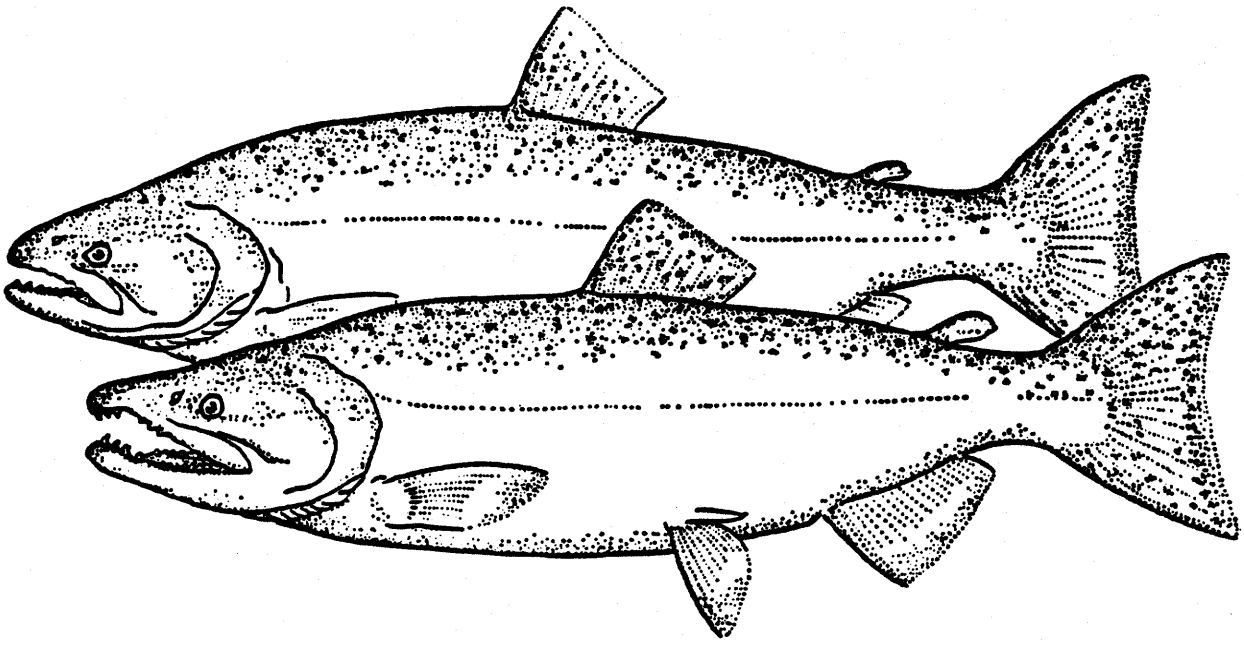
110

FRO-340A

January 1998

# SPRING AND SUMMER CHINOOK SALMON SPAWNING GROUND SURVEYS ON THE ENTIAT RIVER, 1997



Fish and Wildlife Service

**U.S. Department of the Interior**

# Spring and Summer Chinook Salmon Spawning Ground Surveys on the Entiat River, 1997

Prepared by:

David G. Carie
Fishery Biologist

January 1998

**U.S. Fish and Wildlife Service**
**Mid-Columbia River Fishery Resource Office**
**12790 Fish Hatchery Rd.**
**Leavenworth, WA 98826**

## TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES



## LIST OF APPENDICES



## ACKNOWLEDGMENTS

I would like to thank the USFWS survey crew (Barbara Kelly Ringel, Malenna Jordan, Pamela Olson, and Charles Hamstreet) for their many hours spent in sometimes adverse conditions conducting these surveys. I also thank Phil Archibald, United States Forest Service (USFS) - Entiat Ranger District, for his continued support and assistance in all our endeavors concerning the Entiat Basin. C. Hamstreet analyzed scales taken from carcasses. A special thanks goes to Albert "Shorty" Long and Carl Foss for allowing our crews to park vehicles on their property. As in years past, Shorty provided hot coffee, snacks, and plenty of history lessons on the Entiat area. We greatly appreciate his hospitality and kindness. These surveys would not be possible without the continued support from various landowners in the upper survey sections. Their understanding of our intentions, and importance of these surveys is critical to the success of this ongoing effort.

## INTRODUCTION

Spring chinook salmon *Oncorhynchus tshawytscha* spawning has been monitored in the Entiat River since 1962 by Washington Department of Fish and Wildlife (WDFW) in a seven-mile index area that has been surveyed once annually after the peak of spawning. Summer chinook salmon surveys in the Entiat River have been limited to aerial surveys conducted from Ardenvoir to the mouth (river mile (RM) 0 to 10.4), 1957 to 1991, by Chelan County Public Utility District (PUD). Starting in 1997, Mid-Columbia River Fishery Resource Office (MCRFRO), U.S. Fish and Wildlife Service (USFWS), has been conducting all surveys for spring and summer chinook salmon in the Entiat River. Dam counts at Rocky Reach and Wells dams are also used to monitor salmon runs in the Entiat River area.

This was the fourth year that MCRFRO expanded the spring chinook salmon spawning surveys to include an additional seven miles and conducted multiple summer chinook salmon surveys within a 13 mile section. Surveyors covered approximately 50 percent of the lower 16 miles in search of summer chinook redds. Biologists also searched for sockeye salmon *O. nerka*, since they have been seen in the Entiat River in past years.

The purposes of the USFWS surveys were to:

1. Expand current Entiat River spring chinook salmon spawning surveys to assess spawning distribution over a larger area and more accurately estimate the spawning population.

