State of California

The Resources Agency

DEPARTMENT OF FISH AND GAME

# AN ASSESSMENT OF COHO ON AND STEELHEAD RESOURCE REQUIREMENTS IN REDWOOD CREEK, MARIN COUNTY

By

William M. Snider
Environmental Services Branch
Stream Evaluation Program

ENVIRONMENTAL SERVICES BRANCH

Administrative Report No. 84-1

March 1984

# AN ASSESSMENT OF COHO SALMON AND STEELHEAD TROUT RESOURCE REQUIREMENTS IN REDWOOD CREEK, MARIN COUNTY [1]

by William M. Snider [2]

## ABSTRACT

The coho salmon and steelhead trout resources in the Redwood Creek drainage were assessed relative to a hostel development proposed by California Department of Parks and Recreation. Rearing and spawning habitat distribution, existing environmental alterations and hydrologic conditions were obtained from the literature. Preferred flows for spawning and rearing were preliminarily identified using the Toe-Width Method.

The salmon and steelhead resources have declined well below historic levels due to water diversion and streambed alteration in the lower drainage. Large fish (smolt) habitat has been drastically reduced. The hostel could further impact the remaining large fish habitat by aggravating low flow conditions. Since the preferred spawning and rearing flow - identified using the Toe-Width Method - have low occurrence (less than 10% occurence for spawning and less than 30% for rearing) even the small diversion rates could affect habitat availability, especially rearing. It is recommended that diversion occur only when flow exceeds the preferred levels unless a more definitive flow evaluation method indicates differently.

[1]Environmental Services Branch Administrative Report No. 84-1, March 1984. This report was prepared as part of the Stream Evaluation Program.

[2]Environmental Services Branch, Sacramento, California.

ACKNOWLEDGEMENTS

The data in this report were collected and analyzed by Gary Smith, Don Ward and Bill Cox of the Department of Fish and Game. Charlene Dukes typed the report and Lee Ann Galbreath prepared the graphics.

# TABLE OF CONTENTS

# INTRODUCTION

The Department of Fish and Game (DFG) entered into an agreement with the Department of Parks and Recreation (DPR) on December 27, 1982, to develop stream flow and fish habitat data for Redwood Creek, Marin County, pertinent to a proposed development within Mount Tamalpias State Park (Figure 1). DPR proposes to develop a hostel in the vicinity of Kent Canyon including a water supply system which could include diversion of underflow from Redwood Creek. Streamflow and habitat requirements of steelhead trout, Salmo gairdneri gairdneri, and coho salmon, Onchorhynchus kisutch, resources supported by Redwood Creek are unknown. To evaluate the potential impact of the underflow diversion upon these resources, their requirements and the effect of the diversion upon the flow regime needed to be identified.

The steelhead and salmon resources of Redwood Creek are integral to the natural scene associated with Mount Tamalpias State Park, the Golden Gate National Recreation Area and Muir Woods National Monument, which encompass a major portion of the drainage. The steelhead and salmon runs have already reportedly dwindled well below historic levels and it is the intent of the National Park Service (NPS), DPR and DFG to protect these valuable resources and potentially restore it to its former level.

# BACKGROUND

## Scope of Evaluation

Initially, the agreement between DPR and DFG called for DFG to provide DPR with information to determine: 1) optimum flows for summer habitat of steelhead and salmon; 2) stream flow at which pumping from the underflow from DPR's well would begin to reduce surface flows over what occurs naturally; 3) critical flows that could block or limit upstream adult migration and downstream adult or smolt migration; and 4) the amount of over- summering habitat that could be affected by pumping underflow from DPR's proposed well. Sufficient funds were not available to allow this level of study. Subsequently, DFG prepared a project proposal outlining two independent objectives: 1) to develop quantitative stream flow and fish habitat data in Redwood Creek and to preliminarily determine flows needed to maintain steelhead and salmon spawning and rearing habitat; and 2) to determine the present status of the steelhead and salmon populations. Objective 1 was to be attained by performing a Toe-Width Method (TWM) instream flow analysis (Swift 1976, 1979) to preliminarily identify steelhead and salmon spawning and rearing flow needs. The TWM provides <u>preliminary</u> estimates of flow needs based upon the relationship between the average toe-width of spawning riffles, stream discharge and spawning and rearing habitat. Once DPR clearly identifies parameters such as potential watershed development, water needs and sources, sewage treatment facilities, increased visitor activity and other problems potentially adjunct to DPR development, a more extensive, definitive study, such as an incremental instream flow study (Bovee 1982), may be needed. Additional studies would require additional funding.

