudication suit was filed by the State of New Mexico in 1972. The 1976 Special Master's report to the Court did not resolve the question of federal reserved water rights and recommended that a trial be scheduled to determine whether the United States has a reserved right to instream flows under the Wild and Scenic Rivers Act of October 2, 1968. In December 1978, the Court referred to the Special Master for trial the determination of whether the United States has a right to a minimum instream flow in the Red River. The BLM then sought a Federal reserved water right and asserted a claim to the instream flows necessary to protect and maintain the values of the river. Negotiations with the involved parties began in 1980 to settle and terminate the proceedings without the necessity of further lengthy and costly litigation.

The BLM conducted studies from 1979 to 1980 to quantify the instream flow needs in the lower 4 miles of the Red River to claim a reserved water right. The reserved right was to protect and maintain the particular scenic, recreational, and fish and wildlife values that led to the Red River's designation as a component of the system. The scenic, recreational, and fish and wildlife values are the purposes for which the BLM sought a water right. Since water quality is related to these values, instream flows for waste transport and protection of water quality were also included in the federal reserved right claim.

The doctrine of prior appropriation applies in New Mexico and that doctrine is codified in the surface-water codes of 1907 and the groundwater statutes of 1931. Instream flows are not recognized as a beneficial use of water under New Mexico water law, and the State strongly resisted a reserved right for that purpose.

[1]Paper No. 85193 of the *Water Resources Bulletin.* **Discussions are open until June 1, 1987.**

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A Test of Weighted Usable Area Estimates Derived from a PHABSIM Model

for Instream Flow Studies on Trout Streams

DRAFT

Bob Wiley sent me a copy of your paper on instream flow methodologies. You might be interested in this paper which has been accepted for publication in NAJFM.

Mike Stone

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ASSESSMENT OF THE WATER SURFACE PROFILE MODEL: ACCURACY OF PREDICTED INSTREAM FISH HABITAT CONDITIONS IN LOW-GRADIENT, WARMWATER STREAMS

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ABSTRACT

The Instream Flow Group's (U.S. Fish and Wildlife Service) Physical Habitat Simulation (PHABSIM) model, the major component of the incremental methodology (IFIM) is presently the most widely employed instream flow assessment procedure. PHABSIM consists of both biological and hydrological components. The Water Surface Profile (WSP) hydrologic model is commonly recommended and employed in many PHABSIM applications. While several recent studies have critically addressed and questioned the validity of PHABSIM as a management tool from a biological perspective, there has been surprisingly limited attention given to problems of use, accuracy, bias, and the effect of errors in the WSP hydraulic simulation on the final PHABSIM output (i.e. weighted usable area (WUA) estimates). Therefore, the purpose of this study was to examine the effectiveness of the WSP hydraulic model for predicting hydraulic conditions in low-gradient, warmwater streams in east-central Illinois. Attempts were made to calibrate the WSP model at four locations on the Salt Fork and Middle Fork rivers and compare simulated results to actual measured conditions at different discharges. We conclude that in low-gradient warmwater streams, the WSP model: (1) does not adequately simulate low-flow habitat conditions, due to an inability to calibrate the model; (2) is, at best, difficult to calibrate, even within hydraulically uniform channels; (3) requires several field measurements and calibrations to simulate a sufficiently wide range of naturally occurring flows: (4) provides poor estimates of cell depth and velocity; and, results in highly erratic and often poor estimates of WUA for adults and fry of smallmouth bass. Finally, our results indicate that similar or better estimates of actual WUA can be attained by monitoring the distributions of depth, velocity, and substrate at a series of representative transects at different discharges and interpolating WUA from observed field data using less expensive and time consuming regression models.

KEY WORDS Instream Flow PHABSIM WSP model Smallmouth bass Fish habitat

INTRODUCTION

Maintenance of adequate instream flow is one of the most pressing resource issues facing both industry and government. Adequate flows are fundamental to the well-being of lotic populations and in maintaining the recreational potential of stream systems. Loar and Sale (1981) referred to instream flow requirements as the amount of flowing water within a stream channel needed to sustain, at an acceptable level, the values or uses made of water in the channel. Instream flow issues therefore include biollogical, engineering, social, and economic concerns.

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COMMENTS ON: FISH AND WILDLIFE COORDINATION ACT REPORT -- VERDE, EAST VERDE DIVERSIONS

It looks like there is a built-in catch-22 bottom line re. headwaters to Sycamore Crk. section of Verde R. to effect that this is critical habitat for federally threatened spikedace (and a most significant site because of high proportion of native fishes), therefore no tampering with flows should be allowed. The supporting evidence of IFIM studies is so much window dressing that can be discredited as a valid basis for conclusions, but once discredited, there is no evidence that can support the position that increased diversion will not negatively affect spikedace. They distinctly have the "burden of proof" argument on their side.

Adressing the questions posed in Feb. 1, letter:

1. IFIM . IFIM uses a Physical Habitat Simulation (PHABSIM) model which includes a biological component (HABTAT, the habitat suitability index [HSI] curves for various species) and a hydrological component [Water Surface Profile [WSP]). This allows habitat units expressed as Weighted Usable Area (WUA) to be determined for a range of flows different from the flows for which the HSI curves were developed (as can be seen in appendix to report). During the past few years, my SRP reports have documented the theoretical and empirical lack of biological validity of PHABSIM (the HABTAT component), and a critique of shortcomings apparent in present report are discussed below. The enclosed copy of title page and abstract from recent issue of Regulated Rivers, details the lack of validity of the hydrological component of PHABSIM, the WSP. Thus, the "documentation" based on IFIM in report, such as figures 5-10 of appendix A depicting relative WUA for spikedace and other species at various flows, is erroneous on both the biological and hydrological components.

That is, the biological basis for the data, taken at whatever flows they were obtained from, lacks validity to begin with, and the projections (via the WSP component) of WUA at other flows lacks validity, because of inherent errors in the WSP model component.

A simple common sense approach makes the biological basis of IFIM, as used for report, suspect. For example, if WUA values were truly representative of species success or failure in any particular river section, then the WUA values depicted in figures for various life history stages for the various species should reflect the relative abundance of these species. No such data are given in report to correlate WUA values with actual species abundance. If such data are available, I suspect little or no correlation between WUA and species abundance exists. There are statements in report to the effect that it is not known why non-native species replace native species in section 3 (Perkinsville to Tapco) and why flathead catfish replace channel catfish in Verde - Gila rivers. If the WUA values truly reflected a species well-being or how fully a species is filling a niche, then these questions would be answered. That is, the WUA values in river reach 3 would clearly show a favoring of non-native species (higher WUA) over ~~non~~ native species (lower WUA) in this section and flathead catfish would have higher WUA than channel catfish.

You may note how "professional judgement" was used to defend a no increased diversion decision for river reaches 1 & 2. The WUA for larval and juvenile spikedace increases with reduced flow, but decreases for adults. A "professional judgement" was made that it is the adult habitat that is most limiting (but no evidence is given for this), therefore, no further diversion should be made (which would favor larvae and juveniles according to WUA values). It is mentioned that spawning of spikedace was observed, but the habitat was too difficult to model and simulate. However, fig. 8 (appendix A) depicts spawning WUA values, which drastically decline at flows less than 25 cfs. If the only observation of depth, velocity, and substrate was made at 25 cfs (thus, determined as optimum, or HSI values of 1.0), it would seem obvious that WUA values would decline at other flows. But again, how could they "simulate" the WUA values for spawning at different flows when text says this habitat couldn't be modeled or simulated? It's obvious, that everything possible was done to make 25 cfs the flow of choice. The conclusion stated on A-39 that "the examination of data reveal that withdrawal of any water from the first reach of the river will decrease the weighted usable area available to spikedace", is only partially true because there is no valid basis to associate WUA with meaningful parameters of spikedace abundance and the WUA of larvae and juvenile dace increases with decreased flow. Only adult WUA decreases. This leads to question 2 --

2. Does report analysis support opinion of no diversion above Sycamore Crk. — As my above comments demonstrate, the report analysis can be discredited, but, except for using the data on increased WUA at lower flows for spikedace and making a "professional judgement" that these life history stages are more important than adult (which would say that spikedace would benefit from increased diversion), there is no data or evidence to really support an opinion that diversions would have no effect or a positive effect -- The burden of proof problem.

3. What ways to mitigate? I have never seen this section of the river and any opinion I would give would be tainted by lack of personal familiarity. Typically, mitigation in such a situation would be from a changing flow regime from an upstream impoundment (none on Verde) or habitat modifications designed to supposedly favor key species. The problem here is that the U.S. Fish and Wildlife Service (and Ariz. G.&F.) has declared this category I (unmittigatable) - therefore no mitigation is acceptable, according to the way the dice are loaded.

4. Max. diversion flow + min. flow. There is much narrative touting the value of seasonal high flows, particularly for riparian vegetation. The maximum diversion flow, apparently, is designed to protect the high flow peaks. There should be some room for negotiation on flood flows -- for ex., an increasing percentage of diversion allowed with increasing flows above some "flood" level. This, however, would probably call for a storage reservoir to hold the peak flows diverted during a short time, and a large conveyance system to deliver sporadic flood waters.

5. Min. flow criteria: Typically, hydrographic records are examined to observe historic patterns of $\bar{x}$ annual low flow per 7-10-30 day periods and lowest flows during a 10 yr. period as a basis to negotiate a minimum flow. The assumption is that the present fish populations have historically experienced such flows and survived. Further resolution typically concerns seasonal minimum flows in relation to spawning, juvenile habitat, and overwinter habitat. I doubt that any amount of negotiations will negotiate away minimum flow requirements. It's a concept deeply entrenched in fisheries mitigation.

5. Monitoring. The monitoring proposed seems to be straightforward, "standard methods", and must be agreed on by four agencies -- and I assume what is given in report is what has been agreed upon. I assume that a cost estimate for the monitoring will be forthcoming and the monitoring costs will go to Ariz. G.&F. to support their nongame program and personnel. If costs seem excessive, the work could probably be conducted more economically, and more effectively, if students were hired, perhaps using the "research" for graduate degrees. My main complaint with the "monitoring" work, as with the IFIM work of this report is that it is superficial, two-dimensional. Nothing leading to a fuller understanding of the ecosystem and its species interactions will be learned. If only a fraction of the time and money spent on IFIM studies had been used to fund a truly good biologist, such as an outstanding graduate student, who would have been on the river sections, essentially year-round, observing all life history traits and interactions of all the species under varying flow and habitat conditions, the narrative, natural history type observations, would provide insights for an understanding of what's going on and a basis to predict what would happen with changing flows, For example, if a particular species typically has a 4 or 5 year life span, regular sampling and observation will tell us what years produced the most successful reproduction and what years the poorest by comparing relative abundance of different age groups. Then the flow regimes, temp., etc, could be compared for best and worst years to assess the environmental factors that determined success or failure. This leads to true professional judgement, The IFIM data lead to professional guessing.

The "bottom line" of the report is that the headwaters of the Verde R. to Sycamore Creek is "critical habitat" for a federally threatened species and also resource category I (no loss of existing habitat) because it contains a rare assemblage of native fish species. The IFIM studies are meaningless as a basis to understand precisely what habitat and environmental components determine this species composition. The real influence of the flow regime and if the flow regime could be modified (and habitat modified) to avoid a negative impact or possibly produce a positive impact, can only be guessed at.

The USFWS wants to make IFIM "look good", especially as a conflict resolution tool. Thus, it would probably be best to avoid attacking IFIM until all else fails -- give FWS people a chance to demonstrate the efficacy of IFIM to resolve the conflict -- for ex. larvae and juvenile habitat (WUA) increases with lower flows, thus construction or modifications of adult habitat to boost their WUA, would show higher WUA for spikedace at lower flows. Enclosed is latest issue of Instream Flow Chronicle telling how PHABSIM is used in just such a situation as on the Verde.

Determination of Population-limiting Critical Salmonid Habitats in Colorado Streams Using the Physical Habitat Simulation System

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ABSTRACT: We used the Instream Flow Incremental Methodology (IFIM) and Physical Habitat Simulation system (PHABSIM) to investigate the influence of stream discharge and the concomitant variation in habitat on wild rainbow (*Oncorhynchus mykiss*) and brown (*Salmo trutta*) trout populations in 11 Colorado streams. We identified critical salmonid habitat limitations on 10 of the 11 streams studied over a 13-year period. The 2–4-week-old fry, egg incubation, and spawning life stages were most sensitive to critical habitat "bottlenecks." Linear regression analyses revealed statistically significant correlations ($P \leq 0.05$) between weighted usable area (WUA), an index of physical habitat quality and quantity (determined using PHABSIM), and density (n/ha) of age-1 or -2 rainbow and brown trout in 10 of 11 streams studied. Correlations between WUA (based on mean monthly flow) and density were superior in both accuracy and precision in properly identifying population-limiting events compared to correlations between mean monthly stream discharge (during the critical time period) and trout density.

KEY WORDS: Brown trout, habitat limitations, instream flow, rainbow trout.

INTRODUCTION

Biologists have attempted modeling stream habitat for decades (Fausch et al. 1988). However, few stream habitat models have generated more controversy than the Instream Flow Incremental Methodology (IFIM). In particular, the Physical Habitat Simulation system (PHABSIM) has been a focus of the debate. An early paper by Orth and Maughan (1982) discussing the relative merits of PHABSIM focused the attention. Subsequent papers either criticized the IFIM approach (Mathur et al. 1985, 1986; Shirvell 1986, 1989; Scott and Shirvell 1987), or supported it (Anderson and Nehring 1985; Mosley and Jowett 1985; Orth and Maughan 1986; Irvine et al. 1987). Despite the controversy, the IFIM is still used for stream habitat studies in North America (Reiser et al. 1989) and other parts of the world (Jowett 1992).

The IFIM, developed by the U.S. Fish and Wildlife Service in Fort Collins, Colorado, uses hydraulic simulation techniques to predict changes in water depth, velocity, substrate, and cover on an area basis at different levels of streamflow.

Model output, when fed into the PHABSIM, transforms hydraulic information at various flows into units of physical habitat called weighted usable area (WUA). Quantification of WUA is usually based on fish habitat preferences for water depth and velocity, substrate, and cover. However, other factors (e.g., water temperature, water quality, suspended silt) can be incorporated. Field techniques, theory, and data handling have been described in various publications (Bovee and Cochnauer 1977; Bovee 1978, 1982; Bovee and Milhous 1978; Milhous et al. 1984).

Although PHABSIM is a complex modeling system (Jowett 1992), we believe it is unique among habitat models in its ability to convert stream hydraulic data (measures of energy gain and loss) into habitat units for a variety of fish species and life stages. Several studies have shown that trout innately select feeding and resting positions to maximize energy gain (Jenkins 1969; Bachman 1984; Fausch 1984). They indicate that trout feeding and resting site selection is based primarily on depth, water velocity, and proximity to cover. Ottaway and Clarke (1981) and Ottaway and Forrest (1983) showed that water velocity (a measure of energy) is an important factor negatively affecting salmonid fry survival.

Although the IFIM concept has existed since the 1970's (Stalnaker and Arnette 1976), we believe that the study by Jowett (1992) is the only published account of a rigorous attempt at field validation of the PHABSIM models on many streams. The overall goal of our study was to measure trout population response to temporal and spatial variation in stream habitat (WUA) as quantified by the PHABSIM models. Specific study objectives were to: (1) determine if mean monthly discharge (MMD) or trout habitat units (WUA) were more reliable indicators of trout density over long periods of time (5 years or more) for a wide range of streams and flow conditions (Table 1), and (2) determine if the PHABSIM models could reveal at what life stage habitat perturbations were most limiting to stream trout populations in Colorado.

METHODS

Study Areas

Eleven PHABSIM study sites and 21 population estimation study areas were located on 11 streams of varying size, discharge, and elevations throughout the mountainous regions of Colorado (Figure 1, Table 1). Impoundments, diversions, and flow augmentation (in some instances) affected study stream discharge hydrographs to some degree.

Species composition and diversity varied among study streams. The salmonid populations of the Arkansas, Blue, Rio Grande, South Fork of the Rio Grande, St. Vrain, and Taylor rivers were allopatric brown trout (*Salmo trutta*). Sympatric populations of rainbow (*Oncorhynchus mykiss*) and brown trout comprised the salmonid community in the Cache la Poudre, Colorado, Fryingpan, Gunnison, and South Platte rivers. Salmonids accounted for most of the fish biomass, and species diversity was low in all study streams. Nongame species of the families Catostomidae, Cyprinidae, and Cottidae accounted for most of the remaining density and biomass. Study streams contained from two to six nongame species, including white (*Catostomus commersoni*), longnose (*C. catostomus*), bluehead (*C. discobolus*), and flannelmouth (*C. latipinnis*) suckers, longnose (*Rhinichthys cataractae*) and speckled (*R. osculus*) dace, and mottled sculpin (*Cottus bairdi*).

On most streams (such as the Arkansas River), the PHABSIM study site was contained within (but not coincident to) a population study reach. The PHABSIM study site and population study reach were coincident on the Fryingpan, South Platte, and St. Vrain rivers. On the Cache la Poudre, Colorado, Gunnison, Rio Grande, and South Fork of the Rio Grande rivers, we used a single PHABSIM study site (contiguous with one population study area) to characterize habitat (WUA) availability for two to five population study reaches. In some instances, PHABSIM sites and population study reaches were separated by 30–50 km of river. However, channel configuration and geomorphology were similar within study streams, and flow regime among population study sites was highly colinear within years. The PHABSIM study

TABLE 1
Study stream names, trout population study sites, elevation, and discharge characteristics.

River	Time period (years)	No. population study sites	Study site elev. (m)	Discharge (m^3/sec) × 35.314 = cfs		
				Mean annual	Minimum monthly	Maximum monthly
Arkansas	1979–1985	1	2,098	10.9	6.63	111
Blue	1980–1984	3	2,671	5.87 207	0.88	51.4
Cache la Poudre	1980–1986	5	1,591	11.1	0.48	135
Colorado	1979–1986	2	2,338	22.8	2.64	97.5
Fryingpan	1978–1986	6	2,278	5.38	0.96	26.9
Gunnison	1980–1986	2	1,585	39.7	6.55	227
Rio Grande	1980–1991	3	2,433	25.9	4.70	160
South Fork of Rio Grande	1976–1982	3	2,507	6.06	0.39	49.5
St. Vrain	1980–1984	2	1,613	3.66 129	0.32 11	24.9 879
South Platte	1977–1986	3	2,015	4.79	0.68	27.9
Taylor	1972–1986[a]	3	2,796	5.67	1.36	21.5

[a] Includes data from 11 of 15 years.

sites on the Blue and Taylor rivers were separate from the trout population study areas.

With the exception of the Taylor River, no flow control or modification of stream discharge was undertaken to facilitate habitat alteration or trout population response as part of this study. On the Taylor River, discharge was tightly controlled by a large headwater impoundment. Water stored in Taylor Park Reservoir was released downstream for hydropower, irrigation, industrial, and domestic water needs. Before 1976, the discharge was maintained at unusually high levels (11–17 m^3/sec) from October to mid-December, vacating storage capacity to facilitate capture of spring run-off water the next year. Once adequate reservoir storage space had been vacated, reservoir discharge was reduced to 0.3–1.4 m^3/sec. A study by Burkhard tested the hypothesis that this distorted fall–winter discharge pattern was negatively affecting the Taylor River brown trout population (W. T. Burkhard, unpublished data).

Spring and fall trout population estimates were completed at five stations on the Taylor River in 1974 and 1975 under the high fall–low winter discharge regime. Beginning in 1976, fall–winter discharge patterns were stabilized before the onset of brown trout spawning. A 3-year waiting period (1976–1978) allowed the trout population to restabilize under the new flow regime. Trout population estimation procedures were again initiated from 1979 through 1982 to evaluate the effect of fall–winter flow stabilization on brown trout population density. Although the flow modification study began before our investigation, the results are germane and are included here.

Study Design and Methodology

Field validation of the PHABSIM model involved four phases. First, we set up PHABSIM study sites on 11 streams (Table 1, Figure 1) between 1978 and 1985. Six to ten transects were used to characterize each study site, which varied in length from 100 m to more than 700 m. Field data measurements (water velocity, depth, substrate type, and discharge measurements) were taken at least three different times at each site over one hydrologic cycle as outlined by Bovee and Milhous (1978), and entered into the PHABSIM model for calibration.

Second, we ran calibrated data decks through the PHABSIM model using Habitat Suitability Criteria (HSC) curves for rainbow and brown trout taken from Bovee (1978) and Raleigh et al. (1986) (except for the fry life stage) to produce WUA values by species and life stage for the appropriate range of flows for each study stream. Field observations indicated that the depth and velocity preference curves for newly

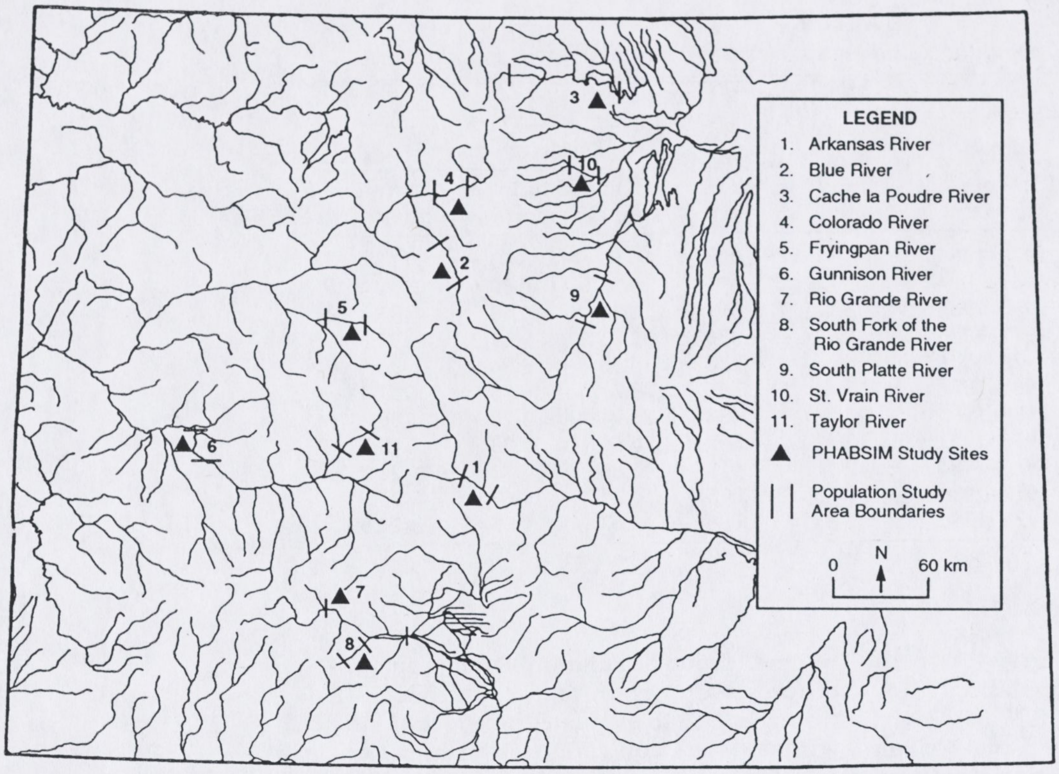


FIGURE 1. ***Drainage map of the mountainous region of Colorado. Numbered triangles denote the approximate location of the Physical Habitat Simulation (PHABSIM) study sites on each stream. Vertical bars denote the approximate boundaries of the trout population estimation study areas.***

emerged rainbow and brown trout fry should be more narrowly defined than those shown in Bovee (1978). Therefore, we developed depth and velocity HSC curves for 2–4-week-old fry based on habitat preferences of more than 350 rainbow and brown trout fry observed over two field seasons (Table 2). For 2–4-week-old fry, all substrates were rated at unity. Our depth and velocity HSC curves for trout fry were very similar to those developed in Montana by Sando (1981). In our study, any use of the term "fry WUA" refers to the habitat of 2–4-week-old trout fry. Weighted usable area for all life stages was calculated using depth, velocity, and substrate preferences. We classified substrate using the modified Brusven Index reported by Bovee (1982).

TABLE 2

Normalized (0.0–1.0) frequency distribution of depth and velocity preferences for 2–4-week-old rainbow and brown trout fry.

Depth (cm)	Normalized frequency	Velocity (cm/sec)	Normalized frequency
0.00	0.00	0.00	1.00
3.05	0.40	3.05	0.45
6.10	1.00	6.10	0.37
9.15	1.00	9.15	0.28
12.19	1.00	12.19	0.10
15.24	1.00	15.24	0.04
18.29	0.30	18.29	0.03
21.34	0.20	21.34	0.02
24.38	0.14	24.38	0.01
27.43	0.04	27.43	0.00
30.48	0.00	30.48	0.00

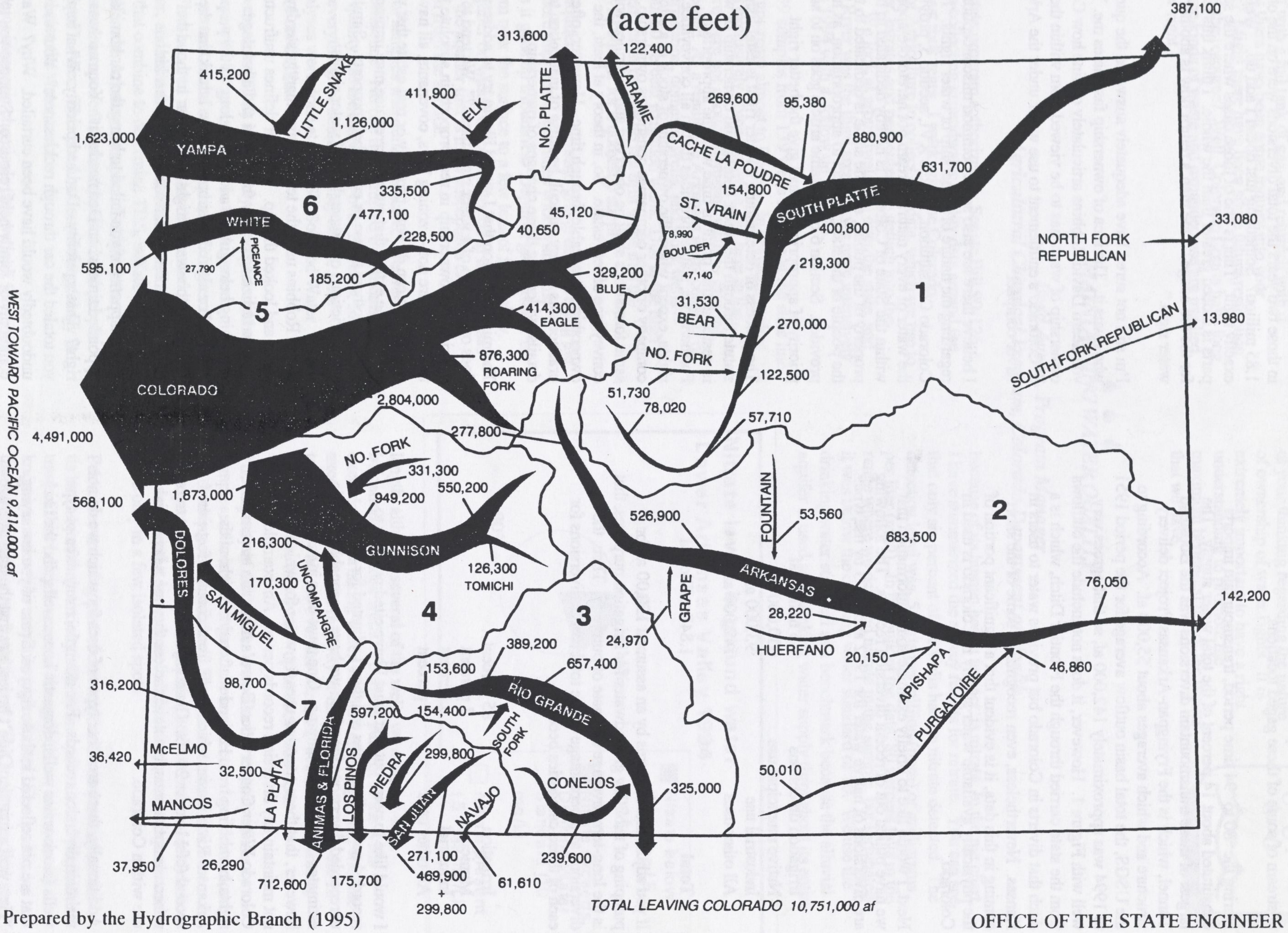
Third, trout population data (species density, biomass, and population age structure) were collected for 5 or more years on each study stream in the fall and occasionally in the spring. This data base was the source for the age-specific estimates of rainbow and brown trout density, the dependent variables to be paired with the independent variables of MMD and WUA.

Fourth, simple linear regression analyses and Pearson correlation coefficients (r)

FIGURE 1. COLORADO

HISTORIC AVERAGE ANNUAL STREAM FLOWS

(acre feet)



Prepared by the Hydrographic Branch (1995)
Historic averages obtained from USGS Water-Data Report CO-93

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COLORADO DIVISION OF WATER RESOURCES

that this report also attempted to estimate the depletions upstream of some of these gaged locations.

During the '80 to '94 time period, transmountain imports constituted about 14 percent of the total water supply. The largest of these transmountain diversions was the Boostead Tunnel, which is the Fryingpan-Arkansas Project delivery structure and which averages about 55,000 af. According to the USGS, the total basin outflow average for the period 1951 to 1994 was approximately 142,000 af, so that agrees very well with Figure 1. However, it does not include the outflows from the state carried through the Frontier Ditch, which is a ditch that diverts in Colorado but provides water to users in Kansas. Nevertheless, even recognizing some of the short coming in this data, it is evident that a significant portion of the physically available water supply in Colorado is used in Colorado.

Next, I would like to briefly examine some information that we have pulled out of recent diversion records. The following are diversions of native water for 1992 and 1993 by use type:

Irrigation diversions	1.5 million af
Native municipal use	630,000 af
Industrial use	93,000 af
All other uses	142,000 af
Total	1.848 million af

If you adjust those figures by an assumed 150,00 af for pumping of tributary groundwater for irrigation purposes, that is the long-term average estimate of pumping. Then, the diversions as a percentage of the total native diversions for each of those categories become:

Irrigation	85 percent
Municipal	3 percent
Industrial	5 percent
All other uses	7 percent

I would like to point out that what I have cited pertains to recorded native diversions and then I adjusted for some unrecorded diversions for which we have reasonably reliable estimates of tributary pumping. One must bear in mind, however, that there are other uses for water for which we do not maintain any diversion records per se. An example is the Colorado Water Conservation Board's minimum stream flow rights, numbering over 120 and scattered throughout the Arkansas River Basin, which range from .5 cubic-feet-per-second (cfs) to over 20 cfs. Generally these are thought to be nonconsumptive uses, but nevertheless they are a beneficial use within Colorado.

Additionally, there are other types of uses for which we do not maintain diversion records. For example, many exempt-type wells (stock-water wells, domestic house wells, and the like) that are not reflected in those figures. Some of you are saying, "Hey, wait a minute. Didn't he just say that the total average native basin supply was something like 750,000 acre-feet, and in those two years the total diversions were on the order of 1.85 million? Something just doesn't add up." Well that is exactly right. This is one of those cases where the sum of the parts is indeed greater than the whole. I think this is the basis for the old adage, "One man's return flow is another man's water right."

I'm still not sure I have adequately answered the question of who owns it. The idea of ownership fascinates me. Yesterday you heard David Robbins articulately outline how Colorado's ownership of water has to be viewed from within the context of Colorado's entitlement to use water under the Arkansas River compact.

I believe there are also some common misconceptions regarding the nature of ownership of water rights. The Colorado Constitution, Article XVI, section 5, provides that the water of every natural stream not heretofore appropriated within the State of Colorado is hereby dedicated to be the property of the public, and the same is dedicated to the use of the people of the state, subject to appropriation, as hereinafter provided. Section 6 of the same article goes on to say that priority of appropriation shall give the better right.