2. Assess the spawning distribution and estimate the summer chinook salmon spawning population in the Entiat River.

3. Add to spawning and population trend analysis data for spring and summer chinook salmon in the Entiat River.

4. Check for possible straying of hatchery spring chinook salmon by retrieving coded-wire tag data from tagged fish.

5. Search for sockeye salmon and identify their spawning areas in the Entiat River.

## STUDY AREA

The Entiat River enters the Columbia River approximately 484 miles and eight dams above the Pacific Ocean. The Entiat River is 52 miles long and begins as meltwater from glaciers and snow (Figure 1). Base flow is 385 $ft^3/s$ (Mullan et al. 1992), and its major tributaries are the North Fork and Mad rivers. Spawning surveys concentrated between Fox Creek Campground and McKenzie Diversion Dam (RM 28-16), because this reach contains most of the suitable spawning habitat. At RM 15 there is a terminal moraine formed by a valley glacier during the Pleistocene. Above the moraine, the valley is U-shaped and below it is V-shaped from stream cutting. Stream gradient below Box Canyon RM 29 to 26 is steep and gravel is only found in small pockets. From RM 26 to 15 the gradient lessens and gravel is abundant. Between RM 15 and RM 2 the river gradient steepens and substrate is mostly cobble and boulder. Below RM 2 the river gradient decreases. There are limited gravel areas around RM 1 and large deposits of silt and sand exist near the mouth. River miles and major landmarks are given in Appendix 1.

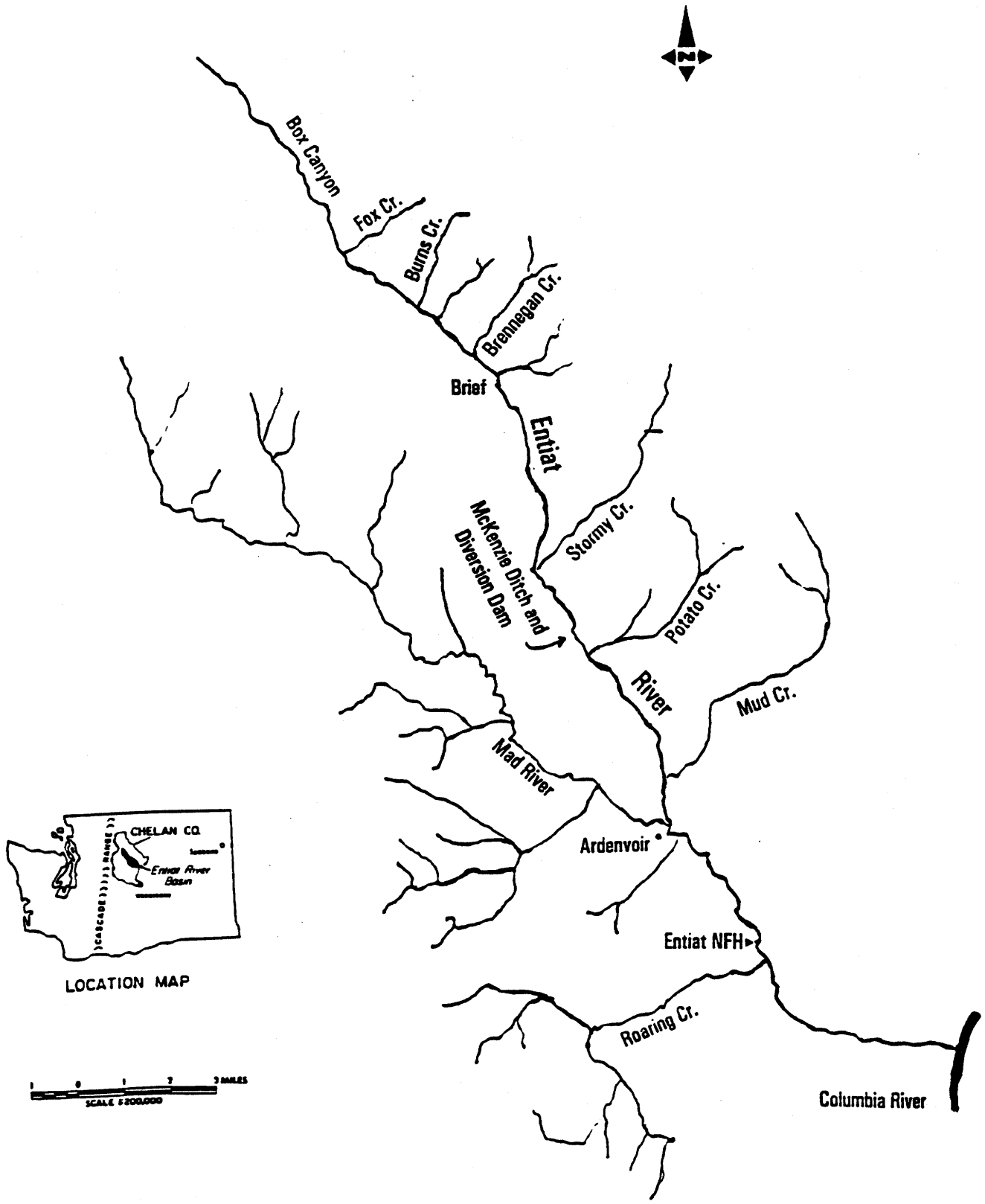



Figure 1. Map of Entiat River showing lower 30 miles (survey area)

## CHINOOK AND SOCKEYE SALMON POPULATIONS

The Entiat River historically supported excellent salmon runs that consisted of chinook (probably spring) and coho salmon (Craig and Suomela 1941). Construction of dams around the turn of the century near the mouth of the Entiat River blocked salmon from their spawning grounds, and salmon runs were essentially nonexistent by 1939 when Grand Coulee Dam was built (Craig and Suomela 1941). As part of the Grand Coulee Fish Maintenance Project mitigation effort, all ascending adult salmon from upriver stocks were trapped at Rock Island Dam from 1939 to 1943 and were relocated to upstream tributary streams below Grand Coulee Dam, including the Entiat River (mainly summer and fall chinook), and to hatcheries, including Leavenworth, Entiat, and Winthrop National Fish Hatcheries (NFH) (Fish and Hanavan 1948). The goal of these efforts was to rebuild salmon runs in the tributary streams and mitigate for lost production above Grand Coulee Dam.