Attainment of Objective 2 involves population sampling within selected

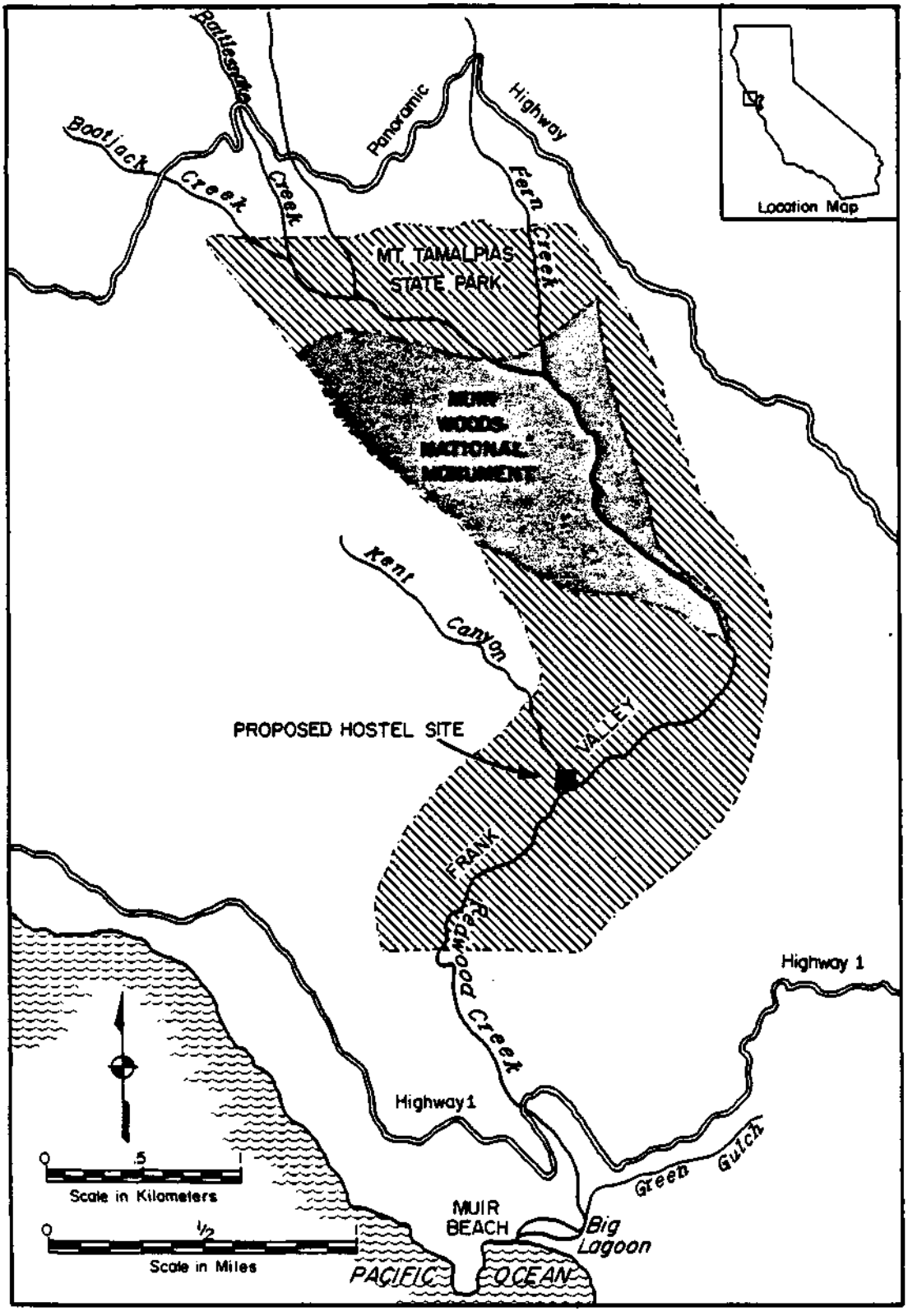


FIGURE 1. LOCATION OF MOUNT TAMALPIAS STATE PARK AND MUIR WOODS NATIONAL MONUMENT WITHIN REDWOOD CREEK DRAINAGE, MARIN COUNTY,

reaches of Redwood Creek. DPR has found Objective 1 acceptable. Acceptance of Objective 2 is dependent upon additional funding.

### Description of the Proposed Project

Development of the Kent Canyon Hostel is part of the general plan prepared for the Mount Tamalpias State Park (DPR 1981). Initially, former classroom buildings will be relocated to the park and converted into a hostel to accommodate 30 people. Hater for the development will be supplied either by the Marin Municipal Water District (MMWD) or by expanding the existing water system to divert underflow from Redwood Creek. The system would include 2 steel tanks to store 1.18 acre-ft. Water would tentatively be diverted only during periods of high runoff between November 15 and April 15. However, DPR has applied for the right to divert 1,830 gallons per day from Rewood Creek underflow.

Sewage disposal will be via a leach field which will potentially return most of the water to the Redwood Creek drainage.

If the initial 30-bed facility does not adversely affect Redwood Creek drainage, an additional 30-bed facility may be built.

## DESCRIPTION OF THE DRAINAGE

### General Setting

The Redwood Creek drainage is situated in the coastal mountains of southwestern Marin County about 10 miles north of San Francisco. The drainage encompasses about 8 square miles, originating on the southern slopes of Mount Tamalpias (2,600-ft elevation) and entering the Pacific Ocean at Muir Beach about 9 miles downstream. Redwood Creek begins at the confluence of Bootjack and Rattlesnake creeks (640-ft elevation), six miles above the mouth (Figure 2). Fern Creek (180-ft elevation, 4.2 miles above the mouth), Kent Canyon (60-ft. elevation, 2.1 miles above the mouth) and Green Gulch (20-ft elevation, 0.3 miles above the mouth) are the major tributaries to Redwood Creek. Bootjack, Rattlesnake, Fern, Spike Buck creeks and upper Redwood Creek flow through deep, V-shaped canyons formed by the rapid runoff down the steep, rocky slopes of Mount Tamalpias. The canyon widens and deposition begins to increase as the gradient lessens near Fern Creek. Above Fern Creek, Redwood Creek flows through a fairly narrow canyon bordered by a redwood and evergreen forest. Below Fern Creek the canyon widens into a flat, alluvial valley (Frank Valley) which is wide and bordered by rolling, grass and shrub covered slopes, interspersed with cultivated crops and eucalyptus groves. Streamside vegetation below Fern Creek is predominantly red alder, providing a dense continuous canopy nearly all the way to the mouth. The final 600 to 1,000 ft of stream passes through an intertidal area and across beach sand into the ocean.

### Climate

The climate of the Redwood Creek drainage is typically cool, with moderately wet winters and cool, dry summers (Lehre 1974). Precipitation increases with elevation, annually averaging 28-30 inches at sea level and 48-50 inches near 2,000 ft.

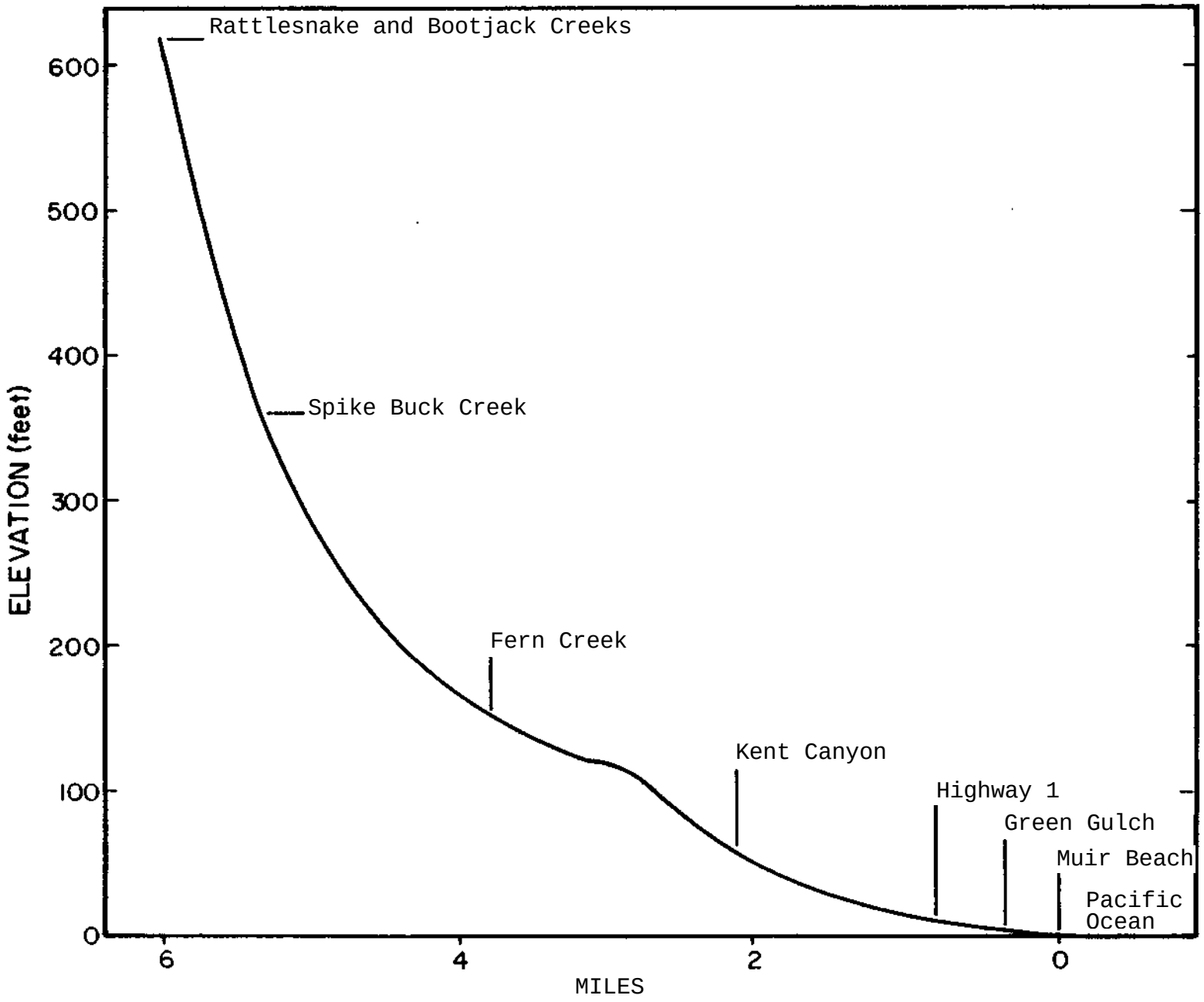


FIGURE 2. PROFILE OF REDWOOD CREEK, MARIN COUNTY.

