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☐ FCR ____ ☐ RSG ____ ☐ ____

May 14, 2001

Matt St. John
5550 Skylan Blvd. Suite A
Santa Rosa, California 95403

Re: Scott River Stream Temperature Data

Dear Mr. St. John:

As you may know, Fruit Growers Supply Company is working together with the Resource Conservation District, Siskiyou County Schools, U.S. Forest Service, and Timber Products Company to produce a comprehensive review of stream temperatures in the Scott River watershed. Together we have collected over 170 datasets at 68 locations throughout the watershed, including several tributaries as well as several locations on the mainstem Scott.

Data has been collected following protocols established by the Fish, Forests, and Farms Community (FFFC) Technical Committee, including instrument calibration and deployment. The data has been used in the development of a comprehensive report describing the current stream temperature conditions in the Scott. Unfortunately this report is in draft form and not available in it's entirety in an electronic form. Hopefully your department can accept the electronic version at a later date.

In essence the data indicates that tributaries to the Scott are significantly colder than the mainstem. The report attempts to explain these findings in terms of geomorphology and hydrology.

Again, I would like to express my hope that your department is sincerely interested enough in local conditions that additional data and information can be submitted at a later date. Feel free to contact me in this regard by any of the means listed below.

Sincerely,

Kelly E. Conner

Kelly E. Conner
Mgr., Forest Inventory

Fruit Growers Supply Company
1216 Fruit Growers Road
Hilt, CA 96044
(530) 475-3453
(530) 475-3398 FAX
Kconner@fruitgrowers.com

Water Temperatures in the Scott River Watershed in Northern California

PREPARED FOR:

The U. S. Fish and Wildlife Service under a grant partially funding the
Siskiyou Resource Conservation District.

RWQCB
REGION 1
MAY 15 2001
☐ LAM ☐ CRJ ☐
☐ RLT ☐ SAW ☐ KAD
☐ FCR ☐ RSG ☐

PREPARED BY:

Danielle Quigley	Siskiyou Resource Conservation District	Etna, California
Stuart Farber	Timber Products Company	Yreka, California
Kelly Conner	Fruit Growers Supply Company	Hilt, California
Jay Power	USFS – Klamath National Forest	Fort Jones, California
Lorrie Bundy	Natural Resource Conservation Service	Weaverville, California

********Preliminary Draft *******

May 13th, 2001

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ABSTRACT

Under section 303(d) of the Clean Water Act the Scott River has been listed as impaired for water temperature levels. To provide the EPA with the most extensive information regarding stream temperatures for the watershed, the USFS, Timber Products Co., Fruit Growers Supply, and the Siskiyou Resource Conservation District have combined data to co-author this report. The objective of this report was to present the distribution of current water temperatures in the Scott River Watershed, and to compile know historical temperature data on the watershed. An additional objective was to describe and discuss the physical and environmental characteristics of the watershed and how those characteristics are influencing water temperatures.

The Scott River is a free flowing system with no impoundments, and provides habitat for fall chinook salmon (Oncorhynchus tshawytscha), spring chinook salmon (Oncorhynchus tshawytscha), Coho salmon (Oncorhynchus kisutch), and Steelhead trout (Oncorhynchus mykiss). Due to the presence of anadromous salmonid species within the watershed and water quality standards requiring cool stream temperatures, monitoring of water temperatures within the watershed has been conducted for many years and continues today by both public and private landowners and agencies, as well as local schools.

A total of 68 separate temperature monitoring locations were established, with 172 datasets collected between 1997 and 2000.

Setting water quality goals and restoration objectives for the Scott River should take into account the variety of physical geomorphic characteristics, and environmental conditions of the watershed.

1.0 INTRODUCTION

On March 7th, 1997; the U.S. Environmental Protection Agency (EPA), the U.S. Department of Justice, and the U.S. Attorney for the Northern District of California filed an agreement in federal district court to settle a lawsuit with 14 environmental and fishing industry groups concerning development of Total Maximum Daily Load's (TMDL) for 17 river basins in Northern California. Under the federal Clean Water Act a TMDL provides the method for assessing the environmental problems in a watershed and developing a strategy to reach acceptable water quality standards within a set time frame. The Scott River was one of the river basins included in the agreement and a TMDL is scheduled for completion by the EPA in 2005.

Under section 303(d) of the Clean Water Act the Scott River has been listed for impaired sediment and temperature levels in excess of water quality standards described in the Clean Water Act or in the North Coast Regional Water Quality Control Board (NCRWQB) Basin Plan

Due to the presence of anadromous salmonid species within the watershed and water quality standards requiring cool stream temperatures, monitoring of water temperatures within the watershed has been conducted for many years. Public and private landowners and agencies have been collecting water temperature information on the Scott River and its tributaries since 1990. This document represents the efforts of biologists, foresters, managers, and various technical support personnel from the USFS, NRCS, RCD, Timber Products Company, and Fruit Growers Supply Company. Under a grant provided by the U.S. Fish and Wildlife Service and with cooperation of the public and private landowners, this technical report seeks to compile known stream temperature information in the Scott River watershed. An additional objective is to describe and discuss the physical and environmental characteristics of the watershed and how these characteristics may influence water temperatures.

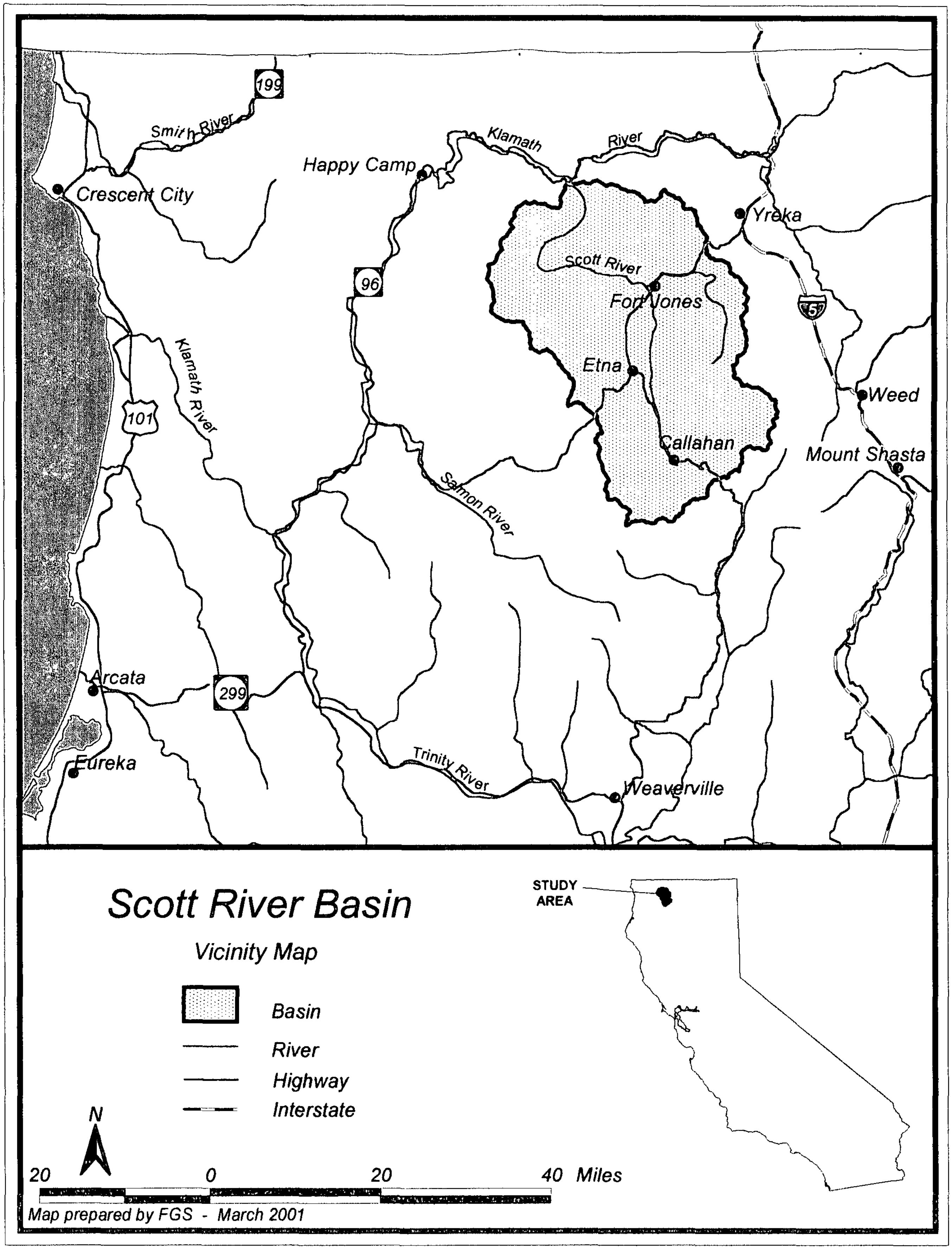


Figure 1. Geographic Location of Study Area.

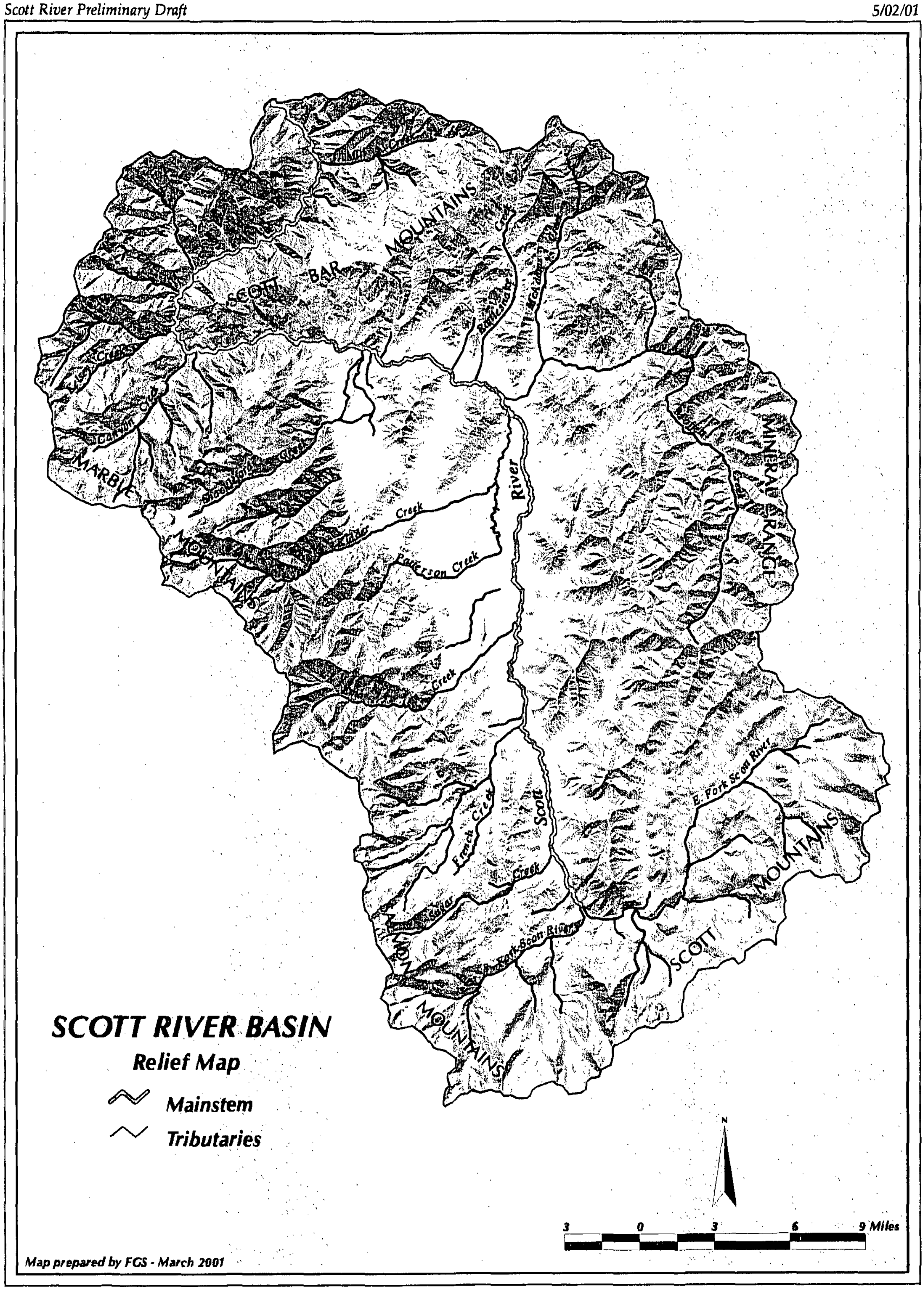


Figure 2. Relief Map of the Scott River Watershed

2.0 ENVIRONMENTAL CONDITIONS

2.1 GEOGRAPHIC RANGE

The Scott River lies in western central Siskiyou County in northern California (Figure 1). The Scott River is part of the Klamath Mountain Province, which encompasses land in both Oregon and California. The Scott River flows northerly to its confluence with the Klamath River near Scott Bar. The Scott River watershed is a large area with substantial variation in geology, geomorphology and climate. The watershed drains a total of 520,612 acres (813 mi^2). The Scott River's headwaters are a horseshoe-shaped range of mountains that surround Scott Valley to the west, south and east.

Scott Valley is bordered on the north and northwest by the Scott Bar Mountains. The Scott Mountains border the south and southeast, and the Salmon and Marble Mountains lie to the west and southwest. In the upper part of the watershed elevations vary from 2,620 -3,100 feet on the valley floor to over 8,000 ft in the high mountain peaks to the south and west. The Scott River enters the Klamath River (RM 143) at an elevation of 1,580 feet.

2.2 TOPOGRAPHY

The Scott River basin is a complex area geologically, with a variety of bedrock and several different geomorphic landscapes. The relief map in Figure 2 shows the varied terrain of the Scott River basin. The basin can be divided into a number of geomorphic landscapes, each with a unique climate, topography, hydrology, and distinctive vegetation.

For the purposes of interpretation this report divides the basin into six geomorphic units based on climate, topography, and hydrology. They are referred to as; East Headwaters, West Headwaters, Valley, Eastside, Westside, and Canyon. Figure 3 shows these units with their respective channel types. The headwaters are divided into East Headwater and West Headwater with the primary difference being the broad alluvial valley characteristic of the East compared to the more rapidly drained narrow alluvial nature of the West. The East Headwater has a large component of irrigated pasture, and the West is generally steeper with shorter tributaries and was hydraulically mined in the late 19th century.

The Valley sub-basin is dominated by the alluvial mainstem of the Scott River with its large-scale dredger tailings and irrigated fields. The river channel in the valley is broad and shallow, as wide as 300 feet. To the east of the Valley is the Eastside unit, which receives very little precipitation and is composed primarily of short gulches that produce limited ephemeral flows.

The Westside unit receives the majority of the annual precipitation in this basin, and produces the greatest yield of flow to the Scott River and the irrigated valley throughout the summer. This unit yields an estimated 100,000 acre feet of runoff during the summer months(Mack et al). This unit is composed of complex watersheds originating in high mountain springs.

In the Canyon unit the Scott River enters a deep canyon. The channel is steep and dominated by large boulders. Tributaries in this unit are steep high-energy mountain channels that route water quickly to the mainstem.

