Water Right Application #30166
El Sur Ranch, Monterey County, California

Biology

BIOLOGY

ESR--22

ASSESSMENT OF HABITAT QUALITY & AVAILABILITY WITHIN THE LOWER BIG SUR RIVER: APRIL–OCTOBER 2004

[BIOLOGY]

Prepared For

Applicant

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Summary of Findings

El Sur Ranch operates two irrigation wells located adjacent to the Big Sur River. The Big Sur River provides a migratory corridor, spawning and egg incubation habitat, and juvenile rearing habitat supporting a population of steelhead *(Oncorhynchus mykiss)*. Steelhead inhabiting the Big Sur River have been listed as a threatened species under the Federal Endangered Species Act. Concern has been expressed regarding the potential for El Sur Ranch irrigation well operations to adversely affect habitat quality and availability for juvenile steelhead inhabiting the lower river and lagoon. A fishery habitat investigation was designed and implemented to provide site-specific field information on instream habitat conditions within the lower reaches of the Big Sur River and the lagoon throughout the summer and early fall of 2004 when El Sur Ranch irrigation well operations occur.

Based upon results of the 2004 fishery investigation we have concluded that the lower Big Sur River and lagoon provide suitable habitat for juvenile steelhead/rainbow trout rearing over the late spring, summer, and early fall period. Habitat conditions within the river, both upstream and downstream of the well location, remained within a suitable range for juvenile steelhead rearing. No adverse effects were detected on instream habitat quality or availability as a direct result of El Sur Ranch irrigation well operations. Additional findings and conclusions of the investigation include:

- Summer baseflows observed during the 2004 investigation were sufficient to provide physical habitat within the lower river and lagoon to support juvenile steelhead/rainbow trout rearing;
- Streamflows were sufficient to maintain connectivity among habitat units throughout the study period, with the exception of the late summer when a sand bar deposit along the beach blocked the lagoon outfall and created a temporary barrier to upstream and downstream steelhead migration. Formation of sand bars is a typical coastal process and did not appear to be the result of irrigation well operations;
- The lower river and lagoon showed evidence of groundwater accretions (upwelling) that contributed to increased summer flows within the lower reaches of the system when compared to upstream reference sites;
- Water quality conditions, including water temperatures, electrical conductivity, and dissolved oxygen concentrations, were within the range considered to be suitable for juvenile steelhead/rainbow trout rearing. For localized areas within the Creamery Meadow reach, available data indicate that groundwater upwelling affected water quality within the river, but that habitat conditions within the surrounding area were within the range considered suitable and may provide a thermal refugia for juvenile steelhead;
- No significant differences in water quality were detected that were correlated or attributed directly to irrigation well operations;
- Juvenile steelhead/rainbow trout were observed rearing within the lower river and lagoon during surveys conducted in July and October. The juvenile steelhead/rainbow trout were characterized as being in good health and conditions, showed good summer survival, good summer growth rates, and evidence of the physiological transformation (smolting) during the fall that is typical of juvenile steelhead preparing to emigrate from the river into coastal waters; and
- Results of the streamflow, connectivity, habitat conditions, water quality measurements, and observations of juvenile steelhead/rainbow trout inhabiting the lower river and lagoon during the 2004 study period provided no evidence of adverse effects on habitat quality or availably as a result of El Sur Ranch irrigation well operations. Similarly, the absence of adverse effects on aquatic habitat serves as an indicator that adverse effects to other sensitive and protected wildlife species inhabiting the area would not be expected, based on environmental conditions and irrigation well operations that occurred during the 2004 study period.

1.0 Introduction

The lower Big Sur River and adjacent habitat supports a variety of fish and wildlife species. Sensitive and protected species inhabiting the area include steelhead (*Oncorhynchus mykiss*)[1], California red-legged frog (*Rana auropa draytonii*), western pond turtle (*Clemmys marmorata*) (Titus *et al.* 2003, BioSystems 1995) and others. Based on resource and regulatory agency concerns regarding the potential for adverse effects to sensitive species and their habitat within the lower Big Sur River resulting from El Sur Ranch irrigation well operations, steelhead were identified as the primary species of interest for this investigation. The response of steelhead to habitat changes within the river resulting from well operations also serves as an indicator of the potential for adverse effects on habitat conditions for other sensitive and protected wildlife inhabiting the area.

Juvenile steelhead/rainbow trout have been reported by Titus *et al.* (2003) to inhabit the lower reaches of the Big Sur River and lagoon (Figure 1), which is used as foraging and rearing habitat throughout the summer and fall months. Habitat quality and availability within the lower river and lagoon for juvenile steelhead rearing is influenced by a variety of environmental factors. These factors, include but are not limited to, seasonal patterns in instream flows, seasonal water temperatures, dissolved oxygen concentrations, electrical conductivity, surface water connectivity among habitat units, habitat diversity (e.g., the occurrence of pool: riffle complexes), instream cover (large woody debris and undercut banks), riparian vegetation, substrate, availability of macroinvertebrates as prey, and a variety of other factors. Many of the factors affecting habitat quality and availability for juvenile steelhead rearing are independent of operations of the El Sur Ranch irrigation wells, such as availability of instream cover, riparian vegetation, and substrate. Other environmental parameters, such as water temperature, dissolved oxygen concentrations, electrical conductivity, and habitat connectivity may potentially be affected by irrigation well operations. To evaluate potential adverse effects to instream habitat a fishery investigation was designed and implemented to provide site-specific field information on instream habitat conditions within the lower portions of Big Sur River and the lagoon throughout the summer and early fall of 2004 when El Sur Ranch irrigation well operations occur.

1.1 PROJECT OBJECTIVES

The primary objectives of the fishery habitat investigation were:

(1) Determine whether or not seasonal changes occur within the lower Big Sur River and lagoon that would adversely affect habitat quality and availability for juvenile steelhead/rainbow trout rearing throughout the summer and fall months;

(2) Assess the potential occurrence of sensitive and protected wildlife species within the area;

(3) If changes in habitat quality and availability are detected within the lower river and lagoon, assess the potential effects of El Sur Ranch irrigation diversion operations on habitat conditions for steelhead and/or sensitive wildlife. Habitat quality and availability for steelhead within the lower Big Sur River were used as an indicator of changes in habitat conditions potentially affecting other sensitive or protected species.

The two fundamental hypotheses being tested by the fishery habitat monitoring program include:

(1) No significant differences exist in habitat quality or availability for juvenile steelhead/rainbow trout within the lower Big Sur River and lagoon throughout the summer and fall; and

(FOOTNOTES)

1 Anadromous steelhead have been listed as a threatened species under the federal Endangered Species Act. NOAA Fisheries has recently proposed also listing resident rainbow trout where they co-occur with steelhead. Since steelhead and resident rainbow trout may co-occur within the lower reaches of the Big Sur River, they are treated together as part of this fishery investigation.

(2) No significant differences exist in habitat quality or availability for juvenile steelhead/rainbow trout rearing between habitat areas within the lower river upstream of the potential influence of the El Sur Ranch irrigation well (reference reach) when compared to habitat conditions within the Creamery Meadow reach and/or downstream within the lagoon (Figure 1).

Specific objectives and evaluation criteria used to assess habitat conditions as part of this survey include:

- Determine if there is a significant reduction in stream flows along the longitudinal gradient from upstream areas outside of the potential influence of the El Sur Ranch irrigation wells and within the lower river adjacent to Creamery Meadow and the lagoon;

- Determine if surface water connectivity is disrupted at any location between the lagoon and the parking area for the Andrew Molera State Park. Loss of surface water connectivity among habitat units would adversely affect steelhead habitat by limiting the ability of juvenile fish to move and forage among various habitat units and, potentially, could result of stranding of juvenile fish within dewatered reaches of the river. Evaluation criteria for use in the field investigations included the identification of any location along the lower river or lagoon where water depth was reduced to less than 2 inches over more than 50% of the wetted channel cross-section;

- Determine if dissolved oxygen concentrations within the lower river or lagoon decrease to a level that would be stressful or unsuitable for juvenile steelhead rearing. For purposes of this evaluation, dissolved oxygen concentrations less than 6 mg/l were identified as stressful and/or unsuitable conditions for juvenile steelhead rearing;

- Determine if water temperatures within the lower river or lagoon are seasonally elevated to a level that would represent stressful or unsuitable habitat conditions for juvenile steelhead rearing. For purposes of this investigation, stressful or unsuitable habitat conditions for juvenile steelhead rearing were identified by average daily water temperatures greater than 20°C (68°F) or maximum daily (hourly) temperatures greater than 24°C (75°F). The assessment of habitat conditions based on water temperature considered both water temperature conditions along the longitudinal gradient of the lower river and lagoon, and the identification of potential cold-water pool refugia habitat that may provide suitable areas for juvenile steelhead to oversummer within the lower river and lagoon;

- Determine if electrical conductivity (salinity) is elevated within the lower river or lagoon to a level that would be considered unsuitable or stressful for juvenile steelhead rearing. Juvenile steelhead are known to successfully rear within brackish water areas in lagoons and estuaries and are tolerant of low levels of salinity during their juvenile rearing period prior to undergoing the physiological smolting transformation when they are adapted to higher salinities in preparation for emigration to marine waters. For purposes of this habitat assessment electrical conductivities within the lower river or lagoon in excess of 1,500 uS/cm were identified as potentially stressful or unsuitable juvenile steelhead rearing habitat;

- Determine if juvenile steelhead growth rates within the Big Sur River are substantially less than growth rates reported from other coastal river/estuarine systems; and

- Determine if juvenile steelhead abundance declines substantially (>50%) over the summer and early fall within the Big Sur River and, if so, is the decline associated with changes in habitat conditions related to El Sur Ranch irrigation well operations.

2.0 Background

2.1 OCCURRENCE OF STEELHEAD/RAINBOW TROUT IN THE BIG SUR RIVER DRAINAGE

Titus *et al.* (2003) compiled the most comprehensive historical summary of the occurrence of steelhead/rainbow trout within the Big Sur River drainage. The following section has been excerpted directly from Titus *et al.* (2003) to provide information on the historical occurrence and habitat conditions within the watershed.

The Big Sur River drainage is currently among the largest of those systems south of San Francisco Bay that remain mostly pristine. Within recent geological history, only the lowermost 12 km (7.5 mi.) or so of the river have been accessible to steelhead. Upstream migration beyond this point in the steep and rugged gorge section of the river has been blocked by a natural bedrock fall. This feature marks the boundary above which the river flows through the Ventana Wilderness within the Los Padres National Forest. Pfeiffer Big Sur State Park is situated immediately downstream from this point along a portion of the lower river where redwoods are a major component of the riparian zone. This far south along the California coast, fog no longer maintains the moisture climate necessary for continuous stands of redwoods, and the steep hillsides that comprise the Big Sur drainage are otherwise dominated by grassland, chaparral, and oak woodland. The lowermost 6.4 km (4 mi.) of the river flow through Andrew Molera State Park.

The following is a chronological rundown of available information on Big Sur River steelhead and resident rainbow trout. The catches of 48 anglers were checked on 1 May 1932, the opening day of the summer trout season (J. H. Wales, CDFG, unpubl. file report). A total of 451 juvenile steelhead/rainbow trout was observed, about 97% of which were age 1+ and 2+ and 10.0–15.0 cm (3.9–5.9 in.) long. The remainder of the observed catch was trout 18.0–25.0 cm (7.1–9.8 in.) in length and ≥ age 2+. Three trout about 30.5 cm (12 in.) in length were reportedly caught, as were three adult steelhead. Recently-emerged steelhead fry were abundant along the stream margins. Wales indicated that juvenile steelhead/rainbow trout were planted in the Big Sur River, but did not know when or how old the fish were at planting.

On 9 April 1940, six adult steelhead were seen in the large pool immediately below the barrier falls, and many more were reportedly seen there a few weeks earlier attempting to ascend the falls (Shapovalov 1940). On 27 March 1946, the CDFG observed a fresh run of adult steelhead in the river, again as far upstream as the barrier falls. Recently emerged steelhead fry were also seen downstream from the falls. In 1953, the CDFG began stocking catchable rainbow trout annually during May–September to support a lower river sport fishery. Prior to that time, rainbow trout fingerlings had been planted for several years. The stocking area was a 5 km (3.1 mi.) reach, mostly within Pfeiffer Big Sur State Park. Resident rainbow trout have not been planted in the Big Sur River since 1975, following adoption of the steelhead rainbow trout policy which prohibits the planting of resident fish in steelhead drainages.

About 19 km (11.8 mi.) of the Big Sur River, from the bottom of the gorge upstream to Sykes Camp in the Ventana Wilderness, were surveyed by the CDFG during July–August 1957. Most of the survey area was upstream from the impassable steelhead barrier, and thus represented the stream portion inhabited primarily by wild resident rainbow trout. The river canyon was narrow and steep-sided, and contained many migration barriers. High quality spawning areas were limited. Rearing habitat was adequate for both juvenile and adult rainbow trout. Rainbow trout, 7.5–25 cm (3–9.8 in.) long, were observed throughout the survey area. However, recruitment to the 1957 year-class was regarded as poor since few young-of-the-year (fish ≤ 5 cm (2 in.) long) were seen.

On 4 January 1961, stream flow just above the lagoon was about 0.6 m^3/s (21.19 cfs), and few adult steelhead had been reported in the river. Two steelhead, about 0.9 and 4.5 kg (2.0 and 9.9 lb.), were caught in the surf outside the lagoon. Other steelhead were also seen outside the river mouth. A 1.4 kg (3.1 lb.) steelhead was captured on 31 January 1961.

Fisher (1961) captured 338 juvenile steelhead/rainbow trout in a downstream-migrant trap in the lower Big Sur River, during 30 April–2 June 1959. The number of downstream migrants captured per day was greatest during the first 3 days of the trapping period, and then decreased sharply and fluctuated around a much lower level through the remainder of the period. Most (87%) movement occurred during the night or early morning. Most downstream migrants were believed to be 1-year-olds. Some 0+ steelhead apparently also entered the trap, although their relative abundance was probably underestimated due to a low trapping efficiency for fish that size. Stream flow in the lower Big Sur River averaged 0.7 m^3/s (24.72 cfs) during the study period, which was uncharacteristically low for the month of May. Thus, these steelhead emigration data may not be representative for normal or wet water years.

On 19 April 1961, young-of-the-year steelhead/rainbow trout were seen throughout the stream reach within Pfeiffer Big Sur State Park, and 12.5–15 cm (4.9–5.9 in.) long juveniles were common. An adult steelhead was caught in the lower river on 31 January 1962. On 28 April 1962, juvenile steelhead captured on hook-and-line in the lower river at a rate of 1.08 trout/angler hour ranged in fork length from 10 to 18 cm (3.9–7.1 in.), and averaged about 14 cm (5.5 in.) (R. N. Hinton, CDFG, intraoffice corr. of 31 May 1962). On 15 May 1962, four steelhead estimated at 61 cm (24 in.) and 1.8–2.7 kg (4–6 lb.), and one at about 36 cm (14.2 in.), were seen in a pool in the lower river area. On 22 May 1962, juvenile steelhead, 5–10 cm (2.0–3.9 in.) long, were common in abundance in pools up to the base of the barrier falls. In 1965, the CDFG estimated the annual steelhead spawning run in the Big Sur River at about 300 fish, based on the observations of local field personnel (California Department of Fish and Game 1965).