Most precipitation occurs between November 1 and April 30 (85-90%), peaking in December and January (Figure 3). The cool summers are due to the cooling influence of the ocean and summer fog. Summer temperatures increase with distance from the coast and from the influence of coastal fog; the mean summer temperature is 60-66 F at sea level, but it is 15-20 F warmer in the inland, fog free areas. Mean winter temperature is 47-50 F at sea-level, but is generally cooler on the upper slopes of Mt. Tamalpias and in the low, narrow valleys.

## Hydrology

Over 90% of the annual runoff occurs between November 1 and April 30, mainly during and immediately following precipitation (Lehre 1974). A graph of flow duration and intensity would closely parallel a graph of precipitation (Figure 3). This is due to 1) steep upper basins promoting rapid runoff, 2) shallow soil and poor permeability resisting recharge and severely limiting storage capacity, and 3) most precipitation falling upon previously saturated ground. Base flow is maintained by slow drainage of water through the soil yielding a low, yet perennial flow in the lower drainage (below 1900-ft elevation). Summer flow has not been gauged in the drainage. However, based upon Lehre's (1974) evaluation of hydrology in the region, a summer flow of about .05 cfs is estimated to occur along the bedrock courses of the drainage, from near Panoramic Highway to near Spike Buck Creek. Summer flow gradually disappears into the shallow alluvium below Kent Canyon, becoming intermittent, disappearing and reappearing as pools and short flowing sections where bedrock encroaches the surface.

## Land Use and Development

Land use and development in the Redwood Creek drainage ranges from open space recreation within Mount Tamalpias State Park and Muir Woods National Monument to moderately dense residential development at Muir Beach. Associated impacts affecting the fishery resource include water diversion, waste water disposal, and streambed alteration.

Four wells currently divert water from the Redwood Creek alluvium. One owned by DPR provides domestic water to two Park residences (about 150 gallons per day) one operated by A. Banducci provides irrigation water to a commercial flower farm located adjacent to Redwood Creek near the mouth, and two owned by Seacape provide water to Muir Beach area residents (Vollintine 1973). The diversons definitely reduce surface water within the last mile of stream (Arnold 1971).

Waste water disposal includes domestic waste disposal to septic systems, and agriculture waste water runoff from the commercial flower farm. Effluent from septic systems close to the shallow ground water, and the runoff of pesticides, have reportedly degraded water quality during low summer flow conditions, by entering pools and creating noxious conditions (Vollintine 1973).

Identified erosion sources in the drainage include the cultivated flower fields, logging activities in upper Kent Canyon (Arnold 1971) and trail development (Vollintine 1973). None of these sources have caused recent

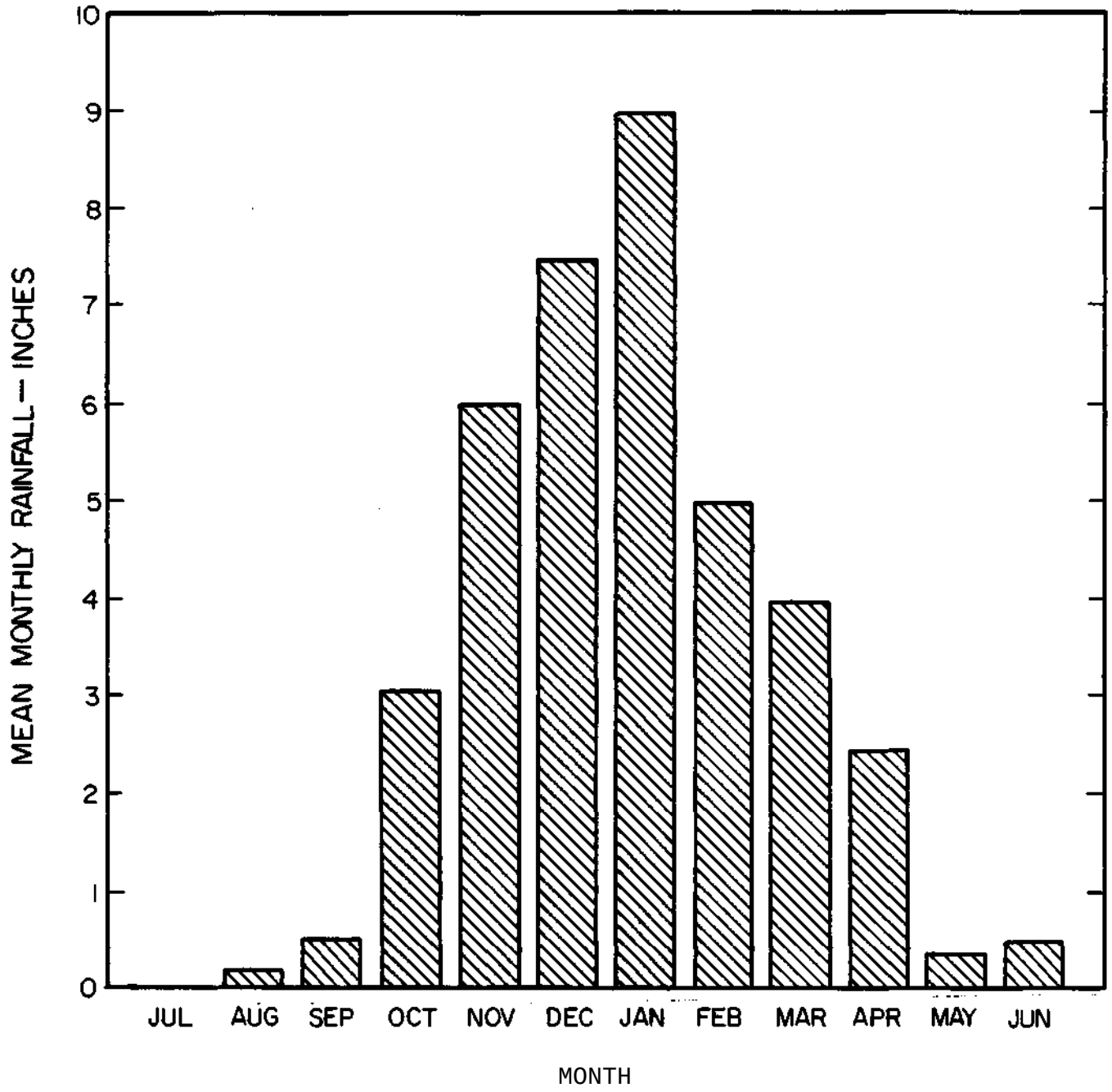


FIGURE 3. MEAN MONTHLY RAINFALL AT MUIR WOODS GAUGE IN REDWOOD CREEK DRAINAGE, MARIN COUNTY.

damage to stream habitat - the logging occurred in the 1960's and apparently caused severe damage at that time.