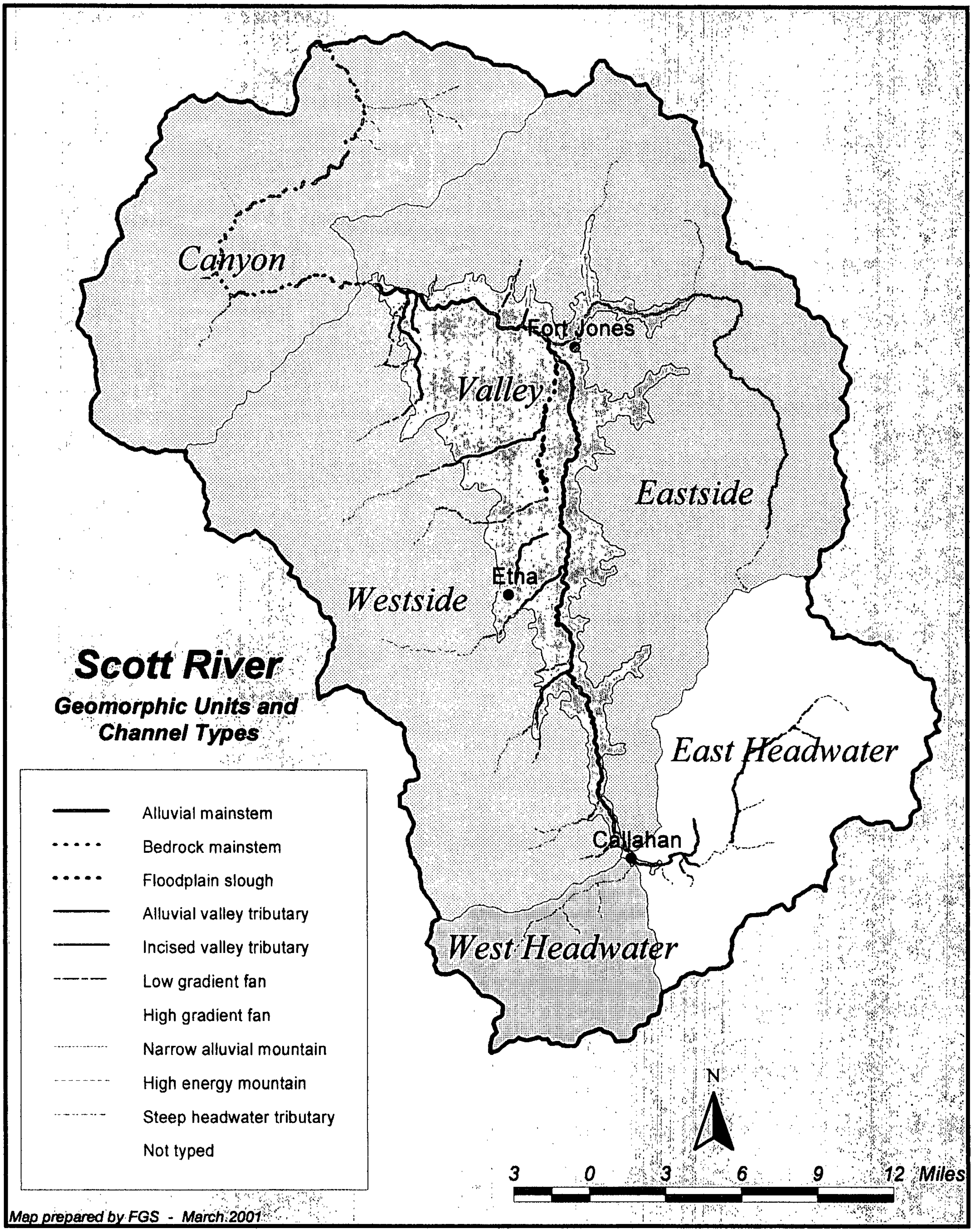
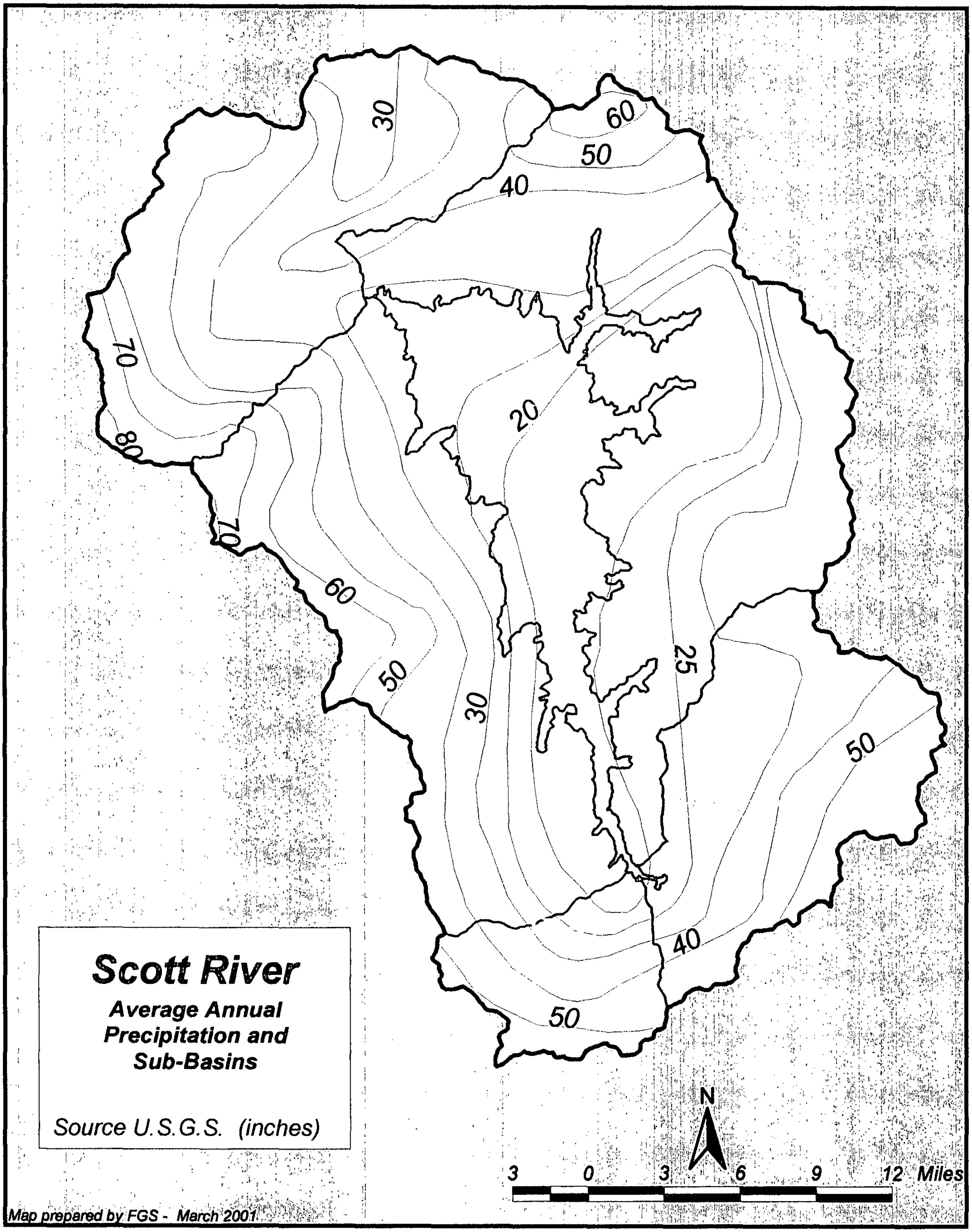


Figure 3. Geomorphic Units and Channel Types



Scott River

Average Annual Precipitation and Sub-Basins

Source U.S.G.S. (inches)

Map prepared by FGS - March 2001

Figure 4. Annual Precipitation Paterns for the Scott Valley

2.3 CLIMATE

Overall, the climate of the Scott River area is a Mediterranean type, with a warm, dry summer season and a cold, wet winter season. Average Daily Air Temperatures in the region around the Scott Valley range from the low 30°'s F in the winter to mid- 90°'s F in the summer. However, there is large variability in local climate due to elevation changes from 8,200' at the high mountain headwaters, to 1, 580' at the confluence with the Klamath. In the rugged mountains to the west and south of the Scott Valley, the climate is colder and dominated by snowfall. At the lower end of the watershed, the climate is warmer with little snow. Figure 5 displays daily air temperature averages and extremes at the National Weather Service Station in Fort Jones.

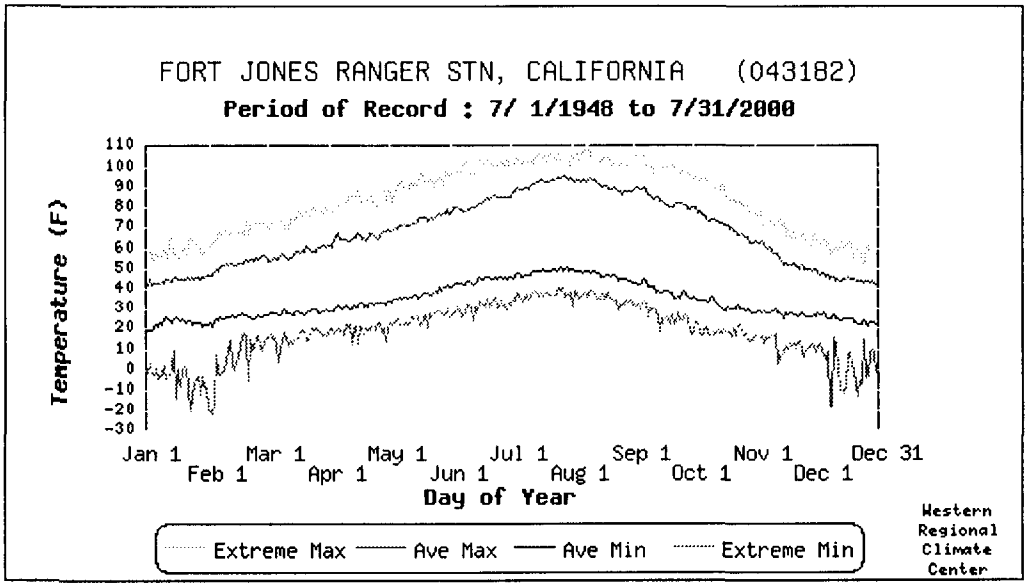


Figure 5. Daily Temperature Averages and Extremes. (From Website reference.)

Precipitation in the Scott River Watershed is produced by storms originating from the Pacific Ocean. Most of the precipitation above 4,500 feet falls as snow. The 7000- 8000' Marble-Salmon-Scott Mountains that lie to the west of Scott Valley exert a strong orographic effect on incoming storms, producing annual precipitation in the range of 60- 80". Most of this precipitation falls in the West Headwaters, Westside and Canyon sub-basins. It is the heavy snowpack in these sub-basins which contribute to the summer flows in the major tributaries. In the Valley sub-basin, annual precipitation declines to 22"-30" and in the Eastside sub-basin precipitation declines to 12" –15". About 80% of the rainfall occurs between the months of October and March (See Figure 6 - Average Monthly Precipitation).

Due to the proximity to the Pacific Ocean, winter storm systems vary between warm and cold fronts. This tends to produce a zone between 4000' and 5000' where precipitation varies between rain and snow, known as the transient snow zone. A cold storm with snowfall followed by a warm storm with rainfall can produce a "rain-on-snow" event which can produce large amounts of runoff. These events have resulted in the floods of record within the basin (1955, 1964, 1997).

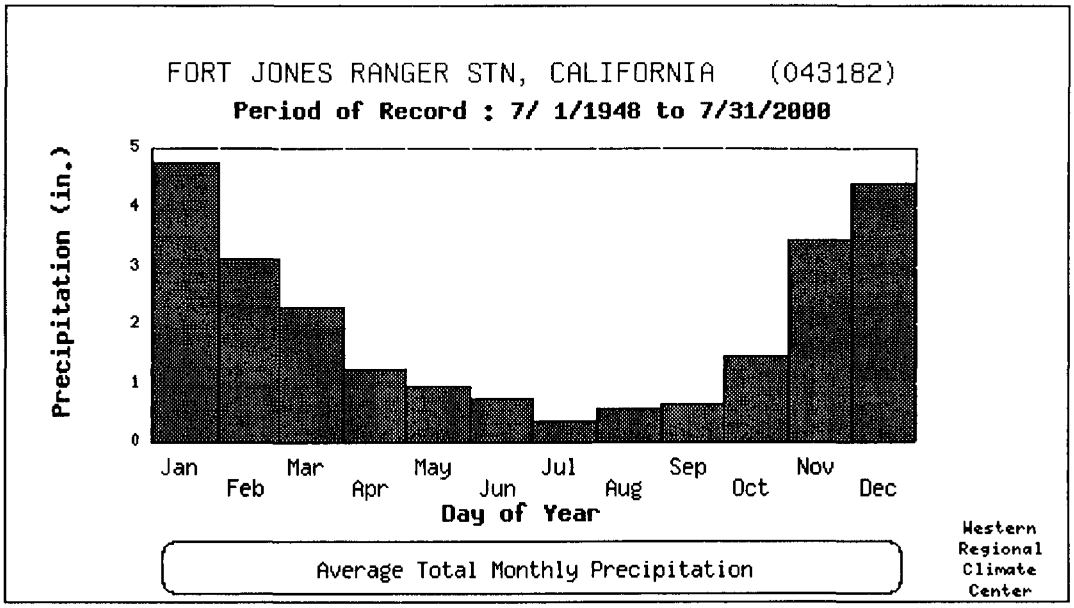


Figure 6. Average Monthly Precipitation. (From Website reference).

Thunderstorms sporadically occur during the generally dry summer months. Generally these localized storms do not have any effect on the flow of the Scott River, but occasionally they are widespread and intense and result in increased flow in the Scott River for several days. When this occurs, it quickly decreases water temperature in the Scott River. These thunderstorms are indicated in Figure 7 as the maximum peaks during the summer months.

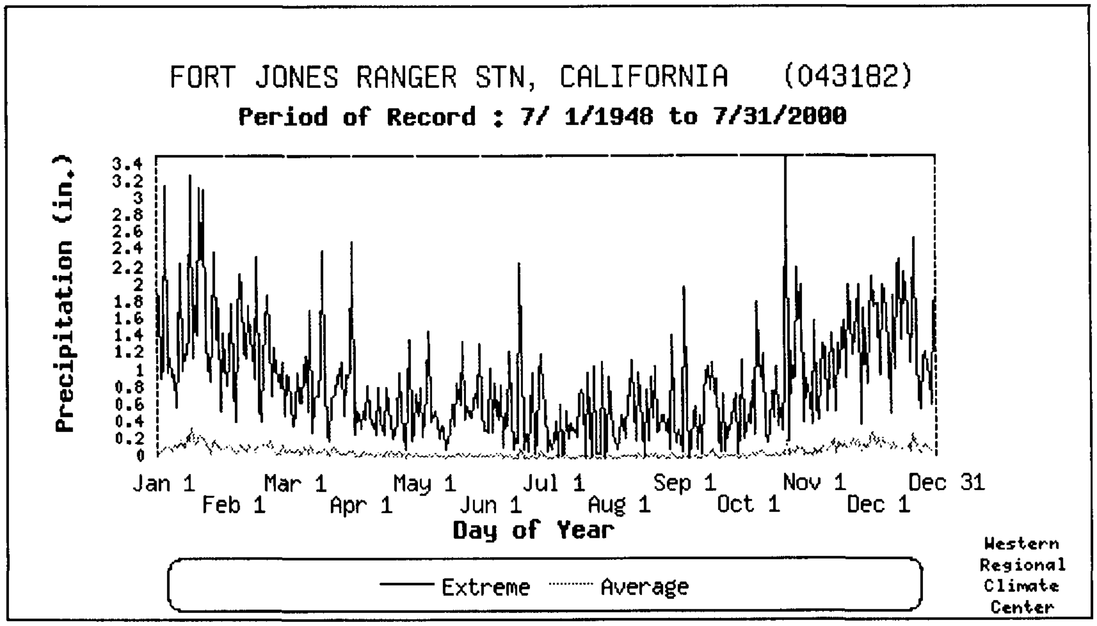


Figure 7. Daily Precipitation Average and Extreme (From Website reference).