The CDFG surveyed the north and south forks of the Big Sur River in August 1978, following the Marble Cone fire of 1977 (P. Chappell, CDFG, unpubl. memo. of 11 June 1979). These headwaters were somewhat degraded due to the fire, yet resident rainbow trout were common in abundance, as determined by hook-and-line sampling. Following several attempts and much discussion over the years regarding removal of the bedrock barrier in the lower gorge, the Big Sur drainage above the barrier was surveyed by the CDFG and USFS during 14 July–4 August 1981 to determine the quantity and quality of stream habitat that would become available to steelhead for spawning and rearing (USFS stream survey reports, and summary by R. C. Benthin, CDFG, unpubl. memo. of 26 August 1981). High quality steelhead spawning and rearing habitats were observed throughout the survey area, including: the entire 21.7 km (13.5 mi.) of the main stem; the lowermost 1.6 km (1 mi.) each of the mainstem tributaries, Ventana and Lion creeks, and the lowermost 160 m (524.9 ft.) of the Ventana Creek tributary, Doolans Hole Creek; the lowermost 7.2 km (4.5 mi.) of the North Fork Big Sur River; and the lowermost 4.0 km (2.5 mi.) of the South Fork Big Sur River up to an 3.7 m (12.1 ft.) high bedrock migration barrier. So, with removal of the bedrock barrier in the lower gorge, at least 36 km (22.4 mi.) of habitat would become accessible to steelhead; an unknown proportion of another 19 km (11.8 mi.) of unsurveyed stream sections would also become available. The mainstem tributaries, Logwood and Terrace creeks, and the North Fork tributary, Cienega Creek, all had an impassable bedrock waterfall at their mouths. The North Fork tributary, Redwood Creek, was full of debris, apparently as a result of the Marble Cone fire. Resident rainbow trout, including young-of-the-year, were abundant in all stream sections surveyed, and occurred in section specific visually-estimated average densities of 40–100 trout/30 m (40-100 trout/98.4 ft.). A subsample of 50 hook-and-line captured rainbow trout averaged about 15 cm (5.9 in.) FL (overall range, 10.0–35.0 cm (3.9–13.8 in. FL)). The USFS stream survey report indicated that the CDFG had planted rainbow trout at Barlow Flat in 1948, but none since that time in the stream area above the gorge. Beginning in the fall of 1981 and through the fall of

1984, a series of modifications was carried out on the barrier to enhance steelhead passage. Six adult steelhead were observed by the CDFG on 18 March 1985 between Barlow Camp and the gorge. Adult steelhead have also been reportedly seen by anglers in upstream areas in subsequent years (K. R. Anderson, CDFG, pers. comm. of 9 July 1992).

On 7 November 1988, abundance estimates of juvenile steelhead were made by the CDFG in two sections of the lower river, each about 46 m long (150.9 ft). Fish were sampled by electrofishing, marked, released, and resampled to make Lincoln-Peterson abundance estimates. In a section just below the confluence with Post Creek, the calculated abundance was 109 trout/30 m (109 trout/98.4 ft.). These fish averaged 84 mm FL (3.3 in.) (range, 55–247 mm FL (2.2–9.7 in.)). The second section, located in Andrew Molera State Park, contained an estimated 128 trout/30 m (128 trout/98.4 ft.). Average fish length was 82 mm FL (range, 55–140 mm FL (2.2–5.5 in.)). A sample of juvenile steelhead was also collected in Molera Park by electrofishing on 17 July 1990 (D. C. Rischbieter, California Department of Parks and Recreation, unpubl. data); these fish averaged 86 mm SL (3.4 in.) (SD = 32 mm SL (1.3 in.); range, 50–175 mm SL (2.0–6.9 in.).

The largest adult steelhead reported from the Big Sur River was an illegal catch that measured 90 cm (35.43 in.) and weighed about 7 kg (15.4 lb.) (Rischbieter 1990a). During the 1992-1993 season, the reported angler catch of adult steelhead in the Big Sur included one 79 cm (31.1 in.) female and several 56 cm (22 in.) fish (M. Fitzsimmons, CDFG, pers. comm. of 13 March 1993). Recent study of juvenile steelhead habitat use in the lower Big Sur River shows that the entire area, from the lagoon to the gorge, remains highly functional for steelhead production (R. G. Titus, CDFG, unpubl. data of 1992–1994). Preliminary analysis suggests that most juveniles leave the stream after only one year of rearing, and that there is a relatively small proportion of mainstem fish that appears to be resident rainbow trout. Most mainstem trout are infested with encysted metacercaria of the monogenetic trematode, Neascus, a condition commonly referred to as "black spot disease".

Resident rainbows are still abundant above the barrier falls in the gorge, and these fish too have black spot disease (C. Carpanzano, U.S. Forest Service, unpubl. letter of 24 September 1993). Some of these trout may be juvenile steelhead, but it is not clear if adult steelhead are still able to negotiate the barrier falls.

STATUS: Overall, the Big Sur River continues to support a healthy steelhead population, one that Nehlsen *et al.* (1991) classified as a stock of special concern.

Juan Higuera Creek

Juan Higuera Creek is the largest perennial tributary to the lower Big Sur River. The CDFG surveyed the creek on 8 August 1961. Steelhead spawning areas were lacking as stream substrate materials were cemented by calcium carbonate precipitates. Rearing habitat in the form of pools and cover also appeared limited. Several potential barriers to upstream movement of adult steelhead were identified. Two small pipe diversions removed water from the stream. No fish were seen during the survey although local residents reported that each small pool in the stream supported one catchable size (15–20 cm (5.9-7.9 in. long)) juvenile steelhead/rainbow trout. Adult steelhead reportedly migrated into Juan Higuera Creek during high flow periods in winter (R. L. Moore, CDFG, unpubl. draft memo. of August 1960).

Another long-time streamside resident and landowner corroborated historical presence of adult steelhead in Juan Higuera Creek (K. Wright for D. Fee, Big Sur, CA, pers. comm. of 4 February 1994). Steelhead were seen and captured in the creek until 1972, when the combined effects of an upslope fire and heavy flooding washed out the road crossing near the creek mouth. A culvert was subsequently installed which then created at least a partial barrier to upstream migrating adult steelhead. Recent study of juvenile steelhead habitat use in the lower Big Sur River reveals that Juan Higuera Creek is still well-populated with juvenile steelhead/rainbow trout (R. G. Titus, CDFG, unpubl. data of 1992–94). Preliminary analysis of population structure suggests that lower Juan Higuera Creek is populated by a mixture of juvenile steelhead and resident rainbow trout, as evidenced by a relatively high proportion of age 0+ fish. What is not clear is whether steelhead actually spawn in the creek and their progeny rear there, or if juvenile steelhead migrate into the creek from the Big Sur River. The population in upper Juan Higuera Creek is much sparser in comparison, and clearly characterized by a higher proportion of larger, older individuals, including mature adults, suggesting a resident rainbow trout population segment.

Post Creek

Post Creek enters the lower Big Sur River within Pfeiffer Big Sur State Park. Shapovalov (1940a) described the creek as "an inconsequential stream that is reported to go completely or nearly dry each summer", in his consideration of potential hatchery sites in the park and vicinity. In contrast, Rischbieter (1990d) noted the creek as an historically perennial stream, and when surveyed by the CDFG in 1980, the creek was identified as an important spawning and rearing area for steelhead. At that time, only the lowermost 275 m (902.2 ft.) of the creek were accessible to steelhead because of an impassable logjam. The stream habitat consisted primarily of small pools and low gradient riffles. The calculated juvenile steelhead abundance for this area was >1,000 fish, or >365 trout/100 m (>365 trout/328.1 ft.) of stream.

The stream habitat at Post Creek has degraded significantly in recent years (Rischbieter 1990d). In 1986, a landslide occurred about 335 m above the creek mouth which introduced a large amount of sediment into the lower creek. The sediment filled in pools and covered spawning gravels. The lower creek went dry during the summer–fall period of the drought years 1988 and 1989. Apparently, drought effects were exacerbated by water withdrawal by the Ventana Inn and other upstream water users. Rischbieter (1990d) concluded that these conditions precluded steelhead use of the creek, and no fish were seen during a brief survey of the lower creek on 18 September 1992 (R. G. Titus, Univ. Calif., Berkeley, unpubl. field notes).

Adult steelhead spawned in lower Post Creek during the wet winter of 1992–93, and steelhead fry were seen in the creek, above the upper road crossing in the campground, on 10 June 1993 (R. G. Titus, CDFG, unpubl. memo. of 12 August 1993). On 9 July 1993, a 64 m (210 ft.) long section, from the upper road crossing to the first foot trail crossing upstream, was sampled by electrofishing. Juvenile steelhead abundance was estimated using the two-pass removal method. The estimated abundance of age 0+ steelhead was about 35 fish (54 fish/100 m (54 fish/328.1 ft.)), and that of age 1+ steelhead was 2 fish (3 fish/100 m (3 fish/328.1 ft.). Age 0+ fish comprised about 94% of the steelhead catch. The mean (± SD) length of age 0+ steelhead was 55 ± 12 mm TL (2.2 ± 0.5 in. TL) (n = 34), and the two age 1+ fish were 101 and 137 mm TL (4.0 and 5.4 in. TL). Age 0+ steelhead also occurred between the upper road crossing and the creek mouth, but no fish were found in the 50+ m (164.0+ ft.) of stream spot-checked immediately above the foot trail crossing. Several potential migration barriers for adult steelhead still exist in lower Post Creek, including the support structure for the foot trail crossing mentioned above, and several logjams that have accumulated large volumes of sediment and gravel. Post Creek has probably supported more extensive steelhead spawning and rearing, as current poor conditions for steelhead production appear to be the product of logging effects and water diversion. It is not known if resident rainbow trout persist in the upper creek area.

2.2 A BRIEF SUMMARY OF STEELHEAD LIFE HISTORY

NOAA Fisheries has listed steelhead inhabiting the Big Sur River as a threatened species under the federal Endangered Species Act (ESA). On August 18, 1997, NOAA Fisheries listed anadromous steelhead inhabiting the South-Central California Coast evolutionarily significant unit (ESU) as a threatened species under the federal Endangered Species Act. The South-Central California Coast ESU (Figure 2) includes all naturally spawned populations of steelhead inhabiting coastal drainages from the Pajaro River (inclusive) to the Santa Maria River, including coastal areas within both Monterey and San Luis Obispo Counties. The Big Sur River falls within the South-Central California Coast ESU and therefore anadromous steelhead inhabiting the river are protected as a threatened species under the ESA. Additional information regarding the protections afforded these steelhead populations are outlined in the Federal Register final rule regarding take of steelhead (50 CFR part 223 dated July 10, 2000). Given the listed status of anadromous steelhead within the South-Central California Coast ESU, as described in the final rules and regulations it is unlawful to harm, harass, kill, or otherwise take a naturally produced steelhead from the Big Sur River. Take is broadly defined under the ESA and includes a wide variety of potential actions that directly affect individual steelhead and/or may directly or indirectly affect their habitat.

Steelhead have not been listed for protection under the California Endangered Species Act. Steelhead have been identified by the California Fish and Game Commission as a species of special concern. The California Fish and Game Commission, which is responsible for designating listed species under the California ESA, has not been petitioned to list of steelhead under state law.

GENERAL

Steelhead are an anadromous species, living part of their life in the ocean but returning to freshwater rivers and streams to spawn and for juvenile rearing (Pauley *et al.* 1986; Figure 3). Adult steelhead enter freshwater rivers and streams in the winter or early spring, usually after several storm events have charged the watershed creating favorable flow conditions, including breaching the sand bar at the lagoon, and move upstream to suitable spawning areas. Spawning can occur in the winter, but more often spawning occurs in the early spring, generally at the tail of pool habitats, in some run habitats, or in riffle areas with clean coarse gravel (Pauley *et al.* 1986; Moyle 2002. During spawning, the female steelhead clears and cleans a depression in the gravel (redd) where eggs are deposited, fertilized, and incubate until hatching. After the eggs hatch, fry emerge from the gravel and disperse through the stream, typically occupying shallow low-velocity areas along stream margins (Reiser and Bjornn 1979). Juvenile steelhead often move to deeper pools and higher velocity areas as they grow, and remain in fresh water for one to two years before migrating to the ocean (Pauley *et al.* 1986; Moyle 2002. Downstream movement of adults after spawning and juveniles migrating to the ocean usually occurs from March through May, depending on stream flow conditions. Adults can spawn more than once, although most do not spawn more than twice.

Clear, cold water, abundant instream cover, well-vegetated stream banks, relatively stable water flow, and stream features including pools and riffles generally characterize steelhead habitat. Adams *et al.* (1973) reported that prolonged exposure of juvenile steelhead to water temperatures of 15°C (59°F) inhibited the physiological transformation to smolts. Zaugg and Wagner (1973) and Zaugg (1981) observed reduced smolting as water temperatures increased above approximately 13°C (55°F). Although optimal water temperatures for steelhead in California are considered to range from approximately 10 to 15°C (50 to 59°F), habitat conditions are generally considered to be suitable for juvenile summer rearing at temperatures below 20°C (68°F) and stressful or unsuitable at higher average daily water temperatures. The 20°C (68°F) criterion represents a water temperature below which reasonable growth of steelhead/rainbow trout may be expected. Data in the literature suggest that temperatures above 21.5 °C (71°F) result in no net growth or a loss of condition in rainbow trout (Hokanson *et al.* 1977). Since the upper incipient lethal temperature for steelhead/rainbow trout is approximately 24°C (75°F; Bell 1973), a binary criterion was developed for determining habitat suitability based on the available literature, suggesting that average daily temperatures should be less than 20°C (68°F) and daily maximum temperatures should be less than 24°C (75°F) to allow acceptable steelhead/rainbow trout growth (Entrix 1995). In the absence of more definitive data on the thermal tolerance of steelhead inhabiting the southern portion of their geographic distribution, and particularly those fish inhabiting the lower Big Sur River and lagoon, the thermal tolerance criteria (frequency of average daily temperatures greater than 20°C (68°F), and frequency of maximum daily temperatures greater than 24°C (75°F) should, therefore, not be used as absolute thermal thresholds, but rather represent general guidelines for assessing the biological significance of water temperature conditions monitored during the 2004 period of these investigations.

Dissolved oxygen concentrations also affect habitat quality and use, physiological stress, and mortality for fish and other aquatic organisms. In general, dissolved oxygen concentrations less than 6 mg/l are considered to be unsuitable for most fish species, including steelhead/rainbow trout (Bell 1973).

A well-developed riparian corridor and instream cover are important components in steelhead streams. Riparian vegetation inhibits erosion of stream banks during high flows, maintains lower stream temperatures, and provides organic input to the stream. Cover, in the form of large woody debris and brush, undercut banks, and other structures (e.g., boulders) provide velocity refuges and reduce the risk of predation. Suitable spawning gravels are 1.3-7.6 cm (0.5 to 3 in.) in diameter, 20.3 cm (8 in.) in depth or more, not heavily compacted, and have low amounts of sand or silt; however, steelhead can successfully spawn in gravels not meeting these characteristics. Good rearing habitat contains low current velocities (such as behind boulders or other velocity barriers) and good cover (e.g., undercut banks, logs or brush, surface turbulence, pool depth). Cobble embeddedness (amount of sediment surrounding rocky substrate) is a measure of shelter availability for aquatic insects (food for fish) and young fish. Embeddedness also indirectly reflects habitat suitability for incubation of fish eggs and for salmonid overwintering.

Streamflow within the central California coastal steelhead range varies seasonally and annually. In California coastal drainages, droughts of one or more years can cause intermittent flow in late summer and fall with reductions in pool depths, reducing the quality and quantity of available habitat. Although steelhead can withstand substantial seasonal and annual fluctuations in stream flow and other physical conditions, prolonged drought can result in substantial mortality to juvenile fish.

MIGRATION

Adult steelhead tend to migrate upstream from the ocean after prolonged storms have generated sufficient runoff conditions to breach a sandbar at the lagoon and provide sufficient water depths to allow fish to move upstream. The migration seldom begins earlier than December and may extend into May if late spring storms develop (Moyle 2002. In central and southern California coastal streams runoff conditions following storm events may not be sufficient to provide for migration until the months of January or February. Most adult steelhead migration and spawning has been documented during the wettest months, January through May (Moyle 2002).

Within central California coastal streams, adult steelhead may be blocked in their upstream migration by bedrock falls, shallow riffles, beaver dams, and, rarely, major logjams. Man-made structures such as culverts, gaging stations, bridge abutments and dams are often significant migration impediments and/or barriers. Some barriers may completely block upstream migration, but many barriers in coastal streams are passable at higher streamflows but may remain an impediment to passage, especially when flows recede. If the barrier is not absolute, some adult steelhead may be able to pass in most years, provided they can time upstream movements to match peak flow conditions.

In coastal streams smolts (young steelhead physiologically transformed in preparation for ocean life) tend to migrate downstream to the lagoon and ocean in March through June. In streams with lagoons, such as the Big Sur River, young-of-the-year fish may migrate downstream in late spring and early summer to spend several months (typically up to one or two years) in the highly productive lagoon habitat and grow rapidly. Early closure of lagoons by sandbars may adversely affect out-migration of smolts.

SPAWNING

Steelhead require spawning gravels (from 0.64 to 10.16 cm (0.25 to 4-in. diameter)) having a minimum of fine material (sand and silt; Bjornn and Reiser 1991). Increases in fine materials from sedimentation, or cementing of gravels with fine materials, restrict water and oxygen flow through the redd (nest) to the fertilized eggs (Suttle *et al.* 2004). These substrate conditions increase egg mortality. In many streams, steelhead utilize substrates for spawning with high percentages of coarse sand, which may reduce hatching success and fry emergence. Large woody debris forms depositional sites for gravel and spawning habitat (J. Merz pers. comm.).