Streambed alteration has been most severe in the lower drainage. Historically, a large, deep lagoon (Big Lagoon) persisted in the lower 900 to 1500 ft of the stream. Today, the upper part of the lagoon area is composed of a large, curved pool, the result of years of dredging and building levees and summer dams. The pool annually fills with the winter runoff, and is cleaned out by bulldozers in the summer. Apparently the pool is used to collect water for irrigating the adjacent fields, and to prevent salt water from reaching upstream to the vicinity of the diversion. A tidal gate is built into the dam preventing upstream movement of tidal flow. The result has been loss of the lagoon. Arnold (1971) also reported that grading within the streambed in the vicinity of the well diversion, associated with the pool, completely destroyed fish habitat in 1968.

## FISHERY RESOURCE

Fishes native to Redwood Creek drainage include steelhead, coho salmon, three-spine stickleback, Gasterosteus aculeatus, prickly sculpin, Cottus asper, and riffle sculpin, Cottus gulosus. Other species have been occasionally found in the tidal area of lower Redwood Creek including striped bass, Morone saxatalis, staghorn sculpin, Leptocottus armatus, and starry flounder, Platyicthys stellatus (Arnold 1971).

Steelhead and coho salmon are anadromous members of the salmonid family. They spend their adult life in the ocean, returning to freshwater streams to spawn. Coho salmon generally enter Redwood Creek to spawn following the season's first major runoff, generally in late November, and continue to enter the stream until late February. Steelhead enter the stream and spawn between December and May. Both species spawn in gravel areas of the stream, generally in the tail end of pools or the head end of riffles, where water depth and velocity are suitable. Eggs are deposited in a series of pits (i.e., redds) dug by the adults, then covered with gravel. The eggs hatch between 80 and 120 days depending upon water temperature. The newly hatched fry remain in the gravel until the yolk sack - which sustains their nutrient - needs - is absorbed. They then emerge into the stream to actively feed. After emergence, the fry usually remain in riffles close to the spawning area. By winter, the juveniles, as they are now called, seek habitat more suited for their larger size, (i.e., large pools with abundant cover) which is usually found in the lower reaches of small coastal streams, predominantly in the lagoon. In this “large fish" habitat the fish grow to between 5 and 7 inches before smolting (a physiological change preparing the fish for life in the sea) and migrating to the ocean. Such smolts generally have spent 1 plus years in the stream prior to migrating. Sometimes fish will leave earlier either due to the lack of large fish habitat, or due to exceptionally rapid growth which stimulates early smolting. Fish generally do not smolt until they are at least 4 inches long (Shapavolov and Taft 1954).

Smolt survival rate to spawning is directly related to the size of the smolt at emmigration. The larger the smolt at migration the greater its survival. Thus, the more large fish habitat, the more large smolts and the

more adults returning to spawn.

Coho salmon juveniles were observed in Redwood Creek during late summer (1967-1968), from the mouth up to the vicinity of Fern Creek, and in Fern Creek up to the 280-ft elevation (Figure 4) (Arnold 1971). Only young-of-the-year juveniles were found above Highway 1; larger (>5 inches), older juvenile salmon were found only in the pools below Highway 1.

Steelhead use a large portion of the drainage (Figure 5). Juvenile steelhead were observed in Bootjack and Rattlesnake creeks up to the 1900-ft elevation, and in Fern Creek up to the 400-ft elevation in 1967 and 1968 (Arnold 1971). Larger, older (>5 inches) steelhead juveniles were observed only from the mouth as far upstream as Kent Canyon.

Data reported by Arnold indicate that suitable spawning and small fish (<5 inches) rearing habitat occurs throughout the drainage, from Highway 1 up into Bootjack, Rattlesnake and Fern creeks (evidenced by the occurrence of the small juvenile steelhead). However, coho salmon, being less tenacious than steelhead during their spawning run, are limited to a lower reach of the drainage by barriers which do not impede the steelhead. Large steelhead juveniles (>5 inches), however, apparently are limited to the lower river, below Kent Canyon, where recurrent pools cooled by resurfacing subterrainean flow and persistent fog provide amenable large fish habitat. Observation of both large and small, coho salmon and steelhead juveniles in small pools below Highway 1 (where a large lagoon once occurred) suggests that the lagoon once provded critical large fish habitat, especially for coho salmon, since large juvenile salmon were only found below Highway 1.

## FLOW REQUIREMENT EVALUATION

### Methods

The TWM was developed in Washington State to provide preliminary planning information on salmon and steelhead flow needs for spawning and rearing. Investigators identified a correlation between stream discharges and the average toe-width of spawning riffles (the width of a cross section measured from the elevation where the streambed and one bank join, to the ground surface at the opposite bank), and the spawning and rearing habitat. The method is generally applicable in streams with alluvial deposited channels, with widths between 15 and 200 ft and maximum gradient from 1.8 to 4.0% (Swift 1979). Redwood Creek between the mouth and Fern Creek generally meets these requirements. The TWM does not identify migratory and flushing flow needs nor does it relate water quality, substrate and cover parameters to spawning or rearing habitat needs. The TWM has limited application in California due to a vast variation in stream morphology. It should be used with caution, and only as a planning aid in stream sections which fit the stream characteristics identified by Swift (1976, 1979); i.e., where stream morphology is alluvial, gradient is between 1.8% and 4%, and stream width is 15 and 200 ft.

Redwood Creek was divided into 6 reaches based upon general stream morphology (Figure 6). Toe-widths were measured at transects which