### *Spring Chinook Salmon*

In the initial years after Grand Coulee Dam was built, little effort was made to re-establish wild spring chinook salmon runs in the Entiat River. Entiat NFH released approximately 1 million sub-yearling and less than 50,000 yearling spring chinook salmon from 1942 to 1944 that were offspring of the upriver stocks collected at Rock Island Dam (Mullan 1987). No spring chinook salmon were released from Entiat NFH from 1945 to 1975. Aside from this, a wild spring chinook salmon run was observed as early as 1956 and 1957, spawning in the area above Stormy Creek (RM 18.4) (French and Wahle 1960). Since 1962 spring chinook salmon redds have been counted in an index section between RM 28 and 21, where a well established spring chinook salmon run has been documented (Figure 2 and Table 1). Entiat NFH resumed spring chinook salmon production in 1974. Egg sources have included Cowlitz River (1974), Carson NFH (1975 to 1982), Little White Salmon NFH (1976, 1978, 1979, 1981), Leavenworth NFH (1979-1981, 1994), and Winthrop NFH (1988). Returning adults that voluntarily entered the hatchery were the primary broodstock in 1980 and from 1983 to 1997.

### *Summer Chinook Salmon*

Although summer chinook salmon are not believed to be endemic to the Entiat River (Craig and Suomela 1941), several efforts were made to establish summer chinook salmon in the Entiat River following completion of Grand Coulee Dam. In 1939 and 1940, a total of 3,015 adult summer chinook salmon, collected at Rock Island Dam from the commingled upriver stocks, were placed in upper Entiat River spawning areas. Only an estimated 1,308 of these survived to spawn (Fish and Hanavan 1948). Entiat NFH reared and released juvenile summer chinook salmon into the Entiat River 1941-1964 and 1976 (Mullan 1987). Egg sources included the commingled upriver stocks intercepted at Rock Island Dam (1939-1943), Methow River (1944), Carson NFH (1944), Entiat River (1946-1964), Spring Creek NFH (1964), and Wells Dam (1974). Summer chinook salmon spawning was monitored by aerial surveys in the lower 10.4 miles from 1957 to 1991. Visibility is usually poor, therefore aerial surveys likely underestimate actual redd numbers. Spawning numbers were never high, with a maximum of 55 redds in 1967. The number of redds declined following the adult return of the 1964 cohort.
This cohort included the last group of fish returning from the summer chinook rearing program at Entiat NFH. For years 1972-1991 aerial redd counts averaged just under five per year.

Table 1. Spring chinook salmon redd counts from annual surveys in the index area, Fox Creek Campground to Dill Creek (RM 28-21), Entiat River, 1962-1997 (see Figure 2).

| YEAR | # OF REDDS | YEAR | # OF REDDS |
|---|---|---|---|
| 1962 | 115 | 1980 | 107 |
| 1963 | 145 | 1981 | 95 |
| 1964 | 384 | 1982 | 107 |
| 1965 | 104 | 1983 | 107 |
| 1966 | 307 | 1984 | 84 |
| 1967 | 252 | 1985 | 115 |
| 1968 | 252 | 1986 | 105 |
| 1969 | 83 | 1987 | 64 |
| 1970 | 70 | 1988 | 67 |
| 1971 | 136 | 1989 | 37 |
| 1972 | 61 | 1990 | 83 |
| 1973 | 229 | 1991 | 32 |
| 1974 | 88 | 1992 | 42 |
| 1975 | 156 | 1993 | 100 |
| 1976 | 47 | 1994 | 24 |
| 1977 | 171 | 1995 | 1 |
| 1978 | 326 | 1996 | 8 |
| 1979 | N/A | 1997 | 20 |

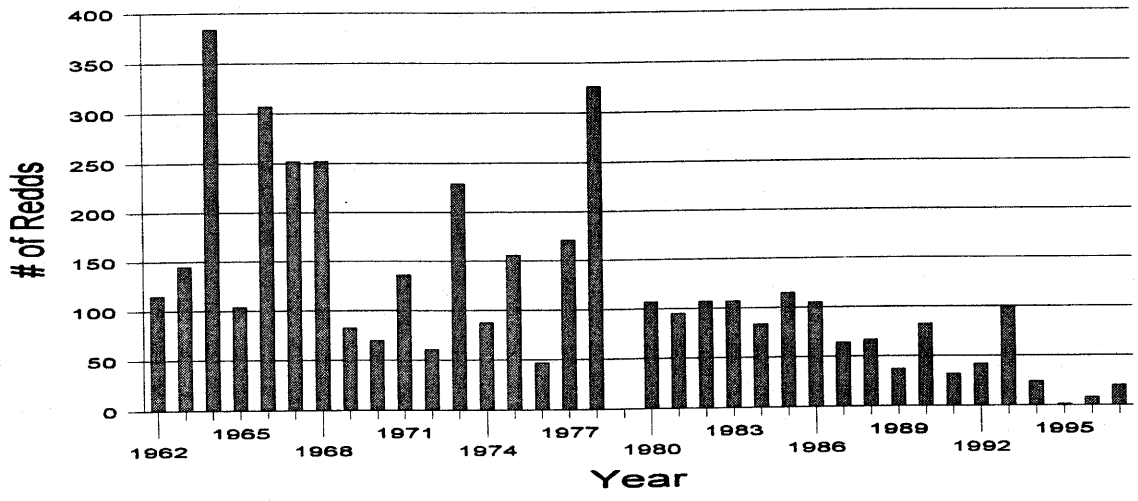



Figure 2. Spring chinook salmon redd counts from annual surveys in the index area, Fox Creek Campground to Dill Creek (RM 28-21), Entiat River, 1962-1997.