The process of determining a water right is established by statute through the water courts, and ownership of water rights is vested at that point in time with the appropriator. Furthermore, statute provides that in all conveyance of water rights, except where the ownership of stock in a ditch company or other companies constitutes ownership, that the same formalities shall be observed and complied with as in the conveyance of real estate. So, in theory at least, the title to ownership is traceable through time. However, often in practice this is very difficult because of inattention to the details evidencing those changes of ownership.

The misconception that I would like to try to address is, "What does ownership of a water right mean?" We tend to think of our rights of ownership in real property in absolute terms. But they really are not -- zoning laws, covenants, all have an effect on what we can do with property or real estate that we may own, to the extent that our preferred use may impinge on the rights of others to use or enjoy their property. Similarly, there are restrictions on ownerships of water rights.

David Robbins used the term usufructuary yesterday. I went home and looked that up. Webster defines usufructuary as the right to utilize and enjoy the profits and advantages of something belonging to another, so long as the property is not damaged or altered.In simpler terms, I think that the rules pertaining to a water right are similar to those that applied to the use of the family car when you were a kid.

What happened if you failed to bring the car home at the appointed time when Dad needed it? Your use was curtailed, right? That's priority - Dad had priority. What happened if you totaled the car through recklessness? Your use undoubtedly would have been curtailed. Why? Waste of a commonly or jointly held resource. Suppose you told the folks that you were going to take the car six blocks to the Malt Shop, you left with a full tank of gas, and returned with it empty. Might there have been some inquiry into your expanded use? Might there have been some future restriction on your use of the resource? Well, Colorado Courts have long held these same kinds of waste and expanded use are implied in every water right.

I hope that I have helped refine some of your thinking regarding the nature of ownership of water rights. It is extremely important to have a right understanding to promote the maximum beneficial use of the waters that we have.

MAINTAINING WATER QUALITY

Brad Austin, Program Manager
Agricultural Chemical Program, Colorado Department of Health

As part of a state program authorized by Senate Bill 90-126, we have been collecting groundwater quality data around the state for the last four years. I work with the Colorado Department of Agriculture to collect this data, which we use to see if fertilizer, nitrates and pesticides are getting into the groundwater. We look at groundwater all over the state, and the Arkansas River was the third area that we have intensively sampled -- in 1994 with a follow up in 1995.

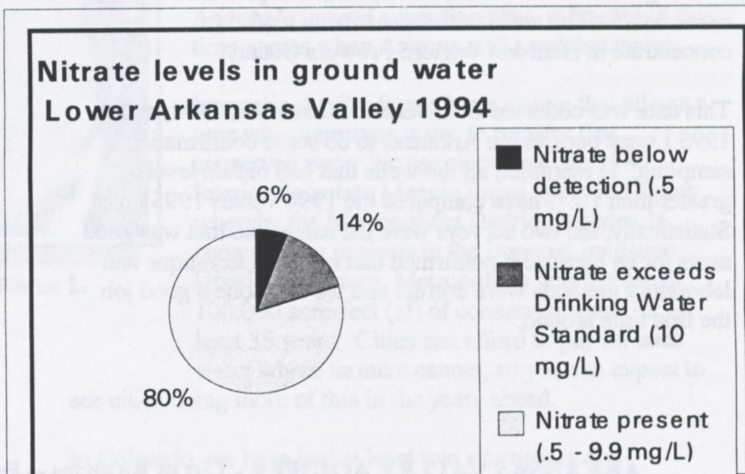
I collected 139 samples from 139 wells starting at the state line and working upstream almost to Pueblo. In previous studies we have used exclusively domestic wells, but here in the Arkansas there were not enough domestic wells to give the coverage I needed. As a result, the Arkansas study consists of a mixture of irrigation, domestic wells, and stock wells -- probably about 50 percent irrigation wells. Due to the high mineral content, most people do not drill wells into the shallow, alluvial aquifer for a domestic supply

The alluvial aquifer is a shallow, sand gravel deposit along the river rarely more than just a few miles wide with some exceptions as it goes up tributaries. Depth of groundwater is anywhere from near the surface to a few tens of feet below. This is the aquifer on which we concentrated in the Arkansas study, as it is the aquifer that is most susceptible to contamination from the surface.

Our analysis of samples was quite extensive. We were trying to establish a baseline. No one had sampled the Arkansas groundwater quality this extensively in over 25 years, so we analyzed for everything we could possibly afford. The inorganic analyses were done at the CSU Soil and Water Laboratory in Fort Collins.

Total dissolved solids (TDS) is probably the largest and best-known problem with the groundwater in the Arkansas. Seventy-five percent of the samples had a TDS higher than 1500 mg/l. Five-hundred would be a recommended limit for drinking water, and even the minimum is close to that. Of all the minerals that combine to determine TDS, sulfate represents about one-half in the Arkansas samples. Sulfate is the dominant mineral component that makes what local people refer to as "hard" water. This is a function of the geology in the valley and also the water use.

One of the major inorganic chemicals that we look for, because of its human health impact, is nitrate. In the pie chart, I have summarized the survey results for nitrate. You can see that only six percent of the wells had no nitrate detected. The detection level was .5 parts per million (ppm) or milligrams per liter (mg/l). In the bulk of the data, 80 percent falls in the range where we detected nitrate in the sample, but fortunately it was below the drinking water standard of 10. We use the drinking water standard as a benchmark because the alluvial aquifer is used as a drinking water supply throughout its entire



length, although several of the wells we sampled were irrigation and stock wells. Fourteen percent of the wells exceeded the drinking water standard of 10 mg/l, and with the exception of one, the majority of that exceedance is in the 10 to 20 range. We are over the standard with that 14 percent, but we are not way over -- up to about double it.

The majority of the aquifer area, like the majority of the samples, falls in the range of above-detection level but below the drinking water standard. The nitrate contamination is widespread throughout the aquifer, but currently at low levels. The samples that have exceeded drinking water standards tend to be only in a few isolated spots.

Pesticides are a big part of our work and a major concern for us because of their toxicity. There are quite a lot of pesticides used in this valley because of the agriculture, and some are known to make their way into groundwater. The pesticides that we analyze for are listed below. The analysis is done at a laboratory at the Colorado Department of Agriculture in Denver. When we talk about pesticide levels, we are talking about micrograms per liter, or parts per billion (ppb).

In the pesticide analysis for all 139 wells, I found only three pesticides, and two of those I found in only one well -- Metolachlor and 2,4-d. The only pesticide that I found to be widespread, in more than one well, was the herbicide Atrazine. This is not surprising, because Atrazine is a very persistent pesticide, highly mobile, and once it gets in the groundwater it tends to stay there.

From left: Brad Austin with Don Magnuson, Cache la Poudre Irrigating and Marke Rude, Kansas Water Commission. **Photo by Karen L. Stewart, Arkansas Valley Journal.**

Although I found it spread throughout a large area in 12 samples, I never found it above a trace level. Trace level means that a chemist positively can identify Atrazine in the sample, but there is not enough present that he can quantify it with a number. This means, for our survey, that the level of Atrazine did not go above .5 P.B. -- a very low levels. That is good news for the Arkansas River. The Environmental Protection Agency considers the maximum allowable level for Atrazine in drinking water to be 3 P.B., and in these samples it never exceeded .5. The wells with the Atrazine tended to concentrate in Bent and western Prowers County.

This data was collected from June to November, 1994, and in 1995 I went back to the Arkansas to do some confirmation sampling. I resampled all the wells that had nitrate levels greater than 10. I have compared the 1994 versus 1995 level. Statistically, the two surveys were the same, and that was good news for us because it confirmed that our field technique and laboratory methods were correct and we had done a good job the first time around.

I also went back and resampled all of the wells where a pesticide was detected, and this time only Atrazine came up. The well with the Metolachlor and 2,4-d didn't show up the second time around, and since that was only a trace level, it is not surprising that it might have disappeared. The range of values went anywhere from .12 P.B. up to one well that had 4.2. That one really shot up and went over the MCL for Atrazine. We will track that one in the future.

In the coming year we will be working along the Front Range, particularly concentrating on some of the urban areas, to see if pesticide and fertilizer use in the urban environment is causing groundwater contamination.

ARKANSAS VALLEY AQUIFER - List of Analytes -- Pesticide Compounds

Name	Use	Name	Use
Alachlor	Herb	2,4-D	Herb
Atrazine	Herb	Dicamba	Herb
Benfluralin	Herb	MCPP	Herb
Chlorpyrifos	Insect	MCPA	Herb
Chlorthalonil	Fung		
Cyanazine	Herb	Aldicarb	Insect
DDT	Insect	Aldicarb Sulfone	Insect
Endrin	Insect	Aldicarb Sulfoxide	Insect
Heptachlor	Insect	Baygon	Insect
Heptachlor Epoxide	Insect	Carbaryl	Insect
Lindane	Insect	Carbofuran	Insect
Methoxychlor	Insect	3-Hydroxycarbofuran	Insect
Metolachlor	Herb	Methiocarb	Insect
Metribuzin	Herb	Methomyl	Insect
Trifluralin	Herb	Oxamyl	Insect
Hexazinone	Herb		

OVERVIEW -- THE FUTURE OF THE RIVER

Ralph Adkins, President of the Board
Southeastern Colorado Water Conservancy District

A River of Dreams and Realities -- I think that what you have heard the past two days makes it very clear that it is no longer a dream; it is the reality of what we face right now. The dreaming is over, the hard, dirty work is here, and time is of the essence.

Ralph Adkins with Marke Rude, Kansas Water Commission. **Photo by Karen L. Stewart, Arkansas Valley Journal.**

Colorado has a history of conflict over water. When I was growing up in Las Animas, as a boy I can remember when two neighbors got into a fight over water and one of them hit the other in the head with a round-point shovel and killed him. Quite a few years later, there was an incident down on the Purgatoire when the water commissioner was out on the ditch bank with a farmer. Another fellow drove up, got out of his pickup with a gun, and started after the farmer. The water commissioner said at that point he went right over the riverbank without any hesitation. In the chase, the chasee was able to grab his gun and he shot the chasor.

Water has been a matter of many conflicts not just in Colorado but all over the West. I hope that we today have outgrown that. Many of the contests have been resolved by compacts. Colorado is a party to nine of them. We are probably the greatest compacted state in the Union with the Colorado River, the Upper Colorado River, the La Plata, the Animas-La Plata, the South Platte, the Rio Grande, the Republican, Costilla Creek, and of course, the Arkansas River.

As we look to the future, we might want to look at the past and see what happened there. Perhaps from what I shall share with you will come some ideas we may be able to use here in the valley as we work to solve our problems with the use of our water, both subsurface and surface. The plans that I will describe have resulted in the conservation and exchange of water among the states on the Lower Colorado River.

In 1993, Secretary Bruce Babbitt approved an arrangement between the Metropolitan Water District of California and the Central Arizona Water Conservation District. Many of you recall the bitter lawsuit between California and Arizona that wound up in the Supreme Court after many years of battling. Under the plan that they worked out, the Metropolitan District will pay Central Arizona to store its unused water in Arizona's underground aquifers. In return, Central Arizona will not divert its Colorado River entitlement in an amount approximately equal to what they have stored underground. Metropolitan will then divert Arizona's unused apportionment, at least until the time comes when Arizona will need that water.

Interestingly, California has a statute that allows a user who conserves water to transfer that conserved water for use elsewhere. In 1989, Interior Secretary Mannie Lujan approved a plan whereby the Metropolitan District finances 16 conservation projects in the Imperial Irrigation District. In return, Metropolitan gets the use of 100,000 acre-feet (af) of conserved water for at least 35 years. Cities can afford to pay for such water where farmers cannot, so you can expect to see cities doing more of this in the years ahead.

In Colorado, we have had at least two attempts in the Legislature with bills that have been introduced to do that very same thing. They both went down to defeat. Whether the changing complexion will result in a different approach we will have to wait to see.

Metropolitan Water District has a contract with the Palo Verde Irrigation District under which the farmers who enroll in the plan get a fixed payment for each acre placed in the plan and an extra payment per acre for every year that the plan is exercised. This plan is for 35 years and the farmers continue their irrigation except in the dry years. There has been some suggestion of that here in Colorado and in the valley, and I think it may be something that we will want to look at in the long pull. We may want to give some serious consideration to it in the years that lie ahead.

Water banking is not a new idea. The seven-party agreement of 1931 incorporated into every Secretarial contract with California water users provisions whereby the Metropolitan Water District, San Diego and Los Angeles could bank up to five million af of water saved by diversions reduced below their entitlements. These contracts reserved to the United States the right to enter into the same kind of contracts in other states -- something to think about with our Reclamation projects here.

In 1933 the Metropolitan Water District and Nevada were at the Secretary's door with plans for banking and transfer of water. For various reasons those plans have been held in abeyance, and one of the reasons is that Arizona came completely unwound when they heard what California and Nevada were thinking about doing and asking for the Secretary's blessing to do. Keep in mind that the Lower Basin States, particularly California and Arizona, have fought for years over the division of their share of the Colorado River, and Arizona did not sign the Colorado River Compact of 1922 until 1944.

Closer to home, we have the Roan Creek project of the Chevron Shale Oil Company and Getty Oil Company located at Debeque, some 24 miles above Grand Junction on the Colorado River. This project has priority dates that are senior to the Fryingpan project. Those water rights were originally secured for the oil shale industry. With the pullback in activity on oil shale development, the companies are looking for ways to protect their decrees against abandonment. One way is the Roan Creek Project, which would lease the water to Nevada in an amount up to 200,000 af for 30-50 years, after which it could be pulled back for use in Colorado.

This raises all kinds of questions: the export statute that we have in Colorado, compact entitlements -- it opens a whole Pandora's box of questions. Backers of the proposal are in court now with a diligence application, and it remains to be seen how that will come out. They are receiving a lot of opposition including the Southeast District, which takes a dim view of that. Many say, "Why worry? It will never come to pass." But let me remind you that a number of years ago people said that John Elliot was crazy to think that he could pull off the Homestake Project. Ask Aurora and Colorado Springs where some of their water is coming from today.

As many of you are aware, Ruedi Reservoir on the Fryingpan River above Basalt was built as a replacement storage facility to hold water that would allow us to divert to Eastern Colorado when there was a Western Colorado call on the river. This structure was built to hold 100,000 af, with up to 28,000 af for East Slope diversion. The Bureau of Reclamation is now involved in the round two water sales selling the remaining uncommitted water in Ruedi. The Fish and Wildlife Service wants it all for fish, including the water that is committed to us. We are monitoring these actions very carefully to always be certain that our rights are preserved. Eternal vigilance is the price of safety, and nowhere is it more true than for our West Slope decrees.

There is also a 15-mile reach on the Colorado River between Palisade and Debeque where the Fish and Wildlife Service is demanding flows adequate to protect the endangered fish. Ten-thousand af of Ruedi storage has already been committed to the reach, with a second 10,000 af to be available on call. That is one more place where we must protect our rights in the days ahead, and will explain in part why the Southeastern Water Conservancy District legal costs are as high as they are.

The coming proposed constitutional amendment, which we have mentioned, states:

> ***...every director of a water conservancy district shall be elected in a nonpartisan election by a majority of the eligible electors who vote thereon. An eligible elector is one who is otherwise eligible to vote under the laws of this State and who has been a resident of the water conservancy district for not less than 30 days, or who, or whose spouse, owns taxable, real or personal property situated in the boundaries of the water conservancy district whether said person resides within the water conservancy district or not.***

I would recommend that you all get a copy, and when you read it carefully you will realize its impact.

What we now face in the Arkansas River in Colorado is the absolute need to work closely together to abide by the results of the Colorado/Kansas lawsuit and the coming rules and regulations that exist as a result. We cannot afford the kind of conflict that we have had in the past. I can recall when the idea first surfaced of having a park along the Arkansas River from Leadville to Pueblo. Quite a few of us said, "No way." We were not about to lose any of our Fry-Ark water to the fish and boaters. But look at what sitting around a table and honestly sharing our concerns has accomplished. Today we are living together, and the upper river has a strong economy built on rafting and boating as well as fishing.

Rest assured that Kansas, having won, will give no quarter in the days ahead as final decisions are made in the lawsuit. Witness the fact that Kansas asked the court for injunctions to stop all pumping until the case is settled. We must work together to bring about the best use of our water with the least injury to our towns and farmers who will be hurt. Some farmers will have to curtail their acreages and some will be forced out of business before this is over. That is a hard fact of life that we may have to face.

In an attempt to make the best of the situation, the Colorado Well Protective Development Association, the Arkansas Groundwater Users Association, and the Lower Arkansas Water Management Association have been formed and are working to solve the problems. CWPDA and AGUA have signed a merger agreement to form one entity above John Martin. They will work with the Southeast District to allocate the District's return flow water and find other water that can be used to make up the consumptive portion of the pumped water.

For a while, at least, it is expected that Pueblo and Colorado Springs will be able to provide some of the make-up water from their surpluses. Over time, as the cities grow, this water gradually will be withdrawn and other means of meeting the need will have to be found. There is some time in this area in which to make the necessary replacements, and it is here that the valley must work together in the closest fashion to meet the needs of our water users.

The same is true of Lawma, located below John Martin Reservoir. It is moving aggressively toward the goal of meeting the usable state line flow requirements, and I think doing a fine job in that direction.

We have come a long way, and I think the Arkansas River Coordinating Committee was a tremendous move in the right direction to bring us together here in the valley to look at the common problems that we face. It will continue to be of help in the days ahead. We can, working together, solve our problems with the least possible hurt to the economy of the valley. To do this will require a much more comprehensive level of administering water rights in the valley. Every well and every headgate will have to be known to the water officials, and it is at that point that I think we have our greatest concern. The key to this whole plan to meet our usable state line flow requirements will be the administration of the rules and regulations. We must have the cooperation of every pumper in the valley as well as the surface people if we are going to accomplish this. It is good to know that the power companies have indicated a willingness to make the pump records available, which will greatly assist in the administration process.

Time is of the essence, and I urge that all of us move as rapidly as possible to solve these problems so we give no opportunity for Kansas or Judge Littleworth to even think about placing a federal river master on the Arkansas River. We must continue to guide our own destiny.

WATER RESEARCH

MANAGEMENT OPTIONS FOR IRRIGATION DISTRICTS AND MUTUAL IRRIGATION COMPANIES

The overall goal of the research is to identify strategies that will maintain the economic and managerial viability of irrigation districts and mutual irrigation companies, while at the same time addressing new environmental concerns.

An interdisciplinary research group at Colorado State University has received funding to study past and present institutional constraints and management innovations in approximately 100 irrigation enterprises (IEs) throughout the West. The project will include specifically *irrigation districts and mutual irrigation companies* (ditch companies) providing water to service areas in the range of 10,000 to 100,000 acres.

The researchers will track the "life histories" of these 100 organizations from 1900 to the present (an historical trends analysis) on a number of key indicators. The sample of IEs selected will carefully represent legal traditions, water conditions, cropping patterns and changing county demographics throughout the region.

Irrigation enterprises of this nature still constitute the primary water management sector in the West, in terms of the amount of water managed. Their economic viability and ability to address changes in agriculture, natural resource management and urbanization are central to maintaining an adequate agricultural water supply. This viability and ability to address change is also central to new environmental objectives. Existing state agency databases, IE annual reports and minutes of meetings, census data, and both federal and state archival materials will be used. These primary databases will be supplemented by individual and focus group interviews of present and past IE board members and officers. The project goals are to:

- address the issues of preserving and maintaining prime irrigated lands in the West;
- reduce conflict over land and water policy in the rural/urban community interface;
- identify institutional constraints that impact IE performance; and
- help IEs identify (and explore financing for) new and innovative management practices.

An interdisciplinary team of research scientists at Colorado State University will conduct the three-year project. John Wilkins-Wells, Department of Sociology, and Raymond L. Anderson, Department of Agricultural and Resource Economics, are the principal investigators.

Funding is provided by the U.S. Bureau of Reclamation's Research and Technology Development function.

NITROGEN IN PRECIPITATION THREATENS ECOSYSTEMS

Alpine watersheds in the Front Range of Colorado exhibit the symptoms of advanced stages of nitrogen saturation, and watersheds in other parts of the state appear to be in the early stages, researchers say. Don Campbell and Carol Kendall of the U.S. Geological Survey, Jill Baron of the National Biological Suvey and Research Ecologist at Colorado State University, and Mark Williams of the University of Colorado reported on jointly conducted research in December.

Snow and rain in parts of the Rocky Mountains contain dissolved nitrate and ammonia in amounts that might affect pristine high-altitude ecosystems. Undisturbed watersheds in most areas are able to retain all of this nitrogen in biological processes, but in some alpine watersheds along the Continental Divide the capacity for uptake of nitrogen is being exceeded. This leads to a condition called "nitrogen saturation" in which nitrate is released into surface waters. The release increases the potential for acidification and eutrophication of lakes and streams.

Sources of nitrogen in snow and rain include emissions from automobiles and power plants, agriculture and natural sources. Atmospheric pollutants may be transported long distances from their source before being deposited in precipitation. Concentrations of nitrate and ammonia in snow and rain are high in northern Colorado relative to other parts of the Rocky Mountains, but not as high as in other areas of the country that exhibit nitrogen saturation, such as the northeastern US.

The monitoring and research were sponsored by the U.S. Geological Survey, the National Park Service, the National Biological Service, the Environmental Protection Agency, the USDA Forest Service, the National Science Foundation, and the State of Colorado. Because of reduced federal funding, monitoring has been discontinued in some sensitive areas. According to a USGS representative, "Progress is being made in understanding nitrogen cycling processes along the Front Range, but without the monitoring in other areas, we will not know if the problem is growing more widespread."

WATER RESEARCH AWARDS

A summary of water research awards and projects is given below for those who would like to contact investigators. Direct inquires to investigator c/o indicated department and university.

Colorado State University, Fort Collins, CO 80523

Economic Research and Analysis of Funding for the Fish & Wildlife Conservation Act, William P. Spencer, Agricultural and Resource Economics. Sponsor: National Biological Survey.

***Hydrological Forecasting System Evaluation**, Lynn Johnson, Atmospheric Science. Sponsor: NOAA.

Ecological Modeling in Support of County Decision Making (GIS), N. Thompson Hobbs, Natural Resource Ecology Lab. Sponsor: Colorado Division of Wildlife.

Environmental Science and Technology Center (ESTC) - Development and Analysis, Freeman Smith, Earth Resources. Sponsor: National Biological Survey.

Multinuclear Magnetic Resonance study of the Interactions of Pollutants with Major Soil..., Gary E. Maciel, Chemistry. Sponsor: Department of Energy.

***Hydraulic Model Study of Rock Creek and Creste Dam Sediment Management**, Albert Molinas, Civil Engineering. Sponsor: Pacific Gas & Electric Co.

***Gas Phase Transport of Volatile Organic Compounds in the Vadose Zone**, David McWhorter, Chemical and Bioresource Engr. Sponsor: University of Waterloo.

***Research Workshop on the Hydrometeorology, Impacts and Management of Extreme Floods**, Jose D. Salas, Civil Engr. Sponsor: National Science Foundation.

***Distribution and Dynamics of Radionuclides in Ecosystems of the Savannah River Site**, Floyd W. Whicker, Radiological Health Sciences. Sponsor: University of Georgia.

Arkansas River Basin Research Study, John D. Stednick, Earth Resources. Sponsor: Colorado Division of Wildlife.

Population Modeling, Gary C. White, Fishery and Wildlife Biology. Sponsor: Colorado Division of Wildlife.

***Flaming Gorge Studies: Technical Integration and Synthesis**, Robert T. Muth, Fishery & Wildlife Biology. Sponsor: Bureau of Reclamation (USBR).

***Larval Fish Laboratory Involvement in Implementing Recovery Actions...**, Robert T. Muth, Fishery & Wildlife Biology. Sponsor: USBR.

***Effects of Winter and Spring Flows on Colorado Squawfish**, Daniel W. Beyers, Fishery & Wildlife Biology. Sponsor: USBR.

***Interdisciplinary Approaches to Identification & Mitigation of NPS Water Quality Impacts**, John D. Stednick, Earth Resource. Sponsor: University of Wyoming.

***Support for the Town of Vail Waste Characterization Study**, Harry W. Edwards, Mechanical Engineering. Sponsor: Town of Vail.

***Stress Factors in Whirling Disease**, Eric P. Bergersen, Cooperative Fish & Wildlife Research. Sponsor: Colorado Division of Wildlife.

The University of Colorado, Boulder, CO 80309

Water Quality Model of Cascade Reservoir, Steven Chapra, Civil Engineering. Sponsor: Superconducting Core Tech. Inc.

South Platte Water Rights Management System -- Maintenance Phase II, Jacquelyn Sullivan, CADSWES. Sponsor: State of Colorado.

The Yampa Basin as a Model for Watershed Problem Solving, David Getches, School of Law. Sponsor: CWRRI.

Urban Water Conservation -- Current Status and New Process-Oriented Approach, James Heaney, Civil Engineering. Sponsor: CWRRI.

Biogeochemical and Hydrologic Controls on Solutes and Flowpaths in Alpine Watersheds, Mark Williams, Institute of Arctic and Alpine Research. Sponsor: National Science Foundation.

Generation of Level 3 SSMR and SSM/I Brightness Temperatures for the Period 1978-1998 and Development of a Snow Cover Extent and Depth Algorithm for Global Change Research, Richard Armstrong, Cooperative Institute for Research in Environmental Sciences. Sponsor: National Aeronautics and Space Administration (NASA).

***Determination and Applications of Satellite-Derived Atmospheric Water Characteristics in Oceanic Regions**, Judith Curry, Atmospheric and Oceanic Sciences. Sponsor: NASA.

***Continue Design and Development of the Power and Reservoir System Model (PRSYM)**, Edith Zagona, Civil Engineering (CADSWES). Sponsor: Electric Power Research Institute.

***Conceptual Planning for Integrated Analyses (Integral) of Water Resource Systems and Power Operations**, Edith Zagona. Sponsor: Tennessee Valley Authority.

***Potential Effects of Global Climate Change on Western River Basins Study**, Edith Zagona, Civil Engineering (CADSWES). Sponsor: USBR.

*Supplement to existing award.

WATER SUPPLY

The Surface Water Supply Index (SWSI) developed by the State Engineer's Office and the USDA/SCS is used as an indicator of mountain-based water supply conditions in the major river basins of the state. It is based on stream flow, reservoir storage, and precipitation for the summer period (May-October). During the summer period stream flow is the primary component in all basins except the South Platte, where reservoir storage is given the most weight. The following SWSI values were computed for each of the seven basins on July 1, 1995 and reflect conditions during the month of August.

Basin	Jan. 1, 1996 SWSI Value	Change From Previous Mo.	Change From Previous Yr.
South Platte	+2.9	0.0	+3.5
Arkansas	-0.5	-1.3	+0.2
Rio Grande	-3.5	+0.2	-5.5
Gunnison	-2.3	+054	-4.0
Colorado	+1.7	-0.6	+2.5
Yampa/White	-0.7	-2.4	+0.2
San Juan/Dolores	-2.7	+0.5	-4.3

SCALE

-4	-3	-2	-1	0	+1	+2	+3	+4
Severe Drought		Moderate Drought		Near Normal Supply		Above Normal Supply		Abundant Supply

UNIVERSITY WATER NEWS

SPOT INSPECTION OF FLUMES SHOWS AGING AND MAINTENANCE NEEDS

The Parshall flume is one of the most accurate and dependable open channel flow measurement instruments when properly installed and maintained. A recent spot assessment and inspection of flumes in the field, however, has indicated that inadequate maintenance can result in underestimating the amount of water the flumes convey. Data and observations collected during the assessment of 66 Parshall flume field sites across Colorado indicate that the flow measurement and monitoring network is aging and in need of maintenance and/or upgrading.

The Parshall flume was developed at Colorado State University nearly 70 years ago, and hundreds are placed throughout the state to ensure that water is allocated appropriately for agricultural use. Generally, they are constructed of concrete, metal or fiberglass materials for durability, and because of the material weight, long-term consolidation of the foundation soils may result in settlement of the flume. Other adverse influences include weather cycles of wet/dry-freeze/thaw-heat/cool, and vibrations from agricultural equipment. These adverse effects can result in inaccurate flow measurement information for users.

The field assessment found that the discharge measured by the majority of the Parshall flumes underestimates the true amount of water conveyed through the ditch and/or lateral system. Thus, many water users receive more water than their appropriate allocation.

Summary of Measurement Errors

Condition	% Observed
Discharge Overestimated	42
Discharge Underestimated	58
Total Error Less Than 3%	39
Total Error Less Than 5%	59

The assessment resulted in the following recommendations:

- A comprehensive study of flumes should be performed throughout the state.
- Water districts, irrigation districts and reservoir owners need a data base that describes the status of the water measurement system.
- A state water congress should be held to inform and/or alert water users of the system status.
- Alternatives should be devised for maintaining and/or upgrading the system.
- Cooperative Extension should implement an educational program to inform water users how they can adjust, maintain, replace, and/or repair Parshall flumes.

The field inspection of sample Parshall flumes across Colorado was undertaken by Professor Steven R. Abt and students of CSU's Civil Engineering Department with assistance from specialists of CSU's Cooperative Extension. It was funded by the Agricultural Experiment Station.

*For information about the report, **Condition Assessment of Parshall Flumes in Colorado**, by Steven R. Abt, Bryan C. Ruth, Travis L. Brisendine, Cara M. Mitchell and Chad M. Lipscomb, contact Professor Abt at Phone 970/491-8203, FAX 970/491-8671, or e-mail abt@lance.colostate.edu.*

WET SPOTS ON THE WEB

Find Water-Related Information Quickly and Easily

by Julie Eyre

Since the last "*Wet Spots*" article, more water resources information has continued to become available. Some has been brought to our attention by the readers of *Colorado Water*, and some has been discovered by surfing the web. In any case, we have found several more pages that we think will be of interest to water professionals.

Government Information Available:
The U.S. Government Printing Office has made available government documents through the world wide web, and dial-in access. The Congressional Record, Federal Register, and congressional bills are all available to search free of charge. Also available on the home page is information available through Federal Depository Libraries, and the ability to connect to the Consumer Information Catalog, which allows the public to order publications produced by numerous Federal Agencies. All of this information can be found at the following url: http://www.access.gpo.gov/su_docs;

through telnet:
telnet to swais.access.gpo.gov; then login as guest;

or through dial-in:
call 202-512-1661; type swais and login as guest.

Water Conservation Districts:
The Southwest Water Conservation District has gone on line. Available on the home page is information about the history of the Southwest Water Conservation District, an excellent list of water terms and definitions, and water information for the Four Corners area. The url is located at:

http://web.frontier.net/SCAN/wip/wiphome.html.

Graduate Degree in Water Resources Science:
For those interested in a graduate degree in Water Resources Science, the University of Minnesota has created a home page with program requirements, application requirements, faculty, and curriculum. The url is located at:

http://www.soils.agri.umn.edu/academics/gradstudes/wrs

Colorado Water Resources Research Institute:
CWRRI has developed an on-site wastewater treatment homepage to give homeowners some ideas when central sewer is not an option. Some of the articles contain information particular to Colorado, while others contain more general information. A list of links was also compiled that relate to on-site wastewater treatment. The url is located at:

http://www.colostate.edu/Depts/CWRRI/onsite/home.html.

Water Web:
This home page provides a large amount of water information quickly. It is designed to provide water users around the world with information regarding all water technology. The url is located at:

http://www.waterweb.com/.