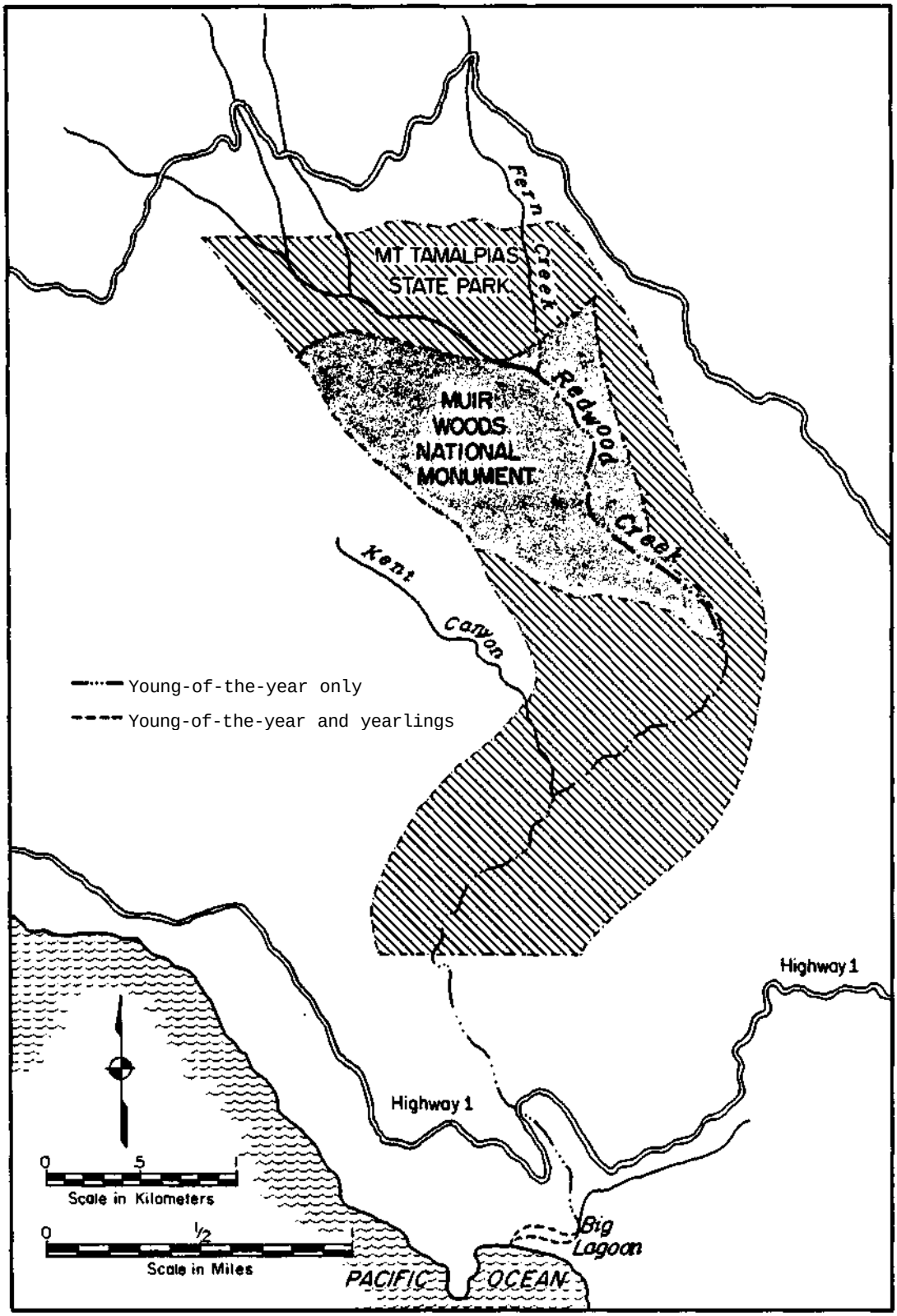


FIGURE 4. LOCATION OF YOUNG-OF-THE-YEAR AND YEARLING COHO SALMON HABITAT IN REDWOOD CREEK DRAINAGE, MARIN COUNTY.

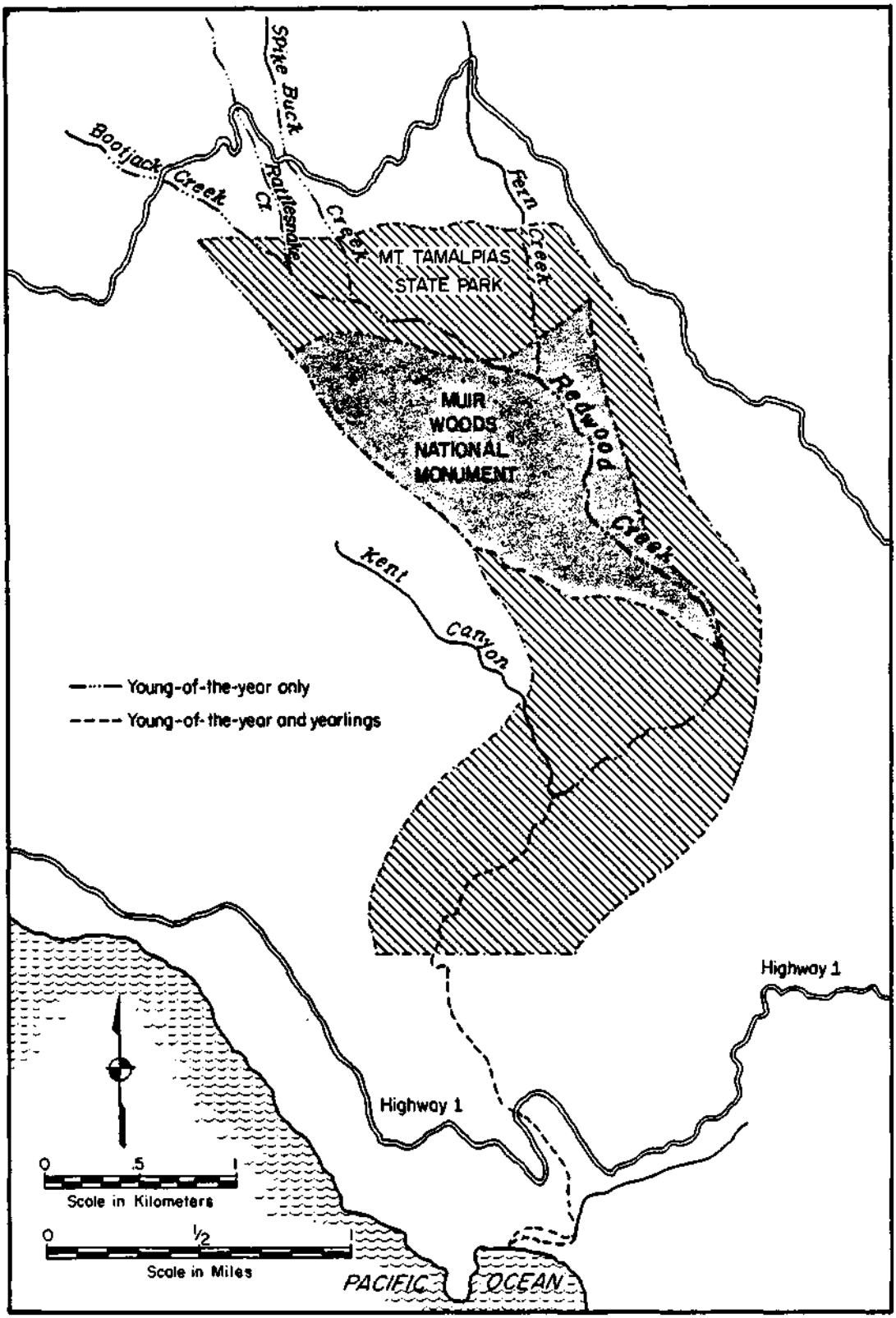


FIGURE 5. LOCATION OF YOUNG-OF-THE-YEAR AND YEARLING STEELHEAD TROUT HABITAT IN REDWOOD CREEK DRAINAGE, MARIN COUNTY.

characterized the condition within each reach (Table 1). Measurements were made in April 1983.

Critical flow requirements for adult migration were determined using the Thompson method (Thompson 1972). The depth of critical riffles (i.e., wide, uniformally shallow riffles) were measured along a transect following the line of least depth at various flows. At least *25%* of the transect length, or a continuous 10 *%* of its length must be at least 0.6 ft deep to provide passage for coho salmon or steelhead. The low flows meeting the minimum criteria at each riffle were averaged for the entire stream to identify the minimum flow for passage.

## Results

Reach 1 did not meet TWM criteria: morphology was not alluvial, gradient was greater than 4%, width was less than 15 ft and substrate was boulder and bedrock. Morphology of reaches 2 through 6 was alluvial and did meet the TWM criteria.