### *Sockeye Salmon*

Sockeye salmon are not indigenous to the Entiat River (Craig and Suomela 1941) and have only been stocked on two occasions, in 1943 and 1944, from Lake Quinault and Lake Whatcom stocks (Mullan 1986). A small run of sockeye salmon became established in the Entiat River, and Entiat NFH collected sockeye salmon from 1944 to 1963 for planting elsewhere (Mullan 1986). Sockeye salmon were observed spawning in the Entiat River from 1945 to 1955, and 75-150 were counted in incidental counts between 1969 and 1981 (Mullan 1986).

## METHODS

### *Spring Chinook Salmon*

Methods for surveying spring chinook salmon were consistent with those used historically in the index area by WDFW. The survey area was divided into several reaches and single surveys of each reach were conducted after peak spawning in mid-September and early October by two persons walking downstream and counting redds, live, and dead fish. Only well established redds were counted. Dead fish were measured to the nearest centimeter (fork length), gender identified and scale samples taken when possible. All redd locations were marked with biodegradable flagging on nearby vegetation to distinguish them from summer chinook redds in subsequent surveys. Landowners were contacted by mail to notify them of the spring and summer chinook salmon spawning surveys and to seek permission to access their property as surveyors walked downstream.

The index area, from Fox Creek Campground to Dill Creek (RM 28-21), was surveyed on September 11, 1997, by USFWS for evidence of spring chinook salmon spawning. USFWS, with assistance by USFS - Entiat Ranger District personnel, surveyed from Dill Creek to McKenzie Diversion Dam (RM 21-16) on September 12 , 1997, and from RM 28-16 on October 2-3, which was also the first summer chinook survey.

We estimated the number of spring chinook salmon spawning in the Entiat River by expanding redd counts using two different estimators. The estimator of 2.4 chinook salmon adults per redd is widely used and generally accepted in the mid-Columbia basin. This estimator is used under the assumption that all redds were counted. Another estimator used by WDFW is 3.5 spring chinook salmon per redd. This estimator is used to determine the number of spawning spring chinook adults in the Entiat River given redd counts from only the index area (RM 28-21).

### *Summer Chinook Salmon*

Methods were the same as for spring chinook salmon surveys with a few differences in area surveyed and survey frequency. The area from Fox Creek campground to McKenzie Diversion Dam (RM 28-16) was divided into several reaches and each was surveyed two to three times by two surveyors. Redd locations were marked with biodegradable flagging on nearby vegetation, and carcasses were cut in half to prevent recounting. The number of summer chinook salmon that spawned was estimated by expanding redd counts using the estimator of 2.4 chinook salmon per redd. The lower 16 miles was covered by bicycle and only river portions within view of Entiat River Road were covered. Therefore, approximately 50 percent of this stretch was surveyed.

Temperature probes were placed in the main spawning areas to help assess its affect on egg mortality (Appendix 2).