International Association of Hydrological Sciences:
The International Association of Hydrological Sciences (IAHS) is the international nongovernmental organization which deals with hydrology and water resources. The IAHS has created a home page that contains information on IAHS statutes and bye-laws, newsletters, and lists of publications and conferences. The home page is still under construction, but stop by and check it out. The url is located at:

http://www.wlu.ca/~wwwiahs/index.html

COLORADO WATER KNOWLEDGE HOMEPAGE

by Julie Eyre

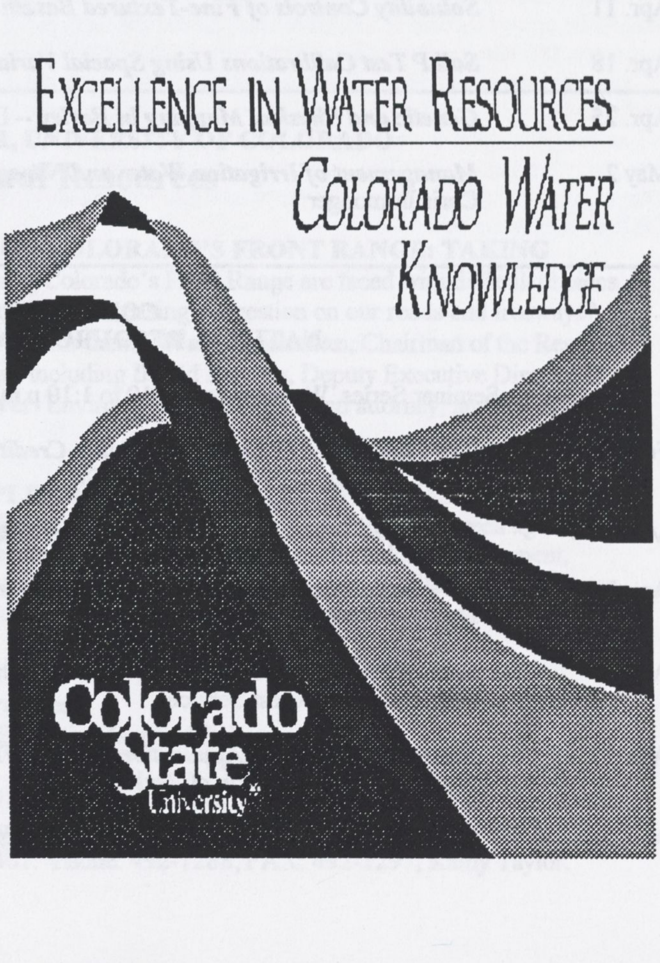
The joint efforts of twelve Colorado Commission on Higher Education (CCHE) undergraduate scholars and several departments at CSU have made the dream of creating a home page that provides basic water information in Colorado to the public a reality. The departments that have participated include the Department of Civil Engineering, the Department of Earth Resources, and the Department of Chemical and Bioresource Engineering. Topics covered on the home page include five sections: An Overview; Sources, Uses, Management, and Conservation; Aquatic Life, Wetlands, Water quality, and Environmental law; Water Administration; and Frequently Asked Questions.

The overview contains information on a variety of basic water concepts. A section is devoted to a summary of Colorado water history from prehistoric times to the present. A description of how geologic features influence the movement of water and distribution can also be found under the overview. Another section is devoted to Colorado's climate, including long-term temperature and precipitation patterns from six stations throughout the state.

The sources, uses, management and conservation section contains interesting maps and data, including a map of the river basin boundaries in Colorado. Links have been made available to water conservation sites. Water use, listed in categories and by the amount of water each category uses each year, can also be found in this section.

The aquatic life, wetlands, water quality and environmental law section has links to environmental sites and definitions of water-

(*Colorado Water Knowledge* as seen on the Worldwide Web)



related terms. Pictures and descriptions of aquatic organisms can be found. A description of wetlands in Colorado and links to EPA pages are available. Links to environmental law-related sites are also provided under this section.

The water administration section provides information to those interested in water law. There is a summary of Colorado water rights laws and information on how to obtain a water right. A map of the transmountain water diversions from the Colorado river basin to the Arkansas, South Platte, and Rio Grande river basins is provided, along with a description of the projects. Descriptions of water compacts Colorado has made with neighboring states is also provided.

The frequently asked questions section has three different areas of focus along with links to other pages with frequently asked water questions. The areas include water rights, water quality, and septic systems.

Also provided on the web page is a water fact of the week, and a place to send questions and comments. The information listed above is a brief summary of all the options available. Please take some time to check out this page. A lot of effort has gone into compiling all of the information. The Colorado Water Knowledge page can be found at:

http://www.cnr.colostate.edu/CWK/index.html

SEMINAR SERIES

COLORADO STATE UNIVERSITY
SOIL AND CROP SCIENCES DEPARTMENT

Faculty/Graduate Student Seminar, Spring Semester, 1996, Thursday at 3:10-4:00 p.m., C146 Plant Sciences Building. Coffee and cookies at 2:45 p.m. in C146 Plant Sciences Building. Coordinator: Jim Quick, 970/491-6483.

Mar. 1 — ***Ten Years Experience with Dryland Farming Systems*** -- Gary Peterson/Dwayne Westfall

Mar. 21 — ***Soil Organic Matter Changes in Intensively Cropped Systems*** -- Rudy Bowman

Mar. 28 — ***Busch Barley Breeding Program*** -- Mike Bjarko

Apr. 4 — ***Pedology and Biogeochemistry on the Island of Hawaii*** -- Gene Kelly

Apr. 11 — ***Solubility Controls of Fine-Textured Basaltic Lunar Simulants*** -- James Oglesby

Apr. 18 — ***Soil P Test Calibrations Using Spacial Variability of Landscapes*** -- Rodrigo Ortega

Apr. 25 — ***Genetic and Physical Mapping in Barley*** -- Deana Namuth

May 2 — ***Management of Irrigation Water and Nitrogen Fertilizer to Minimize Nitrate Leaching to the Groundwater*** -- Chris Iremonger

COLORADO STATE UNIVERSITY
NATURAL RESOURCE AND AGRICULTURAL ECONOMICS

Lunch time Seminar Series, Wednesdays, 12:10 to 1:10 p.m. 110 Animal Science Building.

Feb. 28 — ***The Theory and Practice of Pollution Credit Trading in Water Quality Management*** -- Jennie Hughes, CSU; Dana Hoag, CSU

Mar. 27 — ***Historic Built Resources as an Example of the Double Public Good*** -- Karin Sable, CSU

Apr. 3 — ***How Important is the Contribution of Mineral Production on National Forest to the U.S.?*** -- Deborah Shields, U.S. Forest Service

Apr. 10 — ***Spatial Optimization of Habitat Management for Endangered Species: Ferrets and Owls*** -- John Hof, U.S. Forest Service

Apr. 17 — ***Benefit Transfer: An Application Using WTP for Rural Water Supply Improvements*** -- Steve Piper, U.S. Bureau of Reclamation

Apr. 24 — ***Relevance of Altruism in Benefit-Cost Analysis*** -- Nick Flores, University of Colorado

COLORADO STATE UNIVERSITY
ENVIRONMENTAL ENGINEERING SEMINAR SERIES, SPRING 1996
Department of Civil Engineering

All seminars will be held on **Mondays** from **Noon** to **1:00 p.m.** in the **Student Senate Chambers Room** in the **Lory Student Center**. All are welcome and feel free to bring your lunch.

Feb. 26 ***Environmental Aspects of Xin-Jiang Water Master Plan***
Armando Balloffet, P.E., President, Balloffet & Associates, Fort Collins, Colorado

Mar. 4 ***Contamination at the Denver Federal Center -- Regulations and Responsibilities***
Paul Sealy, Environmental Scientist, Lewis Berger & Associates, Boulder, Colorado

Mar. 18 ***In-situ Bioremediation Techniques***
Bill Mahaffey, Manager Bioremediation Systems, Walsh Environmental Scientists and Engineers, Boulder, CO

Mar. 25 ***South Platte River Channel Rehabilitation for Water Quality Improvement***
Ted Johnson, Senior Environmental Engineer, Camp, Dresser & McKee, Inc., and
Bob Neil, Project Director, Metro Wastewater Reclamation District, Denver, CO

Apr. 1 ***Principal Municipal Wastewater Concerns in Slovakia***
Mike Condran, P.E., Dames & Moore, Denver, CO

Apr. 8 ***Project Management and You, the Engineer***
John Clark, P.E., Senior Project Engineer, RBD Inc., Fort Collins, CO

Apr. 15 ***Colloid Charge Titration: A Promising Tool for Coagulation Control***
Roger Jordan, Professor at University of Colorado, Clear Corp., Boulder, CO

Apr. 22 ***Future Environmental Trends***
Ralph Chapuis, P.G., Director of Engineering, Research Management Consultants, Inc., Golden, CO

Apr. 29 ***Aspects of Wastewater Treatment Plant Upgrading***
John McGee, RBD Inc., Fort Collins, CO

NATURAL RESOURCES LAW CENTER, UNIVERSITY OF COLORADO
Hot Topics in Natural Resources

Tuesday, March 12 -- AIR QUALITY AND TRANSPORTATION ON COLORADO'S FRONT RANGE: TAKING RESPONSIBILITY FOR DIFFICULT CHOICES -- Communities along Colorado's Front Range are faced with difficult choices concerning air quality and transportation. Can we control the "brown cloud" and increasing congestion on our roads and freeways? What decisions and sacrifices mush be made, and who will take responsibility for them? **Wade Buchanan,** Chairman of the Regional Air Quality Council (RAQC), will moderate a panel addressing these issues including **David Pumpu**, Deputy Executive Director of the Denver Regional Council of Governments (DRCOG), **Christine Shaver**, Environmental Defense Fund attorney; and **Ken Hotard**, Senior Vice-President of the Boulder Area Board of Realtors.

Tuesday, April 23 -- THE PROBLEM OF FEDERAL-PRIVATE SPLIT MINERAL ESTATES: WHO HAS CONTROL? Many federally owned lands overlie privately owned oil and gas and mineral rights. Increasingly, the competition between agency multiple use directives and private interest in resource development has resulted in legal battles between the federal government, which seeks to regulate use of the federally owned surface estate for resource extraction, and the private owners of the mineral estates. **Andrew Mergen,** the Center's 1996 El Paso Natural Gas Law Fellow, will look at problems and potential solutions associated with these split mineral estates.

12:00 noon, Holland & Hart, 555 17th St. 32nd Floor, Denver
Box lunches provided
One Hour of continuing Legal Education (applied for)

Prepayment required. $15 if <u>received</u> 3 working days before program; $18 thereafter. Includes lunch. Additional $5 for CLE credit, if desired. Limited scholarships. Register by phone or FAX with credit card or send check payable to the Univ. of Colorado to Natural Resources Law Center, Campus Box 401, Boulder, CO 80309-0401. Phone: 492-1288; FAX: 492-1297, Kathy Taylor.

WATER NEWS DIGEST

WATER QUALITY

Water Pollution Remains Widespread

Nearly 40 percent of lakes, rivers and streams in the United States are too dirty for fishing and swimming despite major federal efforts to combat water pollution, according to a recently released Environmental Protection Agency report. The report's figures are consistent with a similar analysis of pollution in major water bodies issued in 1992. Agricultural runoff containing pesticide residues or other pollutants poses the biggest threat to some water bodies, contributing about 60 percent of the pollution found in rivers and half of the pollution in lakes, the study said. Excessive levels of silt, found in 34 percent of polluted rivers, are a major problem. Storm sewers and municipal waste treatment plants also are major pollution sources, the study added. And of the 1,500 fish consumption advisories issued across the country in 1994, nearly three quarters warned of high levels of mercury.

Washington Post, 12/15/95

Safety of Water Supply Questioned

In a study based on data reported by more than 100 water utilities across the country, the Natural Resources Defense Council said arsenic, radon, or byproducts of chlorination, each considered highly toxic, contaminate the drinking and bathing water of at least 100 million Americans. The findings were challenged by the American Water Works Association. AWWA said the data do not show the that the levels at which people have been drinking for years cause harm. In Colorado, citizens were given good news. An examination of EPA reports from 1993 and 1994, by Clean Water Action and the Colorado Public Interest Research Group (CoPIRG), found that Colorado citizens are drinking water well within the standards for arsenic, radon and trihalomethane (a byproduct of chlorination). The groups point to results elsewhere in the nation, however, as justifying the reauthorization of the Safe Drinking Water Act.

Los Angeles Times 10/27/95, *Denver Post* 10/30/95

Wetlands and Cattails Clean Park Wastewater

When renovations are complete, Island Acres State Park will have a new wastewater treatment system called a sealed or constructed wetlands system. Waste from the park's septic system goes first into a holding tank where solids and fluids separate. The solids eventually will be pumped out and disposed of while fluids go into an aerator chamber where water and bacteria are broken down by bubbling action. The remaining clear fluids are diverted into the sealed wetlands, which are in ponds first lined with heavy plastic and then covered with soil. Cattails then are planted in the soil. The fluids, called treated effluent, are pumped into the wetlands and either evaporate or transpire through the plants. The self-contained system does not discharge any effluent into the water table, thus protecting the environment and saving the cost of state discharge permits.

Grand Junction Daily Sentinel 11/9/95

Summitville Cleanup Costs Keep Growing

The cost of cleanup at the Summitville Gold Mine is now at $105 million and still climbing, according to the lead agency for cleanup of the site, the Colorado Department of Public Health and Environment. The department said the cleanup is running at $25,000 per day. The Environmental Protection Agency took over cleanup of the mine site in Dec. 1991 after Galactic Resources Ltd. of Vancouver, Canada declared bankruptcy and abandoned operation of the mine. Neither the company nor its owner has paid a cent toward the cleanup. It is expected to take from 5 to 10 years to complete water treatment at Summitville.

Denver Post 11/3/95, *Pueblo Chieftain*, 1/6/96

Preliminary Report Shows Potential Problem at Hog Farm

Members of the Water Quality Control Commission want more information about the amount of nitrates in the soil before the state requires National Hog Farms east of Kersey to change its operation. Waste from the 185,000-hog farm is sprayed on about 2,800 acres of farmland by center-pivot sprinklers and nitrogen is supposed to evaporate or be absorbed by crops. A water quality control engineer for the WQCD says there is strong evidence that nitrogen from hog waste has soaked into the ground far enough that plants cannot absorb it. Those nitrates will make their way to groundwater and pollute it, he said. Hog Farm officials promised to give a written response to the state's preliminary report by the end of January.

Greeley Tribune 11/22/95, 1/9/96

Reservoir Caulk Contaminated

Drinking-water reservoirs in northwest Fort Collins contain PCB-contaminated caulk which has been flaking off into the water, say city officials. So far, neither drinking water nor groundwater shows any signs of contamination, but PCB levels in soil outside the reservoirs' drainage sites are ten times higher than the Environmental Protection Agency allows. The city plans to remove the old caulk and replace it with a new, safer sealant, as well as dig up all the contaminated soil. The project will begin in Jan. and last about three months.

Fort Collins Coloradoan 11/17/95

Modest Efforts Are Reclaiming Upper Animas Basin

The Animas River Stakeholders are taking small steps forward to reclaim the Upper Animas Basin, site of abandoned mines that actively drain into the Animas or its tributary creeks. The organization was formed when the Colorado Water Quality Control Commission asked the Colorado Center for Environmental Management in early 1994 to organize the basin's factions into a stakeholders group. In Placer Gulch the Mining Remedial Recovery Co. has moved Sunbank Mine's dump and put in half a dozen settling ponds, bulkheads and limestone to reduce the acidity of surface water flowing downbasin. The Sunbank Project so far has cost $400,000, of which $300,000 was

MRRC's money. Other funds came from the EPA. MRRC came into being and owns the property under reclamation because of a steel company's bankruptcy proceedings. At the Silverwing Mine, active from 1875 to 1965, a small project is underway with private funds ($7,500) to improve water quality. Sunnyside Gold Corp. has spent about $10.5 million on reclamation, begun even before the mine closed in 1991.

Fort Collins Coloradoan 10/21/95

RECREATION/WILDERNESS

GO-Colorado Picks Six Legacy Project Proposals

On January 9 the board for the Great Outdoors Colorado Trust Fund announced it had picked six "concept papers" from across the state to apply for special Legacy Project funds. The Legacy Projects must address regional and statewide needs by providing outdoor recreation, open space, wildlife protection and local government. The proposals were:

- A Denver project to build parks and trails and improve wildlife habitat along 10.5 miles of the South Platte River.
- The Colorado River "greenway" in Mesa County, with new trails, open space, wildlife habitat and other improvements along 29 miles of streams in the Grand Junction area.
- The Historic Arkansas Riverwalk project in Pueblo, to restore and enhance the 1921 Arkansas River channel with park, recreation and aquatic habitat improvements.
- The Yampa River project in northwestern Colorado, to develop recreation opportunities along the river from Yampa and Steamboat Springs to Dinosaur National Monument.
- The Great Plains Reservoirs project in southeastern Colorado, to buy water rights, protect wildlife and improve recreation for a future state park.
- The I-25 Conservation Corridor, with open space, trails, wildlife habitat and recreation areas on 25,000 acres between Denver and Colorado Springs.

GO Colorado established the Legacy program in October to distribute money from lottery revenues that were far greater than predicted, and will announce selected projects in May.

Colorado Springs Gazette Telegraph, 1/11/96

1996 is "Year of the South Platte River"

On New Year's Day, Denver Mayor Wellington Webb proclaimed 1996 the "Year of the South Platte River." Webb pledged that during 1996 the city will accomplish ground breakings for expansion or development of four public parks along the Central Platte River corridor. The city, Great Outdoors Colorado and other partners will have invested more than $5 million in parks and river channel improvements called the Riverfront Park system.

Denver Post, 1/10/96

Pueblo Voters Approve HARP

In November, Pueblo voters OK'd a $12.85 million bond issue for the Historic Arkansas Riverwalk Project. Fewer than 1,000 votes marked the narrow victory of the proposal to reopen the original channel of the Arkansas River and build a San Antonio-style park and commercial district there.

Pueblo Chieftain 12/31/95

Deep Creek Now Eligible for Wild & Scenic Designation

A joint review by the U.S. Forest Service and Bureau of Land Management has determined that Deep Creek is eligible for designation as a national wild and scenic river. The creek runs 15 miles from Deep Lake on the Flat Tops to its confluence with the Colorado River just north of Dotsero. Eligibility is the first of the two-part study process that may lead to wild and scenic designation. A second, more detailed study will be done later to decide whether the designation, which must be approved by Congress, is suitable. Call 945-2521 or 945-2341 (Glenwood Springs) to obtain a copy of the eligibility report.

Grand Junction Daily Sentinel 11/7/95

WATER DEVELOPMENT

Funding Approved for Animas-La Plata

Initial funding of $10 million for the Animas-La Plata project was approved in the 1996 federal water and energy appropriations bill signed by President Clinton in Nov. The project will store water from the two rivers in Ridges Basin Reservoir for use by Indian tribes, farmers and ranchers in Colorado and New Mexico. Sam Maynes, attorney for the Southern Ute Indians, said that although delivery systems are not scheduled to be built until the second phase of the project, the tribes are willing to take their chances as long as their water is stored in the reservoir. Originally, the Indian tribes had insisted on getting their water in the project's first phase.

Pueblo Chieftain, 11/19/95, *Grand Junction Daily Sentinel*, 1/2/96

Final Chapter Not Written on Homestake II

On Dec. 4 Aurora and Colorado Springs lost their court battle to force Eagle County let them develop Homestake II, which would divert more than six billion gallons a year from the Holy Cross Wilderness Area near Vail. This is not the final chapter for the project, however. Under proposed legislation sponsored by Colorado Senate President Tom Norton, Eagle County no longer would have the authority to halt Homestake II. Norton's bill would limit use of special-use permits to regulate public and private projects. In 1974, concerned about growth, the Colorado Legislature passed several measures including one that gave local governments the power to require special-use permits when a project raised issues of "statewide concern." Eagle County used the law to deny Aurora and Colorado Springs a permit to proceed with Homestake II. State Rep. Andy McElhany, R-Colorado Springs, will co-sponsor Norton's bill. Proponents of the bill say it would still allow counties to review projects and request changes that are "reasonable." Opponents contend it would take the teeth out of the law by taking away the ability to veto projects.

Denver Post 12/5/95, 12/12/95; *Colorado Springs Gazette Telegraph*, 1/16/96 (http://www.usa.net/gtwork/today/loc009.html)

Rocky Mountain National Park Wins Battle Over Dam

Officials of Rocky Mountain National Park have won a battle to keep a new dam from being built in the park. Northern Colorado Properties Inc. has deeded over 822 acre-feet of water in Mirror Lake to the park. The company had wanted a dam to hold the water to supply new development.

Fort Collins Coloradoan, 12/16/96

Colorado Springs Studies Water Supply Options

About six years ago, Colorado Springs launched a $500 million, 50-year water study, looking at systems of storage, exchanges and pumping from Twin Lakes in Leadville to reservoirs near Pikes Peak to Lake Meredith in Crowley County. Elephant Rock Dam, three miles north of the mountain town of Buena Vista, was one of the possibilities to provide Colorado Springs water for its growing population. Considering everything from cost to environmental impact to ease of operation, Elephant Rock finished last. The city also is looking at water reclamation -- treating wastewater so thoroughly it can be used for drinking and washing. This would be the most expensive of the city's options, at a cost of about $350 million. Another option is imposing tougher water conservation rules.

Pueblo Chieftain 11/20/95, *Colorado Springs Gazette Telegraph* 1/1/96, *Fort Collins Coloradoan* 1/2/96 (http://www.usa.net/gtwork/archive/Monday,_January_1,_1996.Arc/loc010.html)

Glendale Goes From Wells to Denver Water

On January 10 the City of Glendale officially hooked into Denver's water supply after using wells for the past 44 years. City voters overwhelmingly approved the $9 million water deal in Nov. 1993. Glendale will pay back the $9 million over the next 20 years with revenues from sales tax and water bills. The city will pay Denver $500,000 a year for the water but will continue to bill its residents and maintain its water system. Glendale's water had high but technically safe levels of iron and magnesium which affected its taste and smell and also caused high maintenance costs because of corrosion.

Denver Post 1/11/96

FEDERAL WATER RIGHTS

Cities, Irrigation Company Propose Land Swap

The cities of Fort Collins and Greeley and the Water Supply and Storage Co. have offered to trade 1,108 acres of land in exchange for nine reservoirs, all on national forest land. The entities now own water rights in the nine reservoirs but must gain Forest Service permits to operate the reservoirs. The bulk of the land offered is on the Rockwell Ranch in the Poudre Canyon about 40 miles northwest of Fort Collins. It borders the Comanche Peak Wilderness and Cache la Poudre Wilderness. The reservoirs proposed for the swap include Joe Wright, Barnes Meadow, Chambers Lake, Comanche, Hourglass, Long Draw, Milton Seaman, Peterson Lake and Twin Lakes. Rep. Wayne Allard will introduce the legislation, which must pass Congress. The Forest Service has not decided whether it will support the bill. Trout Unlimited may oppose the legislative initiative.

Fort Collins Coloradoan, 12/8/95, 12/23/95

AG TO URBAN TRANSFERS

Weld County's prime agricultural land is being converted to urban development faster than any county in the nation, according to the Weld County planning director. However, property owners now will have to wait longer to split their land for development. The process to split parcels of land is called a recorded exemption, a land-use tool that allows owners to carve up their land for purposes other than the designated zoning. Previously, landowners could seek to split their land once every five years, but now it will go to ten years. Property owners still will be free to apply for zone changes on their land, but the process is more expensive and time-consuming, and there is no guarantee that commissioners would approve a zone change.

Greeley Tribune 11/27/95

ENDANGERED SPECIES

Romer/Babbitt Sign Endangered Species Agreement

On November 29 Interior Secretary Bruce Babbitt and Colorado Gov. Roy Romer signed an agreement that will give the state a larger role in decisions on endangered species. The objective is to prevent more additions to the Endangered Species Act (ESA) through collaboration between state and federal officials, greater flexibility under the law, and encouraging landowners' voluntary cooperation.

Fort Collins Coloradoan (Associated Press) 11/30/95

USBR to Test Low-Flow Impacts in San Juan

The Bureau of Reclamation's plan to cut San Juan River flow temporarily below Navajo Reservoir, to determine how it affects the Colorado squawfish and razorback sucker, is being questioned by anglers and irrigators. USBR regulates water flow through the dam, which is east of Farmington. The agency would reduce flows to 250 cubic feet per second (cfs), compared with the current 800 cfs, to test the impact on fish and plant life and human activities along the river. Critics say the low flow will harm trout waters below the dam, renowned for prime trout fishing. Another concern is that the low water flow will expose algae to the air and too much sunlight, causing it to die along with bugs, worms and leaches in the algae. The two-week test was to begin Jan. 10 (planned prior to the government shutdown) as a test to see if USBR can run a similar four-month test in 1997.

Denver Post (Associated Press) 12/6/95

CDOW Continues Struggle Against Whirling Disease

The Colorado Division of Wildlife is mounting a two-pronged attack to combat whirling disease (WD) by revamping fish hatcheries and expanding field research. A stocking policy recently adopted by CDOW says no WD-exposed trout will be stocked in WD-free waters or in waters where native trout exist. Eight of the state's 16 hatcheries have tested positive for whirling disease, although at least one subsequently tested negative. Anglers will see a reduction in numbers of fish produced. Some researchers claim operating the hatcheries at 100 percent capacity tends to overstress fish, leaving them more vulnerable to disease. The division also will take $600,000 out of the hatchery capital improvement fund to rework existing disease-free hatcheries and will seek an additional legislative appropriation of $3 million for other hatchery improvements.

Grand Junction Daily Sentinel 11/5/96

WESTERN WATER POLICY

Under the Western Water Policy Review Act of 1992, Congress directed the President to undertake a comprehensive review of federal activities in the 19 western states that affect the allocation and use of water resources, and to submit a report of findings and recommendations to the Senate Energy and Natural Resources Committee, the Senate Appropriations Committee, the House Resources Committee, the House Appropriations Committee, and the House Transportation and Infrastructure Committee. The legislation authorizing the commission noted that at least 14 federal agencies have water-related responsibilities, resulting in "unclear goals and an inefficient handling of the Nation's water policy." It noted that conflicts between competing goals and objectives among federal, state and local agencies and private water users is particularly apparent in the Western States.

The commission will review water resources problems in the 19 Western States including the existing and proposed federal programs, the need for additional water augmentation, the existing institutional arrangements, the legal regime, and the activities, authorities, and responsibilities of federal agencies with direct water resources management responsibility. It will examine these topics over a two-year period of research, field investigations, public discussions, and commission deliberations. The commission will focus on selected river basins in the Western United States. It will hold a series of regional public hearings and prepare a report of its findings.

The commission was chartered by the Secretary of the Interior on Sept. 15, 1995, and Congress extended its existence to Oct. 2, 1997. The commission has tentatively scheduled its first meeting in Portland on Feb. 16-17 at Lewis and Clark College. Senator Mark Hatfield, the Commission's mentor, has been invited to attend and swear in the appointed members.

Commission members are: Denise Fort, University of New Mexico, Chair; Bruce Babbitt, Secretary of Interior (represented by Joseph L. Sax, Counselor to the Secretary); Togo D. West, Secretary of the Army; Huali Chai, Attorney, San Jose, CA; John Davidson, Univ.of South Dakota; Janet Neuman, Northwestern School of Law, Lewis & Clark College, Portland, OR; Jack Robertson, Deputy Director, Bonneville Power Administration, Portland OR; John Echohawk, Native American Rights Fund Boulder, CO; Patrick O'Toole, rancher and former state legislator, Savery, WY; Kenneth L. Salazar, Attorney, Denver, CO; Sen. Frank Murkowski, Chairman, Committee on Energy and Natural Resources; Sen. Larry Craig, Chairman, Subcommittee on Forests and Public Land Management; Sen. Mark O. Hatfield, Chairman, Committee on Appropriations; Sen. J. Bennett Johnston, Ranking Minority Member, Committee on Energy and Natural Resources; Sen. Bill Bradley, Ranking Minority Member, Subcommittee on Forests and Public Land Management; and Sen. Robert C. Byrd, Ranking Minority Member, Committee on Appropriations.

The commission is located at the Denver Federal Center.

COLORADO RIVER BASIN

After a nearly disastrous experience three years ago when initial deliveries of Colorado River water from the Central Arizona Project (CAP) corroded city mains and residential plumbing, Tucson voters have passed an initiative that essentially bans flow of CAP water through the municipal supply system for five years. The initiative, called the Water Consumer Protection Act, requires the city to find other uses for its share of CAP water, such as trading it to mines and farms, using the supply for groundwater recharge, or for watering parks and golf courses. While proponents of the initiative argued that it made no sense for Tucson to use substandard surface water while nearby mines and farms were using enough high-quality groundwater to serve a city of 500,000, others contend that the new directive could force the city to shut down some of its wells and might result in water shortages next summer. A representative of the Arizona Water Quality Association noted that the problem not only existed with the poor quality of CAP water, which has total dissolved solids (TDS) ranging to 690 parts per million, but with a decision by Tucson not to chlorinate the water. Instead, the city switched to ozonation with a residual of chloramine.

U.S. Water News, Jan. 1995

PEOPLE

Richard "Dick" Stenzel is the new Division Engineer for Water Division 1, responsible for administering the waters of the South Platte River Basin. Hal Simpson, State Engineer, made the announcement. Dick was an Assistant Division Engineer in Greeley for several years before he became Assistant State Engineer in 1991. He replaces Alan Berryman who took a position with the Northern Colorado Water Conservancy District.

Eluid Martinez was confirmed as Commissioner of the Bureau of Reclamation by the Senate on Dec. 22 with unanimous consent. Martinez served in the New Mexico State Engineer's Office for 23 years, most recently as the State Engineer.

Gilbert White received the 1995 Volvo Environment Prize at a ceremony in Gothenburg, Sweden, on Oct. 5. Volvo cited White for his work on "the problems of managing natural resources -- especially water -- for human use." White is former director of the Natural Hazards Research and Applications Information Center at the University of Colorado.

MEETINGS

PLANNERS, ENGINEERS AND WATERWAYS

February 29, 1996 -- 8:00 a.m. to 5:00 p.m.
Executive Tower Inn, 1405 Curtis, Denver, Colorado

Featured Speakers:
William Coors, Adolph Coors Company, FOSTERING TEAMWORK AND PARTNERSHIPS
Hon. Wellington Webb, Mayor of Denver (invited), REVITALIZATION OF THE PLATTE RIVER

Case Studies:
ROCKY FLATS--COLLABORATION FOR LONG-TERM RESTORATION
GORE CREEK WATERSHED MANAGEMENT
"CONTEXTURAL DESIGN" THE FUTURE OF WATER RESOURCES
BEAUTY AND FLOOD CONTROL ARE NOT ENOUGH
THE COMMUNITY AS PART OF THE DESIGN TEAM--BIBLE PARK - A CASE STUDY
A SLIDE TOUR OF PROJECTS

For information contact: Chuck McKnight 303/986-1444 or Bill Wenk 303/628-0003.

FIELD SCIENTISTS AND THE SHAPING OF THE AMERICAN WEST

***Presented by* The Center of the American West**
Glenn Miller Ballroom, University of Colorado, Boulder
March 15-16, 1996

The conference will explore over two centuries of discovery through the perspectives of scientists, historians, and diarists. Their stories will provide the backdrop for an exciting and thought-provoking conference into what field scientists perceived the American West once was, what it is today, and what it may hold in the years to come. Principal speakers include: Wes Jackson of the Land Institute, a leading expert on agricultural land-use reform; Robert Bakker, a world-renowned expert on dinosaurs and author of Dinosaur Heresies and Raptor Red; Ted Strong, Executive Director of the Columbia River Inter-Tribal Fish Commission and expert on changing fish populations in the West; Patricia Limerick, a leading Western historian and author of Legacies of Conquest; and Charles Wilkinson, Western author of Crossing the Next Meridian and The Eagle Bird. For registration materials or more information contact the Center of the American West, University of Colorado, Campus Box 234, Boulder CO 80309-0234; Phone 303/492-4879; FAX 303/492-1868; E-mail centerwest@colorado.edu.