Average toe-widths ranged from 16.5 ft in Reach 4 to 21.6 ft in Reach 3 (Table 2). Preferred salmon and steelhead rearing flow accordingly ranged from 8 cfs in Reach 4, 5, and 6, to 12 cfs in Reach 3. Similarly, preferred salmon spawning flow ranged between 22 cfs in Reaches 4, 5 and 6, and 31 cfs in Reach 3, and between 40 cfs and 55 cfs for steelhead. Since average toe-widths were similar in Reaches 4, 5, and 6, flow requirements were also similar. The same relationship was observed between Reaches 2 and 3.

Four potential critical riffles were observed between Fern Creek and the Highway 1 bridge (Figure 7). Thompson criteria depth (i.e., 25% of the transect and 10% continuous) at 4.26 cfs was only 0.375 ft, well below the minimum required 0.6 ft. Measurements were not made at any other flows, however the narrow channel width and well defined banks at these riffles suggested that any moderate increase in flow would probably provide suitable passage.

## Discussion

The flow occurring in Redwood Creek during the spawning season (November through April) is unmeasured. However, using the data prepared by Lehre (1974) to estimate mean daily runoff and flow duration in Marin County streams, it is estimated that 31 cfs (i.e., the maximum preferred spawning flow for salmon) would be exceeded about 10% of the time (Figure 8), that 22 cfs (the minimum flow required for salmon spawning) would be exceeded about 18% of the time and that 25 cfs (the mean spawning flow for salmon) would be exceeded about 15% of the time. Similarly, a flow of 55 cfs (the maximum spawning flow for steelhead) would occur less than 4% of the time, 40 cfs (the minimum steelhead spawning flow) would occur less than 7% of the time and 46 cfs (the mean spawning flow for steelhead) would occur less than *5%* of the time. Preferred rearing flow levels of 8 cfs (minimum) would occur less than 25% of the time and levels of 12 cfs (maximum) would occur less than 18% of the time.

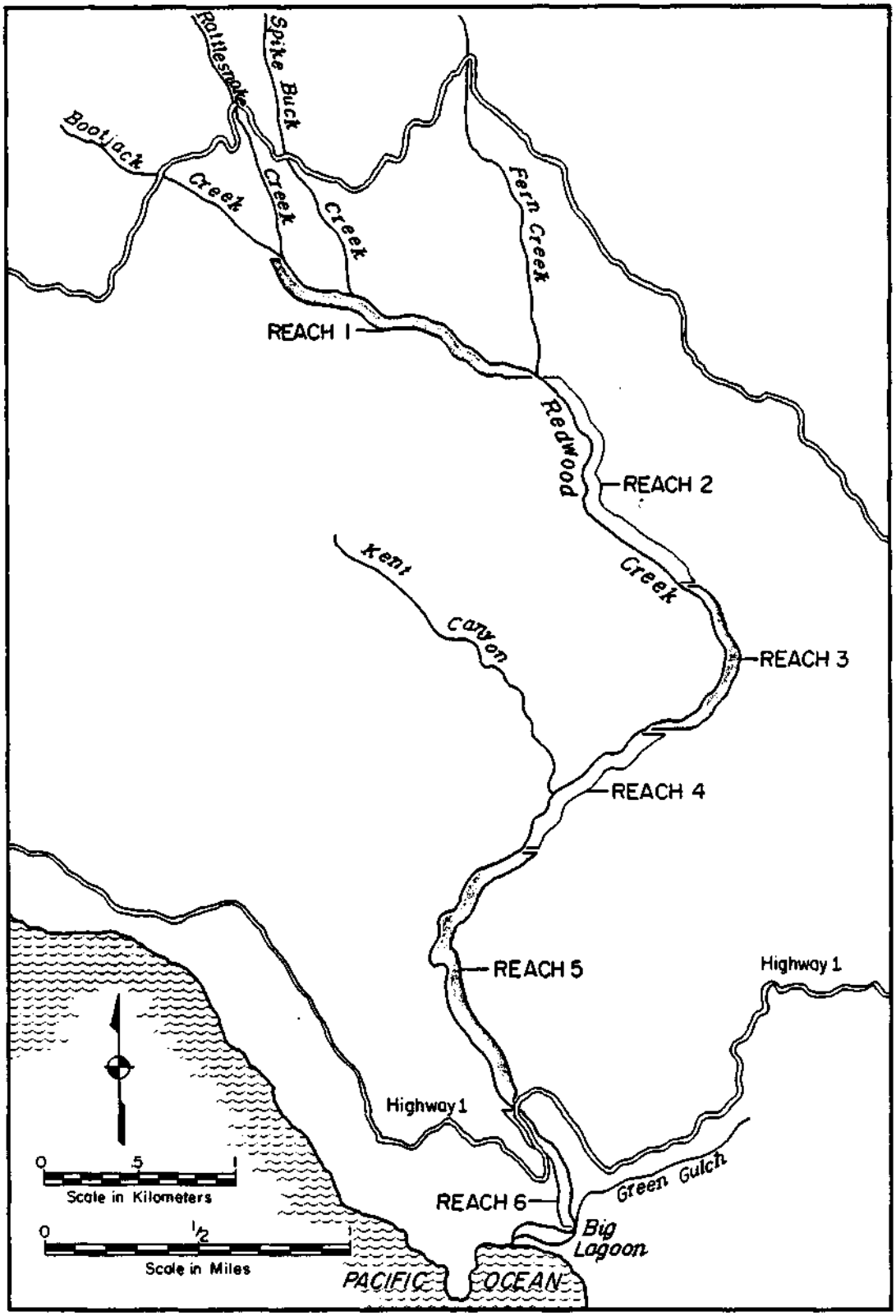


FIGURE 6. LOCATION OF TOE-WIDTH METHOD STUDY REACHES, REDWOOD CREEK, MARIN COUNTY.

TABLE 1. Characteristics of Toe-Width Method study reaches.
Redwood Creek, Marin County.

| Reach | Location | | Description |
|---|---|---|---|
| 1 | Above Fern Creek | a. | Incised, V-shaped canyon. |
| | | b. | Primarily riffle with small cascades, |
| | | c. | Boulder, bedrock, gravel. |
| 2 | Upper Muir Woods National Monument | a. | Narrow valley, 100-150 ft wide. |
| | | b. | Gentle riffles, swift runs, few |
| | | c. | Cobble, gravel-no boulders/ bedrock. |
| 3 | Lower Muir Woods National Monument | a. | Broadened valley. |
| | | b. | Pool/riffle interspersed by gravel |
| | | c. | Large gravel, small gravel. |
| 4 | Kent Canyon vicinity | a. | Broad valley. |
| | | b. | Mostly pool/riffle with few runs |
| | | c. | Large gravel, small gravel. |
| 5 | Highway 1 to Kent Canyon vicinity | a. | Broad valley. |
| | | b. | Runs, deep pools, deep runs, short |
| | | c. | Small gravel, large gravel, sand. |

TABLE 2. Summary of Preferred Spawning and Rearing Flows for Coho Salmon and Steelhead in Redwood Creek, Marin County, Using the Toe-Width Method.