Steelhead that spawn earlier in the winter than others in the population are more likely to have their redds scoured out or buried by sediment deposited during winter storms. Monitoring within coastal streams has documented the majority of spawning and redd sites constructed between February and May, with peak spawning occurring in March and April. Late winter through early spring storms may bury redds resulting in reduced hatching success. Unless hatching success has been severely reduced, survival of eggs and larvae is usually sufficient to saturate the limited available rearing habitat in most coastal streams. Production of young-of-the year steelhead is related to spawning success, which depends on the quality of spawning conditions, ease of adult access to suitable spawning habitat, and ultimately hinges on the timing, frequency, and size of successive storm events once spawning has been completed in the mainstem river or tributaries.

REARING HABITAT

Except in streams with high food production, most juvenile steelhead require two summers of residence before reaching smolt size (Pauley *et al.* 1986). In productive systems with suitable water temperature and food availability, a high proportion of steelhead require only one summer of residence before reaching smolt size. Juvenile steelhead are identified as young-of-the-year (first year) and yearlings (second year). Young-of-the-year steelhead growth and survival appears to be regulated by available insect food, flowing water, dissolved oxygen, and water temperatures. Escape cover (hiding areas provided by undercut banks, large rocks not buried or embedded in finer substrate, surface turbulence, etc.) and water depth in pools, runs and riffles are also important, especially for larger fish. Pool and run habitats are the primary rearing areas for steelhead in summer, with pools, including lagoons, being most important. Availability of cover and cool, well-oxygenated water is an important factor affecting juvenile steelhead survival during the low-flow summer months.

Growth rates of yearling steelhead usually show a large incremental increase from March through May. As smolts mature, physiologically they emigrate downstream to the ocean. For steelhead, which continue to rear in the stream over a second summer, summer growth is typically very low (or even negative in terms of weight). A growth period may also occur in fall and early winter after leaf-drop of riparian trees and before water temperatures decline or water clarity becomes too turbid for feeding.

OVERWINTERING HABITAT

Deeper pools, undercut banks, riparian vegetation, and large, unembedded rocks provide shelter for steelhead against the high flows of winter. Extreme floods may make overwintering habitat the critical factor in steelhead production in some years. In most years, if pools have sufficient larger boulders or undercut banks to provide summer rearing habitat for yearling steelhead, these elements are sufficient to protect juvenile steelhead against winter flows.

RESIDENT RAINBOW TROUT

Resident rainbow trout share many of the same life history characteristics and environmental requirements as described above for anadromous steelhead. Unlike steelhead, which migrate to the ocean for a portion of their life cycle, resident rainbow trout complete their entire life cycle within freshwater environments of streams and lakes. Resident rainbow trout and anadromous steelhead have genetically been identified as the same species, which exhibit two different life history strategies. NOAA Fisheries is currently considering a petition to list resident rainbow trout, which co-occur with anadromous steelhead for protection under the Endangered Species Act.

3.0 Methods

The experimental design for the Big Sur River fishery habitat surveys included comparative observations at specific locations within the lower river and lagoon periodically throughout the summer and fall (April—October) to identify potential changes in habitat conditions that may result from both El Sur Ranch irrigation well operations, in addition to other diversion well operations within the basin, seasonal trends in evapotranspiration by riparian vegetation, and seasonal recession in instream flows within the Big Sur River. The survey design also included comparative surveys at specific locations along the longitudinal gradient between the lagoon at ocean beach upstream into the lower Big Sur River, with the upstream boundary identified as the access trail from the Andrew Molera State Park across the river (Figure 1). The geographic distribution of sampling sites included a series of locations within (1) the lagoon, located downstream of the El Sur Ranch irrigation wells, (2) survey locations within the reach of the lower river adjacent to Creamery Meadow representing the lower river reach adjacent to the El Sur Ranch irrigation wells, and (3) a series of sampling sites located upstream of the potential zone of influence of the wells representing a reference reach. Surveys within the upstream reference sites were used to characterize habitat conditions within a reach of the river thought to be outside the potential influence of the El Sur Ranch well operations. The selection of sampling sites and design of survey methods and protocols was based, in part, on results of a reconnaissance level survey conducted within the river and lagoon on April 18, 2004 as reported to SWRCB in a letter from Jan Jacobson and Paul Horton to Kyriacos Kyriacou dated April 30, 2004.

Elements of the fishery habitat monitoring program briefly described below include (1) water velocity surveys to measure streamflow within the river and inflow into the lagoon (2) periodic water quality and habitat surveys; (3) continuous water temperature monitoring; and (4) snorkel surveys to assess changes in the abundance, size distribution of juvenile steelhead/rainbow trout, and geographic distribution within the river and lagoon between early summer and early fall months. The geographic area included in the fishery habitat investigations extended over a one-mile reach of the river extending from the state park parking area downstream to the confluence between lagoon and the Pacific Ocean (Figure 1).

3.1 VELOCITY AND STREAMFLOW MEASUREMENTS

Streamflow represents an important factor affecting quality and availability of habitat for juvenile steelhead and other aquatic species inhabiting coastal streams. Streamflow also affects water depth and wetted channel area. To document streamflow during the fishery habitat investigation water velocity measurements were made at three transect locations located along the lower river (Figure 4; water velocity and stream flow transects are designated as VT-1, VT-2, and VT-3). Photographs of the three velocity transects are shown in Figures 5, 6, and 7. Each transect location was identified by rebar posts located on the left and right riverbank. During each survey, a tape measure was stretched across the stream channel between the rebar posts and water velocity and water depth was measured at 0.15 m (0.5-ft.) intervals across the channel. Water depth was measured using a top-setting rod. Water velocity was measured using a Marsh-McBirney Model 201D electromagnetic velocity meter. Water flow during each survey (cubic feet per second; cfs) was calculated based on the cross-sectional area of each 0.15 m (0.5-ft.) wide cell (square feet) and the corresponding water velocity (feet per second). The velocity meter was routinely calibrated in accordance with manufactures protocols.

3.2 HABITAT CONDITIONS AND SURFACE WATER CONNECTIVITY

Changes in water surface elevation in response to instream flow rates may result in a reduction in surface water elevations dewatering portions of a river that result in impediments and barriers to migration of fish among habitat units (connectivity), in addition to posing a risk of stranding fish within isolated pools and backwater areas.

SURVEY LOCATIONS

Visual observations of instream habitat conditions were made throughout the reach of the lower river extending from the lagoon outfall to the ocean beach upstream to the state park parking area (Figure 1). The survey reach is approximately one-mile in length. Each survey included observations throughout the entire reach by biologists wading the stream channel from the lagoon upstream.

SURVEY METHODS

Instream habitat conditions identified as potential impediments or barriers to juvenile steelhead/rainbow trout movement among habitats, with particular attention focused on critical riffle areas, were observed throughout the lower river and lagoon during each survey. Conducting the surveys by wading the entire length of the lower river and lagoon allowed the identification of potential passage barriers and impediments that may not have been detected if surveys were conducted at a limited number of access points along the existing hiking trails.

In the event that a specific site was identified as a barrier to juvenile steelhead/rainbow trout movement (e.g., loss of surface connectivity among adjacent habitat units), based on reduced river stage and/or interrupted surface water connectivity, the study protocol required that additional survey transects be established for the purpose of measuring cross-sectional water depths. At each of the locations identified as a barrier to fish movement, a transect was to be established perpendicular to the river flow, marked on both the left and right banks of the channel using rebar posts and flagging tape. A surveyors tape would then be placed across the river channel and water depths measured at 0.5-foot intervals across the channel cross-section. Water depths would be measured using a stadia rod, top setting rod, or similar instrument to determine water depth, at each location across the channel cross-section. Channel cross-sectional water depths at locations identified as barriers to movement would subsequently be measured during each future survey to determine changes in water depth profiles during the summer and fall period.

Additional observations of habitat conditions, including pool water depths and other changes in habitat conditions occurring throughout the seasonal period of these surveys, were documented as part of the general fishery habitat observations made throughout the entire longitudinal gradient of the lower river and lagoon. Results of these qualitative habitat observations were used to help identify trends and changes in habitat conditions occurring within the survey reach that may affect habitat quality and availability for juvenile steelhead/rainbow trout rearing.

SURVEY FREQUENCY

Visual observations of instream habitat conditions and connectivity among habitat units were made during each of the periodic water quality surveys. A reconnaissance survey of habitat conditions was conducted April 18, 2004. Subsequent surveys were conducted approximately twice per month during July—October 2004 (Table 1).

3.3 PERIODIC WATER QUALITY SURVEYS

Water quality parameters, including water temperature, dissolved oxygen concentrations, and electrical conductivity (salinity), affect habitat quality and availability for juvenile steelhead/rainbow trout rearing within a river and/or lagoon. Water quality and habitat surveys were implemented to evaluate conditions within the Big Sur River and lagoon, and to assess the potential effects of El Sur Ranch irrigation well operations on habitat quality and availability for juvenile steelhead/rainbow trout rearing within the lower river and lagoon during summer and fall months.

SURVEY LOCATIONS

Based upon results of the April 18, 2004 reconnaissance survey, twenty-one specific water quality survey sites, (Figure 8), were identified at approximately equal intervals within the lagoon and lower river where periodic grab sample water quality measurements were made using a portable water quality meter. The monitoring locations were numbered from WQ-1, starting in the surf zone downstream of the lagoon discharge, and continued to number WQ-21, the last location adjacent to the state park parking area (Figure 8). Each survey location had three water quality sampling points, near the left bank, near the right bank, and the center of the channel. The three sample points at each survey transect allowed variation in water quality parameters to be observed across the river channel. Table 2 presents a general summary of the water quality monitoring locations.

The geographic distribution of individual survey sites included both locations within the lagoon as well as along transects within the lower river as shown in Figure 8. The specific location of each individual survey site was identified by GPS coordinates and visually using flagging tape to facilitate relocating each specific survey location. At all sites water quality measurements were made at a single depth in the mid-portion of the water column. Increases in pool water depths, particularly in the lower reaches and lagoon, after the sand bar had blocked the lagoon, resulted in increased water depths that precluded wading access to some sampling sites.

SURVEY METHODS

Water quality and habitat surveys were conducted by wading the entire length of the lower river and lagoon, starting downstream of the confluence between the lagoon and ocean beach and progressing upstream to the access trail adjacent to the Molera State Park parking area (Figure 8). Digital photographs were taken during each survey to document instream habitat conditions. Water quality measurements, including dissolved oxygen concentrations (mg/l), water temperature (°C), and electrical conductivity (uS/cm), were measured using portable handheld water quality meters (e.g., WTW Model P4 MultiLine Water Quality Meter, YSI Model 95 dissolved oxygen and water temperature meter, or similar instrumentation). Water quality meters were calibrated using manufacturer protocols and standards prior to each survey.

Water quality surveys were conducted at two-week intervals throughout the period from July 12 through October 28. Table 3 summarizes the water quality survey dates over the period of the monitoring operations of the Big Sur River and shows the water quality parameters measured during each survey. Dissolved oxygen was not measured during the April 18 reconnaissance survey, but all water quality parameters were measured during all subsequent surveys.

3.4 CONTINUOUS WATER TEMPERATURE MONITORING

Steelhead/rainbow trout, a cold-water species, are extremely sensitive to exposure to seasonally elevated water temperatures. Elevated water temperatures, particularly during late summer and early fall months, have been identified as a significant limiting factor affecting habitat quality and availability for juvenile steelhead/rainbow trout rearing within a number of southern and central California river systems. As a result of the sensitivity of juvenile steelhead/rainbow trout to seasonal water temperature conditions, continuous water temperature monitoring was performed at various locations along the longitudinal gradient of the lower river and lagoon as a component of the fishery habitat monitoring program.

SURVEY LOCATIONS

During the April 18 habitat reconnaissance survey five continuous temperature-monitoring locations, designated as CT-1 through CT-5, were identified along the longitudinal gradient of the lower river and lagoon (Figure 9). The five continuous temperature monitoring sites represent the longitudinal gradient within the study area, including an upstream reference site (CT-5), three temperature monitoring sites adjacent Creamery Meadow (CT-2, CT-3, CT-4), and one monitoring location downstream within the lagoon (CT-1). The five continuous temperature-monitoring sites were situated in relatively deep pool habitats. At each of the designated continuous water temperature monitoring sites, water temperature was monitored near the surface (1 foot below the water surface) and on the bottom. The temperature monitoring locations were generally sited in areas that were difficult to access from hiking trails to reduce the risk of vandalism. Despite these precautions, several of the loggers were lost during the study.

A sixth temperature logger (CT-6) was located within the nearshore surf zone along the coast north of the lagoon outlet (Figure 9).

SURVEY METHODS

Water temperature was monitored at each location (Figure 9) using self-contained computerized temperature monitoring data loggers (Optic Stowaway temperature monitoring units). Temperature loggers were periodically calibrated, under controlled laboratory conditions, to NBS traceable standards. Results of temperature logger calibrations were used to verify the accuracy of resulting temperature data and account for instrument error/drift when developing final water temperature monitoring results.

SURVEY FREQUENCY

Water temperatures were monitored and recorded at one-hour intervals from April 18 through October 28, 2004 (monitoring durations varied among sites based on the logger deployment and the loss of loggers). Water temperature loggers were removed from the Big Sur River and lagoon in late October to reduce the likelihood that loggers would be lost during high flow events. Several of the temperature recorders and associated monitoring data were lost because of vandalism, increased flows, and/or surf conditions.

Water temperature data develop during the monitoring program were downloaded periodically during the study from the individual data loggers into Microsoft Excel format. Data from each logger was reviewed and evaluated as part of the quality assurance program to identify potential data outliers, evaluated in accordance with the logger calibration protocol, and adjusted, if necessary, to account for instrument drift as determined by results of the laboratory calibrations. All recorders were found to be within the manufacturer's specifications (0.5°C) and therefore no adjustments to the original field temperature measurements were made. A final water temperature database was documented in tabular format, showing hourly temperatures at each of the designated sampling sites throughout the monitoring period. Water temperature results were also displayed in graphic format and analyzed statistically to determine potential differences in temperatures within sites (surface versus bottom temperature) and among monitoring sites in relationship to El Sur Ranch well diversion operations.

3.5 STEELHEAD/RAINBOW TROUT SNORKEL SURVEYS

Juvenile steelhead/rainbow trout have been reported to rear within the lower Big Sur River and lagoon (Titus *et al.* 2003) during the summer and fall months. As part of fishery habitat investigation, snorkel surveys were performed to characterize the abundance, size and geographic distribution of juvenile steelhead/rainbow trout within the lower river and lagoon. Fishery biologists with experience in identifying and enumerating juvenile steelhead/rainbow trout performed the snorkel surveys. The snorkel surveys followed standard survey protocols.

SURVEY LOCATIONS

Snorkel surveys were conducted on the Big Sur River within a 1.67-km (1.04-mi.) reach extending from the lagoon upstream to Andrew Molera State Park. Eight reaches of varying length (Figure 10; designated as SS-1 through SS-8) were selected for the snorkel surveys based on observed variations in habitat characteristics (e.g., pools, riffles, runs) and were, therefore, not of equal length. Characteristics of the reaches included in the snorkel surveys are summarized in Table 4. Because the distance surveyed differed among the eight reaches surveyed, the number of juvenile steelhead/rainbow trout observed were standardized and presented as the density of steelhead/rainbow trout (number of fish per foot of stream length).

SURVEY METHODS

A team of two divers equipped with wet suits, mask, snorkel, fins, thermometer, pencil and slate performed snorkel surveys (Figure 11). Snorkel surveys were performed by two divers moving in parallel through each reach of the lower river and lagoon using a search pattern that allowed the two divers to survey the entire river cross-section. Swimming upstream along the river margins on opposite banks, divers were positioned so that the maximum lateral area could be observed across the width of the stream channel (approximately 1.2-1.5 m (4-5 ft.) from the stream margin depending on visibility). After the upstream ascent along the margin transects, one diver descended the stream section along the channel center, focusing observations on the mid-line of the channel parallel to the margins. This survey method has been proven to be effective in documenting mid-stream habitat use. Observations were recorded on dive slates and transferred to data sheets after completing the survey of each reach.