HYDROLOGY DAYS 1996

April 15-19, 1996
Colorado State University, Fort Collins, Colorado

Dedicated to Emeriti Professors Everett V. Richardson, Hsieh Wen Shen and Daryl B. Simons
Special Session: Hydraulics and Ecology, General Session: Hydrologic Engineering
Featured Speaker: Professor M. Levent Kavvas, Editor of the Journal of Hydrologic Engineering
Presentations by students in oral or poster form

For information contact:
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Phone: 415/365-4080 FAX 415/365-4080 email: Morelsey@leland.stanford.edu
or
Janet Montera, Civil Engineering, Colorado State University, Fort Collins, CO 80523
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WHAT WE HAVE LEARNED FROM THE BIG THOMPSON FLOOD -- 20 YEARS LATER
Fort Collins, Colorado
July 10-13, 1996

The Big Thompson flash flood on July 31 1976, killed at least 139 people and destroyed over 400 homes, trailers, and businesses. This meeting will focus on the degree to which our vulnerability to flash floods has increased or decreased in the region, the nation, and throughout the world. The conference will examine the effects of rapid urbanization and other land use changes in the American West: the contributions of national associations concerned with flood management, improvements in emergency management and weather forecasting; advancements in flood warning and other technologies; and changes in national programs and priorities. The meeting will include a one-day field trip to the sites of the Big Thompson flood and the Lawn Lake dam break of 1982. For details, contact *Eve Gruntfest, Big Thompson symposium, University of Colorado-Colorado Springs, P.O. Box 7150, Colorado Springs, CO 80933-7150; (719) 593-3531; fax (719) 593-3019; e-mail: ecg@spring.uccs.edu.* Sponsors: Federal Emergency Management Agency and others.

A "LIVING" PERMIT: WHAT DO YOU HAVE ONCE THE INK DRIES?
Friday, March 15, 1996

Co-sponsored by the Natural Resources Law Center, University of Colorado School of Law and the Natural Resources and Environment Section, Boulder County Bar Association

Regulatory agencies often perceive land use and environmental statutes -- and the permits which implement them -- as flexible tools. Many of the regulated community suggest that additional obligations imposed by agencies were never contemplated when the permits were originally issued. The agencies maintain that changed conditions or policies, as well as statutes, regulation and case law, authorize their actions. This symposium will explore the basis for these perceptions from multiple perspectives, examining property rights, the public interest, and the retroactive application of laws.

	By March 8	After March 8
Registration	$100	$110
BCBA Member	95	105
Government, acad, pub interest	65	75
Parking permit	4	5

Make check payable to University of Colorado and send to: Natural Resources Law Center, Campus Box 401, Boulder, CO 80309. Or pay by VISA/MasterCard. Phone Kathy Taylor, (303) 492-1288; FAX 492-1297

ANNUAL SUMMER CONFERENCE -- NATURAL RESOURCES LAW CENTER
BIODIVERSITY PROTECTION AND THE ENDANGERED SPECIES ACT
June 10-12, 1996

The Center's annual conference, June 10-12, will examine the legal framework for protection of biological diversity, the rationale for biodiversity protection and proposals to strengthen, weaken or otherwise modify the manner in which biodiversity is protected under federal and state laws. Particular attention will be given to the Endangered Species Act, its application in regional and local contexts, and the consequences for the species at issue and the local economies. The conference will also address state, tribal, local and private efforts to preserve biodiversity. Brochures will be mailed in the early spring. For more information, contact Kathy Taylor, (303) 492-1288.

SHORT COURSES

INTERNATIONAL GROUND WATER MODELING CENTER
Colorado School of Mines, Boulder, Colorado
1996 Short Course Schedule

For information contact: Office of Special Programs & Continuing Education (SPACE), Colorado School of Mines, Golden, CO 80401. Phone: 303./273-3314.

Date	Title, Instructors, Software	Location
Mar. 11-13	The HELP Modeling Workshop for Landfill Design. Instructors: Paul Schroeder, U.S. Army Corps of Engineers; and Lee Peyton, Univ. of Missouri. Software: HELP, Version 3.	CSM
Apr. 1-2	Introduction to Health Risk Assessment for the Environmental Professional. Instructor: Debra Imel Nelson, Univ. Of Oklahoma. Software: EXCEL.	CSM
Apr. 3-4	Soil and Groundwater Modeling for Risk Assessment and Soil Clean-up Level Evaluation. Instructors: Michael Barden, Wisconsin Dept. Of Natural Resources, and Stephen J. Scott, Environmental Graphics, Inc. Software: AT123D and SESOIL.	CSM
May 13-17	Principles and Applications of Chemical Reaction Modeling in Ground Water. Instructors: Neil Plummer, David Parkhurst and Pierre Glynn, USGS. Software: PHREEQC, PHREEQM, NETPATH, PHRQPITZ.	CSM
May 27-29	Principles and Applications of Aquifer Testing. Instructors: Forest Arnold (IGWMC); Edward Gutentag and Joe Downey, USGS. Software: Aquix4S.	CSM
June 3-5	Subsurface 3D Data Management, Analysis, & Computer Visualization for Site Assessment/Remediation. Instructors: Dennis A. Moon, SSESCO; Stephen A. Krajewski, Industrial Ergonomics, Inc.; Hisham Gaber, Intergraph Corporation; and Stephen J. Scott, Environmental Graphics, Inc.	Milwaukee, WI
June 3-7	Practical Modeling of Three-Dimensional Contaminant Transport and Remedial Action Designs using MODFLOW and MDT. Instructors: Chunmiao Zheng, Univ. of Alabama; and Christopher Neville, S.S. Papadopolus, Inc.). Software: MODFLOW, MDT.	CSM
June 17-21	Parameter Identification for MODFLOW. Instructors: Mary Hill, Richard Cooley and Richard Yager, USGS. Software: MODFLOWP, PEST.	CSM
June 24-26	An Introduction to Ground Water Modeling with Computers for Site Characterization, Exposure Assessment and Site Remediation. Instructors: Paul van der Heijde and Forest Arnold, IGWMC; and Kenneth Kolm, Colorado School of Mines. Software: THWELLS, SOLUTE, CHEMFLOW, ASM.	CSM

Integrated Support Technology for Groundwater Modeling

Colorado State University, Fort Collins, CO, Feb. 26-27, 1996. The course provides an overview of the importance of Hydrogeological Decision Analysis Support Systems for groundwater modeling. The system is based upon a unified integrated system consisting of Geographic Information Systems (GIS), Geostatistical Analysis, Scientific Visualization and Stochastic Groundwater Modeling Modules. The result of such analysis serves the decision makers in solving complex problems in subsurface hydrogeology. Course instructors: Dr. Abdel Abdel-Rahman, Dr. James W. Warner and Dr. Carlos E. Tamayo (Colorado State University). Sponsor: Dept of Civil Engineering, Groundwater/Environmental Hydrogeology Program, Colorado State University, Engineering Research Center, B103. Phone 970/491-8381; FAX 970/491-8554; e-mail twright@vines.colostate.edu.

Design of Water Quality Monitoring Systems

Colorado State University, Fort Collins, CO, June 3-7, 1996. This short course was developed using the collective research and design experience of the instructors over the past 21 years. The course will begin with a review of basic statistics and cover its use in the analysis of water quality data. It will cover detailed procedures for designing a water quality monitoring system including: information expectations, design criteria, network design, operating plans and procedures, and reporting formats and schedules. A free social and recreational program is planned for family members and guests accompanying short course attendees including trips to historic Larimer Square and Estes Park. For information contact:

Water Quality Short Course
Office of Conference Services, Colorado State University
Fort Collins, CO 80523
Phone: 970/491-7501 FAX: 970/491-3568

Future Short Courses at Colorado State University
(Contact Office of Conference Services)

Hazardous Materials/Waste Management Training
June 11-13, 1996.

Activated Sludge Process Control Short Course
June 24-28, 1996.

CALENDAR

Feb. 21-23 12TH HIGH ALTITUDE REVEGETATION WORKSHOP, Fort Collins, CO. Contact: Gary L. Thor, HAR Committee Secretary, Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO, 80523. FAX: 970/491-0564.

Feb. 21-24 SEVENTH AMERICAN FOREST CONGRESS, Washington DC. Contact: Office of the Seventh American Forest Congress, Phone 203/432-5117.

Feb. 23 1996 GOVERNOR'S AGRICULTURAL OUTLOOK FORUM, Denver, CO. Contact: Colorado Department of Agriculture, Phone 303/239-4100.

Feb. 25-28 WATER REUSE 96, San Diego, CA. Contact: Susan Blount, American Water Works Assoc., Phone 303/794-7711, FAX 303/794-8915.

Feb. 27-28 PLATTE RIVER BASIN ECOSYSTEM SYMPOSIUM, Kearney, NE. Contact: Mike Eckert, Platte Watershed Program Coordinator, Phone 402/472-0891, FAX 402/472-6338.

Mar. 7-8 WESTERN WATER LAW, Third Annual Conference, Denver, CO. Contact: CLD International, Phone 303/377-6600.

Mar. 15 WATERSHED PLANNING AND MANAGEMENT, Denver, CO. Contact: Steve Forvilly, Phone 303/286-3325.

Mar. 15-16 FIELD SCIENTISTS AND THE SHAPING OF THE AMERICAN WEST, The Center of the American West, University of Colorado, Boulder, CO. Contact The Center of the American West, Phone 303/492-4879; FAX 303/492-1868; E-mail centerwest@colorado.edu.

Mar. 19-20 AGRICULTURE AND THE ENVIRONMENT: DEFINING THE COMMON GROUND, Denver, CO. Contact: Colorado Alliance for Environmental Education, Phone 303/297-0187; FAX 303/297-0188.

MAR. 20-22 WATER POLICY ROUNDTABLE, Washington, D.C. Contact: Holly Stoerker, Interstate Council on Water Policy, Phone 612/223-5828; or Craig Bell, Western States Water Council, Phone 801/561-5300.

Apr. 15-19 HYDROLOGY DAYS 1996, Fort Collins, CO. Contact: H.J. Morel-Seytoux, Phone 415/365-4080, FAX 415/365-4080, e-mail Morelsey@leland.stanford.edu or Janet Montera, Phone 970/491-7425, FAX 970/491-7727.

June 11-14 COMPUTERS IN AGRICULTURE, 6th International Conference, Cancun, Mexico. Contact: Susan Buntjer, American Society of Agricultural Engineers. Phone 616/428-6327, FAX 616/429-3852, email: buntjer@asae.org.

June 16-19 URBAN WET WEATHER POLLUTION FROM THE STREAM'S PERSPECTIVE, Quebec City, Quebec, Canada. Water Environment Federation. Call 1-800/666-0206, Select Option #4 to put your name on mailing list.

July 14-17 WATERSHED RESTORATION AND MANAGEMENT, Annual AWRA Symposium, Syracuse, NY. Contact: American Water Resources Association, Phone 703/904-1225; FAX 703/904-1228; E-Mail: awrahq@aol.com.

July 21-24 INDUSTRIAL WASTEWATER TREATMENT: MUNICIPAL AND INDUSTRIAL PERSPECTIVES, Indianapolis, IN. Water Environment Federation. Call 1-800/666-0206, Select Option #4 to put your name on mailing list.

Aug. 17-22 10TH ANNUAL RESIDUALS MANAGEMENT BIOSOLIDS SPECIALTY CONFERENCE, Denver, CO. Water Environment Federation. Call 1-800/666-0206, Select Option #4 to put your name on mailing list.

Sept. 22-25 RIVERTECH '96, 1st International Conference on New/Emerging Concepts for Rivers, Chicago, IL. Contact: Rivertech '96, IWRA, University of Illinois, FAX 217/333-9561, E-mail: nbarrett@uiuc.edu.

Sept. 22-26 32ND ANNUAL AWRA CONFERENCE AND SYMPOSIUM, Fort Lauderdale, FL. Contact: American Water Resources Association, Phone 703/904-1225, FAX 703/904-1228, E-Mail: awrahq@aol.com.

Feb. 29-Mar. 1 – Visual MODFLOW
Denver, Colorado – Contact National Groundwater Association, 1-800/551-7379

April 1996 – 4th STORET Modernization Conference
Denver, Colorado – Additional Information 1-800/424-9067

Colorado Water Resources Research Institute
410N University Services Center
Colorado State University
Fort Collins, CO 80523

Robert Behnke
Fishery & Wildlife Biology
Wagar Building

Colorado Water

Newsletter of the Colorado Water Resources Research Institute. Fort Collins, Colorado 80523

WATER ITEMS AND ISSUES . . . *February 1996*

In This Issue . . .

A River of Dreams and Realities
The Arkansas River Basin Forum

held January 3-4, 1996

A look at the issues that confront water users in the Arkansas River Basin --

Colorado State University

Today's Reality, Tomorrow's Dream!

Editorial by Robert C. Ward

"A River of Dreams and Realities" was the theme of the 1996 Arkansas River Basin Water Forum, held January 3-4 in Pueblo. This well-planned and executed meeting generated a fascinating insight, I believe, into what Colorado may be facing in many of its future water management conflicts.

In the Pecos River basin 10 years ago, New Mexico lost a court case with Texas over water rights. Adjustments in water management practices have been implemented during the past 10 years to ensure that both states obtain the water to which they are entitled.

In the Arkansas River basin, Colorado has "lost" a court case with Kansas over water rights. Adjustments are planned in water administration practices to correct the problems identified in the court case. Again, the goal is to ensure that both states get the water to which they are entitled. I put "lost" in quotes because it is not as simple as that word indicates. David Robbins helps us better understand the issues and decisions handed down by the court in a straightforward explanation of what happened in the Colorado-Kansas case on page 3 of this issue of *Colorado Water.*

In both the Pecos and Arkansas River situations, past practices of managing western water resources are called into question. Assumptions on which we have operated for many years are being challenged. Refinements in our water administration practices are being required. Changes in our view of water are being requested. For example, the saying: "I would rather be upstream with a shovel than downstream with a water right" captures an attitude that necessarily is changing in Colorado.

The Arkansas River Forum discussed these and many more issues and concerns over the two days of presentations. It was obvious that the changes being required will cause some hardship in the valley, or at least that is the perception among some of the audience. The manner in which the changes were presented and discussed at the meeting was professional and, yet, sensitive to the concerns of the irrigators who use groundwater in the valley. As has taken place in other states where water quantity and quality problems have impacted agricultural water use, there is a clear need for the public to understand and develop options for the affected farmers. The Colorado legislature will, undoubtedly this session, see bills attempting to give the affected irrigators in the valley options relative to their future farming efforts.

We have chosen several presentations from the Arkansas Forum to transcribe and include in this issue of *Colorado Water* to give our readers an understanding of the changes taking place in the Arkansas Valley. After David Robbins gives his explanation of what was really decided by the Colorado-Kansas court case, Hal Simpson presents the administrative changes being implemented to bring Colorado into compliance with the Arkansas River Compact. Steve Witte presents an overview of water quantity in the valley, and the results of a groundwater quality survey are presented by Brad Austin. Ralph Adkins gives an excellent glimpse of the river's future (this presentation closed the Forum).

I hope the presentations help in gaining a glimpse of what the future might hold for all Colorado river basins. It is clear that Colorado will have to tighten its conjunctive use of ground and surface waters in all river basins. This may mean that we devote more resources to administration of water rights and obtain more complete and accurate information regarding water use. Colorado also needs to find a way to fund studies and research that directly support its efforts to improve its water management system. With CWRRI losing its federal water research funding, this last issue increasingly is in need of attention.

The challenges of living and farming in a river basin can be overwhelming to individual water users when there is uncertainty over downstream water rights, growing urban water demands, and increasing awareness of the need to protect aquatic ecosystems. We need to look for ways to improve the security of water for existing water users while solving future water demands. As faculty understand the issues and concerns of the Arkansas Valley situation, they will be better able to direct their studies and research efforts to support the needs of the irrigators, the urban population, and water managers in the valley.

COLORADO WATER

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Robert C. Ward, Director

THE ARKANSAS RIVER BASIN WATER FORUM: "A River of Dreams and Realities"

WHAT DID THE COURT SAY?

David Robbins, Special Deputy Attorney General
Hill & Robbins, P.C.

(Since 1985 David Robbins has represented the State of Colorado in the U.S. Supreme Court Case of Kansas v. Colorado. This involved the alleged violations of the Arkansas River Compact.)

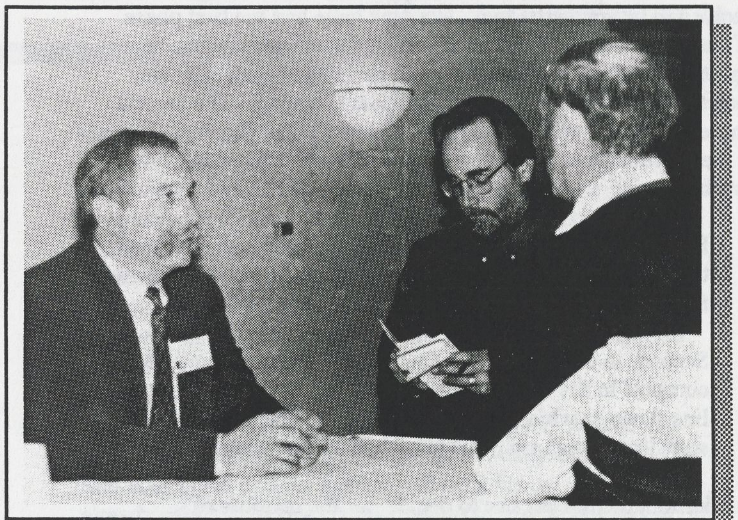
My talk should probably be called, "What Did the Court Say and What Didn't the Court Say?" My partner, Dennis Montgomery, has worked diligently on this case for the last ten years as well. Dennis was instrumental in advocating Colorado's position.

When a state sues a state, the Constitutional framers determined that that litigation would occur in the United States Supreme Court. If you think about history, you will recall that there were 13 colonies, each of which viewed itself as being sovereign and independent. They came together to form the United States. Each of those states was jealous of its prerogatives. The framers of the Constitution decided to allow the adjudication of differences of opinion among these sovereigns by the highest court of the land, and the only constitutional court of the land, the U.S. Supreme Court.

In the early days, when a state sued a state, the court actually listened to the arguments and the evidence and handed down a decision. Over the years, the increasing number of states gave rise to an increasing number of disputes, and with the increase in the number of citizens and the complexity of the laws, the court's docket became more and more crowded. Over the past 30 or 40 years a system of appointing "Special Master" was adopted. The court appoints an individual, who can be a judge or a noted lawyer in the American legal community, to sit and hear the positions of the contesting states and to render to the Supreme Court his recommendation concerning the facts that he has heard and any legal decisions he believes ought to be entered.

The Special Master is not a judge. He is an officer of the U.S. Supreme Court. To those of you who think that Kansas v. Colorado has been in some kind of federal court appellate process, it was not. The case, since 1985 when it was filed, has been under the jurisdiction of the U.S. Supreme Court, and Arthur Littleworth from Riverside, California, a noted California legal scholar in water and natural resources law, has been the Master. He presents his recommendations to the court, and the court then considers those recommendations and hears arguments of the parties. The court is then free to do whatever it likes with those recommendations. The court can throw them out, send them back, tell the Master to start over, appoint a new Master, change whatever findings it wants to change, change whatever rulings of law it wants to change, or, as in this case, it can simply say, "We think you did a good job. We adopt them."

The Constitution did another thing -- it provided that disputes among these sovereigns, who made up the United States, could also be resolved by agreement. This was provided for in the compact clause of the Constitution. It permits states, with the approval of the U.S. Congress, to enter into compacts on issues of common interest and jurisdiction. These are areas where two or more states may assert sovereignty over a particular subject matter and sit down and work out their differences and agree on what the allocation will be. It is a constitutional mechanism that allows states to come to agreement so they are not constantly litigating. The Arkansas River is a classic example. The States of Kansas and Colorado both have water users who depend upon the waters of the Arkansas River both for economic well-being and for protection of environmental interests in the two states. When water demand and consumption occurs in one state, it affects the other state. A compact was entered into to try and resolve those issues.



***From left: David Robbins with Patrick Deiscoll of Denver and Don Magnuson of Cache la Poudre Irrigating.* Photo by Karen L. Stewart, Arkansas Valley Journal.**

I want to emphasize the purpose of a compact in the case of water. It allocates the right to use certain portions of water to two or more states. The fact that compacted water arises in Colorado is irrelevant. Colorado's Legislature, Kansas's Legislature, and the U.S. Congress have ratified a document that says what Kansas is entitled to receive. It is a law of the State of Colorado, entitled to enforcement just like any other law. It is a law of the U.S., entitled to enforcement just like any other national law. Whether you like it or don't like it, think it is fair or unfair, it is the law of the land at this time.

The Master heard claims from the State of Kansas that Colorado had violated the compact between the two states covering the waters of the Arkansas River in three particulars:

- Kansas alleged that the operation of the Trinidad Reservoir and the way in which water was stored in that reservoir was in violation of certain operating agreements entered into between Kansas, the Purgatoire River Water Conservancy District, and the Bureau of Reclamation.
- Kansas also alleged that the operation of winter water storage in Pueblo Reservoir, a feature of the Fryingpan-Arkansas Project, violated the compact by increasing the amount of depletion that occurred to the waters of the Arkansas River.
- Kansas alleged that post-compact wells, numbering some 2,000, had the effect of increasing the amount of depletion to the Arkansas River.

After the Master had heard the preliminary skirmishing, he decided to bifurcate the trial. We now have had the first phase of that bifurcated trial, and that was to determine liability, the question of whether or not Colorado had in any particular way violated the terms of the Arkansas River Compact. The second phase of the trial will be the remedy phase. That is proceeding at the present time. The purpose of the remedy phase is twofold:

First, to determine the amount of depletions in violation of the compact. How much water should have gone to Kansas from 1950 to 1994 that did not go to Kansas?

Second, to determine how Colorado will comply with the compact in the future. How will Colorado ensure the state line flows to which Kansas is entitled (referred to as usable state line flows) are not diminished in the future?

In addition, the Master has to decide, for the quantity of depletions that occurred over the last 45 years or so, what Colorado will do to remedy Kansas or make Kansas whole for the lack of supply.

I want to emphasize this again -- the fact that there is water in the Arkansas River, in the system, does not give the State of Colorado the right to consume it all. Colorado may only divert and consume its equitable share of the waters of the Arkansas River.

The Arkansas River Compact, then, signed in 1948, basically was a stand-still compact. The concept behind it was that the waters of the system were being fully used under many circumstances in both states. In fact, there was insufficient water in the system under many conditions to serve the existing water users in 1948 in both states. The idea behind the compact was that neither state would increase the amount of depletions to the river unless it could show that the increase in use did not deprive water users in the other state of supplies to which they were entitled.

Basically, the concept was to draw a line in 1948 -- anything that happens in either state after '48 that has the effect of depriving users in the other state potentially, potentially, could constitute a violation of the compact. I want to make it clear that in 1948 and today there is unused water in the system under some circumstances, and the compact recognizes a state's right to make use of that unused water, if it can, without injury. That is an important concept.

Usability, as far as the Arkansas River Compact is concerned, is looking at water use in the mirror of 1948. Usable flows means those waters which would have been used in 1948 by the structures and conditions that existed then. In the State of Kansas, a certain number of ditches, under certain flow conditions, received water. There was a certain increment of water that went to recharge for pre-1948 wells in Kansas, and there was also water that flowed across the state line, through Kansas, and right out the other end of the compacted reach at Garden City. The compact framers thought of the water that passed Garden City without anyone diverting it as being unusable. They contemplated that both states, Kansas and Colorado, could undertake steps to try and capture that water. One of the measures to do so was John Martin Reservoir, which would capture and regulate flood flows for the benefit of users in Colorado and Kansas.

The Master, after months of trial held in Pasadena, California, found, and the court confirmed, that of the three Kansas claims the Trinidad claim and the winter storage claim for Pueblo Reservoir were unfounded and not proved and dismissed them both. In the third claim, that post-compact well pumping in Colorado deprived Kansas of water, the Master found that Kansas had proved depletions in violation of the compact, although he didn't quantify how much had occurred.

Importantly, he also found that the State of Colorado and its water officials had been in good faith and had not set about trying to damage Kansas or to take water away from Kansas. They had intended to permit the use of unusable flows in the Arkansas River under the compact, and they did not believe that wells were creating a cognizable harm to the State of Kansas. That is important. That is why the Master will give Colorado a chance to come up with a solution in the future. That is why Colorado will have a say in how to redress that injury. The Master found the injury existed, but it wasn't one that Colorado or Kansas understood or knew about until shortly before the litigation was filed.

Judge Tracey did a wonderful job of talking about the evolution of Colorado water law and some of the important issues that have arisen. Remember, Colorado is a prior appropriation state. The Constitution authorizes water users to use water in accordance with their priorities. When there is insufficient water, more junior water rights have to be shut down, so seniors are entitled to use their supply. Water in Colorado is presumed to be tributary to streams and subject to the appropriation doctrine unless shown in a specific instance to be nontributary and therefore not covered by the doctrine. As a result, wells in tributary formations, just like ditches, are subject to the constitutional doctrine of prior appropriation. That doctrine operates not against all water in the state -- it only operates against the water to which Colorado is entitled under an interstate compact. So, there is a limitation on how much water Colorado water users can divert within the priority system.

Colorado finds itself with approximately 2,000 wells that are junior to our obligations to the State of Kansas. They also are very, very junior to many senior surface water rights and ditches that have existed in the Arkansas basin from the late 1860s and early 1870s. Under any decision of a Colorado court or the current decision of the United States Supreme Court, those more junior wells should not be able to operate unless they replace any injury or depletion that they cause to water which otherwise would be available to Colorado senior surface water rights under the Colorado Constitution or to the State of Kansas under the Arkansas River Compact.

A well permit is very similar to a driving license. It entitles you to drill a well. In that well is water. That water is subject to the constitutional doctrine of prior appropriation. You aren't entitled, simply because you have a well permit, to pump that water unless you are doing it in the priority system or in a way that does not impair senior water rights under the Colorado Constitution.

After the court decided that Colorado had in fact, although unknowingly, been in violation of the Arkansas River Compact, Kansas immediately sought to obtain an injunction requesting that wells in the Arkansas basin be immediately shut off and not be allowed to pump until such time as Colorado and the well owners had convinced the Supreme Court and the Master that Kansas would receive all of the water supply to which it was entitled. The Master, for what I think was good reason, said he would not grant that injunction. He said Colorado was found in violation, but should be given a chance to propose a solution.

Hal Simpson, the State Engineer, is responsible for the future solution, and I am not going to steal his thunder. I do want to say a couple of things, though. Both Colorado and Kansas, through their evidence, showed that the wells in the Arkansas basin were causing stream depletions which to some degree were depleting usable state line flows to which Kansas was entitled under the compact. The State of Kansas is entitled to the protection of the compact and the law of the State of Colorado, which embodies and encompasses the Arkansas River Compact. Colorado does not have a choice. It must enforce those laws so long as they remain on the books, and so we have to propose a solution to the problem.

A well permit is very similar to a driving license. It entitles you to drill a well. In that well is water. That water is subject to the constitutional doctrine of prior appropriation. You aren't entitled, simply because you have a well permit, to pump that water unless you are doing it in the priority system or in a way that does not impair senior water rights under the Colorado Constitution. You all have driver's licenses which the state gave you, but that doesn't mean you can speed. There is another law that says "no speeding," and if you speed or drive drunk you can lose your license. You can drill a well, but that doesn't give you an ironclad right to pump that well and take water that belongs to someone else in this state or the State of Kansas. That is the legal framework with which we are dealing here.

For those of you who think that merely by regulating the use of water and wells there is somehow a government taking involved, let me tell you I think you are in error. The Colorado Constitution does not give you a right to a certain quantity of water. It is a usufructuary right. First, the water belongs to the people of the state subject to your right to make a use of a portion in priority. If you have a well that is junior, you are not in priority if the result of pumping that well injures other more senior water users or users in the State of Kansas under the compact.

Colorado, although unknowingly, allowed the compact to be violated, and Colorado has to solve the problem. We have a legal obligation to deal with what has happened between 1950 and the present. In late October Kansas and Colorado stipulated that the amount of usable state line flow that had been depleted to the State of Kansas by users in Colorado was about 328,000 acre-feet for the period 1950 to 1985. We are negotiating with Kansas today to try to resolve the 1986 to 1994 values. Colorado, at some point, will have to repay Kansas for those depletions, in water or money. In January, Kansas will file a brief. Kansas will tell us what it thinks Colorado ought to do as a legal matter to redress that compact violation. Colorado will respond in May, and Kansas will reply in July. The Master will then hear arguments and decide.

Those hearings will go on over the next several months to a year. If we fail to control post-compact well pumping, the Supreme Court and the Master will do it for us. Kansas has already asked to have a special federal master appointed to run the river. The request has not been acted on, but if Colorado fails to come up with a program that adequately ensures the Master that Kansas will receive the water to which it is entitled under the compact, he will be forced to come up with his own remedy, and Kansas will push very hard for that remedy to be a federal official who has little interest in what goes on in Colorado and has, as a sole, driving purpose, the need to be sure that Kansas gets its water.

Finally, one other point -- Colorado lives by compacts. We expect our neighbors -- Texas, New Mexico, Kansas, Nebraska, Arizona, California, Nevada, Utah, Wyoming -- to live by the terms of those compacts and to allow us to use as much water as we are entitled under those compacts. We also have an equal obligation to comply with the compacts to which we are signatory.

THE NEW RULES

Hal Simpson, State Engineer
Colorado Division of Water Resources

I think the reality of complying with the Arkansas River Compact is now fully upon us. One of the key provisions of the compact was that after December 14, 1948 there was to be no additional water resource development in the Arkansas basin in either state if it depleted usable state line flows. You heard David Robbins say that the Special Master, affirmed by the U.S. Supreme Court, had found that, in fact, around 1500 post-compact wells were constructed in Colorado. They were primarily irrigation wells that did violate Article 4D of the compact, so we are facing that reality. That is, as David indicated, what we are trying to deal with through rule-making.

Before I get into the new rules, I want to give you a little background on why we have to go about this type of water rights administration through rule-making. The role of the State Engineer traditionally has been to administer water rights, and that is done through the priority system that Judge Tracey described so well at lunch. However, when it comes to enforcing certain other types which are not so clear as a water right, such as a compact or bringing a well into the priority system as was required by the 1969 Water Rights Determination Act, we have to follow certain other procedures set forth by statute, and that is called rule-making, or we promulgate rules and regulations -- that is another term for rule making.

The 1969 Act had some very specific requirements or principles that I must follow if I am to promulgate rules dealing either with interstate compacts or the administration of groundwater rights. The 1969 Act brought together the surface water priority system, which dated back into the 1860s, with wells that had never been required to be adjudicated. The 1969 act required them to be adjudicated and thrust into that priority system wells that are a hundred years more junior. To do that, the statutes required that it be done through rule-making, and very specific steps have to be followed. The rules have to be specific to a river basin; they have to be specific to certain types of aquifers; and they have to be able to optimize water use while maintaining the priority system. That is difficult, when you bring wells into the priority system. The rules must be published in every county where they will go into effect at least 60 days prior to their effective date. Since time is of the essence, the water court has to hold hearings on any protest of those rules as soon as they occur.

I want to talk about the existing rules, those that were in effect through the end of 1995, so you know we just aren't stepping forward with rules for the first time in the Arkansas River Basin. In 1973 Clarence Kuiper, the State Engineer at that time, promulgated rules to respond to the 1969 act. As Judge Tracey had indicated, there had been a false start down here in the Arkansas Basin with the Felhauer case, where there were not established procedures set forth by rules on how we were going to administer wells. The division engineer had selected 30 wells very close to the river, and shut those down. That was not acceptable to the district court nor to the Supreme Court, which directed the State Engineer to promulgate rules. In 1973, after the Felhauer case had gone to the Supreme Court and been decided, Mr. Kuiper promulgated rules that basically curtailed pumping in the Arkansas River basin four days per week, allowing pumping three days. They were effective in 1973, and the rules were not protested.