2.4 LANDSCAPE VEGETATION

Due to the complex geology and diverse soils of the Klamath Mountains, the Scott River watershed has a rich diversity of landscape vegetation. The watershed has three dominant landscape vegetation types: valley floor grasslands, foothill chaparral and oak woodland, and mountainous coniferous forests (Mayer and Laudenslayer, 1988).

Valley Floor Grasslands - Annual grasslands and pastures occur throughout the watershed, but primarily within the Valley subbasin, and the alluvial valley of the East Headwaters. These grasslands occur on flat to gently rolling foothills and in some cases are naturally flooded, or seasonally irrigated. Density and height of vegetation can depend on the growing season, soil type, drainage, plant species mix, grazing management, and many other factors. Annual grasslands and pastures often occur adjacent or in association with cropland.

Foothill Chaparral and Oak Woodland - Generally, chaparral types occur at lower elevations and dryer climatic regions on thin, well-drained soils composed primarily of sand, gravel, and rock. Dominant species groups in the foothill chaparral can include huckleberry oak/pinemat manzanita, blue brush, manzanita, juniper, incense cedar, and mountain whitethorn series. Dominant species in the oak woodland can include white oak, chaparral oak, and many species of ceanothus, and manzanita.

Mountainous Conifer Forests - The Conifer forests in general include mixed conifer, ponderosa pine and true fir forests. These forests consist of tall, dense to moderately open coniferous forests with patches of broad-leaved evergreen and deciduous trees and shrubs. Broadleaf trees include Oregon white oak, California black oak, Canyon live oak, maple, chinkapin, and madrone. These mixed types include a dense understory which can include, manzanita, ceanothus, tan oak, chinkapin, dwarf oregon grape, western thimbleberry, rose, and snowberry.

2.5 GEOMORPHOLOGY

The Scott River is a unique northern California river in that its upper and lower segments flow through mountainous terrain, similar to the Trinity or Salmon, yet the middle 30 miles of the Scott flow through a large alluvial valley. There is great diversity in geology and topography between the different sub-basins.

Identifying and classifying streams channel types based on morphologic characteristics provides a method for rating their resulting stream water temperatures and their relative value to anadromous fish species (Murphy *et al.* 1987). (Rosgen is the most commonly used and recently adopted by the Forest Service). Pertinent morphologic characteristics that were considered include general landform, stream order, channel gradient and channel confinement. The large tributaries in the Canyon – Canyon, Kelsey and Tompkins Creeks have been inventoried by the Forest Service using the Region 5 USFS methodology. Portions of Shackleford, Sugar, Patterson, Crystal, and Moffet have been habitat typed by FGS using DFG protocols. However, the main Scott River and most of the tributaries that enter Scott Valley have not been channel typed.

Landform reflects the underlying bedrock and the long-term history of events controlling regional landscape evolution, such as glaciation and tectonic uplift. Stream order and gradient are surrogates for stream energy, which regulates the ability of the channel to transport sediment and large woody debris. Channel confinement governs the ability of the channel to migrate laterally, which in this watershed determines the amount of direct exposure to solar radiation. These basic characteristics influence relative fish value by creating the dominant sediment input processes, large woody debris recruitment process and the water temperature heating and cooling processes.

Many of the stream channels in the study area have undergone enormous changes during recent historic time. For the main Scott River, there were several floods in the 1880's that created severe bank erosion in Scott Valley. Although there is no factual information on the character of the Scott River channel prior to these events, it is clear that this began a period of destabilization of the channel that resulted in a wider and shallower channel. The large winter floods of 1955 and 1964 also had a profound effect on the character of the main Scott River channel. In addition, the Army Corps of Engineers channelized the River and removed much of the riparian vegetation in the 1930's. The net result for the Scott in Scott Valley is now a wide (up to 300'), shallow channel with almost no vegetation cover. This channel is almost entirely exposed to solar radiation resulting in the potential for a large amount of solar heating.

Many of the tributary channels were also affected by the 1955 and 1964 floods, with the '64 flood generally having the greater effect. There is no information on whether the tributary streams were impacted by the 1880's floods. Some of the channels in the study area, notably Tompkins Creek, were also impacted by the New Year's flood of 1997. The typical result of these floods on tributary channels has been to increase channel width and remove riparian vegetation, which increases the exposure of stream water to solar radiation.

2.6 HYDROLOGY

Daily stream discharge is shown in Figure 8. The Mediterranean climate with wet winters and hot dry summers produce yearly discharge pattern that consists of low stream flows in the late summer/early fall and high discharge in the winter. The typical yearly hydrograph can be characterized by 3 phases:

Phase 1 – low summer/fall flows, mid-July to mid-November. Virtually all of the previous winter's snow and rain has moved through the stream system and the Scott is sustained by base flow from groundwater. During dry years, portions of the mainstem Scott River and major tributaries go completely dry.

Phase 2 – Increasing winter discharge in response to rain storms, November – April. Notice the gradual increase in discharge through the winter.

Phase 3 – Spring/Summer snowmelt runoff, followed by a rapid decrease in snowmelt runoff, April to Mid-July.

However, there is also strong variability from year to year based on that year's total precipitation and the timing of precipitation during the winter.

The large variability in elevation, geomorphology and climate between sub-basins results in multiple inputs to the discharge and temperature characteristics of the Scott River. For example, the tributaries on the Westside of Scott Valley contribute a large amount of runoff derived from a mix of rainfall and snowfall. These tributaries provide perennial flows to the mainstem. The tributaries on the eastside of Scott Valley have much less runoff that is derived almost entirely from rainfall, these tributaries only flow ephemerally.

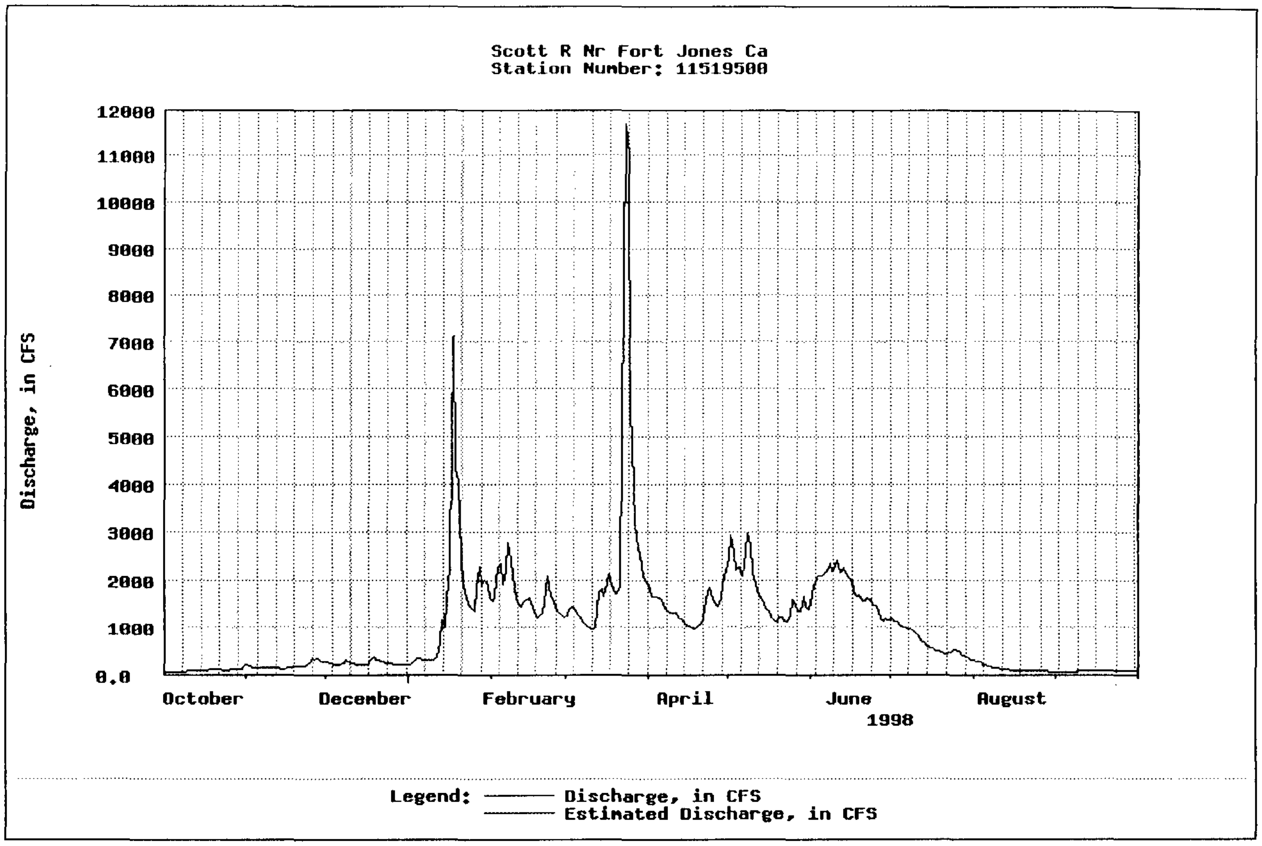


Figure 8. Typical Daily Stream Discharge, Scott River near Fort Jones USGS Gauge.
(From Website reference.)

2.7 GROUNDWATER

The Scott River flows through a large valley, Scott Valley, containing a large groundwater aquifer. The aquifer is comprised of 2 basic geologic components – flood-plain sediments along the bottom of the Valley and alluvial fan deposits along the edges of the Valley. The ground-water storage capacity of sediments lying between 10 and 100 feet below the land surface beneath the entire Valley is estimated to be 400,000 acre feet. Storage capacity in the flood-plain sediments is about 220,000 acre feet (Mack, 1958). The flood-plain deposits have higher permeability than the alluvial fan deposits (Mack). Thus, the flood-plain deposits have a very strong influence on the flow and the temperature of the Scott River in the Valley reach due to the large size of the aquifer, the fact that it consists of very permeable alluvium and the fact that it flows through and interacts with the River for 30 miles. (**need a reference**)

Recharge of the Scott Valley ground water body is caused by direct infiltration of winter precipitation and infiltration from tributary streams as they flow over permeable alluvium in the Valley, especially those streams from the western mountains. The regional aquifer in Scott Valley also receives infiltrated water from the numerous irrigation ditches, but the volume of ditch leakage and its contribution to the aquifer is unknown.

Winter precipitation greatly increases the discharge of the Scott River from November to June. There is a marked peak in discharge from snowmelt runoff from mid-April to June each year. During the dry summer, after the snowmelt has been discharged, the flow of the Scott is sustained by base flow from groundwater. There is no information available on the location, volume and water temperature of groundwater inflow. By late summer, the flow of the Scott at the USGS gage at the lower end of the Valley declines to a very low level. In the last decade the August – September flow averages around 20-25 CFS. In the 40's and 50's this flow was typically around 50 CFS. The cause of this apparent decline is being debated, but is appears to be due to a mix of climatic and water use factors.

During below average water years, surface flow ceases in several reaches of the River in Scott Valley. Groundwater inflow to the River is cooler than surface flow in the Scott River. This is evidenced by the fact that isolated pools during dry periods have cooler water than the flowing stream.

Table I. Capacity of Groundwater Storage Units.

Storage Unit	Location	Area (acres)	Storage Capacity (Acre-ft)
1	Scott River Flood Plain	16,000	220,00
2	Discharge Zone at edge of Western Mountain	6,500	31,000
3	Western mtn fans and Oro Fino Valley	8,400	50,000
4	Quartz Valley	4,800	61,000
5	Moffet-McAdams Creek	2,600	35,000
6	Hamlin Gulch	1,600	10,000

(From Mack et al)

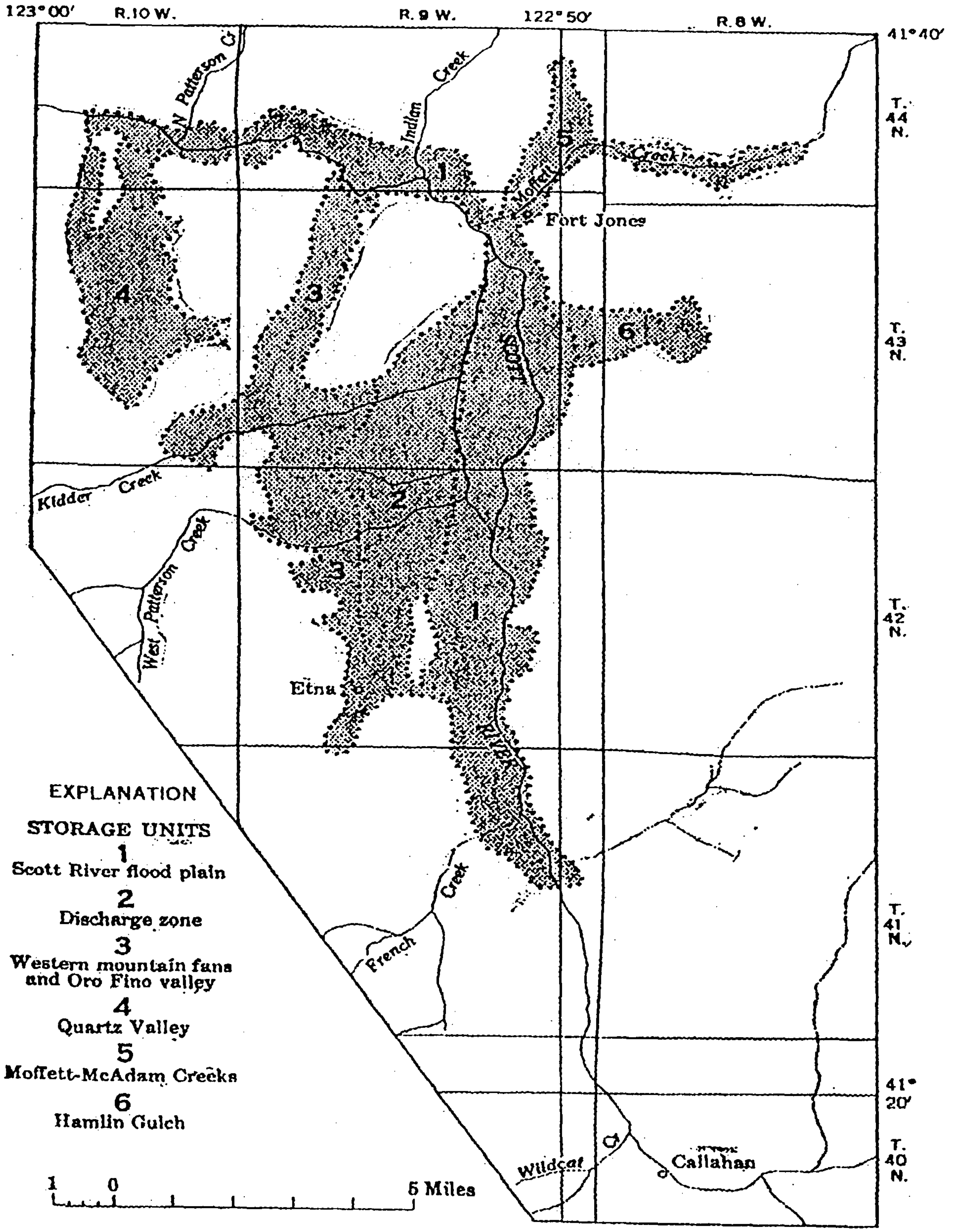


Figure 9. Groundwater Storage Units

3.0 BIOLOGICAL CONDITIONS

Since the Scott River is free flowing with no impoundments, the distribution of anadromous salmonid species is very extensive. Fall chinook salmon, Spring chinook salmon, Steelhead trout, and Coho salmon migrate into the basin, spawn, rear, and out-migrate from the watershed. All of these species are being considered or have been reviewed under the Endangered Species Act (ESA). Both the fall chinook salmon (Oncorhynchus tshawytscha) and the spring chinook salmon (Oncorhynchus tshawytscha) have been petitioned for listing under the federal ESA. The Coho salmon (Oncorhynchus kisutch) has been listed as threatened in the Scott River. The Steelhead trout (Oncorhynchus mykiss) is under review for listing as threatened in the Klamath Mountain Province.