Fish species were determined by certified divers from the Fishery Foundation of California, trained in species recognition, with emphasis in distinguishing between young salmon and trout. Training first consisted of picture identification of the juvenile and adult lifestages of fish known or likely to inhabit the Big Sur River. Second, divers were trained by a senior biologist to correctly identify fish species underwater.

Size estimates are improved by calibrating the diver's underwater vision. Calibration consisted of estimating the size of painted lead weights of known length, underwater. The weights were classified into length classes (i.e., 0-40 mm, 41-60 mm, 61-80 mm (0-1.60 in., 1.61-2.39 in., 2.4-3.1 in.), etc.). Fishery Foundation of California divers have extensive experience in conducting juvenile steelhead snorkel surveys and typically have a standard error from 3-10% in estimating fish lengths underwater.

Snorkel surveys were conducted in July and October to assess changes in the abundance, geographic distribution, and size distribution of juvenile steelhead rearing in the lower river and lagoon over the summer and early fall El Sur Ranch well diversion season. The July and October surveys were performed by the same team of biologists to help reduce the possibility of observer differences among surveys.

4.0 Results

4.1 VELOCITY AND STREAMFLOW MEASUREMENTS

The estimated streamflow measured at transect VT-1 over the period from July 23 through October 28, 2004 is summarized in Table 5 and Figure 12 based on measurements made during both day and night surveys. With the exception of the October 28 survey, which followed a fall storm that resulted in a substantial increase in streamflow (approximately 44 cfs based on daytime measurements), streamflows ranged from approximately 6 to 10 cfs. Stream width ranged from approximately 10.4 to 10.7 m (34 to 35 ft.) with a corresponding mean depth ranging from .26 to .29 m (0.86 to 0.96 ft.) during all surveys except under the higher flows observed in late October (Table 5). Results of streamflow measurements at transect VT-1 represent conditions within the reference reach of the Big Sur River located upstream of the El Sur Ranch irrigation wells (Figure 4).

The estimated streamflow measured at transect VT-2 over the period from July 23 through October 28, 2004 is summarized in Table 6 and Figure 13 based on measurements made during both day and night surveys. With the exception of the October 28 survey, which followed a fall storm that resulted in a substantial increase in streamflow (approximately 1.33 m^3/s (47 cfs) based on daytime measurements), streamflows ranged from approximately .17 to .42 m^3/s (6 to 15 cfs). Stream width ranged from approximately 8.53 to 8.84 m (28 to 29 ft.) with a corresponding mean depth typically ranging from .52 to .55 m (1.7 to 1.8 ft.) during all surveys except under the higher flows observed in late October (Table 6) when mean daytime depth increased to .68 m (2.23 ft.). Results of streamflow measurements at transect VT-2 represent conditions within the Big Sur River within the reach located in the general vicinity of the El Sur Ranch irrigation wells and Creamery Meadow (Figure 4).

The estimated streamflow measured at transect VT-3 over the period from July 23 through October 28, 2004 is summarized in Table 7 and Figure 14 based on measurements made during both day and night surveys. Transect VT-3 was located at the lagoon outfall to the beach (Figure 7). Formation of the sand bar that blocked surface water flow from the lagoon to the ocean during late August, September, and part of October precluded flow measurements when the lagoon outlet was blocked (Table 6). With the exception of the October 28 survey, which followed a fall storm that resulted in a substantial increase in streamflow (approximately 56 cfs based on daytime measurements), streamflows ranged from approximately .23 to .28 m^3/s (8 to 10 cfs). Stream width ranged from approximately 6.10 to 7.01 m (20 to 23 ft.) with a corresponding mean depth typically ranging from .15 to .21 m (0.5 to 0.7 ft.) during all surveys except under the higher flows observed in late October (Table 7) when mean daytime depth increased to .52 m (1.69 ft.). Results of streamflow measurements at transect VT-3 represent conditions within the Big Sur River lagoon outfall located downstream of the El Sur Ranch irrigation wells (Figure 4).

A comparison of flows measured during the day at the three velocity transects showed a general pattern of increasing flows moving from transect VT-1 (reference location) downstream within the river and lagoon (Figure 4). Results of the flow measurements made at the three transect locations were tested to determine if there was a significant change (reduction) in stream flows between the upstream reference location and downstream reaches (Creamery Meadow and lagoon) that would adversely affect habitat quality or availability for juvenile steelhead rearing over the summer and early fall months. Results of statistical analyses of the flow data showed that the median flow measured at transect VT-1 (upstream reference) was .25 m^3/s (8.86 cfs) while the median flow at transect VT-2 (near Creamery Meadow) increased to .27 m^3/s (9.49 cfs); differences in the flows were not statistically significant ($n=13$; $P=0.57$) based on a Mann-Whitney Rank Sum Test for differences. In a similar comparison the median flow value measured at transect VT-3 (lagoon outfall) was .28 m^3/s (9.90 cfs ($n=4$)). Although the median flow at the lagoon was generally higher than flow upstream, the differences were not statistically significant ($P=0.62$ based on a Kruskal-Wallis One Way Analysis of Variance on Ranks). Results of these measurements provide no evidence that changes in flow within the lower reaches of the Big Sur River during the study period resulted in adverse effects on instream habitat conditions for juvenile steelhead. In fact, it appears that there is flow accretion within the study reach, generally resulting in slightly higher flow downstream within the Creamery Meadow reach (transect VT-2) and lagoon (transect VT-3).

4.2 HABITAT CONDITIONS AND SURFACE WATER CONNECTIVITY

Instream habitat conditions within the lower Big Sur River included pool, riffle, run, and glide habitat features, in addition to the pool created within the lagoon. Substrate was predominantly sand and pea gravel, although there were deposits of larger gravels associated with several of the riffles located primarily in the river reaches upstream of Creamery Meadow. The substrate was typically unconsolidated and showed very little evidence of cementation. The stream banks were vegetated by diverse riparian vegetation. Cover habitat was provided primarily by brush within the stream channel, overhanging riparian vegetation and large woody debris. Photographs showing the general habitat conditions along the lower Big Sur River are presented in Figures 15 to 24. Although the lower reaches of the river are characterized as being in good conditions, several localized areas exist where stream bank erosion associated with trails and activity observed. The lower reach of the river was characterized primarily as providing habitat for upstream and downstream adult and juvenile steelhead migration and for juvenile rearing. Based on the size characteristics of the substrate, the habitat within the lower river and lagoon would not be expected to be used extensively for steelhead spawning or egg incubation.

During the April – October period of this investigation, surface water flows were sufficient to maintain connectivity among all habitat units within the lower river and lagoon. During late August (following the August 19 survey), there was an extremely high tide that, combined with large surf, resulted in a large sand deposit along the beach adjacent to the lagoon. The beach sand deposit closed the lagoon outflow, blocking surface water flow from the lagoon to the ocean and the potential movement of steelhead into or out of the lower river and lagoon (Figures 16 and 17). The lagoon remained blocked until after the September 15 survey, when streamflow resulted in breaching of the sand bar (Figure 18). Blockage of the lagoon outlet by the sand bar resulted in a substantial increase in water depths within the lagoon and lower reaches of the river, upstream to approximately velocity transect VT-2 (Figure 4). Water depths within the lagoon increased approximately 1.22 to 1.52 m (4 to 5 ft.) while the lagoon outflow was blocked. After the sand bar was breached, water depths within the lagoon and lower reaches of the river were variable. During high tide, the river flow was impeded by wave action and the water depth would rise. When the tide went out, the river was able to discharge via a shallow channel to the sea (Figure 18) and the river depth decreased 2 to 4 feet within the reach extending from water quality monitoring stations WQ-2 to WQ-5 (Figure 8). The increase in water depth made water quality data collection difficult within the lower reaches.

The observed increases in water depths within the lagoon and lower reaches of the river when the lagoon outfall was blocked affected habitat conditions for juvenile steelhead/rainbow trout. Although deep pools (1.83-3.05 m; 6-10 ft) were within the range of water depths considered to be suitable for juvenile rearing habitat, more productive habitat typically ranges in depth from .15 to .91 m (0.5 to 3 ft.) (Reiser and Bjornn 1979; Bjornn and Reiser 1991; Hopper 1973 cited in Pauley *et al.* 1986).

4.3 PERIODIC WATER QUALITY SURVEYS

Water quality measurements were made at approximately two-week intervals at 21 sampling sites located within the one-mile reach of the river extending from the lagoon upstream to the state park parking area (Figure 8). Results of these water quality measurements were used to assess changes in conditions affecting habitat quality and availability for juvenile steelhead/rainbow trout rearing both seasonally over the summer and early fall months coincident with the El Sur Ranch irrigation seasonal and geographically within the river. Water quality stations included sites upstream of the influence of the El Sur Ranch irrigation wells (reference sites), within the immediate vicinity of the wells (Creamery Meadow reach), and downstream of the wells (lagoon reach). For purposes of the analysis of changes in water quality conditions, water quality monitoring sites WQ-10 to 21 were identified as upstream reference sites, sites WQ-5 to 9 were identified as Creamery Meadow locations adjacent to the irrigation wells, and sites WQ-2 to 4 were identified as downstream lagoon sites (Figure 8). WQ-1 was located within the surf zone. Results of the water quality monitoring program are summarized below.

WATER TEMPERATURE

Results of periodic water temperature measurements within the lower Big Sur River and lagoon are summarized in Figures 25 to 34. Water temperatures, ranging approximately 12 to 13°C (54 to 55°F), were uniform along the river gradient during the April 18, 2004 reconnaissance survey (Figure 25). Water temperatures during the July 12, 2004 survey (Figure 26) showed a general trend of decreasing water temperatures within the lower reaches of the Creamery Meadow area and lagoon (sites WQ-2 to WQ-5) when compared to upstream sites (WQ-11 to WQ-20). Water temperatures during the July 23, 2004 survey (Figure 27) were relatively uniform at approximately 20°C (68 °F) at all sites with the exception of site WQ-8 where a substantial reduction in water temperature was observed. Water temperatures observed during the August 6, 2004 survey (Figure 28) were relatively uniform, ranging from approximately 15 to 17°C (59 to 63°F). During the August 19, 2004 survey (Figure 29), water temperatures were lowest in the lagoon (WQ-2) and near the Creamery Meadow (WQ-8) with a general increasing pattern of temperatures at the upstream sites. Water temperatures observed during the September 2 and 15 surveys (Figures 30 and 31) were similar in showing lowest temperatures within the lagoon (WQ-2) and near Creamery Meadow (WQ-7 to WQ-9), with increasing temperatures further upstream. Water temperatures observed on September 30, 2004 (Figure 32) were relatively uniform, with a small reduction in temperature observed in the lagoon (WQ-2) and near Creamery Meadow (WQ-7 to WQ-8). Temperatures observed on October 15, 2004 (Figure 33) were relatively uniform throughout the reaches surveyed. Water temperatures observed during the October 28, 2004 survey (Figure 34) were higher in the lagoon (WQ-2), declined throughout the lagoon (WQ-2) and were relatively uniform at upstream sites (WQ-3 through WQ-21). The trends in geographic distribution of water temperatures observed during each of the surveys are shown in Figures 35 to 44.

Water temperatures at all sites (Appendix A) were within the general range of habitat conditions considered to be suitable for juvenile steelhead rearing (average daily temperatures less than 20°C (68°F) and peak daily temperatures less than 24°C (75°F). The observed decline in water temperatures observed near the Creamery Meadow (WQ-7 to 9) were hypothesized to be the result of groundwater upwelling (accretions) within the localized area of these measurement sites. At the majority of sites, there were no significant observed differences in water temperatures either across the channel or between surface and bottom measurements. At sites WQ-7 to WQ-9, and particularly at WQ-8, water temperatures near the bottom along the right bank of the river (looking upstream) were noticeably cooler during the summer (August and September) surveys when compared to surrounding waters.

We hypothesized that operation of the El Sur Ranch irrigation wells could contribute to an increase in water temperatures within the Creamery Meadow and lagoon reaches of the river that would adversely affect habitat quality for juvenile steelhead rearing. To test the hypothesis a series of statistical analyses were performed to compare, for each survey, water temperatures measured within the upstream reference sites (WQ-10 to 21), Creamery Meadow reach (WQ-5 to 9), and lagoon reach (WQ-2 to 4). Because of wave action and saltwater intrusion from the ocean into the surf zone, the data from WQ-1 were not included in the statistical analyses. The statistical analyses were performed using a Kruskal-Wallis One Way Analysis of Variance on Ranks to account for the lack of a normal distribution and equal variance among test groups of unequal size and Dunn's Method for pairwise multiple comparisons on ranks.

Results of statistical analyses of water temperatures showed that there were no statistically significant differences among upstream and downstream water temperatures measured during the April survey. Water temperatures observed during the July 12 survey were found to be significantly higher ($p<0.05$) between the upstream reference sites and the lagoon, however differences between the upstream sites and Creamery Meadow and between Creamery Meadow and the lagoon were not statistically significant. Significant differences in temperatures were also detected in the July 23 survey with temperatures downstream in the lagoon significantly ($P<0.05$) lower than temperatures either within Creamery Meadow or the upstream reference sites. Water temperatures observed on the August 6 survey were again found to be significantly lower ($p<0.05$) within the lagoon and within Creamery Meadow when compared to the upstream reference sites. A similar pattern was detected in the August 19 survey when temperatures within the lagoon and Creamery Meadow were found to be significantly lower ($p<0.05$) than those observed within the upstream reference sites. Water temperatures within the lagoon and Creamery Meadow during the September 2 survey were also found to be significantly lower than those observed in the upstream reference sites ($p<0.05$). Temperatures during the September 15 survey were also significantly lower within the lagoon and Creamery Meadow when compared to the upstream reference sites ($p<0.05$). A similar result was detected in the September 30 survey. During the October 15 survey, in the fall as day and night air temperatures are cooling seasonally, water temperatures within the upstream reference sites were found to be significantly lower than temperatures observed in either Creamery Meadow or the lagoon.

Based on results of these water temperature comparisons it was concluded that (1) during the summer 2004, water temperatures observed within the lagoon and Creamery Meadow were typically lower than temperatures observed upstream within the reference sites, which is contradictory to the hypothesis that operation of the El Sur Ranch irrigation wells would result in adverse water temperature conditions for rearing steelhead and consistent with the hypothesis that the lower river and lagoon are influenced by groundwater upwelling (which would be cooler in the summer than surface waters in the river) that contribute to cooler water temperatures within Creamery Meadow and the lagoon, and (2) although differences were detected in water temperatures within the river and lagoon, the observed water temperatures were within the range considered to be suitable for juvenile steelhead/ rainbow trout summer rearing.

Results of the water temperature monitoring surveys showed that during the summer of 2004, water temperatures were within the suitable range for juvenile steelhead rearing. There was no apparent adverse effect on water temperatures within the lower river or lagoon resulting from operation of the El Sur Ranch irrigation wells during the study period. The observed localized reduction in water temperatures within the Creamery Meadow reach would provide a thermal refugia for juvenile steelhead in the event that surrounding temperatures became unsuitable. Juvenile steelhead have been observed in other river systems (e.g., Santa Ynez River) to inhabit localized areas of groundwater upwelling as thermal refugia during summer months.

ELECTRICAL CONDUCTIVITY (SALINITY)

Electrical conductivity, a measure of salinity, was monitored as part of the river and lagoon water quality and fishery habitat surveys. Juvenile steelhead have been observed to inhabit rivers and estuarine lagoons having a relatively wide range of electrical conductivities. For purposes of these investigations, it was assumed that habitat conditions would be suitable for juvenile steelhead rearing if electrical conductivity was less than 1500 μmhos (approximately 0.6 ppt salinity). Results of electrical conductivity measurements made from the lower river and lagoon during each of the 2004 surveys are summarized in Figures 45 to 55. Electrical conductivities observed during the surveys were consistently less that 300 μmhos (salinity less than 0.1 ppt) and were within the range considered to be suitable for juvenile steelhead rearing (Appendix B). As with the water temperature survey results discussed above, a pattern of localized reductions in electrical conductivity was observed, particularly during the summer months, at water quality sites near Creamery Meadow (WQ-7 to WQ-9 with the greatest reduction observed at WQ-8). The localized reduction in electrical conductivity was consistent with the temperature patterns and with the hypothesis that these localized changes in water quality was the result of groundwater upwelling. A reverse gradient of electrical conductivity was apparent with higher conductivity observed in upstream reference sites and a general trend of reduced conductivity moving downstream toward the lagoon. The general pattern of electrical conductivity observed in the river is consistent with the speculation of groundwater accretions within the lower reaches of the river and lagoon. The unusually high electrical conductivity measurement observed within the lagoon (WQ-2) during the October 28, 2004 survey (Figure 54) was the result of salinity intrusion and tidal encroachment from the ocean during high tide (a visible salinity wedge was detected near the lagoon outfall) and disruption of salinity gradients within the lagoon near the mouth by observers making water quality measurements.