At the beginning of 1974 Mr. Kuiper amended those rules and filed another set through the procedure set forth in the statute to start curtailing pumping more. In 1974 there would be five days of no pumping, in 1975 six days, and total curtailment in 1977. These rules were protested vigorously by the groundwater users. There was a trial before the water court in Pueblo. Judge Gobin, the water judge, ruled that the State Engineer had not allowed the 1973 rules to operate long enough to determine through experience and investigations whether in fact they were acceptable or suitable without tightening down on well owners more. The State Engineer appealed that decision to the Colorado Supreme Court, the Supreme Court affirmed Judge Gobin saying, "You didn't conduct the necessary investigations or allow the 1973 rules to operate long enough."

Because of that decision and the fact that there were no requests from well owners or surface water users to change the rules, they have been in effect through the end of 1995 or about 23 years. But in response to the litigation with Kansas, which filed its action in December of 1985, and the trial, which I believe began in 1990, we had a four-year period of very intense studies by both states to develop the basis for the litigation, and those investigations were important to any future rule-making because they provided evidence that could be utilized in future rules. Both states initiated very detailed and similar studies using computer models to evaluate the effect of post-compact wells and the effect of the winter water storage program. Both issues had been alleged to violate the compact by Kansas.

We both quickly learned that the data necessary to drive good computer models was lacking in the basin, so a lot of assumptions had to be made, and both models had their shortcomings. The area of focus for the modeling efforts of both states was the area from Pueblo to the state line. It basically covered the valley fill or alluvial aquifer of the Arkansas River as well as aquifers to the outside of these called bench aquifers or surficial aquifers. Basically, it is an area where there are about 2,000 irrigation wells in existence that have pumped upwards of 250,000 acre-feet (af) of water in certain years. The models were set up in a manner to evaluate both the effect of pumping and then turning off certain switches in a model to evaluate the effect of what the river would have seen in the way of additional flows had there not been pumping. Where would that water have been diverted? Would the senior surface rights have diverted more, or how much really would have reached the state line?

The study period was 1950 to 1985, and both states came down with similar results. It is not surprising, when you think about the hydraulic connection between the alluvial or surficial aquifer and the stream system. If you pump groundwater, and if you consume it in growing crops, you are going to deplete streamflow. That is a fact of physics that you really can't overcome no matter how much you would like to. Both states had similar results, although Kansas' model showed lesser depletions of usable state line flow than Colorado's model, and the Master in his report indicated that he would support using the Kansas model since it showed the lesser depletions and Kansas was the complaining party.

He further found that the 1973 rules were not effective. In other words, that reduction or curtailment of pumping to just three days of pumping per week didn't really reduce pumping, in his opinion. In fact, every year after 1973 the pumping increased or was greater than the 1973 level of pumping. In his report that he filed July of 1994, the Master found, just to reemphasize, that most compact well pumping did deplete usable state line flows. The 1973 rules were not effective. The augmentation plans that allowed certain wells to pump seven days a week were not sufficient in offsetting depletions caused by post-compact pumping. There were some offsets but not complete offsets, so he was critical of the augmentation plans that had been approved in the intervening period. Year by year, the division engineer under the 1973 rules would allow certain groups, if they submitted a plan, to pump seven days a week -- and there was augmentation, but not total augmentation.

One of the more limiting determinations of the Special Master was that the 700 existing pre-compact wells could not pump unlimited with respect to the compact. His finding was that in the period just prior to the signing of the compact the pumping averaged about 15,000 af per year. Colorado had argued that it could have been as much as 40,000 af per year in dry years, and that it should be allowed to pump what was necessary based upon the decree of the pre-compact well. The Master put an annual limit not to exceed 15,000 af on those 700 wells, and so one of the responsibilities under the new rules is how to allocate the 15,000 af to those 700 pre-compact wells.

You heard from Jim Lochhead just before lunch about the Arkansas River Coordinating Committee and how important it was in bringing together all the diverse interests of the valley. I want to say briefly that the committee was, in my opinion, a real success, because the water users, after about three or four months of sparring, sat down around the table and for the next six or eight months worked hard on helping develop workable rules and regulations, helping to find solutions on where we could find augmentation water, and generally working together in a manner I hadn't seen in the Arkansas River Basin in the past. It is the leadership of those 30 individuals who were willing to meet monthly without compensation, some of them driving from near Leadville to Lamar at times just to be public servants, that I think can be credited for the success we had thus far.

I want to take a few minutes to talk about the new rules to let you get a flavor of what we are trying to accomplish, our time lines, and where we are right now. There are two key points that I want you to really understand about these new rules. One is to bring about compact compliance. David Robbins indicated to you that we have no choice. It is the law of the State of Colorado and it is the law of the federal government. It is a compact. We have been found to be in violation, by primarily the pumping of 1500 post-compact wells.

The second issue, which I think is just as important, is that we have about 2000 wells total -- 2200, since some of them are not always pumping in a given year, that also affect senior surface water rights in Colorado. As I indicated, Mr. Kuiper in 1973 started down a path to bring the pumping by junior wells under control and require augmentation. He was not successful, but we cannot overlook all the information we have developed through the investigations related to the litigation with Kansas.

The modeling studies clearly show that when you pump wells in Colorado the primary party affected is the senior surface-water user in Colorado, much more so than any benefit to Kansas under the 1948 compact. You can't overlook that affect, and you can't do rule making, in my opinion, just dealing with the state line or compact issue. They are so intertwined that you have to deal with them together at one time, so the new rules that were filed with the water court in September of 1995 in fact deal with both. I will try to walk through some of the key parts of those rules with you so can understand how we are attempting to bring about compact compliance and also deal with the issue of protection of senior vested water rights in Colorado.

I would like to talk about the scope of these rules. What do they cover and what do they not cover? It is very clear that you understand that they are not totally comprehensive, covering every well in the Arkansas River Basin. They deal first of all with pumping of tributary groundwater, so there are certain types of other groundwater that are not affected, and I will talk about those.

First is wells that divert non-tributary groundwater. They are either decreed or permitted to be pumping non-tributary groundwater. Certain designated groundwater basins exist in the Arkansas River Basin -- the Southern High Plains designated basin, the Upper Big Sandy designated basin, and the Upper Black Squirrel designated basin. Groundwater in these basins is not hydraulically connected to the Arkansas River in any significant way. They are under the jurisdiction of the Colorado Groundwater Commission. Wells in these areas are not subject to these rules.

Certain small-capacity wells for domestic stock watering are exempted from administration in 37-92-602 of the statutes.

Any wells that fall under what we call the "exempt wells" under 602 are not subject to these rules. Certain wells in the Denver Basin aquifers operate under rules promulgated in 1985, and as such they operate outside of the proposed new rules. They pump basically nontributary or not nontributary groundwater from the Arapaho, Laramie Fox Hills, Denver or Dawson aquifers.

Finally, we allowed two other aquifers not to be included in these rules -- the Cheyenne and Dakota aquifers. They are located in the eastern part of the basin and used primarily for domestic supply. The connection with the Arkansas River is very indirect, and so we felt we didn't have the information at this time to include those aquifers in these rules. A number of rural water associations in the La Junta, Lamar, Las Animas area use these aquifers because of the quality. They are not subject to these rules. If you represent any of those areas, I want to make clear that if you have a Cheyenne or Dakota well you are not subject to the new rules.

The rules are numbered 1 through about 18, and I want to talk about three that are the key components -- rules 3, 4 and 5.

Rule 3 deals with the compact issue. How do we bring about compact compliance and stop depletions to usable state line flow? They have a geographic area that is very specific. It is the area that was modeled and studied in the litigation with Kansas, and it covers the valley fill and surficial aquifers between Pueblo and the state line. It involves post-compact irrigation well pumping, and basically the rule says that after April 1 of 1996 these wells cannot pump any longer, or in the alternative they can pump if they operate pursuant to a plan approved by the state and division engineers whereby depletions to usable state line flow are replaced.

Rule 3 also talks about how we allocate that 15,000 af of pre-compact pumping to the 700 or so wells that are pre-compact in nature. The rule clearly sets forth a procedure. We have published a table indicating how much each of those wells would be entitled to pump in the future with respect to the pre-compact pumping allowance. Copies are available through Steve Witte, the division engineer.

The rule uses the Kansas hydrologic institutional model to determine how well we did in replacing depletions to the usable state line flow. That is the tool we are using in the litigation with Kansas that the Master has endorsed. After the end of a year, when all the information is available, the model will be run to determine if the offsets made available by the various groundwater entities in fact did offset depletions to usable state line flow. If for some reason it did not, the shortage would be allocated among the wells on some basis of amount pumped, consumptive use, distance from the stream -- it is all spelled out in the rule. If there is a shortfall, we have to allocate the obligation to replace it, and Rule 3 deals with that.

Rule 4 gets into protection of the senior surface water rights in Colorado. Rule 4 has a very specific geographic area. It is the valley fill and surficial aquifer between Pueblo and the state line as well as the alluvium of Fountain Creek and the alluvium of the Arkansas River between Pueblo and Pueblo dam. This additional area was not modeled in the studies by either Kansas or Colorado, so we expanded the area slightly. In this area all wells, regardless of whether they are irrigation, municipal, commercial or industrial, will not be allowed to pump after April 1, 1996 unless they operate pursuant to a plan approved by the state and division engineer that replaces out-of-priority depletions to senior vested water rights in Colorado. The focus is in Colorado, so if the Catlin Canal is calling, for instance, the plan would have to show that the wells above that can replace their depletions to the Catlin call - or the Fort Lyon call, or the Amity call. It is very important that we start dealing with how we protect our senior surface water rights in Colorado.

Rule 4 further establishes a presumptive depletion to simplify the process for determining depletions. Based upon the investigations and the litigation with Kansas, we have sufficient information to determine what depletions are related to certain types of irrigation applications. If it is a supplemental source of supply, if the well water is used on land that is also irrigated with surface water and the method of application is flood or furrow, the rule says the depletions are 30 percent of the amount pumped. If it is applied on land that receives no other surface water supply, a sole source and the method of application is flood or furrow, the rule indicates that the depletion is 50 percent of the amount pumped. And finally, if it is sprinkler irrigation, the amount of depletion is 75 percent. The rules set these presumptive depletions. They were negotiated over the last several months prior to the filing of the rules, and one of the key issues was to reach agreement on what those presumptive depletions should be.

Rule 5, then, covers the rest of the basin, the area outside what we call the valley fill and surficial aquifer and Fountain Creek alluvium. Everywhere else in the basin a well subject to these rules, pumping tributary groundwater, either must stop pumping on April 1, 1996 or operate pursuant to a plan approved by the state and division engineer whereby out-of-priority depletions to affected senior surface water rights are replaced.

Discussing briefly some of the other rules in the whole set of rules that were filed with the water court -- Rule 11 allows a phase-in in certain respects. Beginning in 1996, we will not phase in replacement of depletions to usable state line flow. All depletions to usable state line flow must be replaced in a plan approved by my office. We are going to bring about compact compliance beginning in 1996. With respect to replacement of depletions to senior surface water rights, we do phase that in over two years, because it is a larger amount of water to acquire and it will take longer to develop replacement resources. In 1996, 60 percent of the out-of-priority depletions must be replaced. In 1997, all out-of-priority depletions must be replaced.

Rule 12 deals with how we get pumping estimates. All of these rules are driven by how much you pump and applying certain depletions to them. In 1994 I promulgated rules requiring that all well owners report the amount pumped on an annual basis but providing monthly values. They must be submitted by the end of January following the water year. Those rules allow that the well owner can install a totalizing flow meter or, if the conditions are appropriate, could utilize a power consumption or power conversion coefficient to estimate the volume pumped based upon a test performed by a certified tester. Rule 12 requires that this information be provided on a monthly basis. It will go to the division engineer who would then utilize certain computer programs that we are developing to estimate the depletions as near as possible to the end of the previous month so we can get a handle on depletions, when they occur, and require that replacement water be made available to either the affected senior surface water rights or to the state line.

Rule 14 requires that an annual operating plan be submitted prior to April 1, 1996 and March 1, 1997 and thereafter. That plan must be approved prior to any pumping in that irrigation season. The sooner the plan can be submitted the better. We are working closely with the water users for the 1996 year so that we can have as much input and review of their plan as possible prior to April 1.

. . . most of the water users and well owners understand what we are up against and that this is not a matter in which we have a lot of discretion on how we bring about compact compliance . . . The Special Master is watching us closely.

What is the current status of the rules? You may be wondering where we are. As Jim Lochhead indicated, there were 18 different protests filed by the end of the protest period, the end of November. Some actually were in support. Individual well owners involved in protesting the rules who are opposed to them probably number less than 20 wells out of possibly 4,000 affected wells throughout the entire Arkansas River basin. That is encouraging to me. It indicates that most of the water users and well owners understand what we are up against and that this is not a matter in which we have a lot of discretion on how we bring about compact compliance. As David Robbins indicated, he doesn't understand the arguments behind some of the takings issues, and we will have to let those be litigated before the water court.

The Special Master is watching us closely. I want to emphasize that point as part of my conclusion. I testified at the end of October and in early November in Pasadena last year about what Colorado was doing to come into compact compliance. I submitted a report to the State of Kansas and to the Special Master which was used to tell him where we were at that time. He made it very clear that he will to continue to monitor what we try to accomplish within the next few months.

I must testify in a hearing in March on where we are, how many protests we have had, the results of hearings by March, and what some of the augmentation entities are doing to bring about replacement of usable state line flows or augmentation of the river in Colorado. He further set a hearing in June giving Kansas the opportunity to then indicate their disagreements with where Colorado is going with respect to coming into compact compliance. I think he has made it clear that he will give Colorado every opportunity to take control of the situation and deal with it within Colorado. I think he recognizes that is the best way. We must, though, make sure that we are really and truly complying with the compact.

The Special Master also made it very clear to me that if we fail, he will not hesitate to take control of the situation. As David indicated, we could end up with a Federal River Master in control of the river, and that is not desirable. We have three federal reservoirs in this basin -- Pueblo Reservoir, Trinidad Reservoir and John Martin Reservoir -- and they could be utilized by federal entities to bring about compact compliance. I don't think we want that. In the alternative, he could issue an order to enjoin all post-compact pumping in Colorado, which is what Kansas sought in 1995, and he told them he would not do that. He wanted to see what Colorado was attempting to accomplish before he would enjoin or curtail pumping in Colorado.

My opinion is, Colorado is taking significant steps to deal with the issue. We are working on important legislation that would provide funding to acquire permanent augmentation water and provide resources to my office to enforce the new rules. We will need about nine additional staff in the field and in the Pueblo Office to properly enforce these rules. The key to success is proper enforcement, so that those who elect to ignore the rules can be brought before the water judge quickly so we can make it clear that we cannot allow people to ignore this important issue. I think the water users and the groundwater entities have made significant progress in developing cooperative plans to deal with the issue. Within a matter of months, Colorado should be in a position to fully replace depletions to usable state line flow in 1996, and will have made a significant step toward replacing depletions to senior vested water rights in Colorado.

HOW MUCH DO WE HAVE AND WHO OWNS IT?

Steve Witte, Division Engineer
Colorado Division of Water Resources

How much water do we have, and who owns it? I wish that these relatively simply questions had relatively simple answers. An exacting quantification of how much water there is within the Arkansas River Basin is complicated by missing or highly variable data; timing and location; shared use of a commonly owned resource which can lead to double accounting; priority; operational decisions; and I'm sure there are several other factors.

To illustrate that, anyone who has any experience dealing with water realizes that the water supply can be extremely variable from one year to the next -- witness last year compared to the year before that -- and it also can vary within the same season. Last year at this time we thought we were headed toward a pretty sorry year. Then, late in the Spring Mother Nature turned all that around and we had a very abundant year.

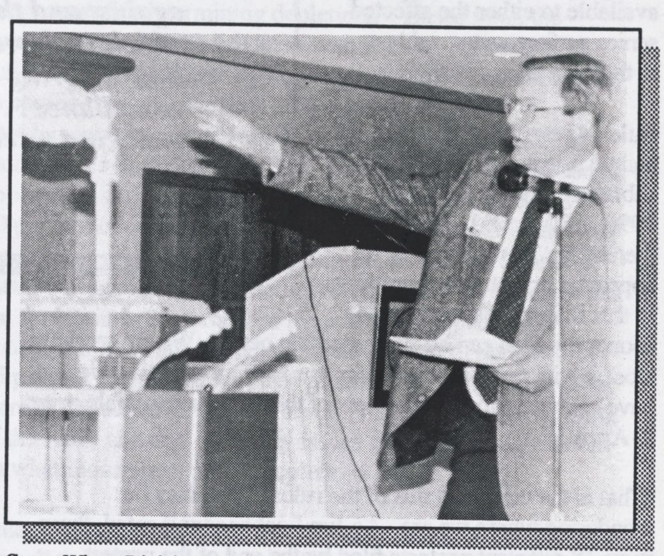
There is always more water available in downstream reaches. For example, there is always more water available in Canyon City than in Leadville, because at that location the Arkansas River has been swelled by a number of tributaries. Regarding double accounting, consider that the water that enhances someone's picnic experience up in the national forest may be the same water that provides for someone else's rafting recreational experience; it may provide someone in Pueblo with a shower; it may irrigate melons in Rocky Ford, and it may also contribute to usable state line flow. So how do you account for that water?

The amount of water that is in the river at any particular location and time, that is available for any particular use, may be subject to Colorado's allocation system which is based on priority of appropriation. Or, it may be the result of someone's operational decision, such as when the owner of a reservoir directs the release of water previously appropriated into the stream system for subsequent use.

Looking at some long-term average stream flows can begin to give one a sense of the net effect of some of these variables on water supply and smooth out the timing consideration by looking at a broader expanse of time.

Figure 1 illustrates how the water supply varies at different locations in relation to the contributing watersheds and the regions of most intensive use. What is shown here are average historical stream flows at various locations. Near Leadville, the number is 278,000 acre-feet (af). I assume this location (further downstream) represents the Portland gage above Pueblo reservoir, where the average annual stream flow is roughly 527,000 af. Contribution of the Fountain is 53,000 af; the Huerfano 28,000 af; the Apishapa 20,000 af; and the Purgatoire roughly 47,000 af. But by the time one gets down to this location (near John Martin Reservoir), the supply has been reduced to 76,000 af and the outflow at the state line is about 142,000 af.

Figure 1 also gives a sense of how the Arkansas compares in its historical yield to some of the other major river basins in the state. In the South Platte, for example, the high is on the order of 880,000 af, and that has reduced by the time it exits the state to 387,000 af, which is considerably more than the



Steve Witte, Division 2 Water Engineer. **Photo by Karen L. Stewart, Arkansas Valley Journal.**

overflow from the Arkansas Basin. The Rio Grande outflow averages about 325,000 af. On the West Slope, you can see without looking at the numbers and just looking at the relative size of the arrows that this is where the real water is in this state.

It should be remembered that these are stream flow figures and will include both transmountain and native components. By summing the average annual stream flow measurements over a period of time for selected gaging stations, one can estimate the average total basin inflow. By doing that for the period 1980 through 1994, I came up with a number of about 875,000 af. Deducting from that the average total transmountain imports over the same period of time (125,000 af known because of independent measurements of water brought into the Arkansas River Basin), I arrived at an average total native inflow of about 750,000 af for the period. One published report that I am aware of has placed this undepleted average annual native supply at 875,000 af, and that is just the native component alone. So, as you can see there can be tremendous variations just by using different time periods, and I suspect

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POTENTIALLY PRODUCTIVE HABITAT:

QUANTIFYING THE TREATY RESERVED WATER RIGHT TO INSTREAM FLOWS

Jim Weber
Policy Assistant
Columbia River Inter-Tribal
Fish Commission

Introduction

The *Winters* doctrine of reserved water rights has been the subject of voluminous publications and exhaustive analyses. This paper will travel little of this well-worn path and instead address the relatively untrammeled issues surrounding a workable definition of a water right sufficient to support a healthy fishery -- specifically the Columbia River anadromous fishery.

Prior to 1855, long before the Columbia River became the backbone of the Pacific Northwest's electric power supply and its tributaries a heavily-tapped source for irrigation water, the river was the world's largest producer of anadromous fish.[1] The migrations of these fish, many of whose lives began in streams as far inland as southern British Columbia and northeast Washington, took them down through the Columbia, out to sea, and as far north as southeast Alaska.[2] Once the fish reached maturity, they were the primary source of food, commerce, and culture for the numerous Indian tribes that lived near the fish's migratory path.[3]

In 1855, to peacefully resolve conflicting land claims in the Pacific Northwest, the United States negotiated numerous treaties with Indian tribes. These Indian tribes relinquished their claims to huge parcels of land and agreed to live on much smaller reservations of their former holdings, on the assurance that they could maintain their traditional lifestyle of harvesting fish at traditional fishing grounds.[4]

In the 130 years since these treaties were executed, the character of the Columbia River and its tributaries have changed dramatically and irreversibly. Once the fertile source of seemingly infinite numbers of fish, the Columbia has been turned into a series of lakes through the construction of dams. One dam, Grand Coulee, forever blocked access to over 1000 river miles of anadromous fish habitat.[5/] This, and the cumulative effects of other dams have eliminated over half of the Columbia Basin's historic fish habitat.[6/] Along with generating power, dams on the Columbia mainstem and its tributaries help provide over 30 million acre/feet of water to irrigate over seven million acres of land.[7/] Irrigation withdrawals from tributaries have further reduced the amount of available habitat by depriving fish of the flows they need for spawning, migration, and sustenance.[8/] However, it has been estimated that if irrigation water use efficiency were increased by 10%,[9/] three million acre/feet of water would be available for other uses, including fishery purposes.[10/]

This paper is not intended to be a diatribe on the water wasted in the process of irrigating crops. Instead, the purpose of this paper is to acquaint water managers with the nature, and especially the extent of the reserved water rights that the four Columbia River treaty tribes possess.[11/] The nature of the tribes' water rights to support their fisheries has been masked by the ongoing disagreement between Indians and non-Indians over who gets to harvest how many fish. Now that state governments are recognizing Indian tribes as co-managers of the fishery resource[12/] and the long-sought Salmon Interception Treaty between the United States and Canada is a reality,[13/] fish habitat questions may receive more attention. As all parties are realizing, disputes over harvest allocation may be moot unless fish habitat is secured; and one of the greatest threat to fish habitat is the lack of suitable stream flows.

The water, needed to turn usually arid Indian reservations into the permanent homelands intended by both the Indians and the federal government, is usually sought by invoking the Winters doctrine. The Winters doctrine, explained in section one, provides that the water needed to provide for the present and future needs of Indian tribes was reserved when the reservation was created. Unfortunately, the Winters doctrine is antithetical to the law of prior appropriation governing non-Indians that often utilize the very waters needed by Indian reservations.[14/] Since Winters rights generally antedate the rights of non-Indian appropriators and cannot be lost through non-use,[15/] Indian tribes can successfully assert water claims that may deprive some long-established non-Indian users of the water they desire.[16/] Since most potential Winters claims have not been asserted, they are perceived by many non-Indians as an ubiquitous threat to the present and future needs of non-Indians in an increasingly water-short West.

The Supreme Court's preferred method of addressing unasserted claims is not to deny Indian tribes the water they need, but instead to adjudicate in one proceeding a tribe's rights for both the present and the future.[17/] The quantification method the Supreme Court has chosen awards water on the basis of the practicably irrigable acreage within a tribe's reservation.[18/] The Supreme Court has eschewed quantifying Indian water rights on the basis of future reservation population needs, based upon its perception that there was and is no feasible way to predict this.19/

This paper asserts that a somewhat similar formula can be used to effectuate reserved water rights for reservations for which securing fishing rights is a primary purpose. Fish, as do crops, need water to flourish. The Supreme Court has already rejected a method that would quantify a tribe's water right on the basis of predicting the number of bushels of corn that the tribe may consume 20 years hence. Given the Supreme Court's interpretation, it would be difficult at best to impose this same rejected method on a source of food (fish) whose potential harvest yield is infinitely more difficult to predict.

To illustrate the parameters of the tribes' reserved rights to water to support their treaty-secured fishing rights, this paper will first describe the origins of the Winters doctrine and its evolution. Next, the Columbia River treaty tribes' treaties will be examined and their three primary purposes described. These purposes are: the right to take fish, the right to take fish at all usual and accustomed places, and agriculture. The geographical aspect of the treaty right is particularly important because these traditional fishing sites are located throughout the Columbia and its tributaries. Thus there must be sufficient water to support harvestable runs of fish at these sites.

The paper then turns to methods used to define Winters rights. Since most reservations depend upon agriculture, the policies behind quantifying Winters rights for agriculture are examined.

No discussion of the extent of the tribal reserved rights can occur without an analysis of the Supreme Court's decision in Washington v. Washington State Commercial Passenger Fishing Vessel Ass'n,[20/] where the Court drew the 50% harvest allocation ceiling and created the "moderate living standard."

Decisions finding reserved water rights for fish are then examined. To secure the habitat needs of fish, it is the biological needs of the fish, not the income of fishers, which frequently guides the courts' decision-making. The courts tend to fashion flexible remedies that are amenable to the needs of both fish and agriculture.

The next section examines recent Supreme Court reserved water rights decisions and notes that the Court's method of addressing water rights conflicts is to promote certainty in the extent of water rights. The Court found that this was one of the virtues of the practicably irrigable acreage standard. A potentially productive habitat standard possesses this same virtue.

Finally, the paper then examines regional fishery enhancement trends stimulated by the Pacific Northwest Electric Power Planning and Conservation Act.[21/] This federally-mandated restoration effort means that, at a minimum, there must be enough productive habitat maintained to support the restored fishery to the extent necessary to offset all hydroelectric-caused losses of anadromous fish.

The Winters Doctrine

Indian leverage over the allocation of western water stems from the Supreme Court's decision 76 years ago in Winters v. United States.[22] The Fort Belknap reservation was established in 1888. The defendants were non-Indian settlers who occupied lands ceded by the tribe. Pursuant to Montana law, the settlers appropriated water from the Milk River, which formed the northern boundary of the reservation. In 1898, the Indians constructed irrigation works, however, the settlers' use of the Milk River waters left little for the tribe. The tribe's suit to enjoin the settlers' diversion of water eventually reached the Supreme Court where the Court held that the tribe had reserved the right to use the waters of the Milk River in the agreement setting aside the reservation.[23]

One of the most cogent explanations of the theory underlying reserved water rights is found in Cappaert v. United States.[24]

> This Court has long held that when the Federal government withdraws its land from the public domain and reserves it for a federal purpose, the Government, by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose of the reservation. In so doing the United States acquires a reserved right in unappropriated water which vests on the date of the reservation[25] and is superior to the rights of future appropriators ... The doctrine applies to Indian reservations and other federal enclaves, encompassing water rights in navigable and non-navigable streams....
>
> In determining whether there is a federally reserved water right implicit in a federal reservation of public land, the issue is whether the Government intended to reserve unappropriated and thus available water. Intent is inferred if the previously unappropriated waters are necessary to accomplish the purpose for which the reservation was created.[26]

The Winters Court easily found the necessary intent to reserve water because, without irrigation, the reservation lands would have been "practically valueless."[27/] Similarly, the Ninth Circuit, in United States v. Ahtanum Irrigation District,[28/] had no difficulty inferring the requisite intent from a treaty executed between the Yakima Tribe and the United States[29/] to reserve water for irrigation[30/].

The Court looked to the intent of the parties in negotiating the treaty, in which the tribe ceded large areas of land to the United States and agreed to live on a much smaller tract. The Court asked: "Did they [the Yakimas] reduce the area of their occupation and give up the waters which made it valuable or adequate?"[31/] The Court then noted a fundamental canon of Indian treaty construction, "the treaty was not a grant of rights to the Indians, but a grant of rights from them -- a reservation of those not granted."[32/] The Court concluded that the Indians surrendered no part of their right to the waters of Ahtanum Creek.[33/]

If this same analysis were applied to the other three Columbia River tribes, a court would almost certainly reach the same results. These three tribes, the Confederated Tribes of the Umatilla Reservation, the Confederated Tribes of the Warm Springs Reservation, and the Nez Perce Tribe, all negotiated treaties with the United States that are virtually identical to that negotiated by the Yakima Indian Nation.[34/] All of these tribes ceded large tracts of land to the United States and reserved exclusive rights to much smaller portions of their once large domains. Their reservations all need irrigation to make the land productive. Thus the conditions necessary to infer an intent to reserve water exist.

The Winters doctrine was reaffirmed in Arizona v. California.[35/] There, as in Winters, the Court found that water from the Colorado River "would be essential to the life of the Indian people and to the animals they hunted and the crops they raised."[36/]

In 1978, the Supreme Court added what may be a new twist to the Winters doctrine when it decided United States v. New Mexico.[37/] Although the case dealt with federal reserved water rights, as opposed to Indian reserved water rights,[38/] the decision now appears to form a pattern for the interpretation of Winters rights.[39/] The issue in New Mexico addressed the amount of water the federal government reserved out of the Río Mimbres when it created the Gila National Forest in 1899. No Indian water rights were at stake. The lower court ruled that only that amount of water necessary for the purposes for which the land was withdrawn had been reserved.[40/] The United States appealed contending that additional water had been reserved for purposes such as recreation, aesthetics, wildlife preservation, and cattle grazing.

Justice Rehnquist's examination of the law of reserved water rights failed entirely to make any distinction between federal reserved rights and Indian reserved rights. The opinion indiscriminately herded Arizona v. California, Winters, and Cappaert v. United States[41/] into the same fold stating that "[e]ach time this Court has applied the 'implied-reservation-of-water doctrine,' it has carefully examined both the asserted water right and the specific purposes for which the land was reserved, and concluded that without the water the purpose of the reservation would be entirely defeated."[42/] The Court justified this approach on the grounds that the reservation is implied and because of the historical Congressional deference to state water allocation laws.[43/] Then, without citation, the opinion asserted:

> Where water is necessary to fulfill the very purposes for which a federal reservation was created, it is reasonable to conclude, even in the face of Congress' express deference to state water law in other areas, that the United States intended to reserve the necessary water. Where water is only valuable for a secondary use of the reservation, however, there arises the contrary inference that Congress intended, consistent with its other views, that the United States would acquire water in the same manner as any other public or private appropriator.[44/]

Thus, for purposes other than the "primary purposes" for which a federal reservation was made, no water was impliedly reserved.

The Court then applied this "primary purpose" test to the legislation authorizing the creation of national forests: the Organic Administration Act of June 4, 1897.[45/] National forests, the Court found, were intended to be reserved for only two purposes: "to conserve the water flows and to furnish a continuous supply of timber for the people."[46/] Therefore, Congress did not intend to reserve water for other purposes, such as aesthetics and wildlife preservation.[47/]

In summary, the preceding cases demonstrate that reservations, created either by the federal government or by Indian tribes through treaties, also reserve appurtenant waters then unappropriated in the amount needed to satisfy the purposes of the reservation. The *New Mexico* decision makes it clear that water is reserved for only the primary purposes of a *federal* reservation.

Applications of the Primary Purpose Test

The *New Mexico* "primary purposes" test was applied by the Ninth Circuit in *Colville Confederated Tribes v. Walton*.[48/] The Colvilles brought suit to enjoin the non-Indian owner of allotted lands from using surface and ground waters in the No Name Creek basin. The Colville reservation was created by executive order.[49/] The court noted that implied reservations are found when they are necessary to fulfill the purposes of the reservation.[50/] The court also stated that since the "Indians were not in a position, either economically or in terms of their development of farming skills, to compete with non-Indians for water rights, it was reasonable to conclude that Congress intended to reserve water for them."[51/] The court noted that, like the Indians of the Fort Belknap reservation, the Colvilles gave up large land holdings when their reservation was created.[52/] Since Congress intended to be fair with the Indians, by reserving waters without which their lands would be useless, the Ninth Circuit found that the executive order creating the Colville reservation also reserved water.[53/] In this manner, the Court found that the requisite intent to reserve water existed.