Each species seeks out and utilizes different habitat for spawning and rearing of young. In addition, each species spawns and rears at different times during the year. Fall and Spring Chinook utilize the mainstem for spawning and rearing, while Coho and Steelhead spawn and rear primarily in the upper tributaries. Chinook spawn in the late fall, after the river begins to cool. In general, the young of the species rear during the winter months and migrate from the system in early May and June. Coho and Steelhead spawn in late winter and early spring. The young of these species spend a year or more in the system before they out-migrate. Consequentially, summer water temperatures are important for their health. Due to the different locations and timing of their lifecycles, each species has different water temperature needs.

4.0 HYDROLOGICAL AND GEOLOGICAL SUB-BASINS

Due to the large variability of climate and geomorphology in the Scott River basin, this investigation has grouped the Scott River into six 'reaches', or sub-basins, with similar geomorphic and hydrologic characteristics. Figure 3 shows the sub-basins and hydrological channel types. The six reaches are: the East Headwaters, West Headwaters, Valley, Eastside, Westside, and Canyon.

EAST HEADWATERS

The headwaters of the Scott River are the East and South Fork which meet at Callahan to form the mainstem of the Scott River. The East Fork drains out of the Scott Mountains, and flows in a southwestern direction to its confluence with the mainstem at Callahan. Elevations in this drainage range from 2,720 feet at Callahan to 8,540' at China Mt. The East Fork drains a total of 72,650 acres, 14% of the Scott River watershed. Annual average precipitation in the East Fork Watershed is 30-40 inches per year. Land use consists of a mix of federal and commercial forestland, rangeland and irrigated agricultural land.

The morphological characteristics of this sub-basin begin with steep headwater tributaries which are generally small, low-order, high gradient streams that transport precipitation in the form of rain. These high gradient streams flow into narrow alluvial mountain channels that are low gradient, moderately confined valley bottoms. These channels are bordered by discontinuous alluvial floodplains.

WEST HEADWATERS

The South Fork drains the Salmon Mountains in the Southwest portion of the Scott Valley, and flows in a northeastern direction towards its confluence with the East Fork. Elevations range from 3,120 feet at

Callahan to 7,400 feet at the divide. The South Fork drains a total of 25,133 acres, 4.8% of the Scott River Watershed. Mean annual precipitation ranges from 40-to 60 inches. This sub-basin is composed primarily of commercial forestland and wilderness areas with scattered rural residences along the South Fork.

The morphological characteristics of this sub-basin include steep headwater tributaries that are generally small, low-order and high-gradient streams. Stream flows are significantly influenced by snow accumulations and runoff, which transport quickly through steep stream reaches to the lower gradient Scott River.

VALLEY

The valley portion of the Scott River runs south to north for about 30 miles, from the confluence of the two Forks, to the beginning of the canyon. Elevation of the valley ranges from 2,630 feet to 3,120 feet. The Valley encompasses 59,877 acres, 11.5% of the watershed. Precipitation ranges from 20-30 inches per year. Land use in primarily agricultural and the land is heavily irrigated. Much of the river has been stabilized to prevent erosion, and is thus more confined than its historic channel. There is little riparian vegetation along the river. Major tributaries to this reach come from Westside mountain streams.

The morphological characteristics of this sub-basin include alluvial valley tributaries which include the lower sections of larger tributary streams where they enter the mainstem floodplain (ex. lower French Creek) Channels are unconfined with gradients of less than 2 percent. This sub-basin also includes the alluvial valley mainstem channel of the Scott River. General landform processes have created a wide, flat floodplain and sinuous channel pattern where bars, islands, side and/or off-channel habitats are common.

The mainstem was dredged from the 1930's to 1950's leaving large-scale tailings from Callahan to French Creek (approximately six miles). These features dominate the hydrologic nature of the river in this reach. The Army Corps of Engineers straightened out the mainstem between Etna and Fort Jones in the 1930's. This drastically altered the hydrologic properties of this river system at both the landscape level as well as locally. The severe flood events of 1955 and 1964 further eroded the stream bank, leaving the river with a wide shallow channel. Today people that live and farm along the river protect their land from erosion by armoring with rip- rap to maintain the current channel position.

WESTSIDE MOUNTAINS

The Marble Mountains to the west of the valley are the source of several perennial streams. Etna, French, Kidder/Patterson, and Shackleford are the major drainages on the Westside. Elevations range from 2,700 ft in Quartz valley to 8,200 ft at Boulder Mtn. The Westside drains 116,342 acres, 22.3% of the watershed. Mean annual precipitation ranges from 30 inches at lower elevations to 80 inches in the upper elevations. Most of the precipitation falls as snow in the upper elevations (above 4,000 feet). This snow accumulation sustains the flow through the early summer months. Land use is primarily wilderness and commercial forestland with rural residences in the lower elevations.

The morphological characteristics of this sub-basin include steep headwater tributaries that are generally small, low-order and high-gradient streams. Stream flows are significantly influenced by snow accumulations and runoff, which transport quickly through steep stream reaches to the lower gradient. These high gradient streams flow into narrow alluvial mountain channels that are low gradient, moderately confined valley bottoms. These channels are bordered by discontinuous alluvial floodplains in the lower reaches.

EASTSIDE FOOTHILLS AND MOFFETT CREEK

The eastside of the valley is dominated by generally dry foothills extending north from the Scott Mountains. Watershed elevation ranges from 2,700 to 6,050 feet. The largest sub-basin is the Moffett Creek watershed, which drains 145,846 acres, or 28% of the Scott river watershed. Moffett Creek and some of its tributaries are the only streams within this region, which flow year round. Average annual rainfall ranges from 12-15 inches.

Tributary streams are typically very short and drain rapidly, running intermittently or seasonally. Land use is primarily range land and federal and commercial forestland. Upland soils are well drained with slow permeability. The upland portion of the watershed has localized sheet and gully erosion. Moffett Creek is the principal stream, and flows in a northwest direction before meeting with the main stem Scott River, north of the town of Fort Jones.

CANYON

The Canyon reach is defined as the first 20 miles of the river from the confluence with the Klamath River. The Marble Mountains and Scott Bar Mountains contribute to the flows in this reach. The canyon drains 97,802 acres, 18.8% of the watershed. The mean annual precipitation is 40 -to 70 inches, with much of the precipitation falling as snow pack in the upper elevations. The mainstem channel through this reach is confined bedrock.

The morphological characteristics of this sub-basin include steep headwater tributaries that are generally small, low-order and high-gradient streams. These steep high-energy mountain channels route snowmelt and runoff quickly downstream through bedrock falls, boulder cascades and steep chutes to the mainstem Scott River.

The mainstem Scott River reach is a bedrock confined colluvial canyon that transports water through a series of bedrock and boulder pools, side channels, and riffles. Due to steep canyon walls a significant amount of topographic shade is cast over the Scott River. Land use in this sub-basin is primarily federal and commercial forestland with wilderness areas in the higher elevations, and scattered residences along the river. The major drainages are Kelsey Creek, Canyon Creek, Boulder Creek, Tompkins Creek, and Mill Creek.

5.0 PHYSICAL WATERSHED PROCESSES AFFECTING WATER TEMPERATURES

As in most watersheds, water temperatures are influenced by many physical processes: topography, geologic history, soils, climate and disturbance patterns. Major influences of stream temperature such as dams or large urban impacts are not present in the Scott River watershed. Many of the physical watershed and heat transfer processes that determine stream temperature have been extensively researched and are well understood (Edinger and Geyer, 1968; Brown, 1969; Brown, 1971; DeWalle, 1976; Theurer et al, 1984; Adams and Sullivan, 1990).

5.1 HEAT TRANSFER PROCESS

The physics of stream temperature has been widely studied and generally most researchers have utilized the heat transfer process to describe predicted changes in stream temperature (DeWalle, 1976; Brown, 1969; Beschta, 1984; Theurer et al, 1984; Adams and Sullivan, 1990).

The transfer of heat energy form the environment into the stream occurs through solar radiation, convection with the air, evaporation, conduction with the soil, and advection from incoming water sources (Brown, 1969; Adams and Sullivan, 1990). Brown (1974) states: "The principal source of heat for small forest streams is solar energy striking the stream surface directly." Convection, conduction and evaporation have minor influences in comparison, depending on local circumstances (Brown, 1976). Of the many possible variables that could influence stream temperature, Adams and Sullivan (1990) found that the five environmental variables of riparian canopy, stream depth, stream width, ambient air temperature, and groundwater inflow regulate heating and cooling of streams.

The physics that affects stream temperature are best understood and supported by research when applied on reaches within a watershed (Brown, 1969; Adams and Sullivan, 1990; Sullivan et al, 1990). Water temperature is always adjusting to the immediate air temperature surrounding the stream or the environmental conditions present in the reach. However, heated water can move downstream through a watershed (Brown, 1971), and overall heating of stream temperatures due to many factors has been reported for very large river systems (Beschta and Taylor, 1988). When compared in field testing the reach based understanding of stream heating is more accurate at predicting daily mean and daily maximum temperatures (Brown, 1969; Sullivan et al, 1990).

Brown (1974) offered the following equation to understand and predict heat gains in streams: "The net rate of heat (Q) per unit area added to the stream...is the algebraic sum of net radiation (Nr) , evaporation (E), convection (H), and conduction (C)." This is written as:

$$Q = Nr +/- E +/- H +/- C$$

To estimate change in water temperature it is necessary to estimate total heat added to the stream and know the total volume of water being heated:

$$\text{Change in temperature} = \frac{\text{Total heat added}}{\text{Total Volume Heated}}$$

Total heat added is the product of the rate per unit area (Q) at which heat is received, the area over which it is received (A), and the time extent of heating (t):

$$\text{Total Heat} = Q \times A \times t$$

Total volume heated is determined by multiplying stream's discharge (D) and time:

$$\text{Total Volume} = D \times t$$

The change in temperature equation now becomes:

$$\text{Change in temperature} = \frac{Q \times A}{D}$$

By using a multiplier of .000267 to handle conversion of units the equation above gives the primary components of changes in stream temperature.

Q, heat added, is a function of solar radiation, which varies during the year according angle of the sun and latitude. Of the components of Q, net radiation (Nr) varies significantly during the day/night cycle, whereas evaporation and convection vary little (Brown, 1969). Conduction is important in the heat transfer process in small, bedrock channels and much less a factor in larger, gravel bed channels.

The factor for surface area, A, also has a direct relationship to the change in water temperature. The surface area is not the actual surface area of the stream, rather it is the surface area of the stream that is exposed to direct solar radiation. Factors influencing A are the actual stream surface area, amount of shading, either from vegetation or topography, and orientation as it affects shading (streams flowing north/south are more exposed to solar radiation than those flowing east/west).

D is the amount of water being heated and has an inverse relationship to changes in water temperature, thus smaller streams will heat up faster than larger streams (Brown, 1969).

5.2 WATER MASS PROCESS

Mixing of water from smaller tributaries into larger streams and rivers has been described (Brown, 1969) and extensively used in watershed monitoring efforts (Caldwell et al, 1991). In general, the proportion (flow) of heated or cooled water entering the stream from a tributary determines the rate of increase or decrease in mainstem stream temperature.

Water temperature balance equation from Brown, 1969.

$$\frac{(T1*Q1) + (T2*Q2)}{Q1 + Q2}$$

T1 = temperature of inflow

Q1 = stream flow of inflow

T2 = temperature of receiving stream

Q2 = stream flow of receiving stream

Streams with lower flows cannot store as much heat energy for downstream transport as streams with large flows. The temperature of a large stream will not be influenced substantially by inflows of smaller tributaries. Research in Washington State found that the effect of major tributaries on mainstem streams or rivers extends 150 meters or less (Caldwell et al, 1991). "The response of larger streams or rivers never exceeded 0.5 C change in temperature attributable to an incoming smaller tributary" (Caldwell et al, 1991). "A lack of response was seen in both cases where warm and cool tributaries flowed into large streams or rivers" (Caldwell et al, 1991).

5.3 PHYSICAL AND BIOLOGICAL CONDITIONS INFLUENCING WATER TEMPERATURE

Physical factors influencing water temperatures include the actual stream surface area, amount of shading, and orientation of the stream channel as it affects shading. The physical surface area of the stream, as represented by wetted width increases as the distance from the watershed divide increases (Sullivan, et al, 1990). Shading, from riparian vegetation or topography tends to decrease as the streams' wetted width increases. Both of these factors together tend to increase the stream's exposure to solar radiation as the streams get larger. Researchers have documented that elevation (as it effects ambient air temperature), and distance from the watershed divide (as it effects surface area) are the two most important factors influencing water temperature in large river systems (Sullivan et al, 1990; OSU, 1996). It follows that the temperature level of a stream in any given situation is primarily determined by its surface area exposed to solar radiation. Effects of shading from riparian vegetation and topography decrease with the width of streams. Large streams will have a large surface area exposed to solar radiation and thus will be heated to a higher temperature than narrow streams.

The fluvial geomorphology of streams, especially larger streams, has a direct effect on the surface area of streams exposed to solar radiation. Braided channels and wide shallow channels will have more surface area than single, narrow and deep channels. Low gradient channels allow for more time (t) of heating than higher gradient channels. The fluvial geomorphology of streams will also determine water temperatures as they are affected by riparian shade. Streams with confined flood plains do not allow for riparian vegetation growth along the banks of the summer low flow channels, and will therefore have higher summer water temperatures than streams with unconfined flood plains.

One of the functions of riparian habitats is to provide for shade to provide for water temperature control. Narrow smaller streams can be easily shaded by a variety of vegetation or by topography. Many studies on small streams have documented the effects of riparian vegetation and its removal on summer stream temperatures (Beschta et al, 1987). Removal of riparian vegetation within small stream riparian areas can significantly increase daily mean and maximum temperatures during the summer months (Brown and Krygier, 1970). Studies of small streams conclude that water temperatures are best predicted by the influences of elevation, riparian canopy closure, water depth, and ground water inflow (Sullivan et al, 1990).

However, within large river systems the main channel can be quite wide or braided and the influences on water temperature are complicated. Generally, the elevation of the large river (Scott River 1,700-2,900ft) is much lower than headwater tributaries (3,000-8,000ft). The difference in local air temperature at different elevations regulates the heat transfer process for each stream reach, as water temperatures are always reaching equilibrium with the local air temperature. Local air temperature effects increase as topographic or vegetative shading is reduced. The wide or braided river also has much higher direct solar radiation, transferring heat to the water surface.