| Reach | Average width (⌈Dft) | Preferred rearing flows (cfs) | Preferred spawning flows (cfs) | |
|---|---|---|---|---|
| | | Salmon and steelhead | Salmon | Steelhead |
| 1 | | DID NOT MEET TWM CRITERIA | | |
| 2 | 21.3 | 11 | 30 | 54 |
| 3 | 21.6 | 12 | 31 | 55 |
| 4 | 16.5 | 8 | 22 | 41 |
| 5 | 16.9 | 8 | 22 | 41 |
| 6 | 16.9 | 8 | 24 | 44 |
| Mean | 18.6 | 9 | 25 | 46 |

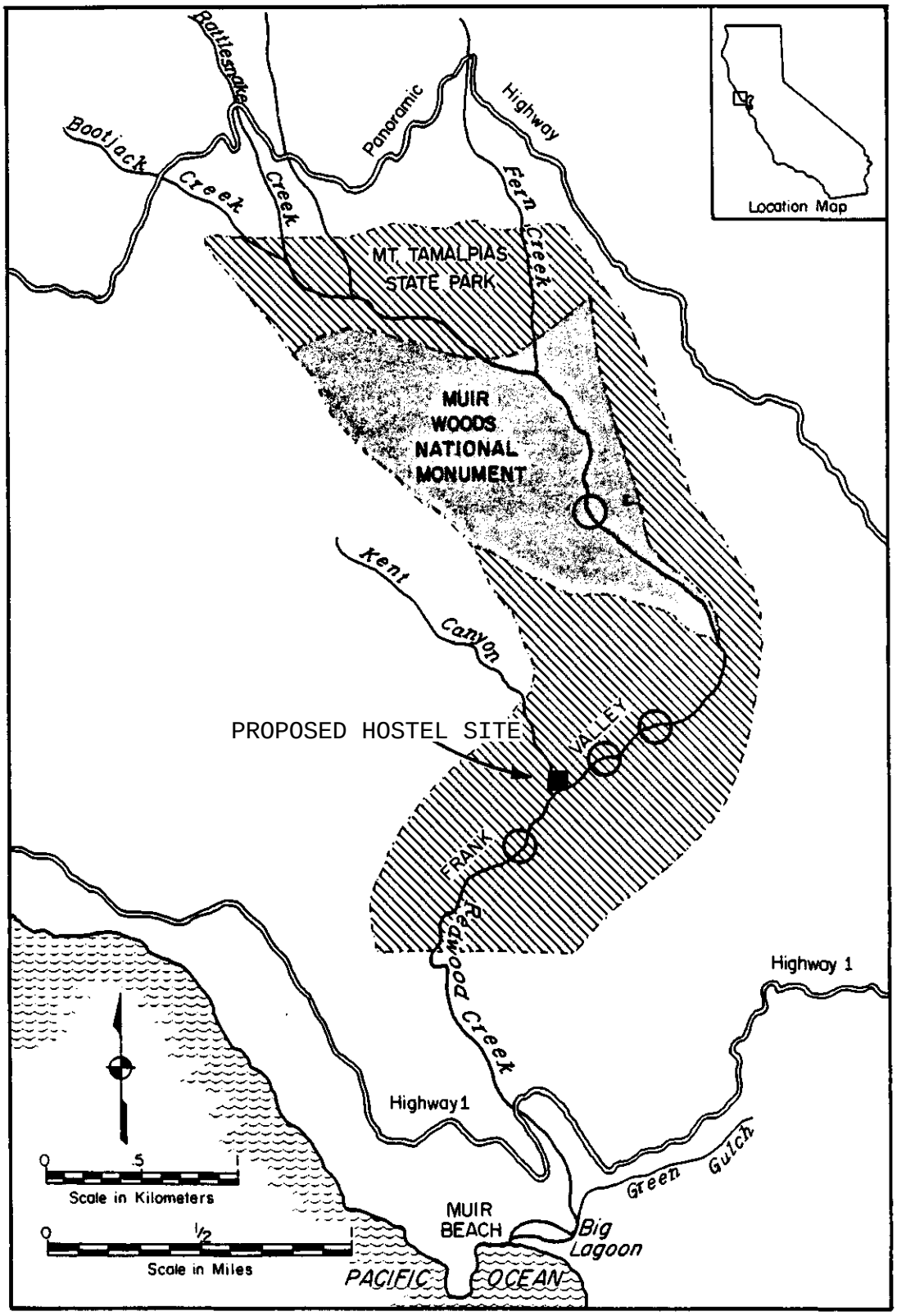


FIGURE 7. LOCATION OF POTENTIAL CRITICAL RIFFLES WITHIN REDWOOD CREEK MARIN COUNTY.