We hypothesized that operation of the El Sur Ranch irrigation wells could contribute to an increase in electrical conductivity (salinity) within the Creamery Meadow and lagoon reaches of the river that would adversely affect habitat quality for juvenile steelhead rearing. To test the hypothesis a series of statistical analyses were performed to compare, for each survey, electrical conductivities measured within the upstream reference sites (WQ-10 to 21), Creamery Meadow reach (WQ-5 to 9), and lagoon reach (WQ-2 to 4). Because of wave action within the surf zone, the data from WQ-1 were not included in the statistical analyses. The statistical analyses were performed using a Kruskal-Wallis One Way Analysis of Variance on Ranks to account for the lack of a normal distribution and equal variance among test groups of unequal size and Dunn's Method for pairwise multiple comparisons on ranks.

Results of statistical analyses of electrical conductivity data showed that there were no statistically significant differences ($p>0.05$) in electrical conductivity between the upstream reference sites, Creamery Meadow, or lagoon during the April survey. Electrical conductivity was significantly ($p<0.05$) lower in the lagoon when compared to Creamery Meadow and the upstream reference sites during the July 12 survey. No significant differences were detected in electrical conductivity during the July 23 survey among sites ($p>0.05$). Electrical conductivity observed during the August 6 survey were found to be significantly lower ($p<0.05$) within both Creamery Meadow and the lagoon when compared to the upstream reference site. A similar result was detected during the August 19 survey in which electrical conductivity within the lagoon and Creamery Meadow was lower ($p<0.05$) than that observed in the upstream reference sites. Electrical conductivity observed in the September 2 survey was also significantly lower ($p<0.05$) within the lagoon and Creamery Meadow than within the upstream reference sites. A similar result was detected based on data collected in the September 15 survey in which electrical conductivity within the lagoon and Creamery Meadow was lower than that observed in the upstream reference sites. During the September 30 and October 15 surveys no significant differences ($p>0.05$) were detected among the upstream reference sites, Creamery Meadow, and the lagoon.

Based on results of these water quality comparisons it was concluded that (1) during the summer 2004, electrical conductivity observed within the lagoon and Creamery Meadow was typically lower than conductivities observed upstream within the reference sites, which is contradictory to the hypothesis that operation of the El Sur Ranch irrigation wells would result in adverse water quality conditions for rearing steelhead, and consistent with the hypothesis that the lower river and lagoon, are influenced by groundwater upwelling (which would have a lower electrical conductivity in the summer than surface waters in the river) that contribute to reduced electrical conductivities within Creamery Meadow and the lagoon, and (2) although differences were detected in electrical conductivity within the river and lagoon the observed water quality conditions were within the range considered to be suitable for juvenile steelhead/rainbow trout summer rearing.

Results of the electrical conductivity measurements showed that habitat conditions within the lower river and lagoon during the period of this survey were within the range considered to be suitable for juvenile steelhead rearing. There was no apparent adverse effect on electrical conductivities within the lower river or lagoon resulting from operation of the El Sur Ranch irrigation wells during the study period. The observed localized reduction in electrical conductivity within the Creamery Meadow reach, and the general patterns of conductivity within the reaches surveyed, are consistent with the hypothesis that groundwater upwelling (accretion) is occurring within the lower river that affect localized water quality conditions, particularly during the lower flow summer and early fall months.

DISSOLVED OXYGEN

Dissolved oxygen concentrations were monitored as part of the river and lagoon water quality and fishery habitat surveys. For purposes of these investigations, it was assumed that habitat conditions would be suitable for juvenile steelhead rearing if dissolved oxygen levels were above 6 mg/l (ppm). Results of dissolved oxygen measurements made from the lower river and lagoon during the 2004 surveys are summarized in Figures 56 to 64. Dissolved oxygen levels observed during the surveys were consistently above 6 mg/l within the river and lagoon, with the exception of localized reductions observed near Creamery Meadow (WQ-7 to WQ-9: Appendix C). The localized reduction in dissolved oxygen concentrations associated with the Creamery Meadow sites are consistent with the hypothesis of groundwater upwelling in the area. The locations of reduced dissolved oxygen levels coincide with observed reductions in water temperature and electrical conductivity discussed above. With the exception of the localized area near WQ-7 to WQ-9, dissolved oxygen concentrations were within the range considered to be suitable for juvenile steelhead rearing.

We hypothesized that operation of the El Sur Ranch irrigation wells could contribute to reduced dissolved oxygen concentrations within the Creamery Meadow and lagoon reaches of the river that would adversely affect habitat quality for juvenile steelhead rearing. To test the hypothesis a series of statistical analyses were performed to compare, for each survey, dissolved oxygen measurements within the upstream reference sites (WQ-10 to 21), Creamery Meadow reach (WQ-5 to 9), and lagoon reach (WQ-1 to 4). Because of wave action and saltwater intrusion from the ocean into the surf zone, the data from WQ-1 were not included in the statistical analyses. The statistical analyses were performed using a Kruskal-Wallis One Way Analysis of Variance on Ranks to account for the lack of a normal distribution and equal variance among test groups of unequal size and Dunn's Method for pairwise multiple comparisons on ranks.

Results of statistical analyses of dissolved oxygen data showed that concentrations within the lagoon during the July 12 and July 23 surveys were significantly higher ($p<0.05$) than observed in Creamery Meadow or the upstream reference sites. Dissolved oxygen concentrations within the lagoon were found to be significantly less ($p<0.05$) than concentrations within Creamery Meadow or the upstream reference sites during the August 6 survey. Dissolved oxygen concentrations within both the lagoon and Creamery Meadow were found to be significantly lower ($p<0.05$) during the August 19, September 2, September 15 September 30, and October 15 surveys when compared to the upstream reference sites. These results are consistent with the observations of localized reductions in dissolved oxygen levels within the Creamery Meadow reach (particularly WQ-8) where reduced water temperature and reduced electrical conductivity, thought to be the result of groundwater upwelling, were observed. Groundwater typically has reduced dissolved oxygen concentrations when compared to aerated surface waters. As a result of the potential confounding effects of groundwater upwelling within the lower river and lagoon on dissolved oxygen concentrations, the incremental effect, if any, of irrigation well operations could not be detected. Although significant differences in dissolved oxygen concentrations were detected among study reaches during the summer 2004 surveys, dissolved oxygen concentrations were within the range considered to be suitable for juvenile steelhead/rainbow trout with the exception of the localized areas within Creamery Meadow (WQ-7 to 9) where reduced dissolved oxygen concentrations thought to be the result of groundwater upwelling were observed.

Results of the dissolved oxygen measurements showed that habitat conditions within the lower river and lagoon during the period of this survey were within the range considered to be suitable for juvenile steelhead rearing. There was no apparent adverse effect on dissolved oxygen within the lower river or lagoon resulting from operation of the El Sur Ranch irrigation wells during the study period. The observed localized reduction in dissolved oxygen within the Creamery Meadow reach is consistent with the hypothesis that groundwater upwelling (accretion) is occurring within the lower river that affect localized water quality conditions, particularly during the lower flow summer and early fall months.

4.4 CONTINUOUS WATER TEMPERATURE MONITORING

Water temperatures were measured hourly at monitoring locations within the lower river, lagoon, and near-shore surf zone to assess seasonal habitat conditions for juvenile steelhead rearing (Figure 9). For purposes of these analyses, average daily water temperatures less than 20°C (68°F) and peak daily temperatures less than 24°C (75°F) were considered to provide suitable habitat for juvenile rearing during the summer and early fall months. Water temperature monitoring results are summarized in Figures 65 to 75. For illustrative purposes, the figures include the 20°C (68°F) average daily and 24°C (75°F) peak daily water temperature guidelines for habitat suitability. Results of water temperature monitoring reflect the seasonal trends with increasing temperatures during the spring and declining water temperatures during the fall. Water temperature monitoring results showed that habitat conditions were within the range considered to be suitable for juvenile steelhead rearing at all sites. These results are consistent with periodic water temperature monitoring results presented above.

4.5 STEELHEAD/RAINBOW TROUT SNORKEL SURVEY

Snorkel surveys were conducted on the lower Big Sur River during July and October of 2004 to determine the distribution, abundance and length frequency of steelhead/rainbow trout within the reach extending from the lagoon upstream to the state park parking area (Figure 10). Comparative fishery surveys during the summer and early fall provided the opportunity to assess changes in oversummering abundance (survival) and size distribution (growth), and provide the basis to evaluate changes in the fishery population over the summer irrigation season. Results of the fishery surveys provide corroboration of habitat quality conditions derived from measurements of physical habitat conditions (stream flows) and water quality conditions.

Three species of fish were observed during the July and October snorkel surveys (Table 8). In order of abundance the three fish species were: juvenile steelhead/rainbow trout, threespine stickleback (*Gasterosteus aculeatus*), and riffle sculpin (*Cottus gulosus*). Additionally, signal crayfish (*Pacifasticus leniusculus*) were observed. Threespine stickleback and riffle sculpin were observed in reaches SS-1 to SS-3. Threespine stickleback were most abundant in the lagoon and lower river reaches near Creamery Meadow and declined in abundance further upstream (Figure 76). Conversely, riffle sculpin were observed in low numbers in the lagoon and Creamery Meadow reaches and increased in abundance further upstream (Figure 76).

A total of 358 juvenile steelhead/rainbow trout were observed during the October survey compared to 417 observed during the July survey (Table 9). Juvenile steelhead/rainbow trout were observed inhabiting all eight reaches surveyed during both the July and October surveys (Figure 77). Observed densities were highest within the lagoon upstream through river mile 0.47 (SS-4); further upstream juvenile steelhead/rainbow trout densities decreased substantially (Figure 77). Highest densities of juvenile steelhead/rainbow trout were observed consistently within the lagoon (reach SS-1) and within reach SS-4 where habitat cover, provided by large woody debris and instream cover (brush) was high. Steelhead/rainbow trout densities were lower within other reaches of the river surveyed during both the July and October surveys (Figure 77). Sixty-five percent of the total number of juvenile steelhead/rainbow trout observed were found in the lagoon (SS-1; Figure 78) during the July survey and 84 % during the October survey. Results of statistical analyses (Wilcoxon Signed Rank Test using fish densities observed within each reach) for the July and October steelhead/rainbow trout surveys did not detect a significant difference ($p>0.05$) in the abundance or geographical distribution of juvenile fish between the two surveys.

The highest densities of juvenile steelhead/rainbow trout were observed in habitat units characterized by extensive instream cover combined with deep water where large schools of juvenile steelhead/rainbow trout were observed. Peak densities (0.49 and 0.39 juvenile steelhead/rainbow trout per linear foot in July and 0.54 and 0.12 trout/ft in October; Table 9) occurred within the lagoon (SS-1) and within reach SS-4, which reflected the preferred rearing habitat conditions for juvenile fish. Localized densities within reaches were often greater as young steelhead tended to congregate in tight schools in specific areas of sampling units. Unlike the July surveys, juvenile steelhead showing characteristics of smolting were observed in the lagoon reach during the October survey. Approximately 80% of juvenile steelhead/rainbow trout larger than 100 mm (3.9 in.) observed during the October survey were either silvery parr or smolt stages.

The juvenile steelhead/rainbow trout observed rearing in the lower river and lagoon were young-of-the-year and yearling age classes ranging in length from approximately 70 to 250 mm (2.8 to 9.8 in.). Comparison of the length frequency distributions for juvenile steelhead/rainbow trout observed in July and in October (Figure 79; Table 10) showed a pattern of increased size and growth over the summer months.

4.6 FISH AND WILDLIFE SPECIES INHABITING THE LOWER BIG SUR RIVER AND WATERSHED

The Big Sur River provides habitat for spawning, egg incubation, juvenile rearing, and upstream and downstream migration by anadromous steelhead. Steelhead inhabiting the Big Sur River have been listed as a threatened species by NOAA Fisheries for protection under the federal Endangered Species Act. The river also provides habitat for resident rainbow trout. Results of the snorkel surveys conducted as part of this investigation confirmed the presence of threespine stickleback and riffle sculpin inhabiting the lower river and lagoon. Tidewater goby, listed as a threatened species by the U.S. Fish and Wildlife Service (USFWS), was not observed in the Big Sur River or lagoon.

A search of the California Department of Fish and Game (CDFG) December 2004 California Natural Diversity Database (CNDDB) for the Big Sur River area (Big Sur 7.5 minute quad: Appendix D) showed that sensitive and protected fish and wildlife reported to occur in the area include black swift (*Cypseloides niger*) a CDFG species of concern, western pond turtle (*Clemmys marmorata*) a CDFG species of concern, Smith's blue butterfly (*Euphilotes enoptes smithi*) a federal endangered species, prairie falcon (*Falco mexicanus*) a CDFG species of concern, steelhead (*Oncorhynchus mykiss*) a federal threatened species and CDFG species of concern, and American badger (*Taxidea taxus*) a CDFG species of concern. Other sensitive and protected wildlife species reported from the Big Sur River include red-legged frogs (*Rana aurora draytonii*), a threatened species, collected during fishery surveys by Rob Titus (BioSystems 1995). Western snowy plover (*Charadrius alexandrinus nivosus*) have also been reported from the general area but were not included in results of the CNDDB search. Tidewater goby and coho salmon, both listed for protection under the federal Endangered Species Act were not observed in the Big Sur River during these studies and have not been reported to occur in the area (CDFG CNNDB 2004, Big Sur quad; BioSystems 1995).

5.0 Discussion and Conclusions

The Big Sur River and lagoon fishery habitat surveys, including consideration of summer flows, habitat characteristics, and connectivity, water quality including water temperatures, electrical conductivity, and dissolved oxygen concentrations, and the abundance, survival, growth, and geographic distribution of juvenile steelhead/rainbow trout within the lower river and lagoon over the summer months, were designed to characterize instream conditions and assess potential effects of El Sur Ranch irrigation well operations on habitat quality and availability for summer steelhead rearing. Results of these fishery investigations are briefly discussed below.

5.1 EL SUR RANCH WELL OPERATIONS

During the late spring, summer, and early fall 2004 period of this investigation El Sur Ranch irrigation well operations varied as shown in Figure 80. Irrigation well operations were used as part of the basis for assessing potential changes in instream habitat conditions potentially affecting juvenile rearing success for juvenile steelhead. Table 11 presents a summary of El Sur Ranch well operations (deliveries in cfs) on each of the days that fishery habitat surveys were performed, and the average deliveries for 3, 5, and 7 days prior to each survey. We hypothesized that the potential effect of irrigation well operations on fishery habitat within the lower river and lagoon would be greatest during periods when maximum diversions from both wells were occurring. The experimental design for the investigation also assumed that potential effects of well operations on fishery habitat would be greatest, if they were to occur, within the reach of the river adjacent to Creamery Meadow and downstream within the lagoon. The investigation included habitat and fishery monitoring at sites located upstream of the potential area of well influence to act as a reference for comparison with downstream habitat conditions.

During a majority of the study period (July 12 to October 15), irrigation well operations typically ranged from approximately 2 to 3.5 cfs (Figure 80). Data from the September 15 and September 30 surveys offer the best opportunity to compare habitat conditions within the river during periods when one irrigation well was operating (September 15 survey) and when both irrigation wells had been operating simultaneously (September 30 survey; Table 11). Changes in instream fishery habitat, particularly in the lagoon and Creamery Meadow reaches during September associated with the sand bar and blocking of the lagoon, however, confound the analyses of potential effects of irrigation well operations on fishery habitat.