6.0 METHODS

Even though this report was completed by compiling data across several ownership's, efforts were made to insure that the information was collected in the same manner for each stream. All data contributors followed the same protocol for launching and placement of hobo-temps. (ref) Nonetheless, we were very cognizant of the fact that all analyses needed to be performed on data that was comparable in nature. As such, the individual data collection methods were compared and if methodologies prevented the use of information the data was excluded from analyses.

6.1 EQUIPMENT

Water temperature was measured with continuously recording electronic instruments. Various models of electronic instruments were used.

Table II. Rated Accuracy of various temperature monitoring devices.

MODEL	INSTRUMENT	TEMPERATURE RANGE	ACCURACY +/-
Hobo Temp	Internal Probe	-20°C to 70°C (-4°F to 158°F)	+/- 0.5°C
StowAway XTI	Internal Probe	-40°C to 75C	+/- 0.2°C
Optic Stowaway	Internal Probe	-5°C to 37°C	+/- 0.2°C
Ryan Tempmentor	Internal Probe	-58°C to 73°C	+/- 0.2°C

Each instrument was calibrated before each field season following calibration protocols described by the FFFC (1996). All the instruments used in this study maintained accuracy standards described in the calibration protocols and described in USGS (1978). Using an EPA certified ASTM thermometer during calibration indicated that accuracy of instruments was +/-0.2 at 0°C.

6.2 FIELD PROTOCOLS

To be consistent with other research, our data has been collected using techniques similar to those described in FFFC (1996) and USGS (1978). Field data recorded included date, time, individual, serial number, activity, location, habitat, water depth, water temperature, air temperature, percent canopy closure, and downloaded computer file name. The field measurements are maintained to verify stream data recordings and allow exchange of stream data between various landowners and agencies.

6.3 DATABASE AND GIS COVERAGES

All stream temperature thermographs were transferred from individual databases to a central database. Due to the large geographic scale of the watershed the distribution of water temperature recording stations were entered into a Geographic Information Systems (GIS). GIS coverages of land ownership, land use, streams, roads, precipitation, soils, and watershed boundaries were also developed for the display and analysis of stream temperatures by sub-watershed.

To better understand stream temperature data over this broad watershed the results will be expressed in both metric and English units. Below is a summary of the conversions between metric and English units.

Table III. Unit Conversions.

Metric Units	English Units
1 Meter (m)	3.28 Feet (ft)
1 Kilometers (km)	0.621 Miles (mi.)
1 Sq. Kilometers (km2)	0.386 Sq. Miles (mi2)
1 Cubic Meters per Second (m3/sec)	35.314 Cubic Feet per Second (ft3/sec)
1 Degree Celsius = (F – 32)/0.55	1 Degree Fahrenheit = (C*1.82)+32
1 Hectare	0.4047 Acres

6.4 TECHNICAL DEFINITIONS

Through the scientific literature many terms are used to describe the metrics used to describe water temperatures. We found that a list of the definitions was quite helpful in fully understanding data from other research, historical data found within the Scott River watershed, and calculations completed for this report. Below is a list of technical definitions that we refer to throughout the report.

Weekly Average Temperature – The average of all temperature readings for any seven day period.

Maximum Weekly Average Temperature (MWAT) – The weekly average temperature of the hottest seven day period

Maximum Weekly Minimum Temperature (MWATmin) – The average of the minimum temperature readings of the hottest seven day period.

Maximum Weekly Maximum Temperature (MWATmax) – The average of the maximum temperature readings of the hottest seven day period.

Maximum Average Daily Fluctuation – The difference between MWATmax & MWATmin for the hottest seven day period.

Maximum instantaneous temperature – This is the highest single recorded temperature for a year. This usually represents the temperature of water for anywhere from one minute to two hours. Much of the historical data was recorded using this metric.

Natural range of variability – The highest and lowest recorded water temperatures in a watershed or sub-basin with relatively little manmade disturbances.

7.0 RESULTS

Analysis of water temperature data collected in the streams of the Scott River basin reflect the controlling influences of the fundamental physical processes affecting water temperatures as described in Section 5.0. The use of data for this report is not to verify research on the subject, but rather to describe the distribution of water temperatures in the mainstem and tributaries in the Scott River. Only a much more detailed and well thought out study design could attempt to verify various findings.

7.1 SPATIAL DISTRIBUTION OF WATER TEMPERATURES

This study utilizes data from 68 separate continuous water temperature monitoring sites with a total of 172 datasets. Most of the data was collected from 1997 to 2000, with a few sites dating back to 1995. Data contributors include the Klamath National Forest, Siskiyou County Resource Conservation District, Siskiyou County Schools, Fruit Growers Supply Company, and Timber Products Company. Using a Geographic Information Systems (GIS) we spatially describe the arrangement of monitoring locations throughout the watershed. The geographic location and ownership of each monitoring site is shown in Figure 10. Site identifiers are provided as reference to data provided in Appendix A.

The monitoring sites are well distributed throughout the watershed. Of the 68 sites, 22 are located in the mainstem and 46 are in tributaries. The following table shows the distribution of monitoring sites and datasets by sub-basin:

Table IV. Temperature Monitoring by Sub-Basin.

Sub-Basin	Acres	Sites	Datasets
Canyon	97,802	14	25
Valley	59,877	17	47
Westside	116,342	23	71
Eastside	145,846	3	7
West Headwater	25,133	5	9
East Headwater	72,650	6	13

The relatively low precipitation and low flows in the Eastside sub-basin explain the ratio of sites to acres for this unit. Many of the tributaries in this sub-basin run intermittently, and not at all late in the summer of in dry years. The gulch nature and the foothill chaparral/oak woodland vegetation of this sub-basin contribute to rapid drainage into the valley bottoms of the major tributaries. As noted previously in this report, this sub-basin contains a relatively large groundwater storage unit.

The mountains located west of the valley receive most of the precipitation and snowpack, thus sustaining most of the surface flow to the mainstem. This and ownership patterns explain the concentration of monitoring sites in the Canyon and Westside sub-basins.

Maximum weekly average temperatures (MWAT) for each monitoring location are presented in Figure 11. The values displayed represent the average for all data available for the years 1995 to 2000. As data was not available for each site for each year, it was determined that for display purposes, averaging provided the most comprehensive view. It can be seen that the coldest temperatures are located in the upper reaches while the hottest are confined to the mainstem through the lower valley.

An effort was made to bracket a few of the tributaries in order to test their effect on the mainstem. Temperatures in the mainstem showed some localized cooling, but this could not be attributed entirely to the influence of the tributaries. Water temperatures of the mainstem remained relatively unaffected by the addition of cooler waters from the tributaries throughout the lower valley and into the canyon. A good example of this is in the Canyon sub-basin where three very cold tributaries (Kelsey, Canyon, and Boulder Creeks) drain into the mainstem in a relatively short distance with no apparent effect on the temperature of the mainstem.

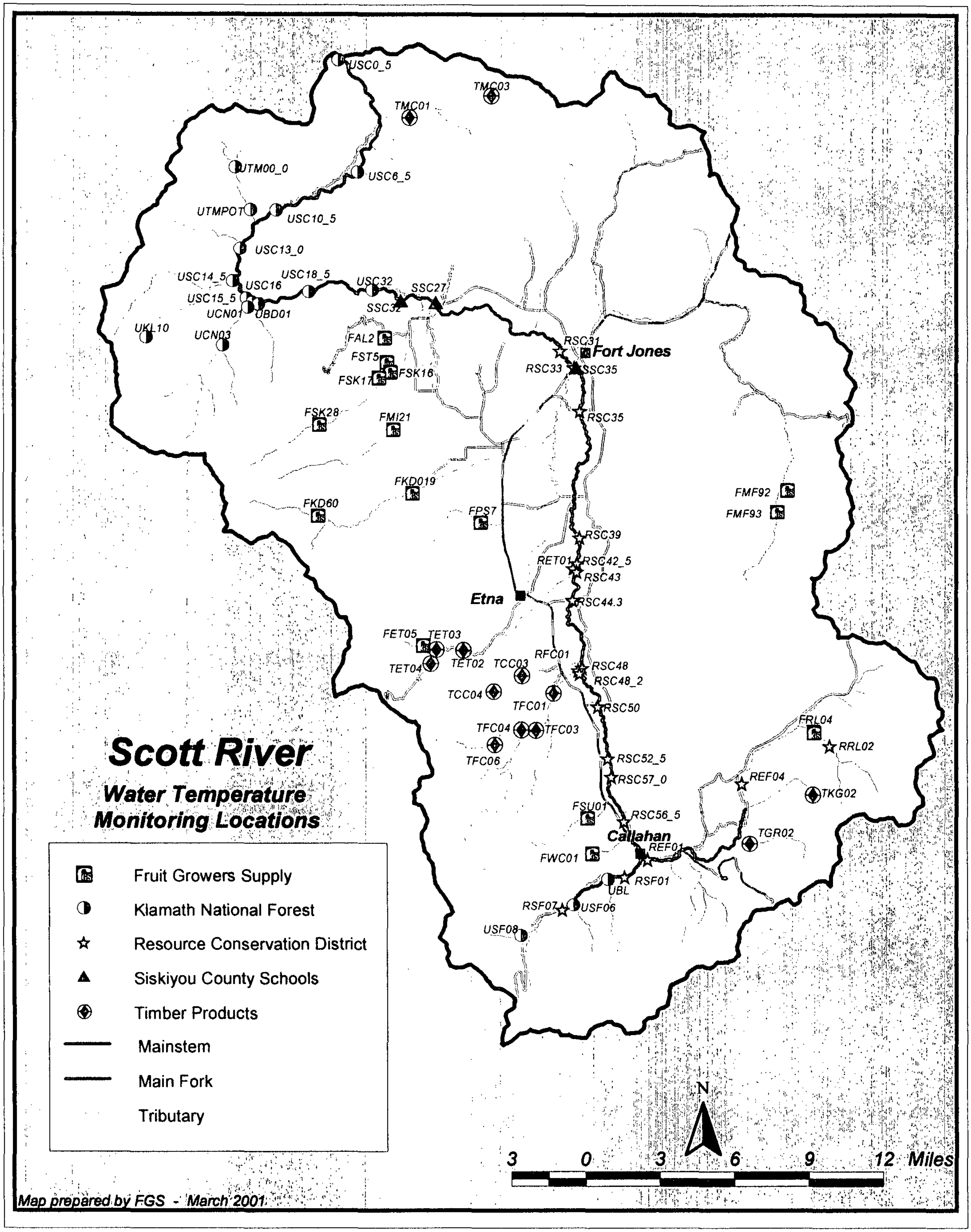


Figure 10. Geographic Location of Stream Temperature Monitoring Devices

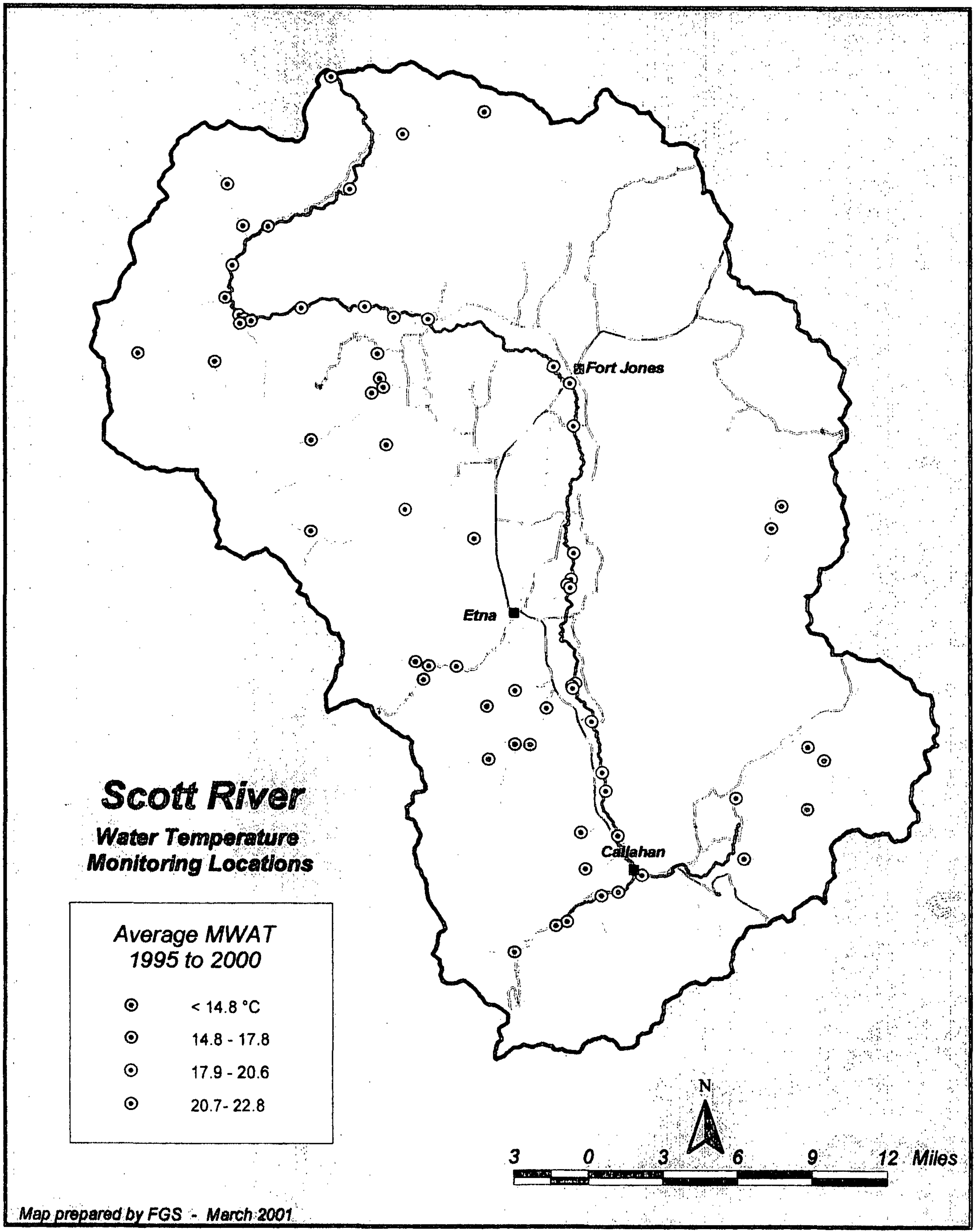


Figure 11. Average Maximum Weekly Average Temperatures (MWAT) - 1995 to 2000

7.2 HISTORICAL RANGE OF WATER TEMPERATURES

Water temperatures have been recorded in Northern California by state and federal agencies and private landowners since the early 1950's. The US Geological Survey (USGS) along with the California Department of Water Resources (DWR) collected water temperatures annually using a variety of field techniques and reported these temperatures by collection station in annual reports (USGS, 1997). The USGS and DWR also summarized the 1951- 1970 annual reports into a reference guide for many of the monitoring stations (Blodgett, 1970).

Historical water temperatures in Northern California watersheds similar to the Scott River watershed indicate that instantaneous water temperatures have exceeded 21°C (70.2°F) since the early 1950's (Table V) (Blodgett, 1970).