***Sockeye Salmon***
Sockeye salmon and/or redds were searched for on all surveys.

***Summer Steelhead Redd Survey on Mad River***
See Appendix 3.

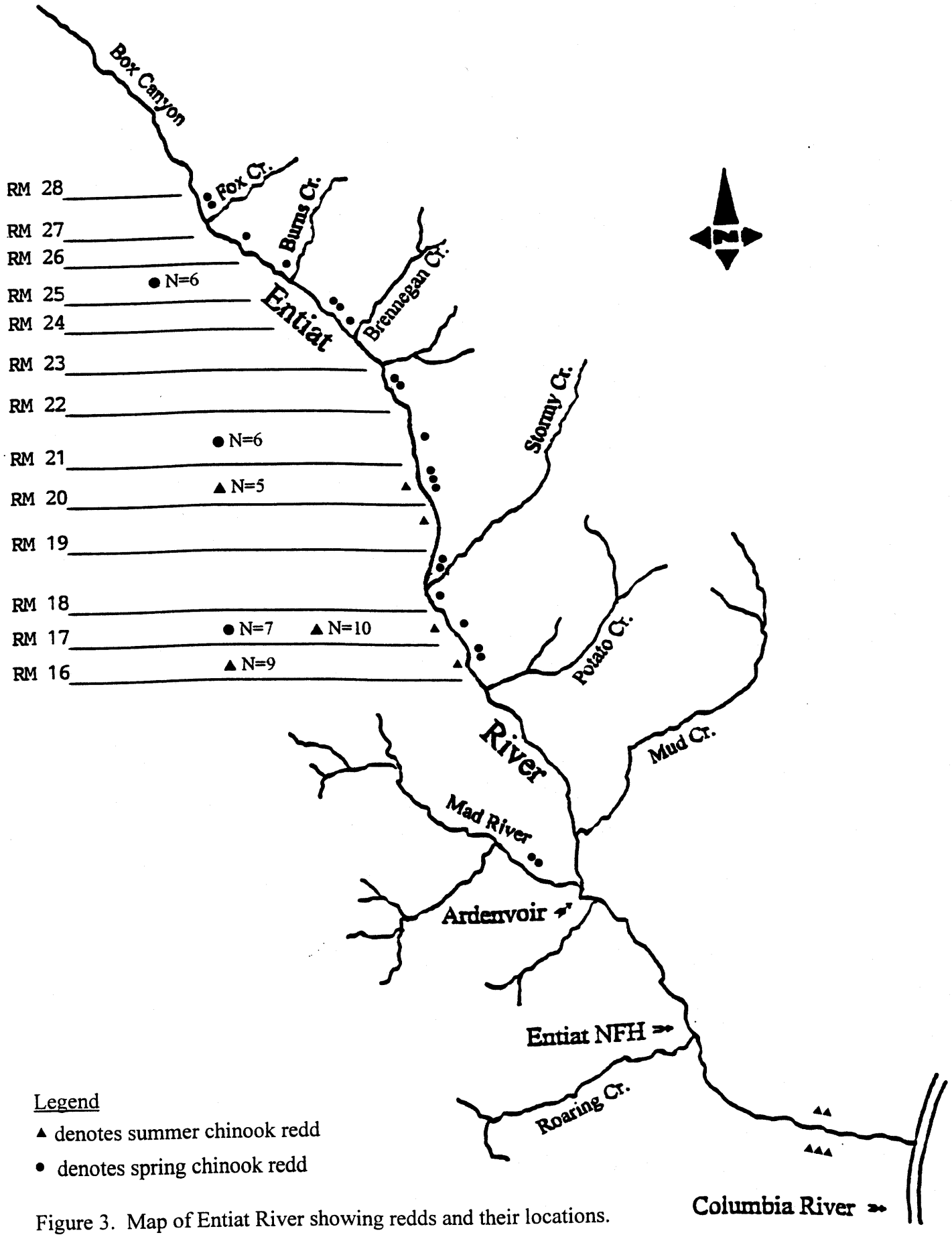
## RESULTS

***Spring Chinook Salmon***
Twenty spring chinook salmon redds were counted in the old "index" area (RM 28 to 21), (Table 1). Below the index area (RM 21 to 16), an additional 17 redds were found and two of these were in Mad River. The complete survey identified a total of 37 redds and seven carcasses (Table 2, Figure 3, and Table 4). The index count was 54 percent of the total as compared to 40 percent in 1996 and eight percent in 1995. The area from RM 28 to 16 probably included all or most of the spring chinook salmon spawning in the Entiat River since spring chinook are not known to spawn in the lower river. However, some spawning gravel (very little) exists in those areas not surveyed (RM 1 - 16), and it is possible that some spawning occurred in that area. For the 1997 "index" count, multiplication of the 20 redds by the estimator of 3.5 fish per redd yields an estimate of 70 spawners. Assuming all redds were counted, the total redd count of 37 multiplied by the estimator of 2.4 fish per redd gives an estimate of 89 adults escaping to spawn in the Entiat River. The peak of spawning appears to have occurred the first week in September (Table 3). No marked spring chinook were seen, however WDFW was recovering snouts from marked fish during their effort to collect genetic information (see below).

***Summer Chinook Salmon***
Twenty-five summer chinook salmon redds were counted in the main survey section (RM 28 to 16), and these were all found below RM 20.3 (Table 2 and Figure 3). Five redds were located at RM 0.5. There was a total of 30 redds and five carcasses found (Appendix 2). The first summer chinook redd was discovered on the October 3rd survey with the peak of spawning occurring the third and fourth weeks in October (Table 3). Multiplying the 30 redds by the estimator of 2.4 fish per redd yields an estimate of 72 summer chinook salmon adults escaping to spawn in Entiat River. This estimate should be considered a minimum since the lower 16 miles were not completely surveyed. No marked hatchery fish were found.

***Sockeye Salmon***
One adult sockeye salmon was observed near RM 16.5 (Kate Terrell, USFWS, pers comm.).

***WDFW Spring Chinook Salmon Genetics Study***
Starting in 1997, WDFW is attempting to take live spring chinook salmon in an effort to determine the genetic make-up of natural spawning fish in the Entiat River. Three of the fish that were taken had coded-wire-tags implanted in their snouts. All three of the fish (one summer and two spring chinook) were strays. One of the tagged spring chinook originated from Methow SFH and the other two were from the Snake River basin (Table 4).




Legend

▲ denotes summer chinook redd

• denotes spring chinook redd

Figure 3. Map of Entiat River showing redds and their locations.

Table 2. Number of redds and their locations on Entiat River, 1997.

| RIVER MILE | # OF SPRING CHINOOK REDDS | # OF SUMMER CHINOOK REDDS |
|---|---|---|
| 27 - 28 | 2 | 0 |
| 26 - 27 | 1 | 0 |
| 25 - 26 | 6 | 0 |
| 24 - 25 | 2 | 0 |
| 23 - 24 | 1 | 0 |
| 22 - 23 | 2 | 0 |
| 21 - 22 | 6 | 0 |
| 20 - 21 | 3 | 5 |
| 19 - 20 | 0 | 1 |
| 18 - 19 | 3 | 0 |
| 17 - 18 | 7 | 10 |
| 16 - 17 | 2 | 9 |
| 0 - 1 | 0 | 5 |
| Mad River | 2 | 0 |
| **TOTAL** | **37** | **30** |