In identifying the extent of the water reserved, the Ninth Circuit utilized the *New Mexico* test.[54] The document that created the reservation provided little with which to work.

> It is hereby ordered that ... the country bounded on the east and south by the Columbia River, on the west by the Okanogan River, and on the north by British possessions, be, and the same is hereby, set apart as a reservation for said Indians, and for such other Indians as the Department of the Interior may see fit to locate thereon.[55]

The court declared that the general purpose of creating Indian reservations is to provide a home for the Indians. This purpose is broad and must be liberally construed.[56] Given the uninformative nature of the executive order, for identifying the purposes of the reservation, the court examined the circumstances surrounding the creation of the executive order, the history of the Colvilles, and the Indians' "need to maintain themselves under changed circumstances."[57]

On these grounds, the Ninth Circuit concluded that one purpose for creating the Colville reservation was to "provide a homeland for the Indians to maintain their agrarian society, and therefore that a reserved right to water for agriculture existed.[58] Looking at the Colville's history of fishing for salmon and trout, the court found that fishing was significant to the tribe's economic and religious lhfe. Thus, securing the right to take fish was also a purpose of the reservation.[59]

Unfortunately, the construction of the dams on the Columbia River destroyed the tribe's historic fishing areas.[60] Here, the court applied the necessary flexibility to adapt to changing circumstances,[61] noted that the tribe had established replacement fishing grounds in Omak Lake,[62/] and found an "implied reservation of water from No Name Creek for the *development and maintenance* of replacement fishing grounds."[63/]

It is important to realize that although the *Walton* court ostensibly applied the *New Mexico* test to identify the purposes of the Colville reservation, the Ninth Circuit actually employed a standard with a more solid basis in law. The court looked to the general intent behind creating Indian reservations (to provide a homeland), it examined the historic economic activities of the Indians (fishing), recognized the need to protect the purposes of Indian reservations and their economic well-being from unforeseen circumstances (e.g., construction of dams or the fish wheel in *United States v. Winans*), and also fully perceived the need to provide for the present and future needs of the tribe.[64/]

Aboriginal Water Rights

An important case distinguishing the *New Mexico* test is *United States v. Adair*.[65/] The United States sought a declaration of water rights for those areas of the Williamson River basin that were either former Klamath Indian reservation lands or were federal lands withdrawn for national forest purposes. The Klamath tribe had hunted, fished, and foraged in this area for more than 1000 years.[66/] The tribe and the United States concluded a treaty in 1864 in which the tribe gave up around 12 million acres of land and agreed to settle on an 800,000 acre reservation.[67/] The reservation encompassed the entire Klamath marsh, an important feeding area for waterfowl and other wildlife.68/

Article I of the treaty provided that the Klamaths enjoyed the exclusive right to hunt, fish, and gather on their reservation.69/ Article II provided funds to promote an agricultural way of life among the Indians.70/ The court held that the tribe's right to hunt, fish, and gather survived the Klamath Termination Act.71/

In analyzing the purposes of the Klamath reservation, the Ninth Circuit looked to the Supreme Court's New Mexico decision for guidance, but noted that both New Mexico and United States v. Cappaert72/ were not "directly applicable" to reserved water rights on Indian reservations.73/ The Court framed the issue by asking:

> whether securing to the Indians the right to hunt, fish, and gather was a primary purpose of the Klamath Reservation. Resolution of this question, in turn, depends on an analysis of the intent of the parties to the 1864 Klamath Treaty as reflected in its text and surrounding circumstances.74/

Given the tribe's history of sustaining itself by hunting and fishing, and given the explicit language in the treaty where the tribe reserved exclusive on-reservation hunting and fishing rights, the court found that continuation of a hunting and fishing lifestyle was one of the primary purposes of the reservation.75/ The court pursued a similar analysis in finding the existence of a primary purpose to promote agriculture. The Court found that Articles II-V of the Klamath Treaty made explicit references to the goal of fostering farming.76/ Therefore, agriculture was also a primary purpose of the Klamath reservation.[77/]

Although the Ninth Circuit acknowledged the existence of New Mexico, the court actually applied an aboriginal rights analysis. Aboriginal rights are based upon "immemorial custom and practices," and these rights remain vested in the Indians unless they are abandoned, granted to the federal government by treaty, or are extinguished by Congress.[78/] As discussed above, the court examined the Klamath's historical lifestyle to identify that which they reserved by treaty. The court also used an aboriginal rights perspective in determining the priority date of the Klamath's fishing and hunting rights. The Ninth Circuit examined the Klamath's treaty noting that Article I ceded "all of [the tribe's] right, title and claim" to most of its ancestral domain, yet reserved for itself the "exclusive use and occupancy" of the very lands in question.[79/] The court found no evidence that the tribe relinquished any rights in the land it reserved and held that the tribe's treaty is a "recognition of the Tribe's aboriginal water rights and a confirmation to the Tribe of a continued water right to support its hunting and fishing lifestyle...."[80/] Since the treaty memorialized the Klamath's uninterrupted and exclusive use of the lands it reserved, the court held that the tribe's hunting and fishing rights had a priority date of time immemorial.[81/] To hold that the priority date is other than time immemorial, such as the date the treaty was concluded, would allow the tribe's right to be reduced by any pre-treaty rights of non-Indians. This would extinguish rights the tribes had reserved.[82/]

This same aboriginal rights analysis is equally applicable to the treaties of the Columbia River tribes. As will be discussed in the following section, the right to take fish both within the reservations and at all usual and accustomed places is a right exercised since time immemorial and reserved in the 1855 treaties. Thus, this right has a priority date, not of 1855, but of time immemorial.

The Columbia River Treaties

The treaties concluded by the four Columbia River tribes are all substantially similar. For example, Article III of the Treaty with the Yakima Tribe states:

> The exclusive right of taking fish in all the streams, where running through or bordering said reservation, is further secured to said confederated tribes and bands of Indians, as also the right of taking fish at all usual and accustomed places, in common with the citizens of the Territory, and of erecting temporary buildings for curing them; together with the privilege of hunting, gathering roots and berries, and pasturing their horses upon open and unclaimed land.83/

The text of the treaty indicates a paramount intent by the parties to protect the Indians' fishing activities. Preservation of the Indians' right to take fish at their traditional places was one of the chief inducements towards concluding the treaties.84/ Judicial decisions also reflect this.

In *United States v. Winans*,85/ the defendant, duly licensed by the state, installed a fish wheel at one of the Yakima's usual and accustomed places and prevented the Indians from fishing there. In oft-quoted terms, the Court characterized the Indians' right to resort to their usual and accustomed places as "a part of larger rights possessed by the Indians, upon the exercise of which there was not a shadow of impediment, and which were not much less necessary than the atmosphere they breathed." 86/ The Court found that the treaty secured to Indians and non-Indians the right to take fish at usual and accustomed places outside the reservations. In addition, the treaty also preserved the Indians' right to build temporary structures at the places for curing fish. 87/ The Court believed that the Indians' interest in these usual and accustomed places held the status of a property right.

> The contingency of the future ownership of the lands, therefore, was foreseen and provided for -- in other words, the Indians were given a right in the land -- the right of crossing it to the river -- the right to occupy it to the extent and for the purpose mentioned. No other conclusion would give effect to the treaty. 88/

The protection accorded the Indians' treaty-secured right to take fish at their usual and accustomed places has also received protection from the exigencies of modern times. For example, Confederated Tribes of the Umatilla Reservation v. Calloway 89/ addressed the threat to fishing sites posed by the Corps of Engineers' "peaking proposal." 90/ The Corps' plan entailed greater use of The Dalles and John Day dams for the generation of power. This would result in a greater influx of water into the Bonneville dam pool (reservoir) and would cause the level of the reservoir to rise as much as three feet. 91/ In turn, this increase would flood fishing sites used by the Indians. 92/ The court held that the Corps could not implement its "peaking proposal" until it had adequately protected the Indians' fishing sites by constructing dikes and the like. 93/

Similarly, the court found in Confederated Tribes of the Umatilla Reservation v. Alexander 94/ that flooding the plaintiffs' usual and accustomed fishing stations with 200 feet of water would result in a material "impairment" of the Indians' use of the sites. 95/ The court enjoined construction of the dam holding that "[t]he right to destroy Indian treaty rights will not be inferred from a general project authorization...." 96/

The Ninth Circuit's most recent examination of the tribes' right to take fish at all usual and accustomed places is in United States v. Oregon. 97/ This suit emanated from action taken by the States of Oregon and Washington to regulate the Indians' 1982 fall season fishery. The parties had previously agreed that non-treaty fishing would take place in the Columbia River below Bonneville dam whereas treaty fishing would occur between Bonneville dam and McNary dam. 98/ The restrictions promulgated by the states restricted the areas in which the tribes could take fish in order to further the state goal of maximizing the harvest of hatchery fish and reducing the deficit owed to the tribes. 99/ The tribes brought suit to enjoin the states' regulations and to permit Indian fishing throughout the area between Bonneville and McNary dams.

The Ninth Circuit's opinion noted that all the parties agreed "that the tribes' fishing right encompasses access to traditional sites as well as a right to a fair share of the catch passing those sites." 100/ The court held that the states' regulations unduly restricted the exercise of the tribes' treaty right to take fish at all usual and accustomed places.[101] Although the court thought the states' regulations might have the long-term effect of enhancing some depressed stocks, it felt that legitimation of the states' purposes would impermissibly erode the geographical component of the tribes' treaty right.[102]

These cases, Winans, Calloway, Alexander, and United States v. Oregon, all demonstrate that the tribes' treaty right to take fish has a geographical component that possesses the status of a right in property. The exercise of this right cannot be abridged except in the interests of conservation of the anadromous fish.[103] Given the terms of the treaties and the preceding judicial decisions, maintenance of the Indians' right to their usual and accustomed places is a primary purpose of the treaties. Since protection of the right to use the usual and accustomed fishing places is an explicit reservation in the treaties, a reservation of water exists necessary to accomplish the purpose.[104]

The consequences of a tribal right to water at all usual and accustomed places are profound. Unlike the rights recognized in Winters, Arizona v. California, Walton, and Adair, a reservation of water for fishery purposes at usual and accustomed places inures to widely distributed locations outside the reservations. Although the locations of all the usual and accustomed places, whose protection is secured by treaty, have not yet been judicially determined, at a minimum they constitute a broad reach of locations where sufficient flows for fishery purposes must exist. Moreover, the treaty right attaches to fish "destined to pass" the usual and accustomed places.[105] Thus, the treaty right to sufficient flows extends even beyond the usual and accustomed places. The nature of the treaty secured flows will be explored subsequently.

The Reservation of a Fair Share of the Harvest

The right to resort to the usual and accustomed fishing places means little if there are no fish there to be taken. This truism was discussed extensively in Passenger Fishing Vessel, where the Court interpreted the meaning of the treaty provisions preserving the Indians' right to take fish in common with other citizens.

Referring to the phrase "right of taking fish,"[106] the Court declared:

> This language is particularly meaningful in the context of anadromous fisheries ... because of the relative predictability of the "harvest." In this context, it makes sense to say that a party has a right to "take" -- rather than merely the "opportunity" to try to catch -- some of the large quantities of fish that will almost certainly be available at a given place at a given time.[107]

Continuing, the Court stated that it was unlikely that the Indians would construe a reservation of the right to take fish "as merely the chance, shared with millions of other citizens, occasionally to dip their nets into territorial waters."[108] Thus, the treaty secures to the Indians a fair share of those fish destined to pass through the tribes' usual and accustomed fishing places.[109] "Neither party may deprive the other of a 'fair share' of the runs."[110]

Agriculture is a Primary Purpose

The first step in determining whether or not agriculture is a primary purpose of the reservation is to examine the document creating the reservation.[111/] As stated earlier, the treaties are all remarkably similar. For example, both the Treaty with the Umatilla Tribe and the Treaty with the Tribes of Middle Oregon provide for the federal expenditure of funds that "will promote their [the Indians'] well-being, and advance them in civilization, for their moral improvement and education, for buildings, opening and fencing farms, breaking land, purchasing teams, wagons, agricultural implements and seeds...."[112/] Both the Treaty with the Yakima Tribe and the Treaty with the Nez Perce Tribe provide for the establishment of agricultural and industrial schools.[113/] All of the treaties provide for federally-funded farmers and superintendents of farming operations.[114/] Clearly, the texts of the treaties place an unmistakable focus on the intent to inculcate an agriculturally-based existence.

Decisive support for the proposition that agriculture is a primary purpose of the treaties, worthy of a *Winters* right to water, is found in *United States v. Ahtanum Irrigation District*.[115/] There the Ninth Circuit, relying on the controlling precedent of *Winters*, found that the Yakima tribe's treaty carried an implied reservation of the waters of Ahtanum Creek.[116/] As stated earlier,[117.] and recognized by the Ninth Circuit, the Yakima's reservation would be virtually valueless without irrigation.[118/] Since the treaties are so nearly congruent, Ahtanum offers further assurance that agriculture is a primary purpose of the reservation for all four tribes.

Definition of the Reserved Right

Ultimately any assertion of water rights boils down to the question of how many cubic feet per second (cfs) or acre/feet each party shall receive. This determination engenders, not only the most contention, but also the most confusion. The next sections of this paper will outline the guidelines set down by the courts. Although, historically, political considerations were not an explicit part of the quantification equation,[119/] the presently increasing demand for a decreasing supply of water has exacerbated tensions between Indians with unquantified Winters rights and aboriginal rights, and those users who stand to lose their water supply if tribal interests are asserted.[120/]

The Supreme Court non-Indian vested interests when it stated, in New Mexico, that the interests of "water-needy" state and private appropriators should be taken into account.[121/] But what about non-Indians who are interested in instream flows? It is doubtful that the Supreme Court intended to create a hierarchy among those who fish for a living and those who farm. The balance that has historically leaned so greatly in favor of consumptive users will have to be adjusted to reflect, not only the tribes' reserved rights to instream flows, but also the needs of others who rely on instream flows. The following sections will discuss the factors courts consider in quantifying water for both agriculture and fish.

Quantifications for Agriculture

As discussed earlier, Winters v. United States established the doctrine of implied reservations of water. By ruling in favor of the Indians, the Court also indicated that these implied reservations could not be defeated by the protestations of white settlers that a judgment for the Indians would deprive their lands of water.[122/] However, it is less than clear how much water was actually awarded to the Indians. This may be because the United States simply sought to enjoin the defendants' diversions. The Ninth Circuit had noted that the tribe had a right to the waters of the Milk River "at least to the extent necessary to irrigate their lands."[123/] The effect of the Supreme Court's decision was to protect existing uses on the reservation.[124/]

The Ninth Circuit set down slightly more specific guidelines in Conrad Investment Co. v. United States.[125/] Noting that the purposes of the reservation included promoting the tribes' self-sufficiency and improvement,[126/] the court implied a reservation of water for the purposes of irrigation, stock watering, domestic, and other useful purposes.[127/] The amount of water decreed was intended to meet the tribe's present and future needs for the above purposes.[128/]

Forty-eight years later, in United States v. Ahtanum Irrigation District,[129/] the Ninth Circuit found that the treaty with the Yakima Tribe[130/] reserved enough water to satisfy the tribe's present and future irrigation needs.[131/] Discussing quantification, the court declared that "[i]t is obvious that the quantum is not measured by the uses being made at the time the treaty reservation was made. The reservation was not merely for present but future use. Any other construction of the rule in the Winters case would be wholly unreasonable."132/ The court also declined to modify its reasoning to ensure a water supply for white settlers.

> As the Winters case, both here and in the Supreme Court shows, the Indians were awarded the paramount right regardless of the quantity remaining for the use of white settlers....It is plain that if the amount awarded the United States for the benefit of the Indians in the Winters case equalled the entire flow of the Milk River, the decree would have been no different.133/

The Ninth Circuit could have brought its Ahtanum decision more in line with its precedent in United States v. Walker River Irrigation District134/ The Walker River Indian reservation was created in 1859 and contained some 1900 irrigated acres by 1886. However, as of 1939, the number of irrigated acres had not materially increased. The United States sought a very large open-ended decree that could be adjusted on the basis of experience.135/ It seems that the court balked at what it perceived to be an overly large demand by the government:

> That a decree of this sort would tend greatly to depreciate the value of the water rights of the upstream owners, and to make impossible any intelligent program of farming, is obvious. So precious is every miner's inch of water in these parched regions that no arrangement should be countenanced which would encourage waste or tend to induce it.136/

Instead of granting the government's wishes, the court declared that 70 years of experience have demonstrated that a decree based upon 2100 irrigated acres would be adequate for the Indians' needs.[137]

The difference between *Walker River* and *Ahtanum* is remarkable. In *Walker River*, the Ninth Circuit railed against waste and bemoaned the hardships that would be inflicted on upstream white settlers, whereas in *Ahtanum*, the Ninth Circuit declared that if the Indians needed all of Ahtanum Creek then they should have it.[138] Unlike the *Walker River* court, the *Ahtanum* court faced a situation where the present needs and irrigation capabilities of the tribe equalled the amount of water in the watercourse. In *Walker River*, the Indians did not yet possess the capability of utilizing all the water in the stream. Perhaps the lesson here is that, the greater the capability of a tribe to make use of the water awarded, the greater the likelihood of a decree that will take future needs into consideration.[139]

Walker River's exclusion of future needs from the quantification calculus does not appear to be good law. Not even the Ninth Circuit follows it.[140] Nor did the Supreme Court's landmark decision in *Arizona v. California*[141] heed *Walker River* in the slightest. This case involved the apportionment of the waters of the Colorado River, of which the Indian claims were a minor part. Looking at the Indian reservations, the court perceived that the lion's share of the reservation land was arid and that any water must come from the Colorado River.[142] The Court held that an award of water must be sufficient to fulfill both the present and the future needs of the Indian reservations.[143] The Special Master, affirmed by the Court, held that there was an implied reservation of enough water "to irrigate all the practically irrigable acreage on the reservations." 144/

Of vital importance is the method that the Court chose to provide for the Indians' future needs. The Court explicitly rejected the State of Arizona's contention that "the quantity of water reserved should be measured by the Indians' 'reasonably foreseeable needs,' which, in fact, means by the number of Indians." 145/ The Court declared, in no uncertain terms, that "[h]ow many Indians there will be and what their future needs will be can only be guessed. We have concluded, as did the Master, that the only feasible and fair way by which reserved water for the reservations can be measured is irrigable acreage. 146/ The practically irrigable acreage standard (hereinafter PIA) is still the proper measure for quantifying Indian reserved water rights claims for agricultural purposes. 147/

The PIA is a production or habitat-based standard. It determines the quantity of water decreed in terms of the amount of land that can be used to grow crops if water can be practicably applied. 148/ The PIA standard does not tell the tribes what they can and cannot grow, but would presumably limit them to growing crops similar to those that would be grown by non-Indians. Nor does the PIA standard limit the Indians' harvest. The limit on harvest is determined, instead, by the amount of irrigable land on the reservation. The PIA standard, although a fixed determination, addresses both the present and the future needs of the reservation by allowing the land to achieve its carrying capacity. The PIA measure does not hinge upon how many mouths there are to feed on the reservation nor does it attempt to establish how much each mouth should receive. That method of determining the Indians' needs was rejected in Arizona v. California in 1963 and again in 1983.149/

The Passenger Fishing Vessel Harvest Standard

Passenger Fishing Vessel held, inter alia, that both Indian and non-Indian fishermen possess a right, "secured by treaty, to take a fair share of the available fish."150/ The Supreme Court went on from there to endorse the district court's determination that the Indian harvest allocations should not exceed 50% of the harvestable fish.151/ Then, carving out new law and materially departing from the precedent established by Arizona v. California, the Court declared:

> It bears repeating, however, that the 50% figure imposes a maximum but not a minimum allocation. As in Arizona v. California and its predecessor cases, the central principle here must be that Indian treaty rights to a natural resource that once was thoroughly and exclusively exploited by the Indians secures so much as, but no more than, is necessary to provide the Indians with a livelihood -- that is to say, a moderate living. Accordingly, while the maximum possible allocation to the Indians is fixed at 50%, the minimum is not; the latter will, upon proper submissions to the District Court, be modified in response to changing circumstances.152

What is a "moderate living?" Does a lawyer derive a "moderate living" from his or her trade? Does a television repair person?153/

Perhaps the reason why the "moderate living standard" (MLS) has not proven to be a truly thorny problem in Pacific Northwest fisheries management is because no one can reasonably contend that the Indians' fish harvest presently yields a moderate living.[154/] This fact was implicitly acknowledged by the Supreme Court in Passenger Fishing Vessel when it stated that the 50% ceiling on the Indians' harvest allocation was necessary "to prevent their needs from exhausting the entire resource and thereby frustrating the treaty right of 'all [other] citizens of the territory.'"[155/]

Moreover, modifying the Indians' harvest allocation downwards, that is, on the grounds that the 50% allocation exceeds the tribes' MLS,[156/] can only be done "in response to changing circumstances."[157/] The Court even provided examples of what it deemed would constitute "changed circumstances."

> If, for example, a tribe should dwindle to just a few members, or if it should find other sources of support that lead it to abandon its fisheries, a 45% or 50% allocation of an entire run that passes through its usual and accustomed fishing places would be manifestly inappropriate because the livelihood of the tribe under those circumstances could not possibly require an allotment of a large number of fish.[158]

The examples provided by the Supreme Court indicate that its real concern is that the prized anadromous fish resource not be "wasted." In both scenarios, the dramatic, but not necessarily sudden, decrease in tribal population or in the abandonment[159/] of the fishery resource, the result would be too little harvest of a harvestable run. Downward modification of a tribe's harvest allocation would not occur in response to the tribe's level of income, but in response to the tribe's non-use of the resource.[160/] Thus, attempts by hopeful non-Indians and state governments to pervert Passenger Fishing Vessel into a mandate for a permanent Indian income ceiling (adjusted for inflation?) 161/ merely diverts all involved from the real issue -- sharing a valuable resource without waste. Passenger Fishing Vessel did not pretend to identify the extent of the fishery resouce, instead it decreed how that resource, ripe for harvest, would be divided.

Judicial Attempts to Apply the "Moderate Living Standard"

Unlike the production-oriented PIA standard developed in Arizona v. California I, the MLS or 50% harvest allocation is a harvest standard. The two standards are not compatible because they attempt to allocate natural resources at opposite ends of their life-cycles. As stated earlier, the Arizona v. California I Court explicitly rejected a harvest standard, that is, a standard based upon the needs of the people who would be consuming the fruits of the resource. The most probable reason why the Passenger Fishing Vessel Court embraced a harvest standard is because that was the precise issue which was presented to the Court. 162/

Despite its unsuitability for use as a quantification of the extent of the tribes' treaty right to take fish, the MLS has been used for that purpose. In United States v. Adair, 163/ the Ninth Circuit held that the Klamath tribe implicitly reserved an amount of water sufficient for its hunting and fishing rights to provide the tribe with a "moderate living." 164/ However, the court demonstrated its understanding that the MLS is a vague and misleading standard that should be construed broadly in favor of the Indians:

> Implicit in this "moderate living" standard is the conclusion that Indian tribes are not generally entitled to the same level of exclusive use and exploitation of a natural resource that they enjoyed at the time that they entered into the treaty reserving their interest in the resource, unless, of course, no lesser level will supply them with a moderate living.165/

Here the Ninth Circuit has indicated that the Klamaths must be allowed to achieve their "moderate living." The court explicitly stated the possibility that the MLS may only be achieved by allowing the tribe to enjoy the "same level of exclusive use and exploitation" it had at the time the treaty was concluded.166/

The purport of this holding is clear. Water flows for fish must be decreed so that the Indians may achieve their "moderate living," whatever that might be. Optimal flows should be decreed to allow the fishery to expand to the extent it can. To provide lesser flows will automatically and arbitrarily limit the extent of the fish resource -- almost certainly at a level below that reserved by the treaty. The Adair court's decree demonstrates its understanding that the MLS is not a device by which the extent of the resource can be determined; it is a device by which, under specific circumstances, the harvest allocation of the tribe may be reduced.167/

The Ninth Circuit's award of water in Colville Confederated Tribes v. Walton168/ further supports the proposition that optimal water flows for fish are appropriate to fulfill a tribe's implied reservation of water for fishery purposes. As stated earlier, the construction of dams on the Columbia destroyed the tribe's historic fishing grounds. In response, the tribe established a replacement fishery in Omak Lake using non-indigenous hatchery trout provided by the federal government. Irrigation withdrawals from No Name Creek during spawning season precluded any natural reproduction by the trout. The court held that the tribe had an "implied reservation of water from No Name Creek for the development and maintenance of replacement fishing grounds." 169/ Thus sufficient flows in No Name Creek are decreed to both develop and maintain a naturally spawning trout population in Omak Lake. At no point did the court state that the extent of the Colville's fishery would be limited by some sort of tribal "moderate living" constraint. The clear implication is that the extent of the fishery will be limited by the carrying capacity of Omak Lake or of No Name Creek, whichever is less.

The holdings in Adair and Walton lead to the same genre of quantifier that was mandated by the Supreme Court in Arizona v. California I and reaffirmed in Arizona v. California II -- a quantification standard based upon production capacity. Regardless of whether or not there exists a MLS (a limit on tribal income derived from fishing), there is a limit on the naturally reproducing fishery resource in the Columbia River and its tributaries that derives from the carrying capacity of the fish habitat. The Columbia River treaty tribes' implied reservation of water, for the purpose of fulfilling their treaty right to take fish at all usual and accustomed places is half of the anadromous fish production potential of the Columbia River and its tributaries -- half of the number of fish produced by all potentially productive habitat (PPH). 170/ Thus, the amount of water implicitly reserved by the tribes is that amount of water that will provide the optimum flows needed for the various stages of the anadromous fish life-cycle so as to support tribal harvest.

The PIA and PPH standards are resource-oriented standards. Underlying the Supreme Court's decision in Passenger Fishing Vessel is the critical need to preserve the resource -- a need which is superior to the rights of both Indians and non-Indians. The Court reiterated Justice Douglas' statement in Puyallup II 171/ that the "Treaty does not give the Indians a federal right to pursue the last living steelhead until it enters their nets." 172/ Similarly, the Passenger Fishing Vessel Court found the imposition of the 50% ceiling on the Indians' harvest allocation necessary "to prevent their needs from exhausting the entire resource and thereby frustrating the treaty right of 'all [other] citizens of the territory.'" 173/

One of the most crucial and unique aspects of the treaty right is that it is a shared right. Both Indians and non-Indians share the bounty of the anadromous fish resource. It is in the interest of both parties that the resource be enhanced. Similarly, the implied reservation of water to fulfill the treaty right to take fish benefits both Indians and non-Indians. In this manner the reservation of water for fishery purposes is truly distinct from reservations of water for agricultural purposes because water used for agriculture inures only to the benefit of those owning the land. Moreover, the anadromous fish resource provides benefits for the Pacific Northwest and beyond. Many of these fish begin their life in Idaho, migrate as far north as southeast Alaska, and then return to spawn in their natal streams.[174/] These fish are a valuable regional and international resource. However, ensuring the survival and eventually restoring this valuable resource cannot be secured by simply agreeing on more equitable harvest allocations. The health and extent of the resource depends upon securing suitable habitat conditions, often substantially obtainable by the provision of suitable water flows.[175/]

Water for Fish

It is a truism that "the most fundamental prerequisite to exercising the right to take fish is the existence of fish to be taken."[176/] Habitat conditions, identified by a joint state and federal fishery study, necessary to ensure the survival of the anadromous fish resource are: "(1) access to and from the sea, (2) an adequate supply of good quality water, (3) a sufficient amount of suitable gravel for spawning and egg incubation, (4) an ample supply of food, and (5) sufficient shelter."[177/] Decisions addressing fishery water needs generally focus on the biological needs of the fish, instead of the harvest aspirations of fishers.

United States v. Anderson[178/] was a water rights adjudication initiated by the United States on behalf of the Spokane Tribe. The court found that the primary purposes of the

Spokane tribe's reservations were: "(1) to insure the Indians' access to fishing places and to fish for food; and (2) promotion of agriculture." 179/

In arriving at an appropriate quantity of water to fulfill the fishery purposes, the court found that the needed quantity of water "to preserve fishing" was "related to water temperature rather than to simply minimum flow." 180/ The parties hotly contested what amount of flow would be needed to provide temperatures that would not threaten fish survival. It is evident from the court's holding that it elected to not squarely resolve the issues. The court stated:

> It is clear that a flow of 20 cfs would not always maintain the water temperature at 68 degrees or below. A flow of 30 cfs, on the other hand, will not always be required to keep the water temperature at this point. Thus, if the appointed Water Master finds, as a result of his experience, that a higher flow is necessary at any time to accomplish the purpose, he is empowered to make the adjustment. If, however, over a period of time, flow and temperature records demonstrate that 20 cfs flow is not realistically related to the maintenance of water temperature at 68 degrees or below, the judgment is subject to modification.181

The court's statement raises a number of questions and indicate some disturbing assumptions.

If the purpose of the flow is to "preserve" fishing, does it "preserve" an already viable and healthy fishery or does it simply "preserve" an already malnourished and marginal fishery? 182/ Does "preservation" allow for "enhancement?" Does the flow "set" by the court limit the extent of the fish population and, if so, why? The implication of the court's decision is that the flow awarded is not the optimum flow, yet the court provides no justification for not awarding the optimum flow. The opinion does not state whether or not the court "balanced" the interests of the fishery with some other conflicting interest.[183/]

At the same time that the _Anderson_ court struggled so mightily with whether 20 cfs or 30 cfs was the appropriate flow for the reservation's fishery purpose, the court had no trouble at all quantifying the tribe's reserved right for agriculture. Here, the court allowed the tribe to benefit from modern irrigation technology so that lands, formerly non-irrigable, could now be considered irrigable and receive water pursuant to the tribe's reserved right.[184/] But perhaps the most revealing part of the court's ruling is its determination of the tribe's right to change the use of its reserved water. The tribe, apparently frustrated by the court's rather miserly award of water for fishery purposes, sought to transfer water used for irrigation to the preservation of the Chamokane Creek fishery. The court held that since the tribe had reserved rights for both fishery and agricultural purposes, and since the tribe had a right to use the reserved water in any lawful manner,[185/] then, "it is permissible for the tribe to transfer its use of water for irrigation (a primary use) to the tribe's fishery (also a primary use) if the tribe wants to enhance its allotment of water to the fishery."[186/]

This aspect of the opinion, as much as the heated controversy over the 10 cfs for fishery purposes, and the court's lack of difficulty at quantifying an award of water for agriculture, indicates either, an almost visceral aversion towards providing adequate flows for fish, or the problems engendered by not having an agreed standard with which to measure the water needs of fish. There is nothing in the jurisprudence of the Winters doctrine that erects any sort of hierarchy amongst the primary purposes of a given reservation. Arizona v. California mandates an award of water sufficient to satisfy the present and future needs of an Indian reservation.[187/] It specifies no hierarchy. Nor does United States v. New Mexico[188/] attempt to set up any hierarchy among primary purposes. That case stands for the proposition that only for the primary purposes of federal reservations can implied reservations of water be inferred.[189/] If an Indian reservation is found to have more than one primary purpose, equal treatment should be accorded those purposes.

Although the Anderson opinion does not indicate what role fishing occupied in the Spokane tribe's culture,[190/] there is ample evidence that fishing was the primary source of food, the economic base, and the central aspect of tribal religious beliefs for the Puget Sound and Columbia River treaty tribes.