Table V. Pre-1964 Flood Maximum Instantaneous Water Temperatures

USGS Station Name	Maximum (°C)	Maximum (°F)	Water Year
South Fork Salmon River near Forks of Salmon	21	70	1961
North Fork Salmon River near Forks of Salmon	22	72	1961
Salmon River near Somes Bar	24	76	1959
Trinity River Above Coffee Creek	24	76	1960
South Fork Trinity River near Hyampom	25	78	1962
South Fork Trinity River near Salyer	28	83	1962
Shasta River near Yreka	31	88	1961
Klamath River near Seiad Valley	26	79	1961

Historical water temperatures have been documented in the Scott River Watershed at eight separate stations (Blodgett, 1970). Due to the various methods, time periods and total number of measurements, limited information and conclusions can be drawn from historical data in the Scott River watershed. In the Scott River watershed the USGS and DWR used the "periodic observation" method for collecting water temperatures. This method entailed using a hand held thermometer and directly reading the thermometer temperature. The stations were located far enough downstream of tributary inflow to ensure that waters were well mixed and usually the stations were associated with water flow gauging stations. Blodgett(1970) reported "...the probable inaccuracies resulting from the sum of instrumental and thermometer placement errors should be less than + or – 1.5° F (+ or – 0.8°C) degrees for periodic data collected with hand-held thermometers." Due to these limitations the authors of this report reviewed the historical information cautiously and used the information only in broad watershed observations.

The instantaneous maximum water temperatures of the eight stations located in Scott River (Table VI, from Blodgett, 1970) indicate that these portions of the Scott River watershed have exceeded 20°C (68°F). The historical water temperatures reported in Table VI were collected prior to the 1964 flood. The 1964 flood had a strong impact on the channel structure. The present day channel is more open and has less vegetation than prior to 1964.

Table VI. Pre-1964 Flood Maximum Instantaneous Water Temperatures in Scott River Watershed.

USGS Station Name	Years Data Collected	Maximum (° C)	Maximum (°F)	Water Year
East Fork Scott River at Callahan	1957 to 1968	27	81	1961
South Fork Scott River near Callahan	1957 to 1960	21	70	1959
Sugar Creek near Callahan	1957 to 1968	20	68	1958
Etna Creek near Etna	1957 to 1962	21	70	1959
Moffett Creek near Fort Jones	1957 to 1968	24	76	1958
Shackleford Creek near Mugginsville	1957 to 1960	21	70	1959
Scott River near Fort Jones	1950 to 1968	26	79	1968*
Canyon Creek near Kelsey Creek	1957 to 1960	18	65	1957

* post-1964 flood

Many of these historical locations are very close to the same locations as the monitoring sites in this study. The Blodgett(1970) report includes periodic observations from the 1950's and 1960's, prior to any significant land management in these tributaries. The table below compares the maximum recordings from the Blodgett report to the maximum readings from this study as well as to the weekly average of daily maximum temperatures for the hottest seven-day period in the study (MWATmax). It can be seen that temperatures of today are comparable to those of decades ago. This correlation between temperatures 40 years ago, and current temperatures during a time when stream channel and watershed conditions have changed, may indicate that stream heating is primarily a function of local climatic conditions.

Table VII. Historical stream temperatures compared to current temperatures.

Location	Blodgett Max (°C)	MWATmax (°C)	Daily Max (°C)
Scott River near Fort Jones	26	27.2	27.6
Canyon Creek	18	16.7	17.2
Moffett Ck near Fort Jones	24	23.4	24.3
Shackleford Ck. near Mugginsville	21	19.0	19.4
South Fork Scott at Callahan	21	20.0	20.5
East Fork Scott at Callahan	27	26.4	27.1
Sugar Ck near Callahan	20	18.1	18.5

7.4 NATURAL RANGE OF WATER TEMPERATURES IN THE SCOTT RIVER WATERSHED

Due to the variation in topography, geomorphology, and many other factors discussed in Section 4.0 of this report the Scott River naturally has a wide range of stream temperatures (Figure 14). Water temperature data has been collected throughout the basin, and some trends can be seen.

There is a wide difference in temperatures in the upper tributaries, and the alluvial reaches of the system. Of the 172 datasets in this study, the range of MWAT is from 10.9°C (51.8°F) in the upper reaches to 23.6°C (74.9°F) in the lower valley. The valley reaches reflect not only natural factors, but the influences of water management. The upper reaches drain primarily wilderness areas with no unnatural influences on water temperature. Here the range of MWAT is 10.9°C to 17.8°C (51.8-64.4°F), with most in the 14.6°C to 16.1°C (58.6-61.3°F) range. These cool temperatures represent higher elevation conditions and primarily snow melt or ground water sources.

No water temperature data exists for the mainstem Scott River in its natural state. As described by fur trappers of the early 19th century (Wells, 1880), the valley was a large swamp due to the large population of beaver and beaver dams. This condition would tend to limit the natural range of water temperatures because of the lack of water movement. Presumably water temperatures in this condition would find equilibrium with the ambient air temperature. This is evident in current data for the mainstem as well. The average MWAT of the mainstem near Fort Jones is 21.3°C (70.7°F), and the maximum average air temperature here since 1948 is 21.7°C (71.5°F). The range of MWAT on the mainstem is 17.1° C to 23.6°C (63.1-74.9°F), with most in the 19.2°C to 22.5°C (66.9-72.9°F) range, and all of the averages above 21°C are located in the lower valley portion of the mainstem or the alluvial flats of the East Fork.

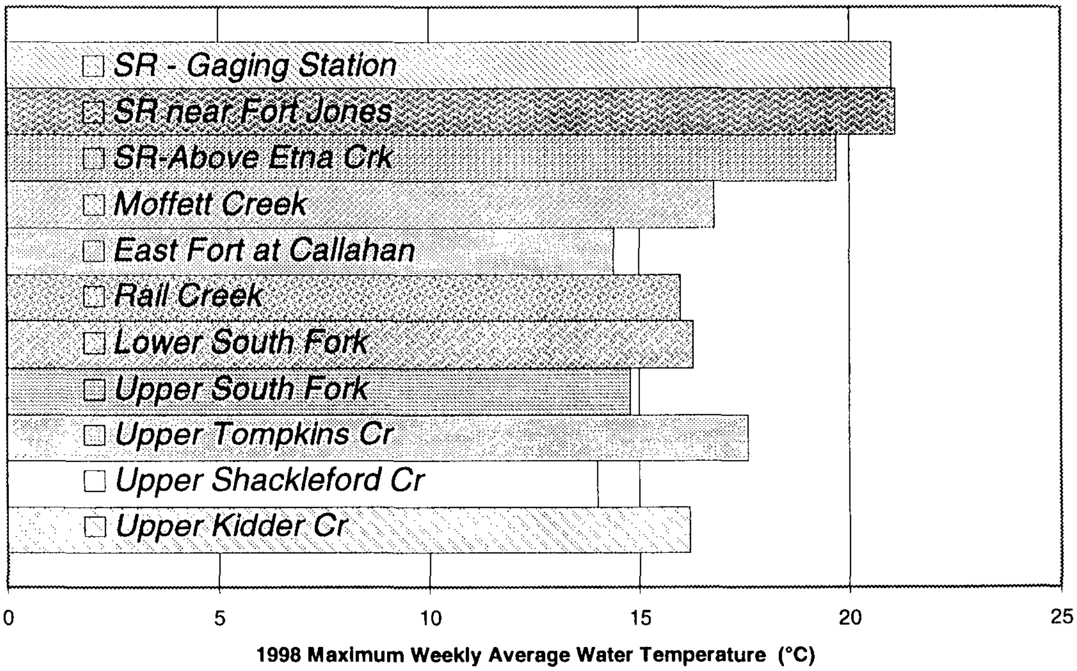


Figure 12. Geographical Variation in Water Temperature at various locations in the Scott River Basin.

7.5 ANNUAL VARIATION OF WATER TEMPERATURE

The variation of water temperatures between calendar years can occur due to many short term and long term watershed processes. Fluctuations in climate from year to year influence water temperatures similarly throughout the basin. The figure below shows the maximum weekly average temperature of the water at various locations for each of the years 1997 to 2000. At all locations water temperatures cooled from 1997 to 1999, then all increased in 2000, in response to a warmer year. These results are supported by many researchers who have found water temperatures of larger river systems to be closely related to ambient air temperatures.

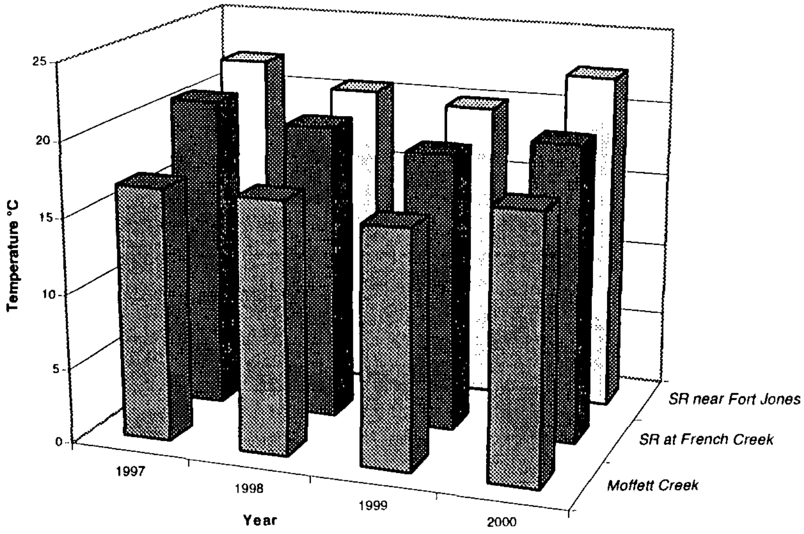


Figure 13. Annual Variation in Water Temperature at various locations in the Scott River Basin.

7.6 INFLUENCES OF AIR TEMPERATURE

Many researchers have found air temperature to be the most significant environmental factor in determining water temperatures as most of the terms in the heat transfer relationships involve local air temperature. At equilibrium, the daily average water temperature is very near the local daily average air temperature for any given site. The controlling factors of air temperature are local climate, elevation, aspect, topography, shade, and air movement.

Paired data for air and water temperature was collected on Shackleford Creek, a B3 channel type, yielding an average baseflow of approximately 40 cfs in the Westside sub-basin. The following graph shows how closely water temperature follows air temperature. Daily and weekly averages are displayed, as averaging masks the localized and short-term fluctuations, thus enhancing interpretation. As air temperatures increase and decrease so do the water temperatures even as flow steadily decreases to base flow conditions at the end of August. This independence of creek stage indicates the overwhelming influence of air temperature. Other factors such as direct solar radiation and stream depth have more influence than air temperatures on daily and local fluctuations in water temperature.

The graph also shows the declining effect of air temperature on water temperature as air temperature approaches its annual average. The temperature of ground water is typically within 1-3°C of the annual average air temperature for any given area. (Lewis) Once the snow has melted stream flow is sustained by ground water, which would obviously then have an influence on stream temperature.

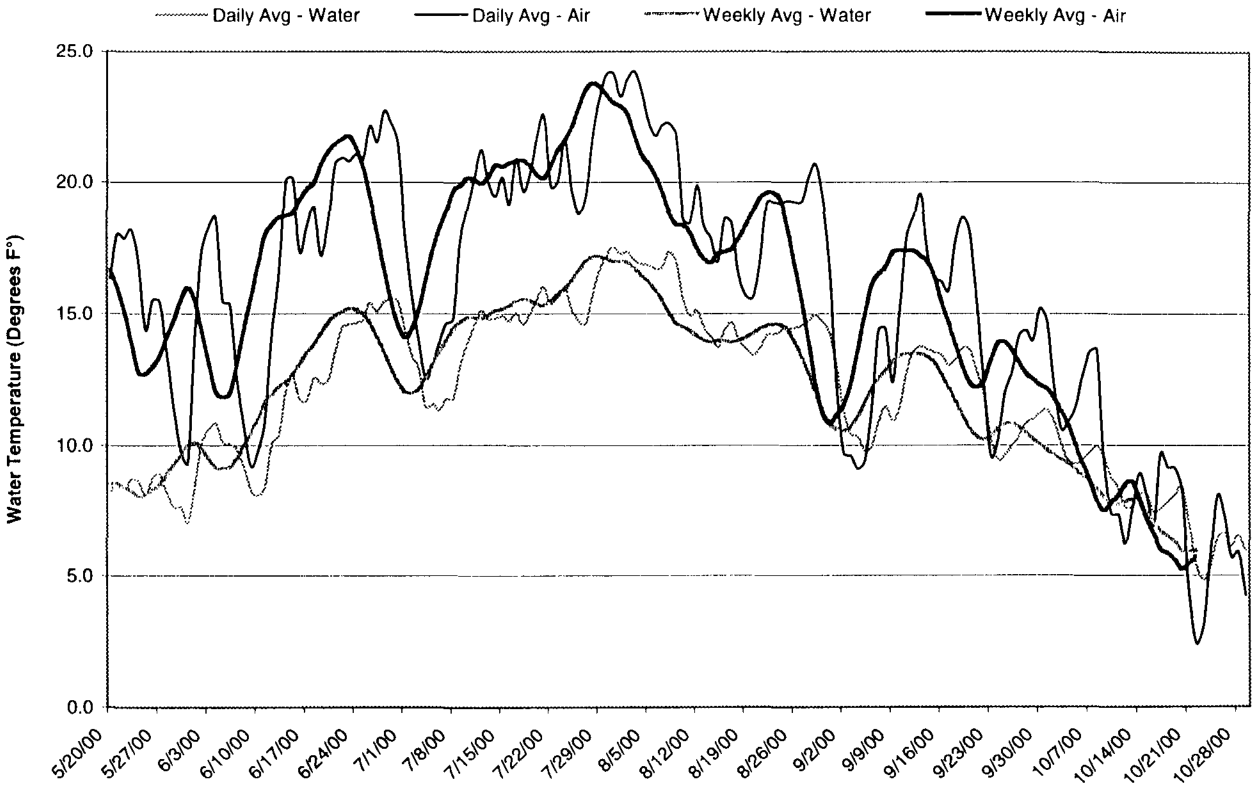


Figure 14. Air vs. Water Temperatures in the Scott River Basin
(Shackleford Creek, summer 2000)

Daily average air and water temperatures are highly correlated ($r^2 = 0.800$, n= 163). As the graph in Figure 15 shows, this relationship is more prevalent above 14°C (57.5°F). Hourly data is less correlated ($r^2 = 0.733$, n=3,912) which suggests the influence of other localized variables. This may include the variable influx of ground water and/or variations in air movement. The graph below shows the correlation of daily average air and water temperatures for Shackleford Creek during the summer of 2000.

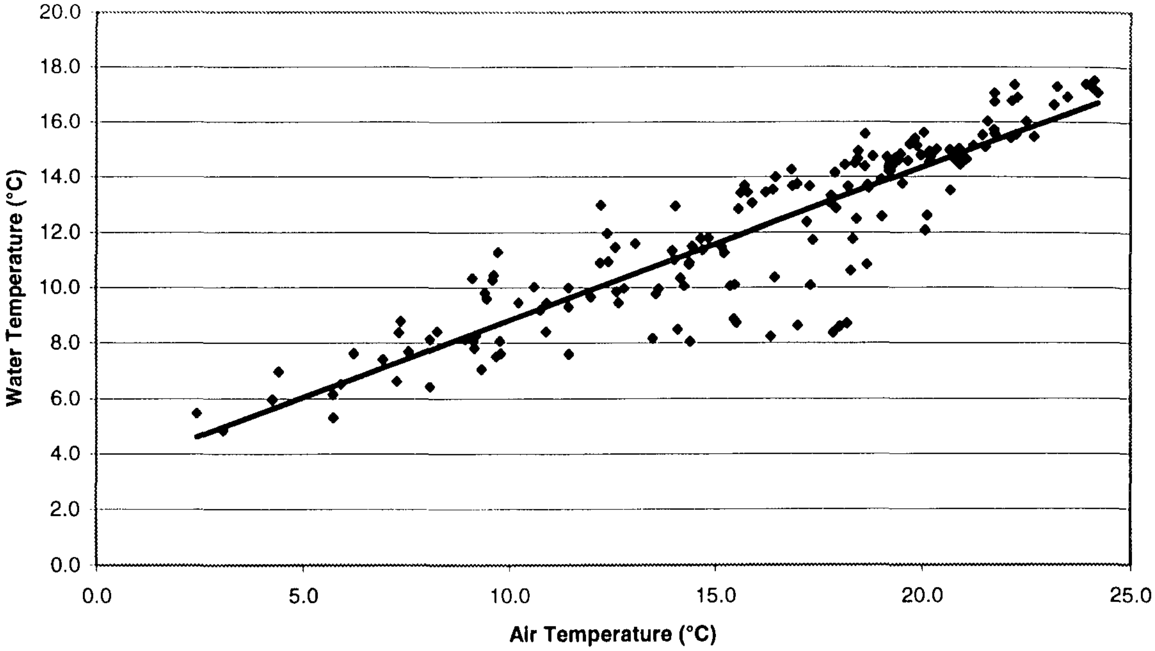


Figure 15. Daily average air vs. water temperatures in the Scott River Basin.
(Shackleford Cr., summer 2000.)