Table 3. Survey dates and number of new redds found, 1997

| SURVEY DATES | SPRING CHINOOK REDDS | SUMMER CHINOOK REDDS |
|---|---|---|
| September 11, 12 | 30 | 0 |
| October 2, 3 | 7 | 5 |
| October 23 | 0 | 11 |
| November 4 | 0 | 12 |
| November 18 | 0 | 2 |
| **TOTAL** | **37** | **30** |

Table 4. Sex, age, and fork lengths of spring and summer chinook salmon carcasses sampled in the Entiat River, 1997.

| Fish # | Sex | Length (cm) | Species | Age | Spawned |
|---|---|---|---|---|---|
| 1. | Female | 72 | **Spring Chinook** | 4 | yes |
| 2. | Female | 70 | " | unk | yes |
| 3. | Male | 89 | " | 4 | |
| 4. | Male | 92 | " | 4 | |
| 5. | Female | 86 | **Summer Chinook** | 4 | yes |
| 6. | Female | 101 | " | 5 | yes |
| 7. | Female | 98 | " | 4 | yes |
| 8. | Male | 86 | " | 4 | |
| 9. | Male | 88 | " | 4 | |
| 10. | Unk | 95 | " | 5 | |

Unk = Unknown

Fish taken by WDFW, Entiat River, 1997

| Fish # | Sex | POH Length(cm) | Species | Age | Place of Origin (tag code) |
|---|---|---|---|---|---|
| 1 | Female | 61 | Sp Ch | 4 | Idaho DFG, Powell Rearing Ponds (10-35-18) |
| 2 | Female | 60 | Sp Ch | 4 | Methow SFH (63-55-51) |
| 3 | Male | 68 | Su Ch | 4 | Idaho DFG, McCall SFH (10-30-40) |

Table 5. Estimated escapement in 1997 of wild spring and summer chinook between Rocky Reach and Wells dams using the difference between dam counts reduced by the number of salmon taken at state and federal fish hatcheries (includes jacks).

| Count | Spring chinook | Summer chinook |
|---|---|---|
| Rocky Reach Dam[1] | 2014 | 6750 |
| Wells Dam[2] | 971 | 2721 |
| Difference | 1043 | 4029 |
| Entiat NFH-# Fish Taken | 275 | 0 |
| Wells SFH-# Fish Taken | 0 | 1181 |
| Potential Entiat R. natural spawners | 768 | 2848 |

[1] Chuck Peven, Chelan County Public Utility District, pers comm. 1997.
[2] Rick Klinge, Douglas County Public Utility District, pers comm. 1997.

## DISCUSSION

Wild spring chinook salmon adult returns to Entiat River in 1997 were again at low levels. The index count of 20 redds is the third lowest on record and 16.5 percent of the 1962 to 1996 average of 121. Since 1980, redd counts have been depressed. Index counts have averaged only 46 redds for years 1987 to 1996. Spring chinook salmon counts at Rocky Reach and Wells dams were also low this year, although much higher than the previous three years (Table 5). Counts at Rocky Reach Dam were 64 percent of the previous 15 year (1982 to 1996) average of 3143, and 48 percent of the same 15 year average at Wells Dam of 2043 spring chinook salmon. Potential adult spring chinook salmon escapement (after deducting hatchery returns) between the two dams is estimated at 768 (Table 5) compared to the number generated by redd expansions of 89. Both methods of estimating the size of the wild salmon spawning population have inherent assumptions that influence their results. Dam counts suffer from possible multiple counts due to fall back and failure to account for pre-spawning mortality. The date for separating the chinook run into spring and summer components is founded on historical dam counts. It does not allow for overlap of run timing between stocks nor annual variability in run timing for each stock. On the other hand, the accuracy of redd counts can be influenced by salmon spawning outside of the survey area, observer error, and/or the use of an incorrect expansion factor to estimate the number of spawners from redd counts. Given the inherent problems with each estimation method, we believe that the expanded redd counts provide a better monitoring tool, compared to dam counts, for determining trends in the Entiat River. We do not believe that the actual number of spring chinook spawning in the Entiat River differs significantly from our estimate of 89 fish.

In 1997 we conducted three full summer chinook surveys and one near RM 0.5 in mid-November (Table 3). The five redds found in the lower river was similar to counts noted from aerial surveys from 1977 to 1991. In 1994 USFWS conducted the first summer chinook redd survey in the Entiat River when eleven redds were found. In 1995 surveyors located 40 summer chinook redds in the same area (RM 28 to 16), and 45 were found in 1996. Counts at Rocky Reach Dam of 6750 summer chinook exceeded the 15 year average (1982 to 1996) of 4641 (Table 5). The difference in counts (after subtracting hatchery brood takes) between Rocky Reach and Wells dams was 2848 fish (Table 5), which greatly exceeds the estimate from the Entiat River redd expansion of 72 (2.4/redd) summer chinook. Had the entire lower river been surveyed (ground or aerial) some additional redds may have been found, although suitable spawning gravels are lacking in this area. The two redds discovered on the November 18 survey may have been fall chinook redds. Again, inherent problems with dam counts cause us to prefer using redd counts to better quantify the number of summer chinook actually spawning in the Entiat River.

No sockeye salmon were seen during these surveys, but one adult was observed by USFWS personnel near RM 16.5 while working on other projects.