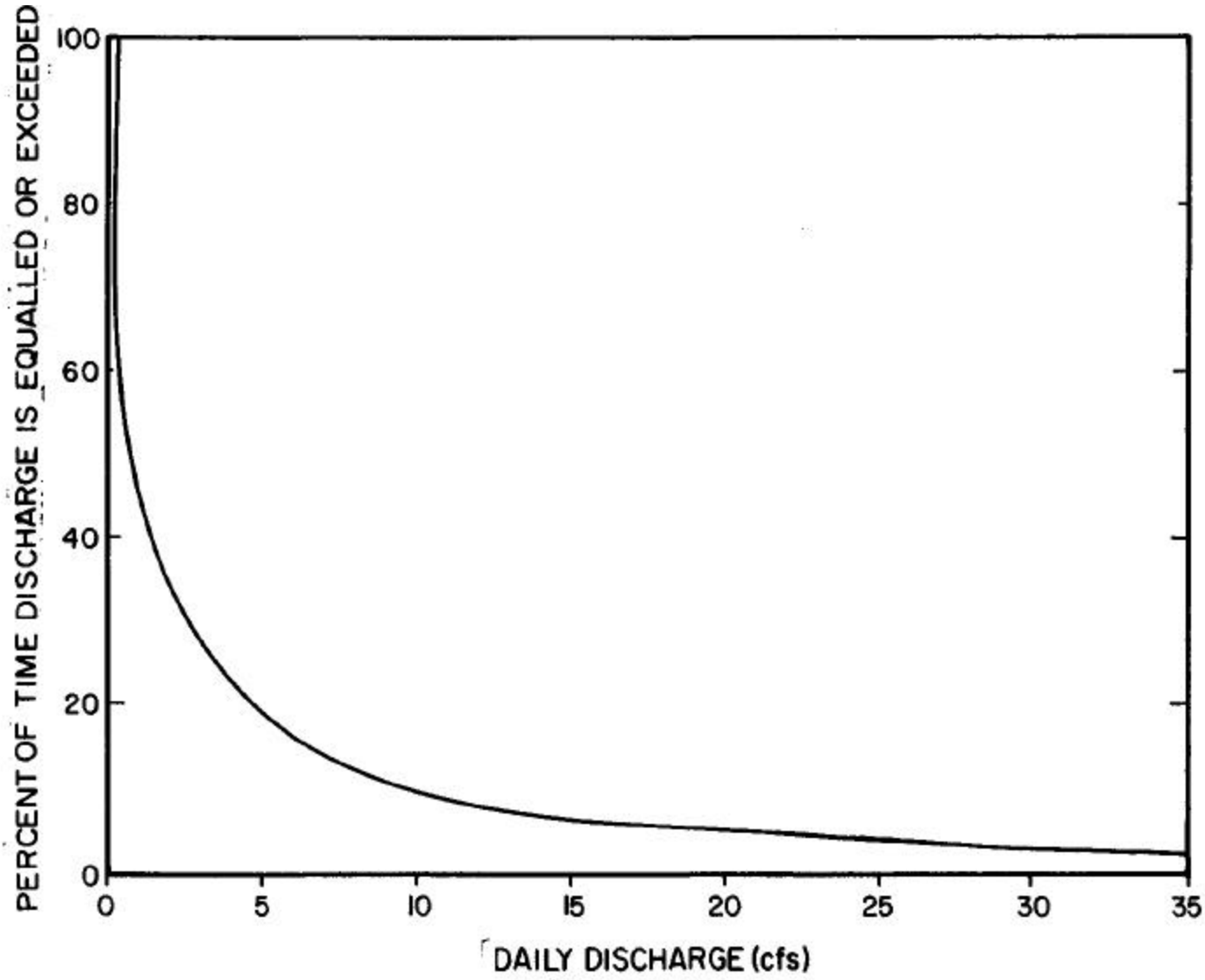


FIGURE 8. PERCENT OF TIME DAILY DISCHARGE IS EXCEEDED NEAR HIGHWAY 1, REDWOOD CREEK, MARIN COUNTY.

The only measured low summer flows in Redwood Creek were 0.56 cfs at Highway 1 Bridge and 0.08 cfs at Pern Creek (September 1974) (Lehre 1976). Lehre also estimated the mean annual low flow in Redwood Creek to be about 0.5 cfs. Steelhead and salmon rearing obviously occurs at such low flows, however, habitat would be significantly increased at 9 cfs.

The minimum flow for migration of adult coho salmon and steelhead over the critical riffles found in Redwood Creek is greater than 4.26 cfs. The minimum required flow cannot be determined without more data. However, the minimum flow is estimated to be between 5 and 15 cfs owing to the narrow, steepsided channel encompassing these riffles.

## DISCUSSION AND CONCLUSIONS

Redwood Creek supports valuable steelhead and coho salmon resources which are integral, important components of the state and national parks' environnments. These populations have reportedly dwindled below historic levels largely due to water diverisons and streambed alterations in the lower drainage. These activities have reduced large fish habitat primarily through the loss of the Redwood Creek lagoon. Further reduction in large fish habitat due to increased water diverison, further streambed alteration, or water quality degradation which could result from increased development in the drainage would be unacceptable.

The TWM evaluation results and limited hydrologic data suggest that preferred flow for both salmon and steelhead spawning occurs during a relatively small period of time, presumably during and immediately following storms. Preferred rearing flows are essentially absent most of the year. The fish population evaluation reported by Arnold (1971), however, indicates that considerably lower flows can sustain spawning and rearing, and that the reach below Kent Canyon is critical to the continued survival of the salmon and steelhead resources since all the large fish habitat occurs in that reach.

The proposed diversion rate of underflow from the vicinity of Kent Canyon is unknown. If the system's total storage capacity (1.18 acre-ft) were diverted over a 24 hour period, the diversion rate would be 0.6 cfs. Spawning and flushing flows during normal and wet years would not be affected by such a diversion rate. Such a diversion during dry years, however, could impinge upon spawning, attraction and flushing flows. In general, diversion when flows are below 25 cfs (preferred salmon spawning flow) in November, and below 46 cfs (mean preferred steelhead spawning flow) from December through April, would decrease spawning habitat.

If the low flow diversion of 1,830 gallons per day were to occur over a 24 hour period, the diversion rate would be less than 0.01 cfs. Although such a low diversion rate would probably not affect low flow habitat availability, care must be taken to assure that the stressful conditions accompanying low flows (e.g., reduced habitat, increased temperature, crowding, etc.) are not intensified or extended. Hence, for planning purposes, and in order to sustain continued viability of Redwood Creek's salmon and steelhead resources, it is assumed that diversion when flow is less than 9 cfs (mean preferred rearing habitat flow) would adversely

affect salmonid rearing habitat availability. The actual reduction in available habitat due to the proposed diversion cannot be determined by the TWM. If it becomes necessary to quantify available habitat and losses at various flows, a more precise method of instream flow assesmnent will be needed, such as the instream flow incremental method.

## RECOMMENDATIONS

1. The water supply for the proposed hostel and any further development within Mount Tamalpias State Park should be obtained from MMWD. This would assure protection and potentially improve the critical low summer flow rearing habitat by the importation of additonal water into the basin.

2. If it is determined that underflow diverson is the only possible water source, diversion should not occur when natural flow is below 25 cfs in November, below 46 cfs from December through April and 9 cfs from May through October, unless a more definitive study, such as an incremental instream flow study, indicates that lesser flows are acceptable. No diversion shall cause an abrupt reduction from the flow existing on April 1 to 9 cfs on May 1. Flow reductions should follow the natural hydrograph to sustain any eggs or sac fry remaining within the gravel and to avoid stranding of fish or any other mortality due to unnatural reductions in habitat.

3. The DPR, the NPS and the DFG should work to eliminate the problems associated with the water diverions near Highway 1. The objective of such a project would be to reestablish the lagoon and other large fish habitat in lower Redwood Creek to restore the steelhead and salmon runs to their historic levels. The Muir Beach residential area should be encouraged to obtain MMWD water. The horticultural activities in the lower drainage should be changed to eliminate activities that affect tidal action, summer rearing flow, migration and water qualty.

4. DPR should install, monitor and maintain a flow gauge capable of measuring the flow immediately downstream of the proposed well. Gauge records should be maintained by DPR and should be available to DFG and other interested parties at any time. Otherwise, DPR shall provide DFG,each January 1,the records for the previous water year.

## REFERENCES

Arnold, John R. 1971. A study of the silver salmon Oncorhynchus kisutch (Walbaum) and steelhead rainbow trout Salmo gairdneri gairdneri Richardson in Redwood Creek, Marin County, California. U.S.D.I. Natl. Park Serv. Contract 4-10-9-990-33. 45 p.

Bovee, Ken D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Information Paper 12. U.S.D.I. Fish Wildl. Serv. Of. Biol. Serv. 248 p.

Department of Parks and Recreation. 1981. Kent Canyon Hostel Mount

Tamalplas State Park, draft E.I.R. Calif. Dept. Parks and Recreation, Sacramento, 19 p.

Lehre, Andre K. 1974. The climate and hydrology of the Golden Gate National Recreation Area. In: The terrestrial environment of the Golden Gate Natioal Recreation Area with proposals for resource management and research. Rpt. to Natl. Park Serv. authorized by Order No. PX 8140WMO. 73 p.

Shapavolov, Leo and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch). Calif. Fish Game, Fish. Bull. No. 98. 375 p.

Swift, C. H. 1976. Estimation of stream discharges preferred by steelhead trout for spawning and rearing in western Washington. U. S. Geol. Surv. Open File Report 75-155. 50p.

Swift, C. H. 1979. Preferred stream discharges for salmon spawning and rearing in Washington. U.S.Geol. Surv. Open File Report 77-422. 51p.

Thompson, K. E. 1972. Determining stream flows for fish life. In: Proceedings instream flow requirements workshop, Pacific Northwest River Basins Comm. Portland, Or. p 31-50.

Vollintine, Larry. 1973. Land use in Redwood Creek watershed, Marin County. U.C. Berkeley class rpt. 135 p. (mimeo).