Many of the primary environmental variables that affect stream temperature also vary systematically within watersheds. The general increase in water temperatures from headlands to lowlands occurs because:

- Air temperature increases with decreasing elevation
- The effect of cool inflowing groundwater decreases proportionally with the increasing volume of streamflow.
- Wider channels result in decreasing effectiveness of riparian shade.
- Wider channels increase the stream surface area thus heat exchange with air and channel bed.

7.7 INFLUENCES OF CHANNEL GEOMORPHOLOGY AND STREAM FLOW

Like any other watershed, flows of the Scott River begin as small headwater streams at high elevations and end at the mouth as a wide, lower elevation river. Stream width naturally increases with accumulated flow and geomorphologic processes. As stream width increases the effectiveness of riparian and topographic shade diminishes to the point where it is no longer a factor. The graph in the figure below shows the trend of increasing water temperatures as the river approaches the confluence with the Klamath River. This is a natural phenomenon common to most systems.

In many cases the alluvial nature of widening streams creates shallow pools and riffles. Decreased stream depth increases the heat transfer process by increasing the surface area to volume ratio and exposure to the heat transfer factors. The influence of stream depth affects both the magnitude of stream temperature fluctuations and the response time of streams to changes in environmental conditions.

Stream temperatures naturally increase in the downstream direction from headlands to lowlands, even under closed forest canopy conditions, and create a characteristic temperature profile (Theurer et al 1984; Sullivan and Adams 1990). This can be seen as the trend line in Figure 17. Heat energy can be transported downstream with flowing water, although various heat transfer mechanisms cause the water temperature to change until the net heat transfer is balanced, i.e., energy in equals energy out. This equilibrium temperature varies with changes in environmental conditions over time and space (Adams and Sullivan, 1990).

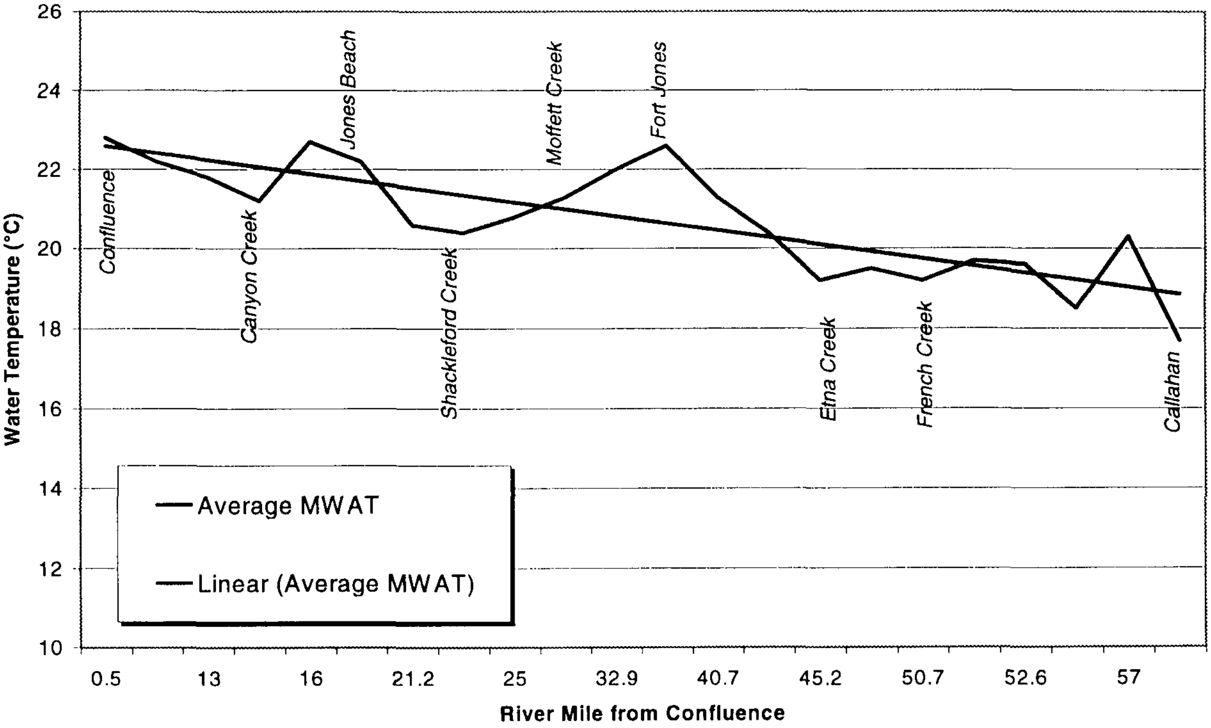
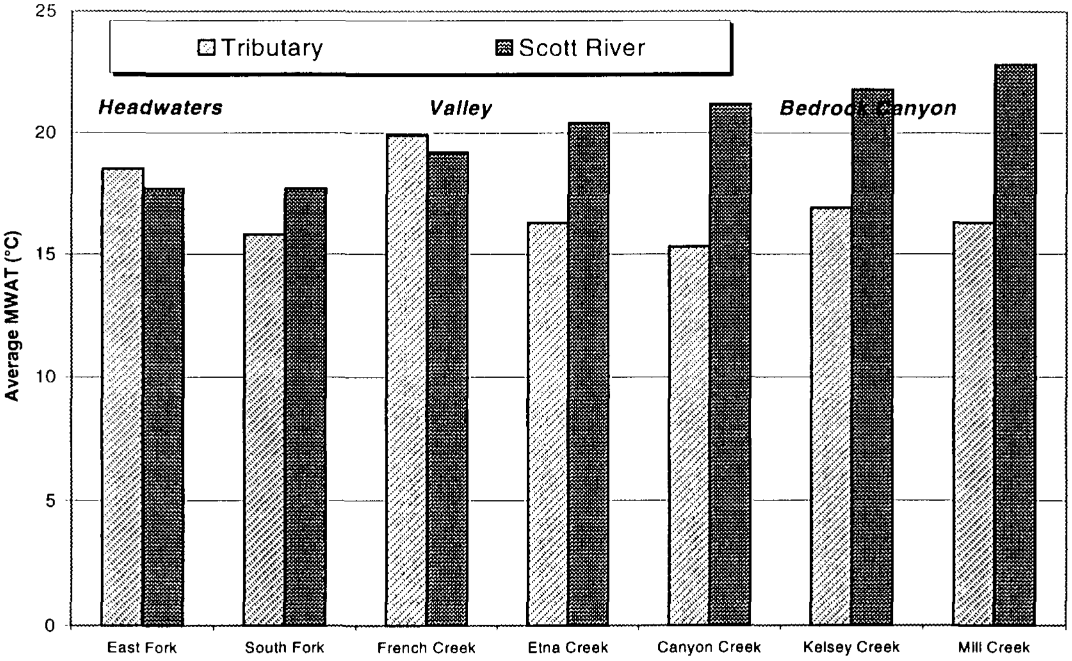


Figure 16. Maximum weekly average stream temperature as a function of river mile.

7.8 INFLUENCES OF TRIBUTARIES ON MAINSTEM WATER TEMPERATURES

Analysis of paired data for water temperatures in tributaries and the mainstem directly below the confluence indicate that little heating or cooling occurs due to tributary flows (Figure 17). This is especially true further downstream as mainstem flows accumulate thus diminishing the proportion of inflowing tributaries and increasing the response time of the mainstem to changes in environmental conditions.

All of the surface waters of the Scott River basin have been adjudicated. Many of the tributaries are diverted into irrigation ditches prior to reaching the valley floor during the summer months. Several larger Westside tributaries (Kidder, Patterson, Mill, and Shackleford) drain into a floodplain slough condition or go underground before reaching the mainstem. This is the result of reduced discharge levels and the low gradient alluvial nature of these reaches. This condition is the controlling environmental factor for water temperatures coming out of these major watersheds.



1995 – 2000 data

(* Note: The East Fork and South Fork meet to form the mainstem Scott River.
The mainstem temperature shown below the two tributaries is taken at the same location.)

Figure 17. Average temperatures (MWAT) of tributaries and the Scott River below each tributary.

It can be seen in the above figure that the mixing of waters from the East Fork and South Fork yield a relatively cool temperature. This marks the beginning of the mainstem. Water enters the upper tailings just below Callahan, and begins to heat, due to being shallow, less than 6 inches during low flow. Sugar Creek enters in the river, and flows under the tailings piles (pers observation). Flowing under the surface of the tailing piles cools the water slightly. The river exits the tailings, and heats up above Faye lane. This heating is due to braiding creating three distinct channels, caused by the 97 flood. The river cools slightly below French and Etna Creek, due to subsurface flows. After Etna Creek the river flows through ten miles of the valley, with no tributary inflow.

Etna Creek is a municipal watershed that contributes a sizeable proportion of cool water to the mainstem yet shows very little cooling effect. From this point the river runs wide, shallow, slow, and in a northerly direction maximizing exposure to solar radiation. It is also in this reach that the river receives water only from irrigated pastures and none from tributaries. Water temperatures steadily increase to a maximum near Fort Jones. Water temperatures cool somewhat as the river turns west, but the accumulated discharge at this point buffers the cooling effects of the very cool tributaries of the Canyon sub-basin.

Most of the significant tributaries discharge on the order of 5 to 20 cfs at baseflow (FGS flow data, unpublished) with an average MWAT of 15 – 17°C (59.3-62.94°F). The average baseflow of the mainstem is on the order of 1200 cfs at 21°C (70.2°F). By Brown's formula these tributaries would only be able to reduce mainstem temperatures by as much as 0.1°C. It would take a tributary of 40 cfs and 14°C (57.5°F) to reduce the mainstem by 0.2°C (.36°F), or 100 cfs at 15°(59.3°F) to reduce it by 0.5°C (.9°F). The contribution of cool tributaries and groundwater between Fort Jones and the confluence with the Klamath River appear to have an accumulated cooling effect on the mainstem (Figure 16), but individually they show very little cooling effect (Figure 17).

Other than water diversions for irrigation the Scott River is a free flowing system. There are no dams on the Scott River. Discharge is relatively constant throughout the summer months (?) controlled primarily by drought and demands for irrigation. Flow in the mainstem is a determining factor in water temperature in that volume has a buffering effect on environmental factors such as the heating effect of air temperature and the cooling effect of tributaries. It may find the same equilibrium, but if flows were maintained at substantially higher levels, it would take longer to achieve equilibrium, thus reducing temperatures on more of the river.

7.9 WATER TEMPERATURES BY GEOMORPHIC SUB-BASIN

In general, our results support the original hypothesis that the six geomorphically distinct sub-basins produce different annual water temperatures. The tributaries within the Canyon(16.4°C, 61.8°F) and Westside (15.8°C, 60.8°F) sub-basins produce similar water temperatures (Figure 19). During seasons when water is present in the channel the Eastside sub-basin produce water temperatures that are slightly higher than the Canyon or Westside tributaries. During seasons when water is absent monitoring devices have been left in dry channels and data was discarded. The tributaries and mainstem within the alluvial Valley sub-basin had the highest water temperatures (21.3°C, 70.8°F). Due to small sample size, conclusions interpreted from the data reported for the West and East Headwaters should be done cautiously. However, the general observations are that the West Headwater streams are cooler than the East Headwater streams. While the various tributaries and mainstem are exposed to similar solar radiation and air temperatures the sub-basins absorb the energy much differently due to the channel geomorphology within the sub-basin.

Table VIII. MWAT and Diurnal Fluctuation by Geomorphic Sub-unit.

Geomorphic Sub-Basins	1997 MWAT	1997 Diurnal Fluctuation	1998 MWAT	1998 Diurnal Fluctuation
Canyon	16.4	3.9	16.4	4.9
Valley	21.3	7.1	18.4	6.3
Westside	15.8	2.9	15.3	3.0
Eastside	15.3	4.0	17.2	6.5
West Headwaters	14.0	3.1	NA	NA
East Headwaters	NA	NA	17.7	7.7

8.0 DISCUSSION

8.1 SUMMARY OF GEOMORPHIC AND ECOLOGICAL CONDITIONS

The results of our examination of historic water temperatures from the 1950's and 1960's in the Scott River watershed indicate that historic water temperatures have routinely exceeded 20°C (68.4°F). Water temperatures measured between 1995 and 2000 appear to be within the range of variability that was observed during the 1950's and early 1960's. Even though climatic conditions have varied, riparian and stream habitats may have varied, we have no information to indicate that water temperatures have varied greatly in the Scott River watershed since the 1950's and 60's. We believe this condition further supports our conclusion that the channel geomorphology and climate of each sub-basin controls the observed water temperatures.

8.2 GEOMORPHIC AND ECOLOGICAL CONDITIONS

East Headwater

There were six (6) temperature monitoring locations on the East Fork Scott River. Four were in upper tributaries and two were in the East Fork itself. MWAT temperatures in the tributaries did not exceed 17.8°C (64.4°F) for any of the years studied. This is similar to temperatures observed in the other tributaries of the system, which did not exceed 17.8°C. As was the trend in the watershed, water temperatures reached the warmest recorded in 2000. Both locations on the East Fork mainstem exceeded 20.7° C (69.7°F) in 2000.

West Headwater

The geography and topography of the South Fork indicates that it should be a cool system. The major tributaries face North and East, giving them maximum protection from summer solar radiation. In addition, this watershed is primarily steep timbered forestland. As such, the tributaries have good riparian cover, providing further protection from solar radiation. Finally, the watershed is small, only 25,000 acres so the water has less opportunity to heat before reaching the mainstem

There were six (6) temperature monitoring locations on the South Fork Scott River. The two in the South Fork itself were monitored for three years, and the average MWAT was 15.8°C (60.4°F), and 14.6°C (58.3°F). Both locations had the maximum recorded temperatures in 2000, but only the location at the mouth exceeded 17°C. The South Fork of the Scott River, during the years studied, maintained summer water temperatures within the suitable range for salmonid rearing.

Valley

It has been shown (Sullivan, et al) that for large river systems the two most important factors influencing water temperatures are elevation (with respect to air temperature) and distance from the watershed divide, as this leads to an increased width to depth ratio. The elevation in the Valley reach varies from 2,700'-2,900'. The orientation of this reach of the river is northerly, until the river reaches Fort Jones. At Fort Jones the river turns west. The North/South orientation exposes the river to maximum summer solar radiation for approximately 30 miles. This reach of the river only has 0-5% riparian cover, exposing the water to solar radiation, as well as heat exchange with the air. As would be expected for a large river system, the water temperatures gradually increase as distance form the headwaters increases.