> From the earliest known times, up to and beyond the time of the treaties, the Indians comprising each of the intervenor tribes was primarily a fishing, hunting, and gathering people dependent almost entirely upon the natural animal and vegetation resources of the region for their subsistence and culture.[191]

It appears that the practice of agriculture, as non-Indians know it, was not the tribes' paramount concern when they signed the treaties.[192/] If anything, agriculture was more of a concern to the drafter of the treaties, the United States. Thus it seems particularly ironic, if not egregious, that the Anderson court assumed such a miserly approach in construing the Spokane tribe's implied reservation of water for fishery purposes. It appears that the court ignored the canon of construction enunciated by the Supreme Court in Passenger Fishing Vessel: "The treaty must therefore be construed, not according to the technical meaning of its words to learned lawyers, but in the sense in which they would naturally be understood by the Indians."[193/]

There is little doubt that one of the reasons why the Anderson court had such difficulty in quantifying the Spokane tribe's implied reservation for fishery purposes is because no clear measure for the right has hitherto been articulated. The PPH standard provides that measure. It requires that a court examine fishery habitat needs on a case-by-case basis, just as it would do if it were determining the number of practicably irrigable acres, and determine what the critical limiting factors are on the fishery habitat's production potential. Under the facts in Anderson, water temperature, not water flow, was the limiting factor. The court then attempted to fashion a decree based on that biological information. Unfortunately, the manner in which it did so appears to leave the habitat constantly on the brink of being hostile to the valuable resource it is intended to foster.

The Supreme Court's decision in Cappaert v. United States[194/] is a good example of tailoring the quantification of a federal implied reservation of water to the needs of a fish resource and to hydrologic reality.[195/] The Court recognized that, although the implied reservation of water doctrine had never been applied to groundwater before, in Cappaert the ground and surface water systems were hydrologically related and the Court found that the defendant's groundwater use was depleting the surface water supply.[196/] One of the purposes of Devil's Hole pool for which the federal government possessed an implied reservation of water, was "for the preservation of the unusual features of scenic, scientific, and educational interest."[197/] The Court found that the Devil's Hole pupfish, found at no other place in the world, was one of the unusual features of scientific interest that the federal reservation sought to preserve.[198/] The Court then stated that "[t]he pool need only be preserved, consistent with the intention expressed in the Proclamation, to the extent necessary to preserve its scientific interest."[199/] Since the pupfish are one of the pool's features of scientific interest, "the level of the pool may be permitted to drop to the extent that the drop does not impair the scientific value of the pool as the natural habitat of the species sought to be preserved."[200/] The appropriate standard is "minimal need."[201/] Thus groundwater pumping should be curtailed "only to the extent necessary to preserve an adequate water level at Devil's Hole."[202/]

If the Anderson court had pursued this analytical method, it would probably have reached a different result. Here the Supreme Court examined the purposes of the reservation and found that the intention was to ensure the survival of the pupfish. The Court examined the factors that threatened the survival of the pupfish. The Court found that a rock shelf was the place where the fish spawned and, as groundwater pumping reduced the level of the pool, this shelf would gradually become exposed.[203] With the exposure of the rock shelf, "the spawning area is decreased, reducing the ability of the fish to spawn in sufficient quantities to prevent extinction."[204] Thus the limiting factor of the pupfish's habitat war a water level that would keep the spawning location covered. Non-flow alternatives were examined. It was found that neither construction of an artificial spawning shelf nor transplanting the fish would preserve the species.[205] Thus the only method by which the preservation of the pupfish could be ensured was by curtailing groundwater pumping to the extent needed to keep the spawning shelf covered.[206]

The Anderson court, in a cursory examination of the purposes for creating the Spokane Indian Reservation, stated that one of the purposes "was to ensure the Spokane Indians' access to fishing areas and to fish for food. Therefore, under the Winters doctrine the tribe has the reserved right to sufficient water to preserve fishing in the Chamokane Creek."[207] The court made no finding as to whether the water awarded was to provide for the present and future needs of the tribe, although it did make that finding when discussing the reservation of water for agricultural purposes.[208] Nor did the court make any finding as to what fish population the reserved water would support. Preservation of the fish species, as in Cappaert, was not the purpose of the Spokane Reservation. Its purpose was to provide fish for food. Thus the amount of water awarded must support a fish population that will provide a harvestable surplus so that the Indians will have fish to eat. Had the court pursued this type of analysis, it might have found it less difficult to resolve the controversy over the 10 cfs for fishery purposes.

Although it is not a Winters doctrine case, the Ninth Circuit's decision in Kittitas Reclamation District v. Sunnyside Valley Irrigation District 209/ contains useful guidelines for identifying fishery water needs. This case emanates from the impacts caused by the Bureau of Reclamation (BR), operator of the Yakima project, on the Yakima River Spring Chinook fishery.

It is the instinct of Spring Chinook salmon to migrate into freshwater during spring, but to wait until September and early October to spawn. Historically, this was the time when stream flows would be at their lowest level. It is the "genius" of the Spring Chinook's genetic make-up to wait until this early fall low flow period to spawn because, historically, the eggs would then almost always be assured of sufficient water. 210/

However, in the early fall of 1980 the BR, in response to the needs of irrigators, released large amounts of water into the Yakima River from storage reservoirs. The Spring Chinook, migrating up the Yakima River during what they thought was the low flow period of the year, spawned in twelve to eighteen inches of water, as is their custom. However, once the need for irrigation water ended, the BR drastically reduced water releaser to begin the process of storing water for the next irrigation season. This reduction in flow would have left approximately 60 redds (nests of salmon eggs) high and dry and would have been lethal to the eggs. 211/ The Yakima Indian Nation requested the Water Master to maintain water releases that would prevent the redds from being "de-watered." The Water Master turned to the federal district court for instruction. Due to the immediacy of the problem, the district court ordered the release of the necessary water until another hearing could be held in November of 1980. At the next hearing, the district court: (1) authorized the continued release of water, as necessary, to preserve the redds; (2) authorized the use of non-flow methods to preserve the redds, such as transplanting the redds or building berms that would channel water over the redds; (3) authorized regular monitoring of the redds' condition; and (4) directed that various methods be developed for solving the dilemma that would accommodate the needs of both irrigation and fish in future irrigation seasons (such methods would include regulating water releases during the spawning season). The affected irrigation districts appealed the decision.[212/]

The issues before the Ninth Circuit were very narrow. The Ninth Circuit characterized its appellate duty as deciding "whether the district court had authority to order water released."[213/] The court tailored its decree to address the particular harms presented. It did not address the question of whether the fish population should be enhanced and to what extent. The decision is instructive because (1) it recognized that in addressing difficulties confronting fish habitat, the biological needs of fish are the primary consideration; and (2) that a flexible remedy, a remedy that offers both flow and non-flow solutions and that allows some managerial discretion, can best accommodate all the interests involved.[214/]

Both Kittitas and Anderson delegated a significant amount of managerial discretion to the water masters charged with managing the stream systems. These courts realized that the management of water is an ongoing activity that must consider myriad varying conditions and that must be able to respond quickly to emergencies, such as the threat to fish in Kittitas. Courts can best aid this process by clear, but flexible guidelines. The Kittitas decision exemplifies this by informing the Water Master that the redds must be protected and then listing various options which the Water Master may choose.[215/]

Certainty of Water Rights

Recent Supreme Court decisions addressing implied reservations of water indicate that the Court believes that a good way to resolve water rights controversies is by promoting certainty in the extent of water rights. In United States v. Nevada,[216/] the Pyramid Lake Paiute tribe asserted that they had an implied reservation of water to support the Pyramid Lake fishery. The tribe claimed that, although the United States had asserted Winters claims for water for agriculture in an earlier action, the federal government had not asserted claims for water for the fishery. The Court found that the interest in certainty of adjudicated water rights is vital.[217/] The Court held the tribe bound to the earlier decree on the basis of res judicata.[218/]

In Arizona v. California II,[219/] the Supreme Court addressed, inter alia, "whether the determination of practicably irrigable acreage within recognized Reservation boundaries should be re-opened to consider claims for 'omitted' lands for which water rights could have been sought in the litigation preceding the 1964 decree." 220/ The Court noted that its decision in *Arizona v. California I* 221/ had awarded the tribes water rights based on the number of practicably irrigable acres, a standard that would allow "a present water allocation that would be appropriate for future needs." 222/ The Court then stated:

> Therefore, with respect to the question of reserved rights for the Reservation, and the measurement of those rights, the Indians, as represented by the United States, won what can only be described as a complete victory. A victory, it should be stressed, that was in part attributable to the Court's interest in a *fixed* calculation of future water needs. 223/

The Court then held that the tribes' claim for an award of water for the "omitted" lands was barred by *res judicata*, despite the presence of a clause in the 1964 decree 224/ allowing modification of the decree. 225/ The Court held that Article IX, the clause in the 1964 decree, is only available for unforeseen issues not previously litigated or for changed circumstances. 226/ The Court also found that improved irrigation technology, that would increase the number of practicably irrigable acres, did not constitute a good reason for reopening the decree. The Court remarked "such technological improvements will continue indefinitely, and if a basis for recalculating the extent of irrigable acreage, the decree would have no finality at all." 227/

In response to the tribes' attempt to augment their award of water, the states 228/ contended that the PIA standard should be reconsidered in light of _New Mexico_ and _Passenger Fishing Vessel_.[229/] The Court declined to open this "Pandora's Box, upsetting the certainty of all aspects of the Decree."[230/]

It appears that the Supreme Court's strategy in adjudicating Indian reserved water rights is to award a "lump sum" of water, based upon a standard that allows for present and future needs, and then let the decree stand inviolate -- regardless of technological advancements. The problem with this approach is that it does not address the contemporary need for flexibility in resolving water disputes -- particularly those between instream uses and consumptive uses. The Supreme Court's fixation on certainty tends to increase adversity instead of inducing accommodation.

The Potentially Productive Habitat Standard and Current Enhancement Trends

In accord with the interest of conserving the resource for the benefit of both Indians and non-Indians that the Supreme Court seeks to further, the PPH standard delineates a water right for fishery purposes that will satisfy the treaty tribes' present and future needs. By examining the biological needs of fish in a stream or river, flows can be decreed that will optimize fish production. This production standard will evade the dilemma recognized by the Ninth Circuit in _Adair_, that the tribes' treaty right may not be fulfilled if less than optimal flows are decreed.[231/] This is especially appropriate since the Supreme Court identified a method for reducing the tribes' harvest allocation[232/] and has recently stated twice that it will not reopen a decree to augment Indian reserved water allocations.[233/]

A water right based upon potentially productive habitat will also help further the Pacific Northwest's efforts, pursuant to the Pacific Northwest Electric Power Planning and Conservation Act (Regional Act),[234/] to restore fishery losses caused by the development and operation of the Federal Columbia River Power System (FCRPS) in the Columbia and its tributaries.[235/] The Northwest Power Planning Council[236/] is the entity charged by federal law with planning and overseeing the restoration of Columbia River fisheries to the extent those fisheries have been adversely impacted by the development and operation of the FCRPS.[237/] At present, the Council is in the process of devising a method to first, assess the losses incurred by the fisheries due to hydroelectric power and, second, devise production goals to restore the fisheries.[238/] Both loss assessment methods the Council is currently considering include determinations of losses due to loss of habitat.[239/] The Council is relying heavily on the production potential of Columbia River tributaries because so much of the mainstem Columbia habitat has been destroyed by the dams.[240/] However, regardless of which loss assessment method the Council chooses, its restoration measures will largely address habitat needs.[241/] The Council anticipates extensive offsite enhancement to restore the fisheries. Offsite enhancement includes "water storage projects, water purchases, and other habitat and passage improvements addressing problems caused by irrigation, logging practices, industrial development, and other sources of fish declines in the Columbia River Basin."242/

These fishery restoration activities are the product of the well-considered judgment of both Congress and the region that fishery restoration through habitat enhancement is essential to the Pacific Northwest. At an absolute minimum, the treaty tribes possess an implied reservation of water sufficient to support the habitat needs of the total number of fish that will eventually be restored to the region.243/ The Indians' harvest allocation will be 50% of the total of these fish that are destined to pass the tribes' usual and accustomed places. The other half, of course, benefits non-Indian fisheries.

Conclusion

The greatest threat to the fulfillment of the Columbia River treaty tribes' right to take fish emanates from widely varied, but ongoing activities that adversely impact anadromous fish habitat. The Columbia River anadromous fishery has sustained decades of degradation from dam operation, timber harvest, and wasteful irrigation practices. The fishery retains little of its former resilience. Management by the federal and state governments has brought the anadromous fishery to its present decayed state.

A healthy expanding anadromous fishery has never been a truly vital goal of the federal and state governments. Fishery needs have been either "expendable" or an onerous constraint on more desirable activities, e.g. timber harvest. See generally

Nez Perce National Forest Draft Environmental Impact Statement (1985). As long as a healthy fishery is viewed as a "constraint" as opposed to a positive goal, the resource will never be accorded the opportunity to achieve its current potential.

It is extremely unlikely that a state or federal entity will shoulder the burden of developing the legal and biological justifications for a fishery that will fulfill the treaty right. Since the federal and state governments serve diverse and often conflicting constituencies, it is the responsibility of the interested Indian tribes to delineate the parameters of fishery management methods and goals. Until recently, there existed no principled method of identifying the water that the treaty Indian tribes reserved to effectuate their right to take fish. A water right for fisheries purposes based on full utilization of all potentially productive habitat could fill that gap. Long-term protection of Columbia River basin anadromous fish habitat can become a reality only if the treaty fishing tribes direct their co-management authority and biological expertise toward that result.

1/ See M. Blumm, Hydropower vs. Salmon: The Struggle of the Pacific Northwest's Anadromous Fish Resources for a Peaceful Coexistence with the Federal Columbia River Power System, 11 Envtl. L. 211, 212-13 (1981).

2/ See, C. Wilkinson & D. Conner, The Law of the Pacific Salmon Fishery: Conservation and Allocation of a Transboundary Common Property Resource, 32 U. Kan. L. Rev. 17, 22-26 (1983).

3/ Id. at 26-30.

4/ See generally Sohappy v. Smith, 302 F. Supp. 899 (D. Or. 1969), subsequent orders aff'd, United States v. Oregon, 529 F.2d 570 (9th Cir. 1976); Washington v. Washington State Commercial Passenger Fishing Vessel Ass'n, 443 U.S. 658 (1979).

5/ E. Chaney, A Question of Balance: Water/Energy - Salmon and Steelhead Production in the Upper Columbia River Basin (1978) at 4.

6/ Id.

7/ Id at 19.

8/ Id.

9/ See, E. Chaney, note 5 supra, at 19, where he states that some analysts believe that a 10% increase in efficiency would be "virtually effortless and totally painless."

10/ Id.

11/ The four Columbia River Treaty Tribes are: The Yakima Indian Nation, the Confederated Tribes of the Umatilla Reservation, the Confederated Tribes of the Warm Springs Reservation and the Nez Perce Tribe.

12/ See generally Pacific Salmon Treaty Act, Pub. L. No. 99-5, 99 Stat. 7 (1985). See also 1985 Ocean and In-River Management Agreement for Upper Columbia River Fall Chinook and Coho Salmon (May 22, 1985) found in United States v. Washington, Civil No. 9213-Phase I (W.D. Washington at Seattle); Confederated Tribes and Bands of the Yakima Indian Nation, et al. v. Baldrige, et al., Civil No. 80-342 (W.D. Washington at Seattle); and United States v. Oregon, Civil No. 68-513 (D. Or.).

But see Columbia River Inter-Tribal Fish Commission, CRITFC News, Vol. 8, No. 1 (June 1985), discussing the dispute between Idaho sports-fishers and the Columbia River treaty tribes over the harvest of steelhead trout.

13/ See Salmon Interception Treaty, January 28, 1985, United States Canada. See also Pacific Salmon Treaty Act, Pub. L. No. 99-5, 99 Stat. 7 (1985).

14/ See United States v. Anderson, 9 Indian L. Rep. 3137, 3138 (E.D. Wash. 1982). See also F. Cohen, Handbook of Federal Indian Law (1982) at 578:

> By contrast, water rights acquired under the prior appropriation system are limited in quantity to the amount actually applied to beneficial use. Unlike riparian rights, appropriative rights may be abandoned, or forfeited for non-use for a period of years set by state statutes. In times of shortage, the holders of "junior" rights, those with later priority dates, must forego their use of water from a particular water source in favor of senior appropriators on the same water course.
>
> Indian reserved water rights differ significantly from both riparian and appropriative rights. They are not based on appropriation and actual beneficial use and they are not lost by non-use. Sufficient water is reserved to fulfill the purposes for which a reservation was established. The priority of the water right is no later than the date on which a reservation was established which, in the case of most Indian reservations in the West, is earlier than the priority of most non-Indian water rights. Thus, a reservation established in 1865 which starts putting water to use for agricultural purposes in 1981 under its reserved rights has, in times of shortage, a priority that is superior to any non-Indian water right with a state law priority acquired after 1865. Unlike riparian rights, Indian reserved rights are not ratably reduced in times of shortage. For these reasons, Indian rights are generally prior and paramount to rights derived under state law.

(Citations omitted).

15/ Id.

16/ Id.

17/ See Arizona v. California II, _____U.S._____, _____, 103 S. Ct. 1382, 1390 (1983).

18/ Id. See also Arizona v. California I, 373 U.S. 546, 599-600 (1963).

19/ Id.

20/ 443 U.S. 658 (1979).

21/ 16 U.S.C. < 839 et seq. (1982).

22/ 207 U.S. 564 (1908).

23/ *Id.* at 576.

24/ 426 U.S. 128 (1976).

25/ Pacific Northwest Indian fishing rights secured by treaty should have a priority date, not as of the date of reservation (1855), but as of time immemorial. These rights were confirmed, not created, by the treaties concluded with the United States. *See United States v. Adair*, 723 F.2d 1394, 1412-14 (9th Cir. 1984). *See also United States v. Winans*, 198 U.S. 371, 381 (1905). *See generally* J.B. Martin, *Who Owns the Rain: An Analysis of Recent Western Indian Water Cases from an Aboriginal Right Perspective* (August 1980) (unpublished manuscript available at Columbia River Inter-Tribal Fish Commission).

26/ *Cappaert*, 426 U.S. at 138-39 (citations omitted). *See also* F. Cohen, *Handbook of Federal Indian Law* at 575-76 (1982) (hereinafter *Cohen*).

27/ *Winters*, 207 U.S. at 576.

28/ *United States v. Ahtanum Irrigation District*, 236 F.2d 321 (9th Cir. 1956), *cert.denied*. 352 U.S. 988 (1957), *rev'd*, 330 F.2d 897 (9th Cir.), *reh. denied*, 338 F.2d 307 (9th Cir. 1964), *cert. denied*, 381 U.S. 924 (1965).

29/ Treaty with the Yakima Tribe, June 9, 1855, 12 Stat. 951. Given the similarity between the Yakima's treaty and the treaties executed by the Nez Perce Tribe, Confederated Tribes of the Umatilla Reservation, and the Confederated Tribes of the Warm Springs Reservation, it would be virtually inconceivable that a court could fail to find the requisite intent in any of the treaties. *Compare* Treaty with the Nez Perce Tribe, June 11, 1855, 12 Stat. 957; Treaty with the Tribes of Middle Oregon, June 25, 1855, 12 Stat. 963; Treaty with the Umatilla Tribe, June 9, 1855, 12 Stat. 945.

30/ *Ahtanum*, 236 F.2d at 325.

31/ *Id.* at 326.

32/ *Id.*, quoting *United States v. Winans*, 198 U.S. 371, 381. *See also Washington v. Washington State Commercial Passenger Fishing Vessel Ass'n*, 443 U.S. 658, 680 (1979) (hereinafter *Passenger Fishing Vessel*).

33/ *Ahtanum*, 236 F.2d at 326.

34/ Compare: Treaty with the Nez Perce Tribe, June 11, 1855, 12 Stat. 957; Treaty with the Yakima Tribe, June 9, 1855, 12 Stat. 951; Treaty with the Tribes of Middle Oregon, June 25, 1855, 12 Stat. 963.

35/ 373 U.S. 546 (1963).

36/ Id. at 599.

37/ 438 U.S. 696 (1978).

38/ The distinction is discussed in F. Cohen, Handbook of Federal Indian Law at 584-85 (1982).

> Indian water rights differ from non-Indian federal reserved water rights .... The priority of Indian rights may, in some cases, predate the establishment of the reservation. In addition, since the primary purpose for which most Indian reservations were established was to provide for an economically self-sufficient place of residence, in most cases Indians are entitled to significantly greater quantities of water than other federal land areas. Congress is presumed to have dealt fairly with Indian tribes: the documents establishing the reservations are not to be interpreted narrowly, and ambiguities are resolved in the Indians' favor. Different rules of construction apply in determining the reserved rights of other types of federal reservations.

(Citations omitted). For example, the federal reserved rights doctrine prevents the imposition of state water statutes in national forests "only to the extent that the application of such state laws will interfere with the primary federal objectives in creating such federal reservations." Id. at n. 45, citing United States v. New Mexico, 438 U.S. 696, 702 (1978). In contrast, there is a general reluctance to countenance the imposition of state laws and objectives on Indian reservations. See Cohen, at 582.

Another important distinction between federal reserved rights and Indian reserved rights is that federal lands may be disposed of at will whereas some Indian water rights are considered valuable property compensable under the Fifth Amendment. Id. at 585.

39/ See e.g. Colville Confederated Tribes v. Walton, 647 F.2d 42, 47 (9th Cir. 1981). But see United States v. Adair, 723 F.2d 1394, 1408-10 and n. 13 (9th Cir. 1984), where the court identifies the distinction between Indian reserved rights and federal reserved rights, finds United States v. New Mexico non-binding under the facts, but still follows a somewhat similar analysis.

40/ New Mexico, 438 U.S. at 698.

41/ 426 U.S. 128 (1976). In Cappaert, the United States sought to enjoin the defendant from pumping groundwater from his wells for any purpose other than to provide a domestic water supply. The United States demonstrated that the defendant's withdrawal of groundwater was seriously depleting the water supply in the Devil's Hole pool in the Death Valley National Monument. Devil's Hole contains a species of fish found no where else in the world, the Devil's Hole pupfish. The district court found that Devil's Hole and the defendant's well were hydrologically connected, that the defendant's pumping had seriously lowered the water level in Devil's Hole thus placing the pupfish's ability to spawn in grave peril, and that structural (non-flow) alternatives such as construction of an artificial spawning shelf or transplantation would not stave off extinction. Id. at 136.

The Court then examined whether or not the federal government possessed a reserved right to water for the preservation of the pupfish. The Court found that when the federal government created the Devil's Hole component of the Death Valley National Monument, water for Devil's Hole pool was explicitly reserved. Id. at 140 (emphasis added). In addition, the Court found that the government's purpose for reserving the pool was to preserve the "unusual features of scenic, scientific, and educational interest." Id. at 141. The Court then held that this purpose would be fulfilled if the level of the pool was only permitted to drop to the extent the pupfish's ability to preserve itself was not impaired. The standard is the minimal need of the pupfish, no more. Id. at 141.

Note the narrowness of the opinion, the painstaking examination of the purposes of the federal reservation, and the tailoring of the remedy to satisfy the minimal needs -- perpetuation of the species -- of the pupfish, one of the purposes of the reservation. This analytical approach is appropriate in determining the purposes and quantities of water involved in federal reservations See note 38, supra.

42/ New Mexico, 438 U.S. at 700. See also Id. at n.4. The purposes of Indian reservations are not to be construed so narrowly. "Congress is presumed to have dealt fairly with the Indian tribes: the documents establishing the reservations are not to be interpreted narrowly, and ambiguities are resolved in the Indians' favor. Cohen, at 584, citing United States v. Shoshone Tribe, 304 U.S. 111, 116 (1938). See generally note 38 supra.

43/ New Mexico, 438 U.S. at 701-2.

44/ Id. at 702. See Fairfax and Tarlock, No Water for the

Woods: A Critical Analysis of United States v. New Mexico, 15 Idaho L. Rev. 509, 526 (1979) where the authors indicate that Rehnquist's development of this new factor in federal reserved water rights analysis demonstrates his dislike of the doctrine in general.

45/ 16 U.S.C. < 473 et seq. (1976).

46/ New Mexico, 438 U.S. at 707, quoting 30 Cong. Rec. 967 (1897) (remarks of Congressman McRae).

47/ Id. at 712-13. Justice Powell's dissenting opinion does not accept the majority's conclusion that forest wildlife are not part of the forest:

> I do not agree, however, that the forests which Congress intended to 'improve and protect' are the still, silent, lifeless places envisioned by the Court. In my view, the forests consist of birds, animals, and fish -- the wildlife -- that inhabit them, as well as the trees, flowers, shrubs, and grasses.

Id. at 719. It seems that the Court's method of reducing federal reserved water demands is to minimize the number of purposes for which water may be reserved. Notably, all nine justices agreed that adjudications of federally reserved rights must take into account those whose water rights will be impacted by the federal requirements. Id. at 705 and 718.

48/ 647 F.2d 42 (9th Cir.), cert. denied, 454 U.S. 1092 (1981).

49/ Executive Order of July 2, 1872, reprinted in 1 Kappler, Indian Affairs and Treaties, 916 (2d Ed. 1904). The Winters doctrine is applicable to reservations created by executive order. Walton, 647 F.2d at 46 n. 7, citing Arizona v. California, 373 U.S. 546, 598 (1963).

50/ Walton, 647 F.2d at 46, citing Winters, 207 U.S. at 576.

51/ Walton, 647 F.2d at 46.

52/ Id. at 46-7.

53/ Id. at 47, citing Arizona v. California, 373 U.S. at 600.

54/ Id. at 47. Unfortunately, the court inexplicably neglected to draw the distinction between federal reserved rights and Indian reserved rights. It did not acknowledge that New Mexico did not involve Indian reserved rights. However, the Ninth Circuit did later draw the proper distinction when it decided United States v. Adair, 723 F.2d 1394, 1408-10, and n. 13 (9th Cir. 1984).

55/ Walton, 647 F.2d at 47, quoting Executive Order of July 2, 1872, reprinted in 1 Kappler, Indian Affairs and Treaties, 916 (2d ed. 1904).

56/ Walton, 647 F.2d at 47. The court also remarked that the reservation was created for the benefit of the Indians, not the federal government. Id.

57/ Id. at 47, citing United States v. Winans, 198 U.S. 371, 381 (1905). The court stated that Congress viewed farming as only the first step in the "civilizing" process. Thus flexibility of purpose is implied. Walton, 647 F.2d at 47 n.9. In the context of changed circumstances, the court cited, inter alia, United States v. Finch, 548 F.2d 822, 832 (9th Cir. 1976) where the Ninth Circuit ruled that the federal government intended that the Indians be able to sustain themselves "from any source of food available." Walton, 647 F.2d at 47 n.10. Finally, Winans held that modern contrivances such as a fish wheel, capable of destroying whole runs of fish, could not be used to defeat the Indians' right to take fish from their usual and accustomed places. Winans, 198 U.S. at 381. See also Passenger Fishing Vessel, 443 U.S. 658, 679-81 (1979).

58/ Walton, 647 F.2d at 47.

59/ Id. at 48.

60/ Id.

61/ See note 57, supra.

62/ These replacement fishing grounds consisted of yearly planting of non-indigenous hatchery trout. Despite the tribe's best efforts to make the lower reaches of No Name Creek suitable for these trout to spawn, irrigation use of the creek's water during the spawning season precluded any appreciable spawning by the stocked fish. Thus, yearly stocking of hatchery fish was necessary to maintain a fishery. See Walton, 647 F.2d at 45.

A large percentage of the anadromous fish that migrate up the Columbia River each year are hatchery fish. In 1984, it is estimated that 78% of all steelhead migrating up the Columbia River were hatchery fish. See Washington Department of Game, Oregon Department of Fish and Wildlife, Columbia River Inter-Tribal Fish Commission, Joint Steelhead Sampling Study (October 1984) (available at Columbia River Inter-Tribal Fish Commission).

63/ Id. at 48 (emphasis added). At the time the treaties between the United States and the Nez Perce, Umatilla, Warm Springs, and Yakima tribes were concluded, no one envisioned that the Columbia River anadromous fish runs would diminish to their present sorry state. See Passenger Fishing Vessel, 443 U.S. at 675, where the Court states that "[a]t the time the treaties were executed, there was a great abundance of fish and a relative scarcity of people. No one had any doubt about the Indians' capacity to take as many fish as they might need." As will subsequently be made clear, the flexibility of purpose exercised by the Walton court should be used in quantifying the water reserved by the Columbia River tribes. It is presently a fishery in the nascent stages of restoration. See generally, Northwest Power Planning Council, Columbia River Basin Fish and Wildlife Program (1984) (available at Northwest Power Planning Council, 700 S.W. Taylor, Portland, Oregon 97205).

64/ This concern for the present and future is demonstrated in two ways. First, as stated earlier, the court declared that a purpose of the reservation was to develop and maintain the Omak Lake fishery. Second, the court found a reserved water right to provide for the present and future agricultural needs of the Indians. See Walton, 647 F.2d at 47-8, citing Arizona v. California, 373 U.S. at 600-1.

65/ 723 F.2d 1394 (9th Cir. 1984). The Ninth Circuit's scholarly and exhaustive analysis of whether the district court should have dismissed the federal water adjudication in favor of a contemporary state adjudication is beyond the scope of this paper. The purpose of this paper is to identify the guidelines that any court, state or federal, should utilize in identifying reserved rights for fisheries purposes. Theoretically, both jurisdictions should apply the same criteria. However, there is a long history of state hostility to Indian tribes. See Passenger Fishing Vessel, 443 U.S. at 669 and 696 n.36. See also Cohen at 583 n.36: "One of the primary reasons for broader federal jurisdiction over Indians' reserved water rights is that the states have historically been considered the Indians' 'deadliest enemies.'" Id., citing United States v. Kagama, 118 U.S. 375, 384 (1886). See also L. Claiborne, Deputy Solicitor of the United States, Remarks at the Conference on the Federal Impact on State Water Rights (June 11-13, 1984) (available from University of Colorado Law School Natural Resources Law Center), where he stated that one of the devices that will be utilized to reduce Indian water claims, where they might exhaust the available waters and require non-Indians to relinquish existing uses, will be allowing state courts to quantify Indian water rights, subject only to United States Supreme Court discretionary review in cases of manifest error.

66/ Adair, 723 F.2d at 1397.

67/ Id. at 1398, citing Treaty between the United States and the Klamath and Moadoc Tribes and the Yahooshin Band of Snake Indians, October 14, 1864, 16 Stat. 707.

68/ Adair, 723 F.2d at 1397-98.

69/ Id. at 1398, citing to the Treaty between the United States and the Klamath Tribe, supra at n.67.

70/ Adair, 723 F.2d at 1398, citing to the Treaty between the United States and the Klamath Tribe, supra at n.47, 16 Stat. 708.

71/ 25 U.S.C. << 564-564w (1976). A discussion of the termination issue is not within the scope of this paper. However, the basis of the court`s ruling that termination did not end the Klamath`s water rights comes from <564m(a) of the Termination Act: "Nothing in section 564-564w of this title shall abrogate any water rights of the tribe and its members." Adair, 723 F.2d at 1412. And the Ninth Circuit had, prior to this action, held that the Klamath`s hunting and fishing rights survived the Termination Act. See Kimball v. Callahan, 493 F.2d 564, 568-69 (9th Cir.) cert. denied, 419 U.S. 1019 (1974) (Kimball I); Kimball v. Callahan, 590 F.2d 768, 775 (9th Cir.), cert. denied, 444 U.S. 826 (1979) (Kimball II).

72/ 426 U.S. 128 (1976). See note 41 supra.

73/ See Adair, 723 F.2d at 1408-10 and n.13.

74/ Id. at 1409, citing Passenger Fishing Vessel, 443 U.S. at 675-76; Winters, 207 U.S. at 575-76.

75/ Adair, 723 F.2d at 1409.