Table 6. Annual fish counts of spring and summer chinook and sockeye salmon at Rocky Reach Dam, 1962-1997, and Wells Dam, 1967-1997.

| | Spring Chinook | | Summer Chinook | | Sockeye Salmon | |
|---|---|---|---|---|---|---|
| Year | Rocky Reach | Wells | Rocky Reach | Wells | Rocky Reach | Wells |
| 1962 | 3,697 | | 9,295 | | 9,870 | |
| 1963 | 4,644 | | 5,776 | | 37,046 | |
| 1964 | 6,536 | | 10,752 | | 32,159 | |
| 1965 | 2,755 | | 15,975 | | 31,735 | |
| 1966 | 6,962 | | 19,445 | | 129,557 | |
| 1967 | 5,560 | 1,157 | 15,558 | 12,504 | 109,434 | 113,232 |
| 1968 | 6,422 | 4,931 | 14,721 | 8,922 | 91,376 | 81,530 |
| 1969 | 4,400 | 3,599 | 12,996 | 6,846 | 20,374 | 17,352 |
| 1970 | 4,375 | 2,670 | 11,822 | 8,003 | 57,251 | 50,677 |
| 1971 | 4,132 | 3,168 | 10,031 | 5,988 | 49,838 | 48,172 |
| 1972 | 3,894 | 3,616 | 5,577 | 4,141 | 26,978 | 33,398 |
| 1973 | 4,344 | 2,937 | 9,683 | 5,052 | 48,856 | 37,178 |
| 1974 | 4,263 | 3,420 | 8,274 | 4,567 | 20,976 | 16,716 |
| 1975 | 3,353 | 2,225 | 15,367 | 8,522 | 26,925 | 22,286 |
| 1976 | 1,892 | 2,759 | 7,771 | 7,901 | 27,205 | 27,619 |
| 1977 | 5,948 | 4,211 | 10,593 | 7,527 | 25,648 | 21,973 |
| 1978 | 7,396 | 3,625 | 8,095 | 6,419 | 8,157 | 7,458 |
| 1979 | 2,203 | 1,103 | 8,577 | 10,080 | 28,747 | 22,655 |
| 1980 | 1,866 | 1,182 | 5,367 | 4,892 | 29,906 | 26,573 |
| 1981 | 3,529 | 1,935 | 4,668 | 4,276 | 30,649 | 28,234 |
| 1982 | 2,815 | 2,401 | 2,705 | 3,349 | 17,379 | 19,005 |
| 1983 | 3,406 | 2,869 | 2,777 | 2,821 | 26,069 | 27,925 |
| 1984 | 4,171 | 3,280 | 5,875 | 5,941 | 73,290 | 81,054 |
| 1985 | 8,910 | 5,257 | 5,937 | 4,456 | 54,077 | 53,170 |
| 1986 | 4,300 | 3,150 | 5,554 | 4,178 | 32,912 | 34,876 |
| 1987 | 3,586 | 2,344 | 4,078 | 3,142 | 41,115 | 39,948 |
| 1988 | 4,959 | 3,036 | 3,683 | 2,775 | 34,090 | 33,980 |
| 1989 | 3,316 | 1,740 | 5,654 | 3,333 | 16,176 | 15,895 |
| 1990 | 1,951 | 981 | 4,297 | 3,354 | 9,296 | 7,597 |
| 1991 | 1,401 | 779 | 3,158 | 2,028 | 27,439 | 27,492 |
| 1992 | 2,774 | 1,623 | 2,257 | 1,967 | 41,804 | 41,844 |
| 1993 | 4,256 | 2,444 | 4,980 | 3,603 | 28,318 | 23,038 |
| 1994 | 388 | 257 | 7,293 | 4,891 | 1,680 | 1,662 |
| 1995 | 290 | 103 | 5,638 | 5,043 | 4,985 | 4,892 |
| 1996 | 628 | 387 | 5,737 | 4,479 | 21,741 | 17,701 |
| 1997 | 2,014 | 971 | 6,750 | 3,902 | 30,485 | 25,304 |

## REFERENCES


Combs, B.D. 1965. Effect of temperature on the development of salmon eggs. Progressive Fish Culturist. 27(3): 134-137.

Craig, J.A., and A.J. Suomela. 1941. Time of appearance of the runs of salmon and steelhead trout native to the Wenatchee, Entiat, Methow and Okanogan rivers. Unpublished MS, USFWS. 35 pp. plus 18 affidavits and accompanying letters of corroboration. *in* Mullan et. al. 1992, Appendix J.

Fish, F.F. and M.G. Hanavan. 1948. A report on the Grand Coulee Fish Maintenance Project 1939-1947. USFWS, Special Scientific Report 55. 63 pp.

French, R.R. and R.J. Wahle. 1960. Salmon runs - upper Columbia River, 1956-57. USFWS, Special Scientific Report 364.

Mullan, J.W. 1986. Determinants of sockeye salmon abundance in the Columbia River, 1880s-1982: A review and synthesis. USFWS Biological Report 86(12). Leavenworth, WA. 136 pp.

Mullan, J.W. 1987. Status and propagation of chinook salmon in the mid-Columbia River through 1985. USFWS Biological Report 89(3). Leavenworth, WA. 111 pp.

Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, J.D. McIntyre. 1992. Production and habitat of salmonids in Mid-Columbia River tributary streams. USFWS Monograph I. Leavenworth, WA. 489 pp.