5.2 VELOCITY AND STREAMFLOW MEASUREMENTS

A comparison of instream flow measurements during the September 15 and September 30 surveys, representing periods of one and two well operations (Table 11) at the upstream reference site (VT-1) showed wetted channel widths of 10.52 and 10.49 m (34.5 and 34.4 ft.) during the two surveys. Average channel depth was .26 and .28 m (0.86 and 0.91 ft.) on September 15 and 30, respectively. Streamflow at VT-1 was 6.3 and 8.1 cfs during the two survey dates. Wetted channel widths at the Creamery Meadow site (VT-2) were 8.69 and 8.71 m (28.5 and 28.6 ft.), with corresponding average water depths of .52 and .54 m (1.72 and 1.77 ft.) measured on September 15 and 30. Streamflow increased from 6.1 to 7.4 cfs on September 15 and 30. Because of the lagoon blockage by the sand bar, flows could not be measured during the September surveys at the lagoon outfall (VT-3). Comparison of the flows and channel conditions between September 15 and 30 showed an increase in channel width, increase in channel depth, and an increase in streamflows despite the increase in irrigation well operations from one to two pumps. Surface water flows maintained habitat connectivity and there was no apparent adverse effect on streamflows or habitat conditions within the Creamery Meadow reach during the September surveys under the two different irrigation well operating scenarios.

5.3 HABITAT CONDITIONS AND SURFACE WATER CONNECTIVITY

As noted above, there was no loss of surface water connectivity (Appendix E) among habitat units within the lower river and lagoon during the period of this investigation. Formation of the sand bar blocking the lagoon outfall during the late summer did restrict potential movement of steelhead into and out of the river, until the bar was breached in the early fall. Formation of sand bars blocking flow and fish access to rivers and lagoons is a common feature of central and southern California river systems. Formation of the sand bar and sediment movement along the coast is a natural process driven by longshore ocean currents, tidal conditions, wave and storm activity. Breaching of the bar typically results from a combination of river flows and coastal processes. There was no evidence developed as part of this investigation that El Sur Ranch irrigation well operations resulted in formation of the bar.

5.4 WATER QUALITY

Water quality conditions within the lower river and lagoon were compared from the September 15 and 30 surveys, representing periods of one and two irrigation well operations. We hypothesized that irrigation well operations could contribute to an increase in water temperatures, an increase in electrical conductivity, and/or a reduction in dissolved oxygen within the Creamery Meadow and lagoon reaches when both wells are operating when compared to operation of a single irrigation well. Water temperatures during both the September 15 and 30 surveys were found to be significantly cooler within the Creamery Meadow (WQ-5 to WQ-9) and lagoon (WQ-2 to WQ-4) sites when compared to the upstream reference sites (WQ-10 to WQ-21). Electrical conductivities significantly lower within the Creamery Meadow and lagoon reaches during the September 15 survey while no significant differences in conductivity were detected among the survey reaches on September 30. Dissolved oxygen concentrations were found to be lower in the Creamery Meadow and lagoon reaches, when compared to upstream reference sites, during both the September 15 and 30 surveys. Water quality conditions within the Creamery Meadow and lagoon reaches were within the range considered to be suitable of juvenile steelhead rearing with the exception of reduced dissolved oxygen levels within the Creamery Meadow reach (WQ-7 to WQ-9 and particularly WQ-8). The localized reductions in dissolved oxygen concentrations within the Creamery Meadow reach were greater during the September 15 survey when compared to results of the September 30 survey (Figures 61 and 62). If irrigation well diversions were the cause of the localized reduction in dissolved oxygen, we would have expected the magnitude of the reduction to be greater when irrigation well operations were greatest (e.g. September 30 following a period when both wells were in service). The fact that water temperatures and electrical conductivity were both lower in the Creamery Meadow and lagoon reaches on both September 15 and 30 suggests that groundwater upwelling and flow accretions within the lower river and lagoon were contributing to the observed changes in water quality conditions rather than El Sur Ranch irrigation well operations.

5.5 STEELHEAD/RAINBOW TROUT SNORKEL SURVEY

Conditions within the Big Sur River and lagoon were ideal for snorkel surveys. Visibility was 3.67-4.57 m (12-15 ft.) and the river was less than 9.14 m (30 ft.) wide in most areas, which allowed for total lateral coverage. One exception was in reach SS-4 where instream brush filled the channel. The potential for avoidance and re-counting juvenile steelhead /rainbow trout was high in this reach. During the July survey, the juvenile steelhead/rainbow trout observed in the lagoon were congregated into schools and were not uniformly distributed. The distribution of juvenile steelhead/rainbow trout within the lagoon during the October survey was more random. Juvenile steelhead/rainbow trout were distributed throughout the lagoon and were actively feeding and moving. Multiple passes were made by the divers to provide complete coverage but the potential for avoidance and re-counting was high.

The classical coastal stream fish assemblage was observed during surveys within the Big Sur River and lagoon. Non-salmonids were not observed in proximity with juvenile steelhead/rainbow trout in any reach surveyed; therefore, interspecific competition is not expected to be a significant factor affecting steelhead within the lower river and lagoon. Divers observed four riffle sculpin greater than 150 mm (5.91 in.) in length inhabiting reaches SS-3 and SS-6. Sculpin of this size are known to prey upon young-of-the-year steelhead/rainbow trout (T. Cannon, pers. comm.). The relatively low numbers of sculpin observed in this size class suggests that predation is not a significant factor affecting juvenile steelhead/rainbow trout survival during the summer months. Tidewater goby were not observed in the lower river or lagoon during the snorkel surveys.

No obvious limiting factors to juvenile steelhead/rainbow trout survival were observed during the surveys. Spawning habitat was marginal throughout the surveyed reaches due to substrate size and abundant fines. Habitat conditions remained relatively constant between the July and October surveys. The formation of a sand bar across the river mouth prohibited adult and juvenile steelhead migration into and out of the river until the bar was breached. Formation of a bar completely blocking the lagoon is a rare occurrence according the park ranger and usually breaches during the first large rain event.

We postulate that the distribution of juvenile steelhead/rainbow trout within and among reaches of he lower river and lagoon reflect the quality of available habitat. The availability of instream cover, including brush and riparian vegetation within the river and along the channel margins was a significant factor affecting the geographic distribution of juvenile fish. Within certain reaches, habitat associations were less obvious. For example within the lagoon (reach SS-1) juvenile steelhead/rainbow trout were observed actively feeding on the surface during the October survey and did not show the strong habitat associations observed during the July survey. Preferred habitat appeared to be deep water combined with a cover component in all other reaches.

The high degree of smolting and relatively random distribution observed in the lagoon reach during the October survey may suggest that a large proportion of the juvenile steelhead population rearing in the lagoon reach was preparing to emigrate to the ocean when conditions permit. During the October survey, the majority of juvenile steelhead/rainbow trout (84% of the fish observed) inhabited the lagoon, which may affect density dependent factors such as growth and habitat selection for rearing steelhead. Growth rates for juvenile steelhead/rainbow trout observed between July and October in this study (Table 12; Figure 81) were compared to growth rates reported for other coastal rivers in California. It was hypothesized that if El Sur Ranch irrigation diversions were adversely affecting habitat conditions within the lower river and lagoon then growth rates of juvenile steelhead/rainbow trout in the Big Sur River would be lower than observed in other river systems. Results of the comparison, however, showed that juvenile growth rates in the Big Sur River are among the highest when compared to results from other river systems (Table 12; Figure 81). Cannata (1998) and Zedonis (1992) reported the highest growth rates for juvenile steelhead were observed from mid-September through October, after sand bars had blocked the lagoon mouths and freshwater had accumulated in the lower reaches of the river. The lowest summer growth rates were observed during the July-August period immediately following blockage of the lagoon by sand bars (Cannata 1998; Zedonis 1992) while the estuarine portion of the lagoon was in a transitional state. Because of the survey timing on the Big Sur River, differences in seasonal growth rates in response to blockage of the lagoon by the sand bar could not be determined. Results of the comparison of juvenile steelhead/rainbow trout growth rates indicate that habitat conditions within the Big Sur River and lagoon were suitable for juvenile rearing over the summer and early fall period when deliveries were being made from the El Sur Ranch irrigation wells.

Results of the juvenile steelhead/rainbow trout growth rate comparison are consistent with information from the snorkel surveys regarding changes in abundance over the summer. During the July survey, 417 juvenile steelhead/rainbow trout were observed in the river reaches surveyed (Table 13). During the October survey, 358 juvenile steelhead/rainbow trout were observed. The change in observed juvenile steelhead/rainbow trout abundance between July and October (a reduction of 59 fish) reflects an oversummering survival rate of 86% (a 14% reduction in abundance). The estimated survival rate from these surveys assumes that there was no immigration or emigration of juvenile steelhead/rainbow trout from the surveyed reaches over the summer months. Results of these analyses suggest that oversummering survival in the Big Sur River is extremely high for juvenile steelhead/rainbow trout which is consistent with observations of habitat quality and availability over the summer months, consistently suitable water quality conditions, the absence of predatory fish within the lower river and lagoon, minimal evidence of mammalian or avian predation, a complete prohibition on recreational angling within the lower river and lagoon, and good summer baseflows that provided physical habitat and surface water connectivity among habitats throughout the lower river and lagoon during the period of this investigation.

In contrast, young-of-the-year steelhead abundance was observed to decline substantially in the Maistee River (a tributary to Lake Michigan) over the summer (survival rate 1.7 %) as a result of exposure to elevated water temperatures (average daily water temperature greater than 20°C (68°F) Woldt and Rutherford 2002). Good oversummer survival of steelhead in the Little Maistee River (survival 87.6%), comparable to that estimated for the Big Sur River, was observed when average daily water temperatures were within the range considered to be suitable for juvenile rearing (average temperatures were 17°C (63°F) Woldt and Rutherford 2002).

Steelhead/rainbow trout observed in the Big Sur River and lagoon during the July and October surveys were characterized as healthy and in good conditions, showed evidence of good growth over the summer, appeared to have high summer survival, and showed characteristics during the October survey of the physiological transformation (smolting) in preparation for emigration downstream to the ocean. Results of these observations of oversummering abundance and survival within the Big Sur River showed that habitat conditions and juvenile steelhead/rainbow trout survival rates were good over the summer and early fall period when the El Sur Ranch irrigation wells were in service.

5.6 SENSITIVE AND PROTECTED SPECIES

A variety of sensitive and protected fish and wildlife species are known to inhabit the lower Big Sur River and adjacent areas (Section 4.6). As part of this investigation it was assumed that steelhead and their habitat would serve as an indicator of potential changes or adverse effect on other sensitive species. Results of the 2004 fishery and aquatic habitat surveys of the lower Big Sur River did not detect significant changes in aquatic habitat conditions that would adversely impact habitat quality of availability for steelhead or other species. Although localized changes in habitat conditions were observed, these changes were associated with closure of the sand bar and lagoon, subsequent breaching of the sand bar, and localized groundwater upwelling. Results of the 2004 investigations provided no evidence of significant changes in aquatic habitat (e.g., disruption of habitat connectivity, unsuitable water quality, etc.) resulting from El Sur Ranch irrigation well operations or adverse effects on sensitive species habitat within the lower river.

6.0 Summary of Conclusions

Based upon results of the 2004 fishery investigation we have concluded that the lower Big Sur River and lagoon provided suitable habitat for juvenile steelhead/rainbow trout rearing over the late spring, summer, and early fall period. Habitat conditions within the river, both upstream and downstream of the well location, remained within a suitable range for juvenile steelhead rearing throughout the summer and fall monitoring period. No adverse effects on instream habitat quality or availability as a direct result of El Sur Ranch irrigation well operations were detected. Additional findings and conclusions of the investigation include:

- Summer baseflows observed during the 2004 investigation were sufficient to provide physical habitat within the lower river and lagoon to support juvenile steelhead/rainbow trout rearing;
- Streamflows were sufficient to maintain connectivity among habitat units throughout the study period, with the exception of the late summer when a sand bar deposit along the beach blocked the lagoon outfall and created a temporary barrier to upstream and downstream steelhead migration. Formation of sand bars is a typical coastal process and did not appear to be the result of irrigation well operations;
- The lower river and lagoon showed evidence of groundwater accretions (upwelling) that contributed to increased summer flows within the lower reaches of the system when compared to upstream reference sites;
- Water quality conditions, including water temperatures, electrical conductivity, and dissolved oxygen concentrations, were within the range considered to be suitable for juvenile steelhead/rainbow trout rearing. For localized areas within the Creamery Meadow reach, available data indicate that groundwater upwelling affected water quality within the river, but that habitat conditions within the surrounding area were within the range considered suitable and may provide a thermal refugia for juvenile steelhead;
- No significant differences in water quality were detected that were correlated or attributed directly to irrigation well operations;
- Juvenile steelhead/rainbow trout were observed rearing within the lower river and lagoon during surveys conducted in July and October. The juvenile steelhead/rainbow trout were characterized as being in good health and conditions, showed good summer survival, good summer growth rates, and evidence of the physiological transformation (smolting) during the fall that is typical of juvenile steelhead preparing to emigrate from the river into coastal waters; and
- Results of the streamflow, connectivity, habitat conditions, water quality measurements, and observations of juvenile steelhead/rainbow trout inhabiting the lower river and lagoon during the 2004 study period provided no evidence of adverse effects on habitat quality or availably as a result of El Sur Ranch irrigation well operations. Similarly, the absence of adverse effects on aquatic habitat serves as an indicator that adverse effects to other sensitive and protected wildlife species inhabiting the area would not be expected, based on environmental conditions and irrigation well operations that occurred during the 2004 study period.

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8.0 FIGURES & TABLES

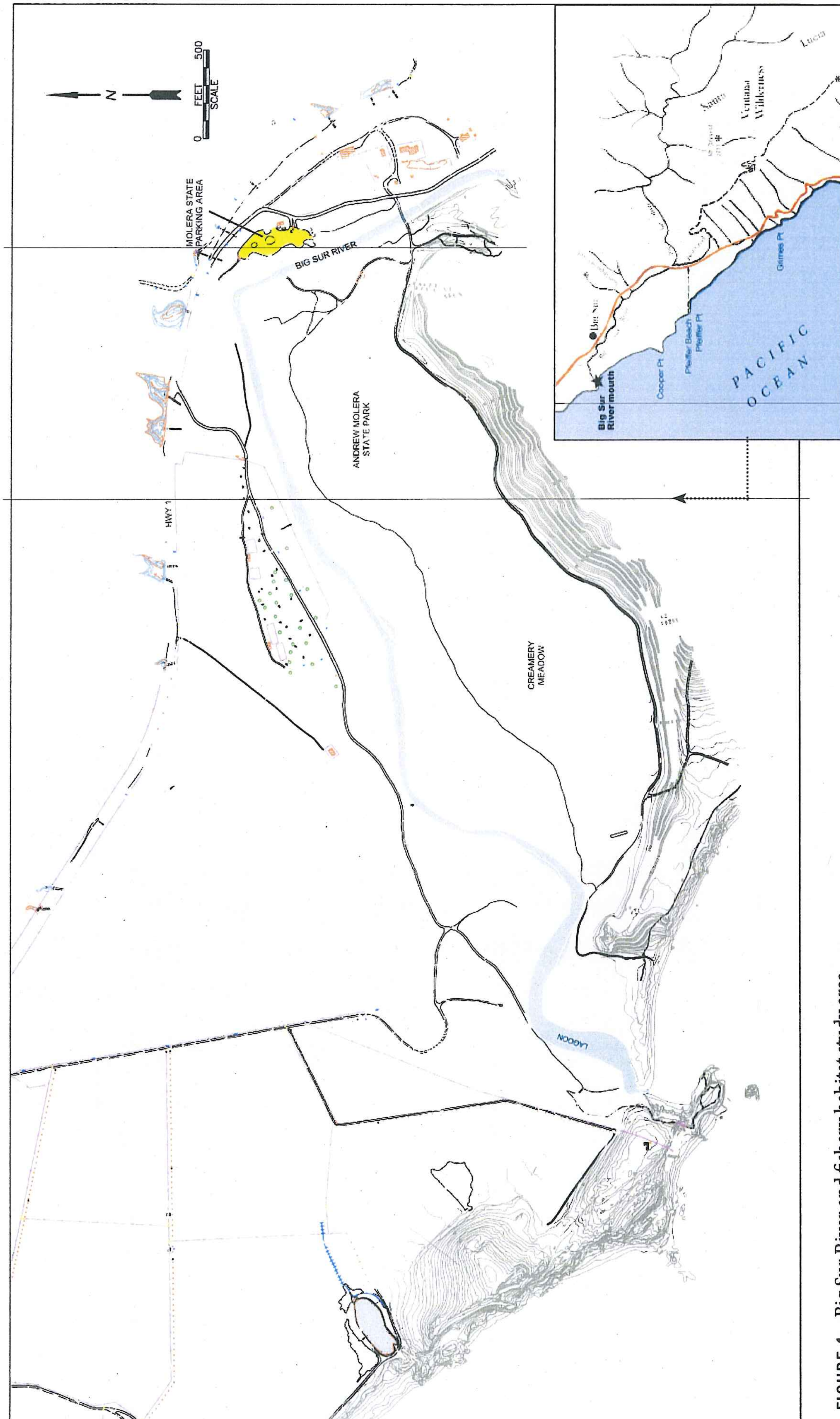

FIGURE 1. Big Sur River and fishery habitat study area.