There are 13 monitoring locations in the 28 miles between Fort Jones and Callahan. This sub-basin is best understood as two units. The confluence of the two forks to Etna Creek (13 miles) is the upper unit, and Etna Creek to Fort Jones. In the upper reach MWAT temperatures recorded were in the range of 17.1°-20.7°C, (62.8 - 69.26°F) with temperatures increasing with distance from the headwaters. Below Etna Creek the temperatures gradually increase to a high of 23.6°C (maximum MWAT for all years). The reach from Etna Creek to Fort Jones has no tributaries to provide a cooling influence, it is believed that groundwater does not enter the river until Fort Jones. Therefore, this stretch of the river is subject to heating through exchange with the air, and exposure to solar radiation, without the mitigating influence of tributary or groundwater inflows.

Eastside

There are two temperature monitoring locations within the eastside region, one on Moffett and one on Sissel. Temperatures are relatively high, due in part to the exceptionally low flows and shallow depths. Only Moffett Creek and a few tributaries in this sub-basin flow year round. Most of the eastside system flows only ephemerally during severe storm events. It is not uncommon to have tributary streams be disconnected during the summer or winter for extended reaches and be disconnected from the mainstem Scott River. Due to small sample size, conclusions interpreted from the data reported for the East Foothill and Moffett Creek should be done cautiously.

Westside and Canyon

The Westside sub-unit is the most varied of the six. It is composed of many large subwatersheds, each with different land management practices, geology, hydrology and topography. The Westside has many perennially flowing tributaries, some of which provide habitat for anadromous salmonids. Temperature monitoring in this sub-basin has shown that most of the tributaries reach a maximum of 16-18 degrees Celsius during the summer months. Temperatures in the Westside unit during the study period did not exceed 20 °C.

At the USGS gage, the Scott River enters a bedrock canyon for 19 miles prior to its confluence with the Klamath River. The elevation at the mouth is 1580 feet and mean air temps are greater that in Scott Valley. The upper ½ of this reach is a deep canyon with large mountains on the west and south side. However, in the lower ½ of this reach the canyon opens up and the canyon walls provide less topographic shading. There are several large tributaries –Boulder, Canyon, Kelsey, Middle, Tompkins and Mill – in this reach. The aspect of the canyon reach is variable because the River makes a large loop.

The River appears to experience a 1° C decrease in MWAT just below Jones Beach. The slight cooling effect is due either to topographic shading or the cool water from the 2 tributaries in this reach (Boulder and Canyon Creeks). Then by Scott Bar the River increases in temperature to MWAT levels similar to the average in Scott Valley.

At the lower elevation at the end of the Canyon reach, mean air temperatures are greater, which results in an increase in water temperature. The rocky canyon may also be transferring heat into the River.

The Westside Mountains and Bedrock Canyon geophmorphic sub-basins produce the lowest streams temperatures in the watershed. Tributary reaches within these sub-basins support MWAT stream temperatures that range from 14 to 16°C (57.2-60.8°F). Maximum stream temperatures last only one to two weeks, then drop off again. The channel geomorphology of narrow transport channels and close proximity to headwater springs and snowpack combine to create lower stream temperatures. During the peak of the summer air temperature (i.e. more intense solar radiation) these stream reaches also have lower diurnal fluctuation that other sub-basins.

8.3 WATER TEMPERATURES AND SALMONID REARING

Existing laboratory studies of water temperature relationships with anadromous salmonids indicates that optimal mean summer temperatures for steelhead and coho rearing are from 10-14 °C. (Reiser and Bjornn). As suggested by National Marine Fisheries Service (NMFS) the biological MWAT for anadromous salmonids in northern California is 17.8°C. The standard set by NMFS to determine the effects of proposed projects on water conditions is less than 20.5 °C. The upper lethal temperatures for anadromous salmonids is reported at 24.1-25.2 °C. Our results found that tributaries originating in high elevation undisturbed watersheds had MWAT water temperatures between 10.9 °C and 17.8 °C. Our review of historic instantaneous water temperatures in the mainstem range from .18 to 27°C. The results of this study indicate that current water temperatures of the Westside and Canyon sub-basins fall within the natural and historic range of variability. Existing water temperature within the Valley sub-basin are within the temperatures of those recorded in the 1950's and 1960's, which routinely exceeded 20.5 °C.

Salmonid rearing in the Scott River basin occurs primarily in some of the major tributaries of the Canyon and Westside, in the mainstem Scott River, and the South Fork Scott(West Headwater). Fall Chinook use the mainstem of the river for the majority of their spawning and rearing. They spawn from October to December, and the young of the year outmigrate from the system starting as early as February into late-June. At the end of June 2000, the river reached a daytime high of 22°C at Fort Jones, and a nighttime low of 16°C. Juvenile trapping shows that fish move through the system during the night, and seldom move in the daytime. While mainstem temperatures exceed optimal levels for salmonid rearing, the time period when temperatures are elevated does not overlap with the timing of fish utilization of the habitat.

Coho and Steelhead primarily use the major tributaries for spawning and rearing. Both species spawn in late winter and early spring. Young of the species typically spend 1-2 years in the system before they outmigrate. Mainstem and tributary summer temperatures are of primary concern for these two species. During the course of the study, the 2000 was the highest recorded temperatures. Temperatures in the major tributaries and the South Fork did not exceed 20°C, and many locations remained below 18°C. In addition, maximum recorded temperatures are usually in the late afternoon, and the river can cool by 2-6 °C during the course of the night. Scott River mainstem temperatures are of concern for Steelhead and Coho because they must outmigrate from the system. Preliminary results from juvenile trapping shows that outmigration occurs from February through June, before river temperatures have reached maximum temperatures.

8.4 RECOMMENDATIONS FOR FUTURE MONITORING

Many voluntary and regulatory mechanisms have been in place for many years that have monitored existing water temperatures in the watershed. From these efforts the data presented in this report was made possible. Future monitoring efforts should consider the results and discussions in this report and recognize the following fundamental watershed conditions that are controlling water temperatures in the Scott River watershed:

(1) Each unique geomorphic and ecological sub-basin within the Scott River watershed has very different water temperature patterns and environmental influences.

(2) The static physical influences including topography and geomorphology, and the annually changing influences of air temperature, groundwater and solar radiation strongly influence water temperatures in the watershed.

(3) The habitat needs and rearing locations of anadromous salmonids within the watershed, vary depending on the species, and time of year.

With these factors in mind, the following recommendations are made for future monitoring efforts.

(1) Sediment Deposition - Results indicated that Scott River mainstem deposition areas at Jones Beach, Fort Jones and Callahan supported water temperatures that are higher than what might be expected. Additional investigation into the relationship of fine and coarse gravel deposition, inter-gravel flow and ground water influences in these reaches would be insightful.

(2) The observed annual fluctuation in air and water temperatures in the watershed indicate that a more thorough investigation of historic air temperatures is warranted. Analysis of annual air temperature fluctuations might provide insight into the range of water temperature conditions that has occurred historically and is likely to occur in the future.

(3) Tributary effects - An effort should be made to determine the effect of individual tributaries on mainstem temperatures. This includes measurement of flows at each tributary, to determine surface vs. subsurface flows.

(4) Groundwater - Groundwater is a major contributor to maintaining summer flows. Temperature monitoring stations should be established to bracket known inflows of groundwater. The relationship between surface and groundwater should be researched.

(5) Riparian Monitoring - Temperature monitoring stations should be established along the mainstem at locations of riparian replanting efforts, and on tributaries which are experiencing natural regeneration. Water temperatures should be monitored as well as rate of riparian growth, in relation to stream shade provided.

(6) Temperature monitoring data should be analyzed in relation to the various life stage needs of salmonid species utilizing the stream in question. This report describes water temperatures in comparison to a natural range of variability within the watershed. Future biological monitoring should investigate the response of anadromous fish species to this range of water temperatures.

9.0 CONCLUSIONS

We feel our temporal and spatial understanding of stream temperatures in the Scott River watershed in northern California support these conclusions:

(1) Water Temperatures in the headwaters and primary tributaries draining primarily wilderness areas have a temperature range of 10.9 - 17.8 °C, with most in the range of 14.6 -16.1°C. This can be interpreted as the natural range of water temperatures for Scott River tributaries.

(2) Most of the tributaries in the Scott River Watershed fall within the range of natural variability for the watershed.

(3) Water temperatures in the Scott River mainstem do not vary greatly with those observed in the 1950's and 1960's

(4) Each sub-basin in the Scott River watershed has a unique set of geomorphic and climatic conditions which influence water temperatures.

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Appendix A

MWAT data for each monitoring station.

Station	**CALWATER 2.2**		**Maximum Weekly Average Tempurature (MWAT)**							
Number	**RBUASPW**	**PWSNAME**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**Max**	**Avg**
FAL2	1105420904	Snitklaw Creek			15.4	15.2	14	16	16	15.2
FET05	1105420403	Mill Creek			0	15.6	13.9	15.7	15.7	15.1
FKD019	1105420701	Babs and Fork Kidder Creek			20.1	0	17.4	18.5	20.1	18.7
FKD60	1105420707	Upper Kidder Creek			17.2	16.2	14	16.9	17.2	16.1
FMB3	1105420905	Meamber Creek			15.6	0	0	0	15.6	15.6
FMF92	1105420505	Skookum Gulch			0	0	16.3	18.6	18.6	17.5
FMF93	1105420505	Skookum Gulch			16.9	16.8	15.8	17.6	17.6	16.8
FMI21	1105420902	Mill Creek			16.6	14.5	15.8	16.1	16.6	15.8
FPS7	1105420703	Patterson Creek			17.7	17.6	16.4	18.1	18.1	17.5
FPT12	1105420805	Patterson Creek			10.9	0	0	0	10.9	10.9
FRL4	1105420102	Rail Creek			0	0	0	17.4	17.4	17.4
FSK16	1105420901	Lower Shackleford Creek			17	16.6	0	0	17	16.8
FSK17	1105420901	Lower Shackleford Creek			0	0	14.5	17.2	17.2	15.9
FSK28	1105420906	Upper Shackleford Creek			14	14	12	14.3	14.3	13.6
FST5	1105420904	Snitklaw Creek			13.5	14.1	13.1	14.1	14.1	13.7
FSU01	1105420305	Sugar Creek			0	15.5	14	16.7	16.7	15.4
FWC01	1105420304	Wildcat Creek			0	17.2	15.7	17.4	17.4	16.8
REF01	1105420303	Lower Scott River			0	14.4	19.4	21.6	21.6	18.5
REF04	1105420104	Kangaroo Creek			0	21	0	21.4	21.4	21.2
RET01	1105420403	Mill Creek			0	16.3	0	0	16.3	16.3
RFC01	1105420402	Upper French Creek			20.7	19.7	18.1	21.1	21.1	19.9
RRL02	1105420102	Rail Creek			0	16	15.1	17.3	17.3	16.1
RSC31	1105420803	Lower Indian Creek			21.7	21.1	19.9	22.5	22.5	21.3
RSC35	1105420706	Fort Jones			23.1	0	21	23.6	23.6	22.6
RSC39	1105420503	Shell Gulch			22.1	20.5	19.9	22.5	22.5	21.3
RSC42_5	1105420704	Middle Kidder Creek			20.6	20	0	20.6	20.6	20.4
RSC43	1105420408	Clark Creek			20.7	19.7	0	17.2	20.7	19.2
RSC44_3	1105420408	Clark Creek			19.5	0	0	19.4	19.5	19.5
RSC48	1105420408	Clark Creek			20.9	18.2	18.7	19.1	20.9	19.2
RSC48_2	1105420408	Clark Creek			20.8	19.7	18.5	19.8	20.8	19.7
RSC50	1105420405	Lower French Creek			19.6	19.2	0	20	20	19.6
RSC52_5	1105420405	Lower French Creek			0	17	19.9	0	19.9	18.5
RSC56_5	1105420405	Lower French Creek			0	18.3	17.1	0	18.3	17.7
RSC57_0	1105420405	Lower French Creek			0	0	0	20.3	20.3	20.3
RSF01	1105420303	Lower Scott River			0	16.3	13.8	17.3	17.3	15.8
RSF07	1105420301	South Fork Scott River			0	14.8	13.5	15.4	15.4	14.6
SSC27	1105420804	Rattlesnake Creek			21	0	19.8	0	21	20.4
SSC32	1105420905	Meamber Creek			0	0	19.8	21.8	21.8	20.8
SSC35	1105420706	Fort Jones			22.8	0	21.2	0	22.8	22
TCC03	1105420408	Clark Creek			15.3	14.8	13.4	15.6	15.6	14.8
TCC04	1105420408	Clark Creek			14.1	0	0	0	14.1	14.1
TET02	1105420403	Mill Creek			0	15.4	13.5	16.1	16.1	15
TET03	1105420403	Mill Creek			0	0	13.8	0	13.8	13.8
TET04	1105420403	Mill Creek			14.1	13.9	12.1	16.2	16.2	14.1
TFC01	1105420402	Upper French Creek		18.6	0	16.2	17.8	18.6	18.6	17.8

TFC03	1105420401	Meeks Meadow Creek			0	0	14.4	18.4	18.4	16.4
TFC04	1105420401	Meeks Meadow Creek		0	16.5	16.2	0	0	16.5	16.4
TFC06	1105420401	Meeks Meadow Creek			15.5	15.6	13.4	15.9	15.9	15.1
TGR02	1105420105	Big Carmen Creek			0	0	16	18.5	18.5	17.3
TKG02	1105420104	Kangaroo Creek			0	0	11.6	12.3	12.3	12
TMC01	1105410304	West Mill Creek		16.2	16.5	16.3	15.2	17.1	17.1	16.3
TMC03	1105410304	West Mill Creek			0	0	0	14.2	14.2	14.2
UBD01	1105410102	Boulder Creek		14.4	14	0	0	0	14.4	14.2
UBD03	1105410102	Boulder Creek			0	0	0	0	0	0
UBL	1105420303	Lower Scott River		16	0	0	0	0	16	16
UCN01	1105410101	Lower Canyon Creek			15.4	15.2	0	0	15.4	15.3
UCN03	1105410101	Lower Canyon Creek		15.5	15	0	0	0	15.5	15.3
UCN05	1105410104	Upper Canyon Creek			0	0	0	0	0	0
UKL10	1105410204	South Fork Kelsey Creek		10.9	0	0	0	0	10.9	10.9
USC0_5	1105410305	Franklin Gulch		22.8	0	0	0	0	22.8	22.8
USC10_5	1105410306	McCarthy Creek		0	0	0	0	0	0	0
USC13_0	1105410202	Middle Creek			21.8	0	0	0	21.8	21.8
USC14_5	1105410201	Kelsey Creek		16.8	17.4	16.6	0	0	17.4	16.9
USC15_5	1105410202	Middle Creek		21.2	0	21.1	0	0	21.2	21.2
USC16	1105410102	Boulder Creek			22.7	0	0	0	22.7	22.7
USC18_5	1105410102	Boulder Creek		22.4	0	22	0	0	22.4	22.2
USC32	1105420905	Meamber Creek	20.2		0	21	0	0	21	20.6
USC6_5	1105410301	Big Ferry Creek		21.9	22.9	21.8	0	0	22.9	22.2
USF06	1105420302	Fox Creek		14.9	0	0	0	0	14.9	14.9
USF08	1105420306	Little Jackson Creek		14.6	0	0	0	0	14.6	14.6
UTM00_0	1105410203	Tompkins Creek			16.9	17.6			17.6	17.3
UTMPOT	1105410203	Tompkins Creek			17.3				17.3	17.3