# APPENDICES

Appendix 1. River mile index of the Entiat River from the mouth to Box Canyon.

| River-mile | Description |
|---|---|
| 0.0 | Mouth of Entiat River at river-mile 483.7 on Columbia River |
| 0.3 | Head of Pool from Rocky Reach Dam |
| 3.1 | Entiat River Road Bridge |
| 4.5 | Entiat River Road Bridge |
| 7 | Entiat National Fish Hatchery |
| 10.4 | Ardenvoir Road Bridge at Ardenvoir |
| 10.6 | Mad River |
| 15.2 | Potato Creek |
| 16 | McKenzie Ditch and Diversion Dam |
| 18.4 | Stormy Creek |
| 18.9 | "Watch for Ice" sign on Highway |
| 21.2 | Dill Creek |
| 23.1 | Preston Creek |
| 23.4 | Brief bridge |
| 23.9 | Brennegan Creek |
| 25 | McCrea Creek |
| 25.5 | Burns Creek |
| 27.7 | Fox Creek |
| 28 | Fox Creek Campground |
| 28.6 | Tommy Creek |
| 28.9 | Lake Creek Campground |
| 29.2 | Box Canyon |

mileage may not be exact

Appendix 2. Temperature monitoring on Entiat River, 1997

***Temperature Monitoring***

It has been demonstrated that if chinook salmon eggs are initially exposed to water temperatures less than 42.5°F significant mortality will likely occur (Combs 1965). If water temperature is 42.5°F to 56°F for the first 72 hours after deposition, a subsequent drop in temperature below this threshold will not cause abnormal mortality. At the time summer chinook salmon are spawning in the Entiat River, water temperatures are very close to, and sometimes below, this lower threshold.

To help determine the potential impact on summer chinook populations in the Entiat River caused by this temperature variance, USFWS installed temperature recording devices in the spawning areas. Two "Hobo" temperature probes (Onset Computer Corp.) were placed at RMs 21 and 17. Temperature variation between the two units was less than 1°F. Data indicates that during peak spawning of summer chinook salmon in 1997, temperatures dropped below this lower threshold (Figure 4). How this may affect smolt production is unknown. River temperature data obtained from Entiat NFH (ENFH) showed on average a 2.5° increase over our recorders (ENFH is about twelve miles downstream of survey area).

USFWS is currently attempting to gather information on out-migrating spring and summer chinook salmon in Entiat River using an eight-foot rotary screw-trap. In 1997 we captured summer chinook fry during the trapping period from April to early June so some summer chinook are likely produced by fish spawning in the Entiat River.

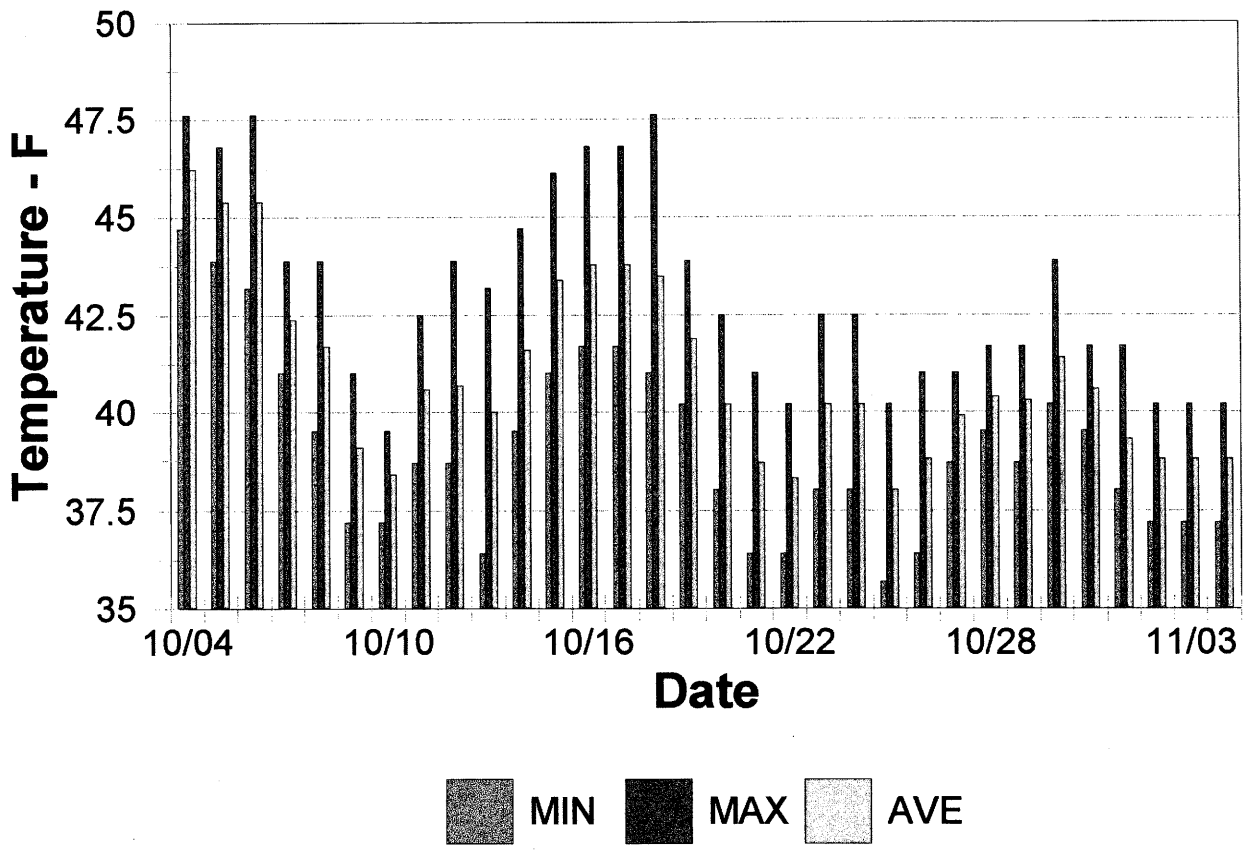

Entiat River - 1997
Daily Temperatures 10/4 - 11/4
Temperature - F
50
47.5
45
42.5
40
37.5
35
10/04
10/10
10/16
10/22
10/28
11/03
Date
MIN
MAX
AVE

Figure 4.