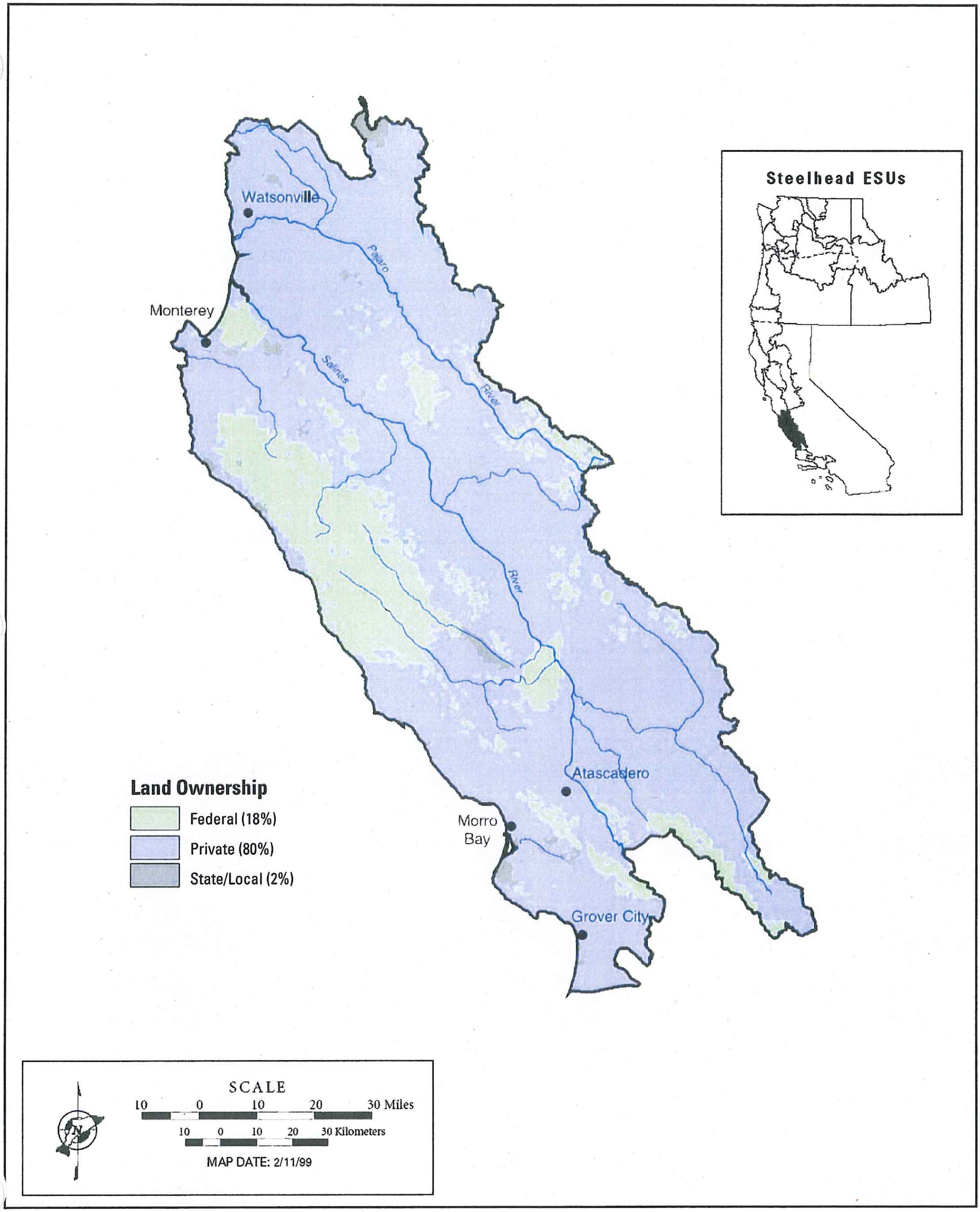

FIGURE 2. Steelhead Evolutionarily Significant Units (ESU) (source: NOAA Fisheries 2004).

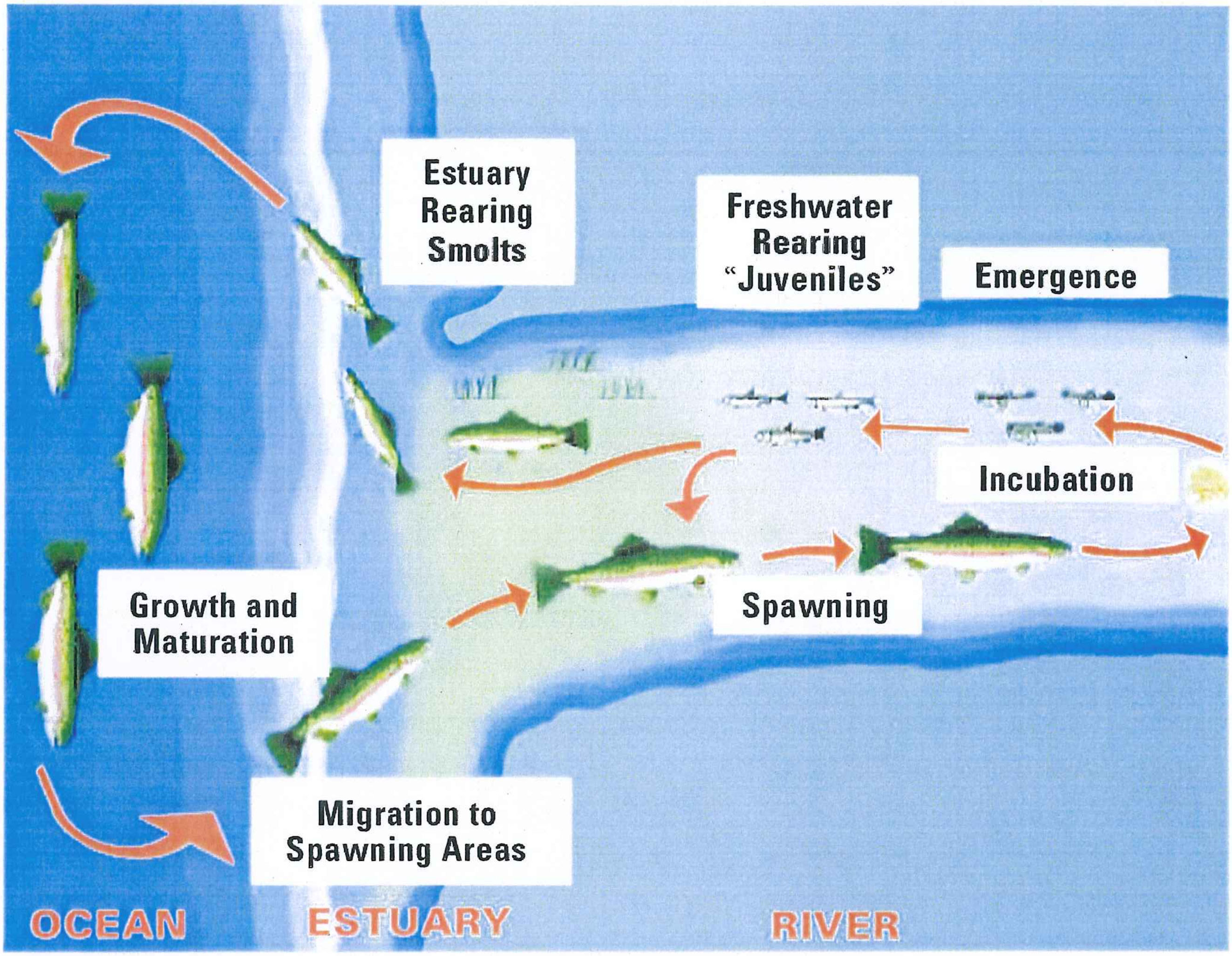

FIGURE 3. Life cycle of steelhead (source: Sonoma County Water Agency).

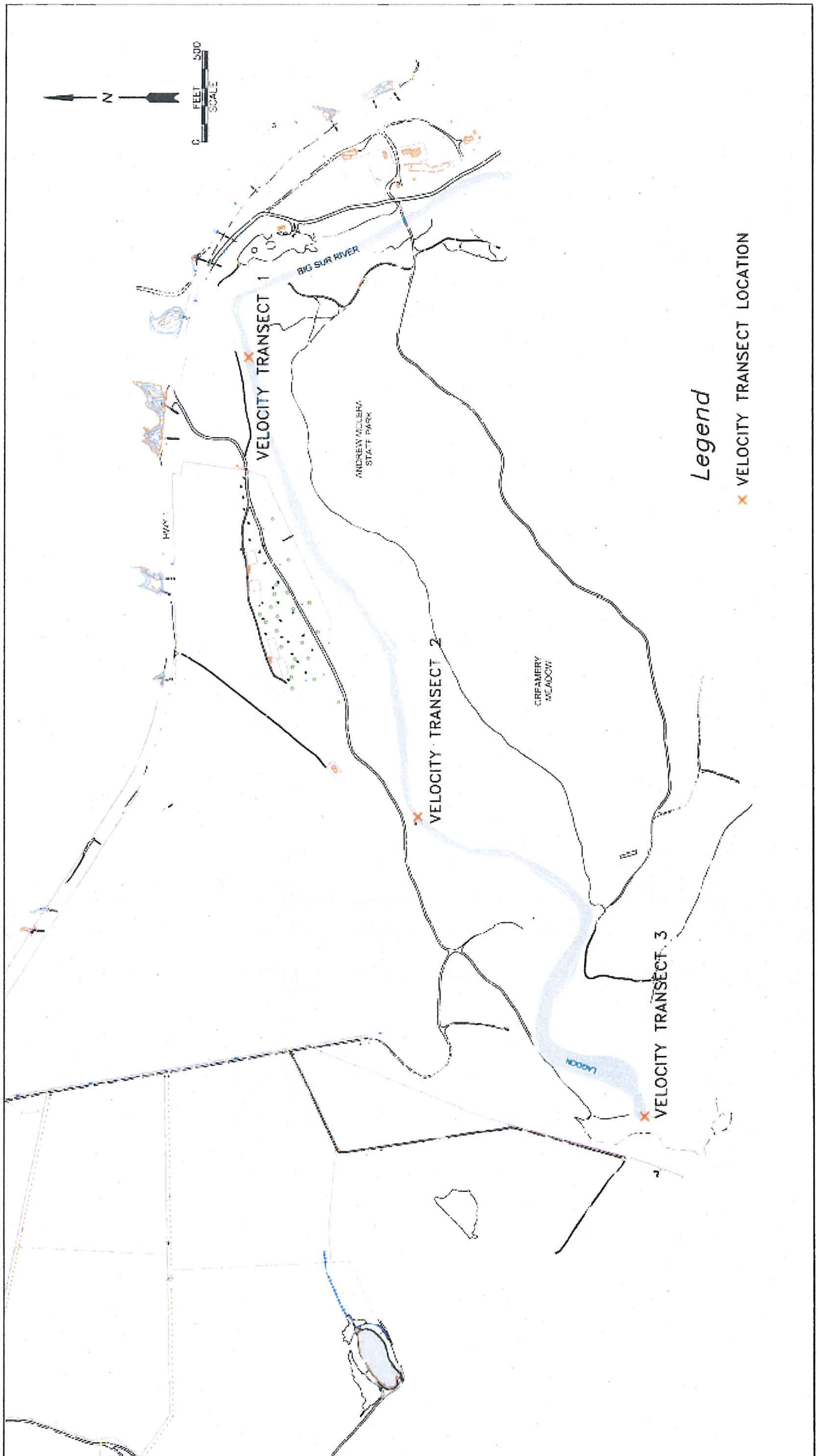

FIGURE 4. Location of water velocity transects (VT-1, VT-2, and VT-3).

FIGURE 5. Velocity transect VT-1, representing the upstream reference site, located in a shallow riffle-run habitat with extensive riparian vegetation.

FIGURE 6. Velocity transect VT-2 showing a pool habitat downstream and riffle habitat upstream of the site.

FIGURE 7. Velocity transect VT-3 and outfall channel from the lagoon to the ocean before the lagoon pool was blocked by sand deposits.

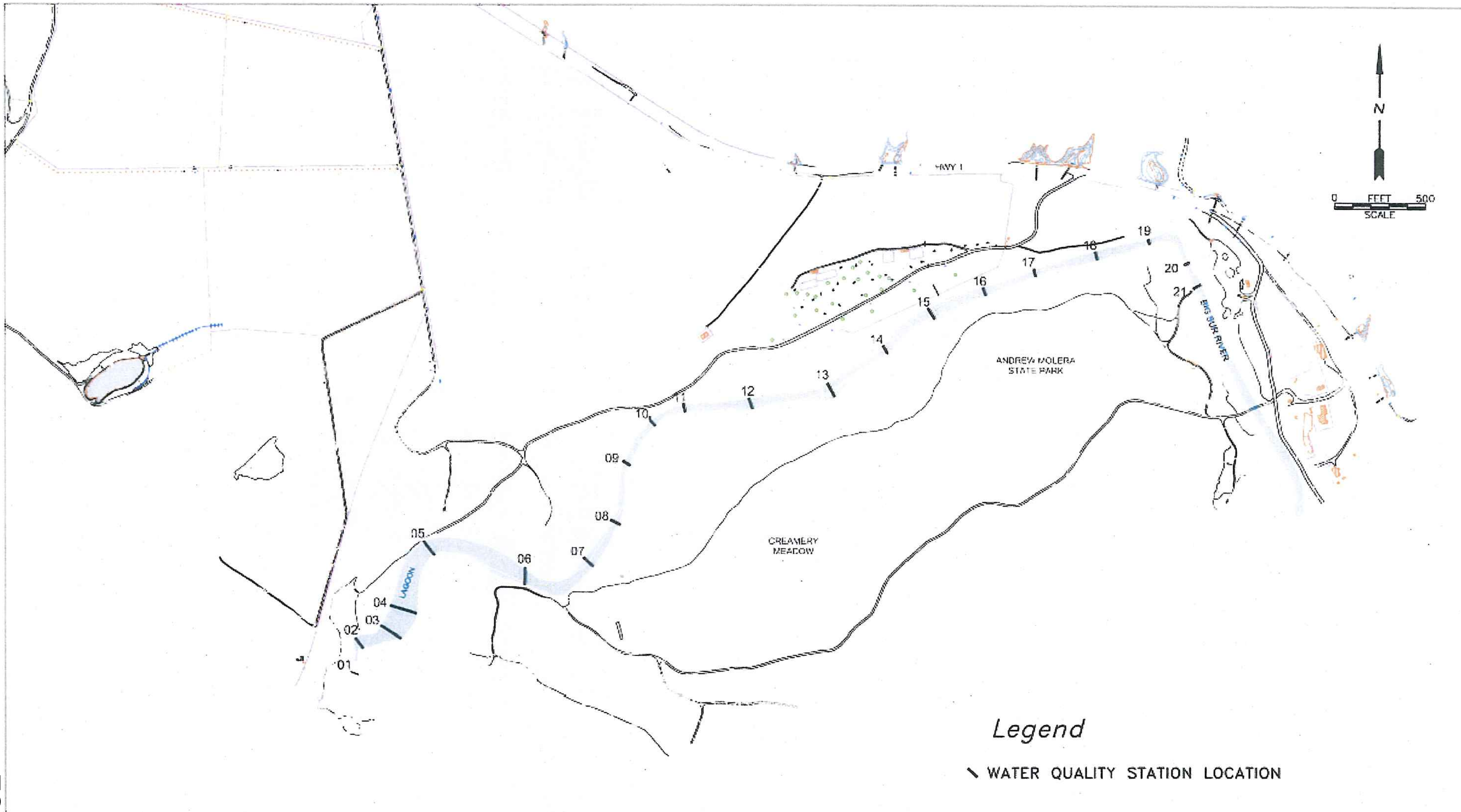

FIGURE 8. Location of periodic water quality (WQ) surveys within the lower Big Sur River and lagoon.