76/ Id. at 1409-10. Article II of the Klamath Treaty provides "that moneys paid to the tribe in consideration for the land ceded by the treaty `shall be expended ... to promote the well-being of the Indians, advance them in civilization, and especially agriculture, and to secure their moral development and education.`" Id. at 1410, quoting 16 Stat. 708 (emphasis supplied by the court).

77/ The approach adopted by the Adair court indicates that the purposes of a reservation, for which water is reserved, are those purposes the parties intended to serve at the time the treaty, Act of Congress, or executive order was executed. Contemporary needs are not the determining factor in identifying reservation purposes. Thus, unless a tribe had a history of mining or unless parties to the treaty, act of Congress, or executive order envisioned mining as a purpose of the reservation at the time the document was executed, there was no water reserved for mining.

However, contemporary necessities are not automatically excluded from the analysis. In Walton, the Ninth Circuit identified a reservation purpose to promote fishing. Subsequent to the creation of the reservation, dams were constructed on the Columbia River that destroyed the Colville's traditional fishery. Walton, 647 F.2d at 48. The court then found an implied reservation of water from No Name Creek to develop and maintain the replacement fishing grounds in Omak Lake. Id. See also Passenger Fishing Vessel, where the Supreme Court discusses United States v. Winans, 198 U.S. 371 (1905). The Passenger Fishing Vessel court indicated its belief that the treaty right is amenable to protection from unforeseen circumstances. Passenger Fishing Vessel, 443 U.S. at 680-81.

78/ See Cohen, at 442-43.

79/ See Adair, 723 F.2d at 1413-14.

80/ Id. at 1414.

81/ Id.

82/ Id. But see Id. at 1416 n. 25 where the court contrasts the aboriginal native of hunting and fishing rights with the implied nature of water for agriculture. The historical exercise of hunting and fishing rights compels an earlier priority date than agricultural water rights.

83/ See Treaty with the Yakima Tribe, June 9, 1855, Art. III, 12 Stat. 951, 953. Compare Treaty with the Umatilla Tribe, June 9, 1855, Art. 1, 12 Stat. 945:

> Provided, also, that the exclusive right of taking fish in the streams running through and bordering said reservation is hereby secured to said Indians, and at all other usual and accustomed stations in common with citizens of the United States, and of erecting suitable buildings for curing the same ....

Id. at 946 (emphasis added). Unlike the Yakima's treaty, the Umatilla's treaty refers to "stations." In Confederated Tribes of the Umatilla Reservation v. Alexander, 440 F. Supp. 553 (D. Or. 1977), the court found that "the term 'station' in this particular treaty was intended to designate the same kinds of fishing locations as the phrase 'grounds and stations' in the other Northwest Indian treaties." Id. at 555.

The Yakima's treaty refers to "citizens of the Territory" whereas the Umatilla's treaty refers to "citizens of the United States." The meaning of these phrases is presently being litigated. If the tribes prevail, potentially all fish destined to pass the tribes' usual and accustomed places caught by non-Indians would be counted in the non-Indian share of the harvest. See Columbia River Tribes' Motion to Appear and File Amicus Brief, United States v. Washington, Civ. No. 9213 (W.D. Wash.) (Phase I) (Request for Determination on Accounting of Non-Treaty Catch).

84/ In Sohappy v. Smith, 302 F. Supp. 899 (D. Or. 1969), subsequent orders aff'd, United States v. Oregon, 529 F.2d 570 (9th Cir. 1976), the court noted that "[a]t the time of presenting the treaty to the Cayuse, Walla Walla and Nez Perce for signing, Governor Stevens prompting a reluctant Nez Perce Chief stated: 'Looking Glass knows that he can ... catch fish at any of the fishing stations.'" Sohappy, 302 F. Supp. at 906 n.1, quoting Record of Proceedings, Walla Walla Valley Treaty Council, June 9, 1855 at 145.

85/ 198 U.S. 371 (1905).

86/ Id. at 380.

87/ Id. at 380-81.

88/ Id. at 381. See also Seufert Brothers v. United States, 249 U.S. 194 (1918). The Court declared:

> During all the years since the treaty was signed they have been accustomed habitually to resort for fishing to the places to which the decree of the lower court applies, and they have shared such places with the Indians of other tribes from the south side of the river and with white men. This shows clearly that their understanding of the treaty was that they had the right to resort to these fishing grounds and make use of them in common with other citizens of the United States ....

Seufert Brothers, 249 U.S. at 198-99.

89/ No. 72-211, slip op. (D. Or. August 17, 1973).

90/ The term "peaking" refers to the methods utilized to generate electricity during the times of greatest or "peak" demand, usually day-time periods. Hydroelectric power is particularly well-suited to this purpose because its output can be increased or decreased more quickly and economically than can that of conventional thermal plants. See Id., slip.op. at 4.

91/ Id. Because of the extensive use of the Columbia River banks below Bonneville dam by such entities as Portland, Oregon, fluctuations in the water level below the dam must be kept within specified limits. Thus, Bonneville pool would absorb the fluctuations in the upstream releases. Id.

1. "[T]he state cannot so manage the fishery that little or no harvestable portion of the run remains to reach the upper portion of the stream where the historic Indian places are located." Sohappy, 302 F. Supp. at 911.

2. "The protection of the treaty right to take fish at the Indians' usual and accustomed places must be an objective ... co-equal with the conservation of fish runs for other users." Id.

3. "The state may use its police power only to the extent necessary to prevent the exercise of that right in a manner that will imperil the continued existence of the fish resource. Id. at 908. See also Puyallup Tribe v. State of Washington, 414 U.S. 44, 49 (1972) (Puyallup II) where Justice Douglas stated that "the Treaty does not give the Indians a federal right to pursue the last living steelhead until it enters their nets."

102/ United States v. Oregon, 718 F.2d at 305.

103/ See Sohappy, 302 F. Supp. at 908; Passenger Fishing Vessel, 443 U.S. at 682.

104/ Cappaert, 426 U.S. at 139.

105/ See Passenger Fishing Vessel, 443 U.S. at 679 and 685. See also Sohappy, 302 F. Supp. at 911.

106/ Passenger Fishing Vessel, 443 U.S. 678 (emphasis supplied by the Court).

107/ Id.

108/ Id. at 679.

109/ Id.

110/ Id. at 684-85. See also Sohappy, 302 F. Supp. at 911, subsequent orders aff'd, 529 F. 2d 570, 573 (9th Cir. 1976). In Passenger Fishing Vessel, the Court stated:

> The purport of our cases is clear. Non-treaty fishermen may not rely on property law concepts, devices such as the fish wheel, license fees, or general regulations to deprive the Indians of a fair share of the relevant runs of anadromous fish in the case area. Nor may treaty fishermen rely on their exclusive right of access to the reservation

> to destroy the rights of other "citizens of the territory." Both sides have a right, secured by treaty, to take a fair share of the available fish. That, we think, is what the parties to the treaty intended when they secured to the Indians the right of taking fish in common with other citizens.

Passenger Fishing Vessel, 443 U.S. at 684-85.

111/ See Adair, 723 F.2d at 1409; Walton, 647 F.2d at 47.

112/ Compare Treaty with the Umatilla Tribe, June 9, 1855, 12 Stat., 946 Art. II, with Treaty with the Tribes of Middle Oregon, June 25, 1855, 12 Stat. 963, 965 Art. II (emphasis added).

113 See Treaty with the Yakima Tribe, June 9, 1855, 12 Stat. 951, 953, Art V; Treaty with the Nez Perce Tribe, June 11, 1855, 12 Stat. 957, 959 Art. V.

114/ See Treaty with the Umatilla Tribe, June 9, 1855, 12 Stat. at 947 Art. IV; Treaty with the Yakima Tribe, June 9, 1855, 12 Stat. at 953 Art. V; Treaty with the Nez Perce Tribe, June 11, 1855, 12 Stat. at 959 Art. V; Treaty with the Tribes of Middle Oregon, June 25, 1855, 02 Stat. at 965 Art. IV.

115/ 236 F. 2d 321 (9th Cir. 1956), cert. denied, 352 U.S. 988 (1957), rev'd, 330 F.2d 987 (9th Cir.), reh. denied, 338 F.2d 307 (9th Cir. 1964), cert. denied, 381 U.S. 924 (1965).

116/ Id. at 325.

117/ See text accompanying notes 27 - 34.

118/ Ahtanum, 236 F.2d at 325.

119/ See Cohen, at 587:

> In determining water rights for Indian reservations, courts are not to engage in balancing the competing interests of Indian and non-Indian users. (Cappaert, 426 U.S. at 18 n.4) Fulfilling the purposes of the reservation may result in economic hardship or may even leave non-Indian interests without a water supply at all. (Ahtanum, 236 F.2d at 327) Those problems may be addressed by Congress subject to constitutional limitations; they cannot justify an "equitable apportionment" or reduction of water rights by the judiciary. (Arizona v. California, 373 U.S. at 597).

Id. (some citations omitted).

120/ See generally Laird, Water Rights: The Winters Cloud Over the Rockies: Indian Water Rights and the Development of Western Energy Resources, 7 Am. Indian L. Rev. 155 (1979). See also note 14, supra.

121/ New Mexico, 438 U.S. at 705. See also Id. at 719, where the dissenting opinion states that the implied reservation doctrine "should be applied with sensitivity to its impact upon those who have obtained water rights under state law and to Congress' general deference to state water law." However, Indian property rights in water, protected by the Fifth and Fourteenth amendments, cannot be taken on the basis of Supreme Court dicta. Moreover, Indian reserved water rights are determined on the basis of the treaty or statute memorializing the reservation -- not on the basis of the doctrine of equitable apportionment. See Arizona v. California, 373 U.S. gat 597.

122/ See Winters 207 U.S. at 570 and 576. To rule otherwise would mean that when the Indians gave up the majority of their land to live on a reservation, they also gave up the water necessary to make that reservation liveable. Id. at 576.

123/ Winters v. United States, 143 F. 770, 749 (9th Cir. 1908).

124/ See J.B. Martin, Who Owns the Rain, note 25, supra at 8, citing F. Trelease, Federal-State Relations in Water Law 21 (Legal Study Number 5, National Water Comm'n) (1971).

125/ 161 F. 829 (9th Cir. 1908).

126/ Id. at 832.

127/ Id. at 831.

128/ Id. at 832.

129/ 236 F.2d 321 (9th Cir. 1956), cert. denied, 352 U.S. 988 (1957), rev'd, 330 F.2d 897 (9th Cir.), reh. denied, 338 F.2d 307 (9th Cir. 1964), cert. denied, 381 U.S. 924 (1965).

130/ Treaty with the Yakima Tribe, June 9, 1855, 12 Stat. 951. For discussion of the treaty's purposes, See text accompanying notes 106 - 113.

131/ Ahtanum, 236 F.2d at 327.

132/ Id. at 326.

133/ Id. at 327.

134/ 104 F.2d 324 (9th Cir. 1939).

135/ Id. at 340.

136/ Id.

137/ Id.

138/ One commentator evaluates Walker River thusly:

> Drawing upon the [Walker River] court's perceived need to independently evaluate the quantity of water needed by the tribe, several commentators have identified a standard variously labeled as a "present uses and needs" or "past experience" standard. The result is to distort Walker River, implying that the decision represents a divergence from other cases, such as Conrad. A more realistic interpretation would be that the court used overly broad language in its attempt to ensure that it provided no more water than was presently needed, implicitly recognizing that if the needs expanded the decree could likewise be expanded. In that sense, and in response to the government's inflated request, the court adverted to "past experience as a guide. Nevertheless, Walker River has gained a reputation as an anomaly and therefore has been described as no longer good law.

See J.B. Martin, Who Owns the Rain?, note 25, supra at 15.

139/ A basic rule of Indian reserved water rights is that these rights are not lost through non-use. Cohen at 578. However, this general rule is beginning to be challenged. Louis Claiborne, Deputy Solicitor General of the United States, believes that one method that may be used to reduce Indian water claims will be to impose "a rule of loss of right through non-use if there is no actual beneficial use on the Reservation within some reasonable time." See L. Claiborne, Remarks at the Conference on the Federal Impact on State Water Rights (June 11-13, 1984) (available at Natural Resources Law Center, University of Colorado School of Law). See also Remarks of Charles Roe, Senior Assistant Attorney General for the State of Washington, at Conference on Water Resources Allocation (June 8-11, 1981((available at University of Colorado Law School), where he states that dormant Indian water rights should either be exercised within a reasonable time, or extinguished, with compensation coming from the federal government. See also Remarks of Peterson Zah, Chairman, Navajo Nation, at the Conference on Indian Water in the West: A Planning Agenda for the Future (Nov. 28-30, 1984) (conference summary or transcripts will be available in spring or summer of 1985 from the American Indian Lawyer Training Program, Oakland, California) where he stated that the best way for the Navajo's to protect their water supply would be to dam up all water on the reservation. "If we don't do that, we'll lose it."

140/ See note 133 supra. See also Ahtanum, 236 F.2d at 327-28. See also F. Trelease, Federal-State Relation in Water Law 21 (Legal Study Number 5, National Water Comm'n) (1971) at 163; See also Comment, Federal Reserved Rights in Water: The Problem of Quantification, 9 Tex. Tech. L. Rev. 89, 103 N.91 (1977).

141/ 373 U.S. 546 (1963).

142/ Id. at 598.

143 Id. at 599-600.

144/ Id.

145/ Id. at 600-601.

146/ Id. at 601.

147/ See Arizona v. California II, _____U.S._____, 103 S. Ct. 1382, 1370 (1983).

148/ Evaluating the economic considerations involved in determining what lands are economically and feasibly irrigable is not within the scope of the paper. Projects can be made economically feasible or non-feasible depending upon what costs and benefits decision-makers elect to include in the cost/benefit analysis. The selection of discount rates can be particularly controversial because it involves an essentially subjective choice. For that matter, should contemporary cost/benefit analysis methods be used or should past methods be used? Some argue that using present cost/benefit standards to measure PIA penalizes Indians relative to the more relaxed, if not lax, standards that have benefitted non-Indian irrigation projects developed in the past. See generally Brookshire, Economics and the Determination of Indian Reserved Water Rights, 23 Nat. Resources J. 749 (1983).

In any determination of the practicability of expenditures related to Indian reserved water rights, it is essential to remember the federal government's trust responsibility to the Indian people. See Cohen, at 599, citing Pyramid Lake Paiute Tribe v. Morton, 354 F. Supp. 252, 256-58 (D.D.C. 1972). See also Bureau of Reclamation, Umatilla Basin Project: Planning Aid Report at 69 (Jan. 1983) (available at Bureau of Reclamation Pacific Northwest Region Office, Boise, Idaho) where the Bureau states that an adverse cost/benefit ratio may be offset by the resulting "beneficial social impacts to the tribes."

149/ Arizona v. California I, 373 U.S. 546, 600-601 (1963); Arizona v. California II, _____U.S._____, _____, 103 S. Ct. 1382, 1390 (1983).

150/ 443 U.S. at 684-85.

151/ Id. at 685-86. The term "harvestable" means that number of fish remaining to be taken by any and all fishermen after subtracting the number of fish needed for spawning escapement. See United States v. Washington, 384 F. Supp. 312, 343 (W.D. Wash. 1974) (Phase I). Spawning escapement often, but not always, refers to that number of fish "which are reasonable and necessary to the perpetuation of a particular run or species of fish." Id. at 342. See also Sohappy, 312 F. Supp. at 908.

152/ Passenger Fishing Vessel, 443 U.S. at 686-87 (footnote omitted).

153/ Perhaps the inutility of the "moderate living standard" is best illustrated by the fact that the determination of the appropriate moderate living of an Indian fishermen smacks of the same decision-making entailed in a governmental entity deciding how many rubles a good factory worker should earn.

154/ But see D. Pitts, The Recent "Moderate Living" Limit to Indian Treaty Fishing Rights: A Critique (Dec. 1980) (unpublished paper written for a Seminar in Pacific Salmon Law, Lewis and Clark Law School) at 28, where he states that:

> [o]n June 25, 1980, the State of Washington filed interrogatories and requests for production on the United States. The State seeks information on Indians who are authorized to fish, type of gear used in fishing, tribal income from fishing and non-fishing activities, federal income tax returns for tribes and Indian corporations, grants received, grant eligibility criteria, tribal lands, market value and highest and best use of lands, sale and lease disposition of lands, other natural resources owned by the tribe, individual incomes, percentage of income from fishing, and more.

Id., citing Interrogatories and Request for production to United States of America, filed June 25, 1980, in United States v. Washington, Civ. No 9213 (Phase I). See also Note, United States v. Washington (Phase II): The Indian Fishing Conflict Moves Upstream, 12 Envtl. L. 469, 491-94 (1982).

155/ Passenger Fishing Vessel, 443 U.S. at 686. See also Adair, 723 F.2d at 1415.

156/ The Indians' right to take fish is a class right, not a personal right. See Passenger Fishing Vessel, 443 U.S. at 679.

157/ Passenger Fishing Vessel, 443 U.S. at 686-87.

158/ Id. at 687.

159/ Indian treaty hunting and fishing rights are valuable property rights. See Cohen, at 468. See also Menominee Tribe v. United States, 391 U.S. 404, 413 (1968). Congress possesses the authority to abrogate or modify Indian treaty rights, however, the intent to do so is not lightly imputed and must be clearly expressed. See Cohen at 468, citing Pigeon River Improvement Slide and Boom Co. v. Charles W. Cox, Ltd., 291 U.S. 138, 160 (1934). See also Menominee Tribe, 391 U.S. at 413.

The Passenger Fishing Vessel Court referred to tribal abandoment of fisheries. The tribe's intent to abandon its valuable treaty fishing right should be imputed no less lightly than Congress' intent to abrogate.

An analogy to the concept of "abandonment" in water law may be helpful.

> Abandonment is a voluntary matter. After an appropriation of water has been completed, "the courts will not lightly decree an abandonment of a property so valuable in a semi-arid region such as this."
>
> Whether a water right has actually been abandoned "depends on the facts and circumstances surrounding each particular case, tending to prove the essential elements of abandonment, viz., the intent and the acts of the party charged with abandoning such right.
>
> Both intent and relinquishment of possession are essential to constitute an abandonment of a water right.
>
> * * * *
>
> The intent to abandon the water right must be accompanied by an actual relinquishment of its possession, that is, a cessation of control and use of the water.

See 2 Hutchins, Water Rights Laws in the Nineteen Western States, at 261-63 (1974) (citations omitted).

160/ In its example, the Court stated that a 50% harvest allocation would be manifestly inappropriate if the tribe "should find other sources of support that lead it to abandon its fisheries. Id. at 687 (emphasis added). The Court's concern is not with the "other sources of support," but with the tribe's abandonment of its fisheries.

161/ See note 150 supra. See also Arizona v. California II, _____ U.S. _____, 103 S.ct. at 1395;

162/ Passenger Fishing Vessel, 443 U.S. at 674

163/ 723 F.2d 1394 (9th Cir. 1984). For further information on the facts and purposes of the treaty in question, see text accompanying notes 65 - 78, supra.

164/ See Adair, 723 F.2d at 1414-15.

165/ Id. at 1415 (emphasis added).

166/ Id.

167/ See Passenger Fishing Vessel, 443 U.S. at 686-87.

168/ 647 F.2d 42 (9th Cir.), cert. denied, 454 U.S. 1092 (1981).

169/ Walton, 647 F.2d at 48 (emphasis added).

170/ See A. Sanders, The Northwest Power Act and Reserved Tribal Rights, 58 Wash. L. Rev. 357 (1983). There the author states:

> The "moderate" standard, if applied, should be done so consistent with prior precedent limiting uses of natural resources to productive uses and prohibiting waste. The measure of the [Indians'] right is half of the habitat's natural production potential. The present treaty share is not enough to meet tribal needs. It seems a waste of time to speculate now about what was required by prior generations of Indians, or might be required by future generations.

Id. at 378-79.

Given that there exists a 50/50 allocation of harvestable fish between Indian and non-Indian fishermen, it is essential that the fishery resource be brought into full production so that the tribes' right can be effectuated, not eroded. Since it is not known whether production from presently existing and potentially usable habitat would supply a sufficient number of fish to fulfill the treaty right, further habitat degradation cannot be tolerated.

States do not possess the authority to abrogate treaty rights. Similarly, states do not possess the authority to cause a de facto abrogation of treaty rights by promoting or sanctioning piece-meal reductions of the Columbia basin's fish production capacity. Thus further state-sanctioned damage to fish habitat is either a violation of federal law or an implicit decision to cause a proportionate reduction in the non-Indian fish harvest allocation.

171/ Washington Department of Game v. Puyallup Tribe, 414 U.S. 44 (1973) (Puyallup II).

172/ Passenger Fishing Vessel, 443 U.S. at 684, quoting Puyallup II, 414 U.S. at 49.

173/ Passenger Fishing Vessel, 443 U.S. at 686.

174/ See generally C. Wilkinson & D. Conner, The Law of the Pacific Salmon Fishery: Conservation and Allocation of a Transboundary Common Property Resource, 32 Kans. L. Rev. 17 (1983).

175/ See generally United States Fish and Wildlife Service, National Marine Fisheries Service, Eastern Oregon Anadromous Fish Habitat Restoration Project, John Day River Basin, Fish and Wildlife Planning Aid Report (March 1981) (available at U.S. Fish and Wildlife Service, Portland, Oregon).

176/ See United States v. Washington, 506 F. Supp. 187, 203 (W.D. Wash. 1980) (Phase II). In November 1982, a three-member panel of the Ninth Circuit issued an opinion reviewing the district court's 1980 decision (694 F.2d 1374 (9th Cir. 1982)). In April 1983, the Ninth Circuit, en banc, vacated that decision and decided to rehear the case. See Anadromous Fish Runs and Indian Treaty Rights: The Boldt II Saga, Coastal Law Memo, Issue 4 (October 1983). The case was re-argued, en banc, in October 1983. In April 1984, the court requested the parties to address the Ninth Circuit's appellate jurisdiction with respect to the hatchery fish issue and the environmental issue, and in May 1984, the parties briefed the jurisdictional issues. On December 17, 1984 an en banc panel of the Ninth Circuit dismissed the entire appeal for lack of jurisdiction. The State of Washington requested a rehearing, the court granted it and filed the final opinion on April 29, 1985. The en banc panel held that "issuance of the declaratory judgment on the environmental issue is contrary to the exercise of sound judicial discretion," and vacated the district court's decision. See United States v. Washington, Civ. No. 9213 slip op. at 9-10 (9th Cir. April 29, 1985) (Phase II). However, the court affirmed the district court's holding that hatchery fish must be included in the Indians' harvest allocation. Id. at 13.

177/ Joint Statement Regarding the Biology, Status, Management, and Harvest of the Salmon and Steelhead Resources of the Puget Sound and Olympic Peninsular Drainage Areas of Western Washington (1973) at 17, found in United States v. Washington, 506 F. Supp. 187, 203 (W.D. Wash 1980).

178/ 9 Indian L. Rep. 3137 (E.D. Wash. 1982).

179/ Id. at 3139.

180/ Id. Water temperature can be the habitat factor that limits anadromous fish survival. See e.g. John Day River Habitat Restoration Project, note (171), supra at 7.

181/ Anderson, 9 Indian L. Rep. at 3139 (emphasis in text).

182/ Passenger Fishing Vessel has already answered this question in the negative. If the Supreme Court felt that the treaty fisheries need only be preserved at a marginal or minimal level, the Court would have analogized to its holding in Cappaert. See text accompanying notes 167-181, infra. Instead it specifically excluded Cappaert by basing the MLS on the precedent of Arizona v. California and its predecessors." See Passenger Fishing Vessel, 443 U.S. at 686 (emphasis added).

183/ The nature of the compromise is particularly mysterious, given the court's statement that "the tribe has a prior reserved right to all or practically all of the waters of Chamokane Creek. Id. at 3140. See note 114, supra which states that Indian reserved rights are not to be "balanced" with the interests of subsequent appropriators.

184/ Id. It would seem that a logical area for "compromise" would be in the inclusion of formerly non-irrigable lands into the category of irrigable lands. However, the Washington Department of Ecology did vigorously contest this aspect of the court's ruling. See Id.

185/ Id at 3139, citing Walton, 647 F.2d at 48.

186/ Anderson, 9 Indian L. Rep. at 3139. It should be noted that the Washington Department of Natural Resources contended that the tribe did not have the right to change the use of the water. Id. It is not apparent from the opinion whether the Department of Natural Resources thought that it might be able to somehow reduce the tribe's award of water or if its opposition to this change of use was simply hostility to the idea of providing flows for fish.

187/ See Arizona v. California, 373 U.S. 546, 600 (1963). See also Arizona v. California, _____U.S._____,_____, 103 S. Ct. 1382, 1390 (1983). The Anderson court acknowledged that Arizona v. California I stood for this proposition, nor did it attempt to construe that decision as creating any sort of hierarchy amongst the purposes of a reservation. See Anderson, 9 Indian L. Rep. at 3140.

188/ 438 U.S. 696 (1978).

189/ Id. at 702. There the Court found that preserving water flows for fish was not a primary purpose of the federal reservation, but a mere secondary purpose. Id. at 714-15.

190/ That the tribe sought to transfer water allocated for agriculture to supplement the meager fishing allocation probably speaks for itself.

191/ Sohappy v. Smith, 302 F. Supp. 899, 906 (D. Or. 1969). The court also pointed out that the tribes were reluctant to sign the treaties until they were assured that the treaties ensured their right to go to their usual and accustomed places to take fish. Id. See also A. Sanders, The Northwest Power Act and Reserved Tribal Rights, 58 Wash. L. Rev. 357 (1983), where the author states:

> The Northwest tribes were primarily fishing societies, who also relied on hunting and gathering. The abundant fish resource was the lifeblood of their economy and culture. To protect salmon and trout, tribes had customs to prevent pollution of rivers, particularly during spawning. They practiced religious rights to ensure the return of anadromous fish. When Governor Stevens undertook to negotiate the release of Indian land claims in Washington Territory, he realized that the Indians would be far more willing to give up their land if they knew their fisheries would be secure.

Id. at 362. See also Adair, 723 F.2d at 1409-10 n.15, where the court states that "[i]n fact, the Government was probably aware that hunting and fishing held the greatest promise for sustaining the Klamath on their reservation: The land ... is a high, cold plain ... too frosty to raise cereal or roots with success, and fit only for grass."

192/ See Sohappy, 302 F. Supp. at 906 N.1, where the Court notes that Governor Stevens assured Nez Perce Chief Looking Glass that the Nez Perce will be able to "catch fish at any of the fishing stations." See also Passenger Fishing Vessel, 443 U.S. at 667:

> It is perfectly clear, however, that the Indians were vitally interested in protecting their right

to take fish at usual and accustomed places, whether on or off the reservation, and that they were invited by the white negotiators to rely and in fact did rely heavily on the good faith of the United States to protect that right.

(citations omitted).

193/ Passenger Fishing Vessel, 443 U.S. at 676, quoting Jones v. Meehan, 175 U.S. 1, 11 (1899).

194/ 426 U.S. 128 (1976).

195/ See note 41, supra, for the facts of the case.

196/ Cappaert, 426 U.S. at 136 and 142.

197/ Id. at 141, quoting Presidential Proclamation No. 2961, 3 C.F.R. 147 (January 17, 1952) (emphasis added).

198/ Cappaert, 426 U.S. at 141.

199/ Id. (emphasis added).

200/ Id.

201/ Id. "The implied-reservation-of-water-rights doctrine, however, reserves only that amount of water necessary to fulfill the purpose of the reservation, no more." Id.

202/ Id.

203/ Id. at 133-34.

204/ Id. at 134.

205/ Id. at 136.

206/ Id. at 141.

207/ Anderson, 9 Indian L. Rep. at 3139.

208/ Id. at 3140.

209/ Civ. No. 80-3505 (9th Cir. June 14, 1985) (amended opinion).

210/ Id., slip op. at 3. See also Brief for the United States on Behalf of the Yakima Indian Nation, at 6-7 Kittitas Reclamation District v. Sunnyside Reclamation District, Civ. No. 80-3505 (9th Cir. 1982).

211/ Kittitas, slip op. at 3; Brief for the United States, note 206, supra, at 12.

212/ Kittitas, slip op. at 3-4.

213/ *Id*. at 2.

214/ Since the district court issued its decision in *Kittitas*, the needs of both fish and agriculture have been accommodated. No agricultural water right has received less water as a result of this decision. However, some irrigators have been forced to modify their diversions slightly to ensure that the same amount of water would be diverted. Telephone Interview with Onni Paralla, Engineer, Bureau of Reclamation (September 16, 1985).

215/ An example of providing useful guidelines while allowing plenty of room for "local" managerial discretion is contained in the Pacific Northwest Electric Power Planning and Conservation Act, <4(h)(6), 16 U.S.C. <839B(h)(6)(1982). There, Congress directed that "[t]he Council shall include in the [fish and wildlife] program measures which it determines will ... be based on, and supported by, the best available scientific knowledge; utilize, where equally effective alternative means of achieving the same sound biological objective exist, the alternative with the least economic cost."

216/ _____U.S._____, 103 S. Ct. 2906 (1983).

217/ *Id*. at 2925.

218/ *Id*. at 2924-25.

219/ 103 S. Ct. 1382 (1983).

220/ *Id*. at 1389-90.

221/ 373 U.S. 546 (1963).

222/ *Arizona v. California II*, 103 S. Ct. at 1390.

223/ *Id*. (emphasis in text).

> Recalculating the amount of practicably irrigable acreage runs directly counter to the strong interest in finality in this case. A major purpose of this litigation, from its inception to the present day, has been to provide the necessary assurance to states of the Southwest and to various private interests, of the amount of water they can anticipate from the Colorado River System.

Id. at 1392.

224/ Article IX of the 1964 decree states:

> Any of the parties may apply at the foot of

this decree for its amendment or for further relief. The Court retains jurisdiction of this suit for the purpose of any order, direction or modification of the decree, or any supplementary decree, that may at any time be deemed proper in relation to the subject matter in controversy.

225/ Arizona v. California II, 103 S. Ct. at 1394-95.

226/ Id. at 1391.

227/ Id. at 1395 n. 18. Note the Court's somewhat stringent view of "changed circumstances." No court should utilize a less stringent standard if asked to modify the tribes' harvest allocation downwards. See Passenger Fishing Vessel, 443 U.S. at 686-87.

228/ Arizona, California, Nevada, New Mexico, and Utah.

229/ Arizona v. California II, 103 S. Ct. at 1395.

230/ Id. The Court stated that "we are not persuaded that a defensible line can be drawn between the reasons for reopening this litigation advanced by the Tribes and the United States on the one hand and the States on the other." Id.

231/ Adair 723 F.2d at 1415. See also text accompanying notes 158 - 162, supra.

232/ See Passenger Fishing Vessel, 443 U.S. at 686-87. See also text accompanying notes 146 - 156, supra.

233/ See United States v. Nevada, 103 S. Ct. at 2924-25; Arizona v. California II, 103 S. Ct. at 1391-95. See also text accompanying notes 218 - 233, supra.

234/ Pacific Northwest Electric Power Planning and Conservation Act, 16 U.S.C. <839 (1982).

235/ Regional Act, <<2-4(h), 16 U.S.C. <<839-839B(h). For a thorough discussion of the havoc wreaked on Columbia River fisheries by the FCRPS, See M. Blumm, Hydropower vs. Salmon: The Struggle of the Pacific Northwest's Anadromous Fish Resources for a Peaceful Coexistence with the Federal Columbia River Power System, 11 Envtl. L. 211 (1981).

236/ The Council is comprised of eight members, two each appointed by the Governors of the States of Oregon, Washington, Idaho, and Montana. See Regional Act, <<4(a)(1) - 4(a)(2)(B), 16 U.S.C. << 839B(a)(1) - (a)(2)(B). The Council is charged with, inter alia, developing and adopting a program to protect, mitigate, and enhance fish and wildlife, including related spawning grounds and habitat, on