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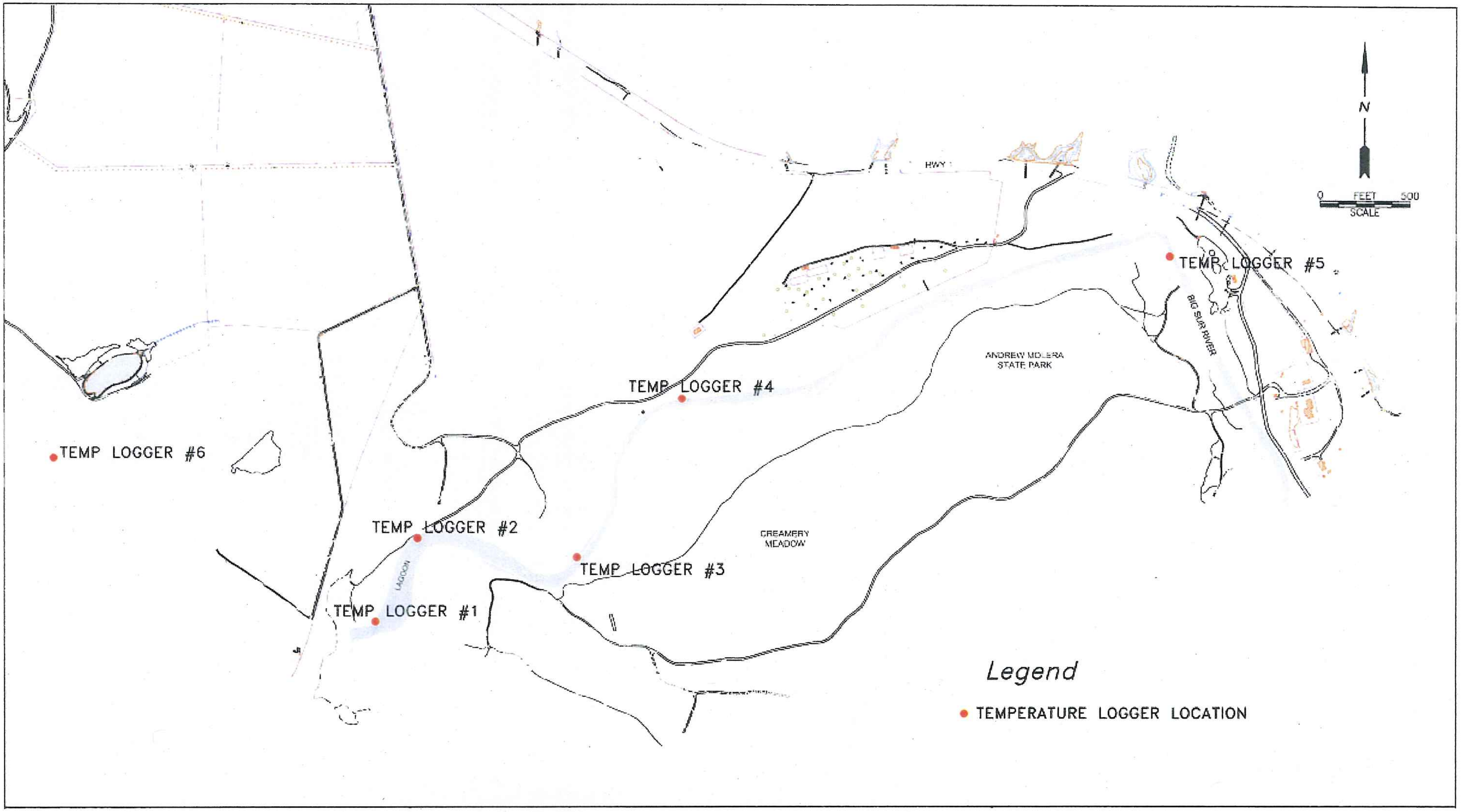

FIGURE 9. Location of continuous water temperature (CT) monitoring sites within the lower Big Sur River, lagoon, and nearshore coastal waters.

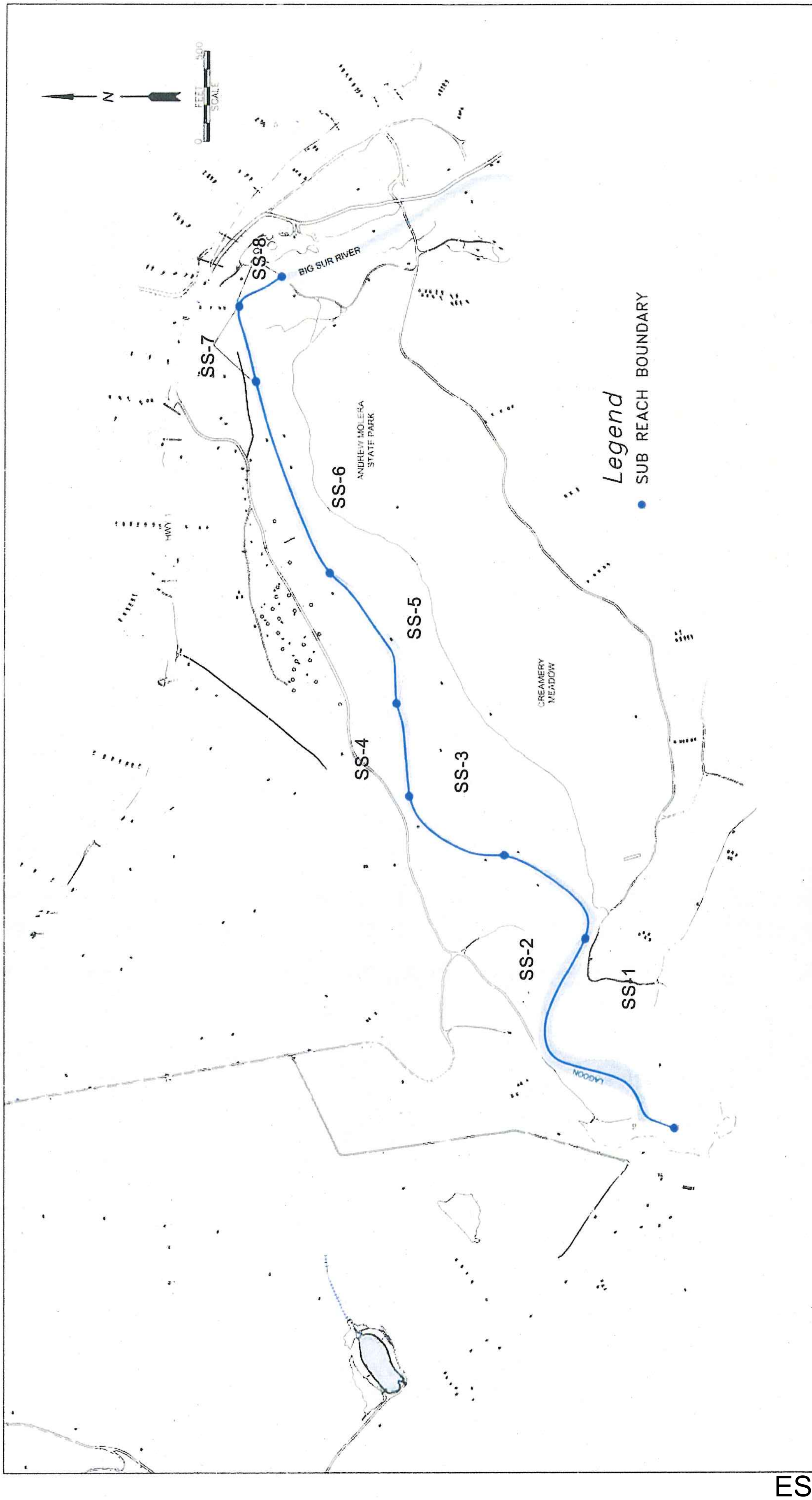

FIGURE 10. Snorkel survey (SS) reaches within the lower Big Sur River and lagoon.

FIGURE 11. Photograph of divers performing steelhead snorkel surveys within the lower Big Sur River and lagoon.

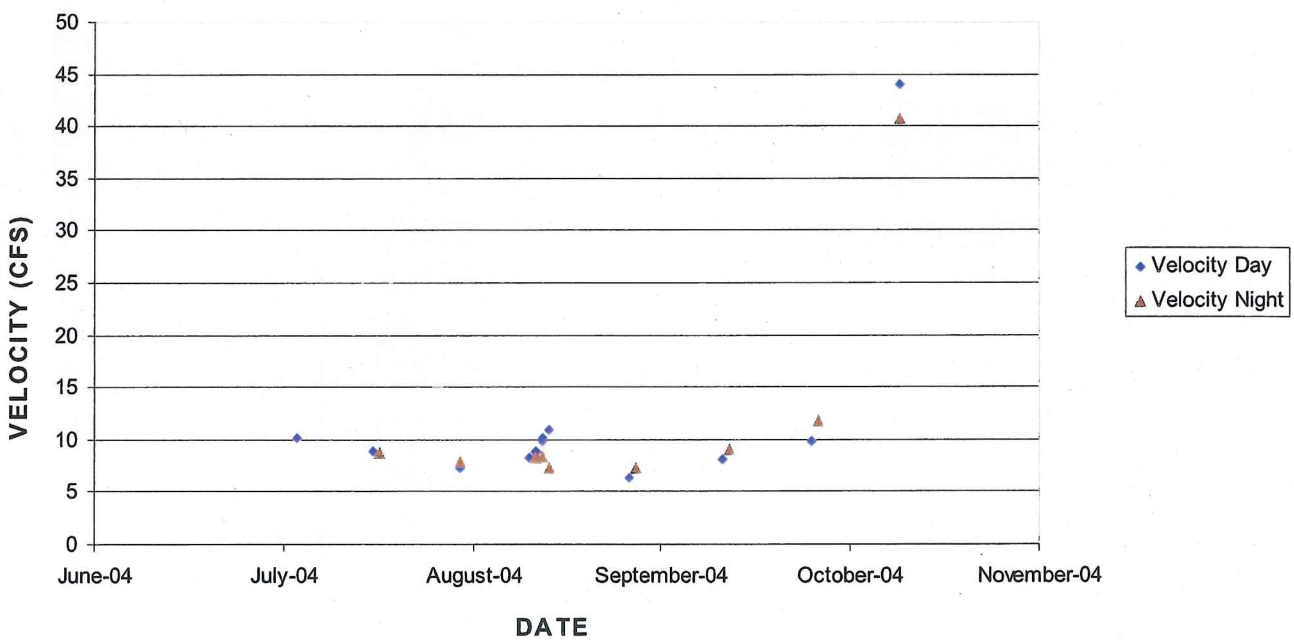

FIGURE 12. Estimated streamflow at transect VT-1 – upstream reference location.

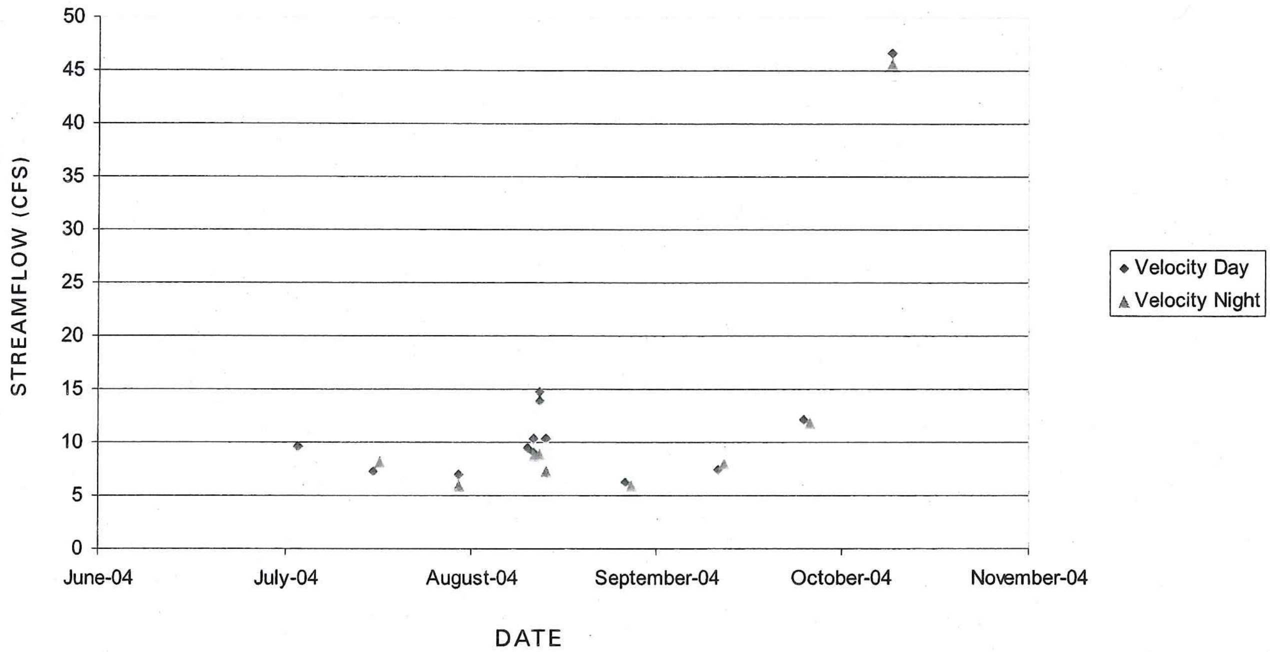

FIGURE 13. Estimated streamflow at transect VT-2 – Creamery Meadow location.

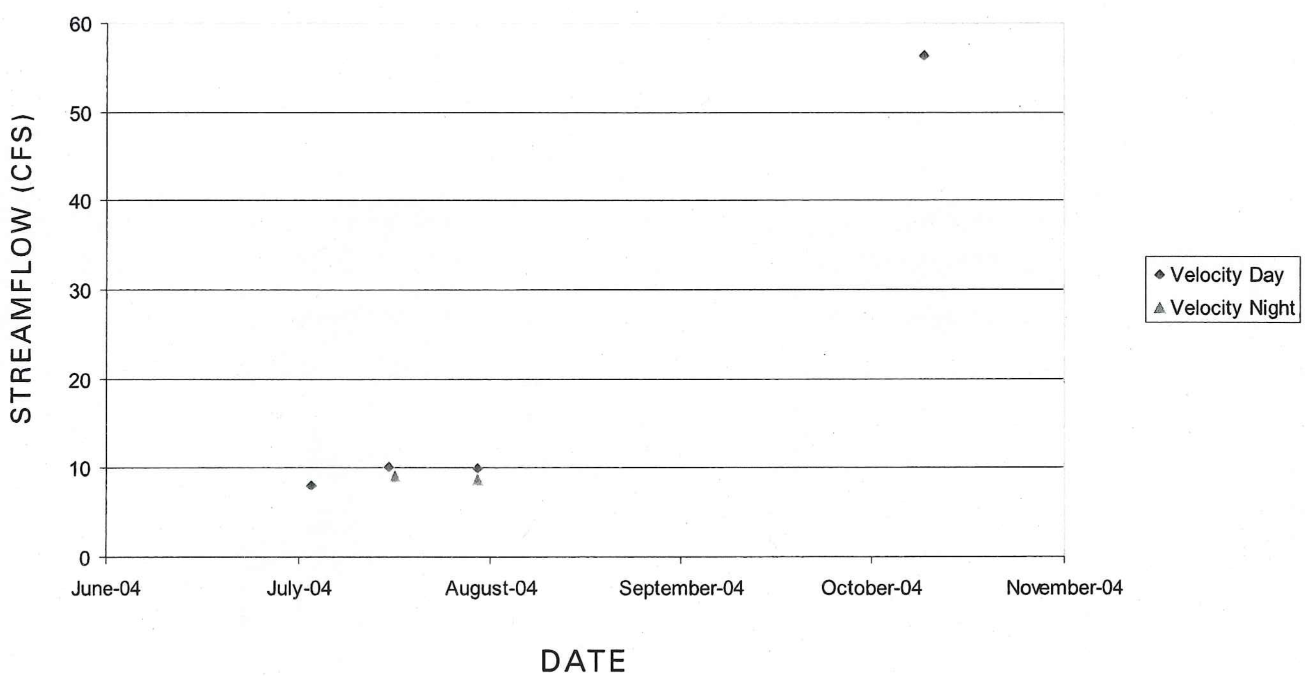

FIGURE 14. Estimated streamflow at transect VT-3 – lagoon outfall.

FIGURE 15. Lagoon pool showing discharge before sand bar deposition caused blockage. Outflow at "S" bend is site of VT-3.

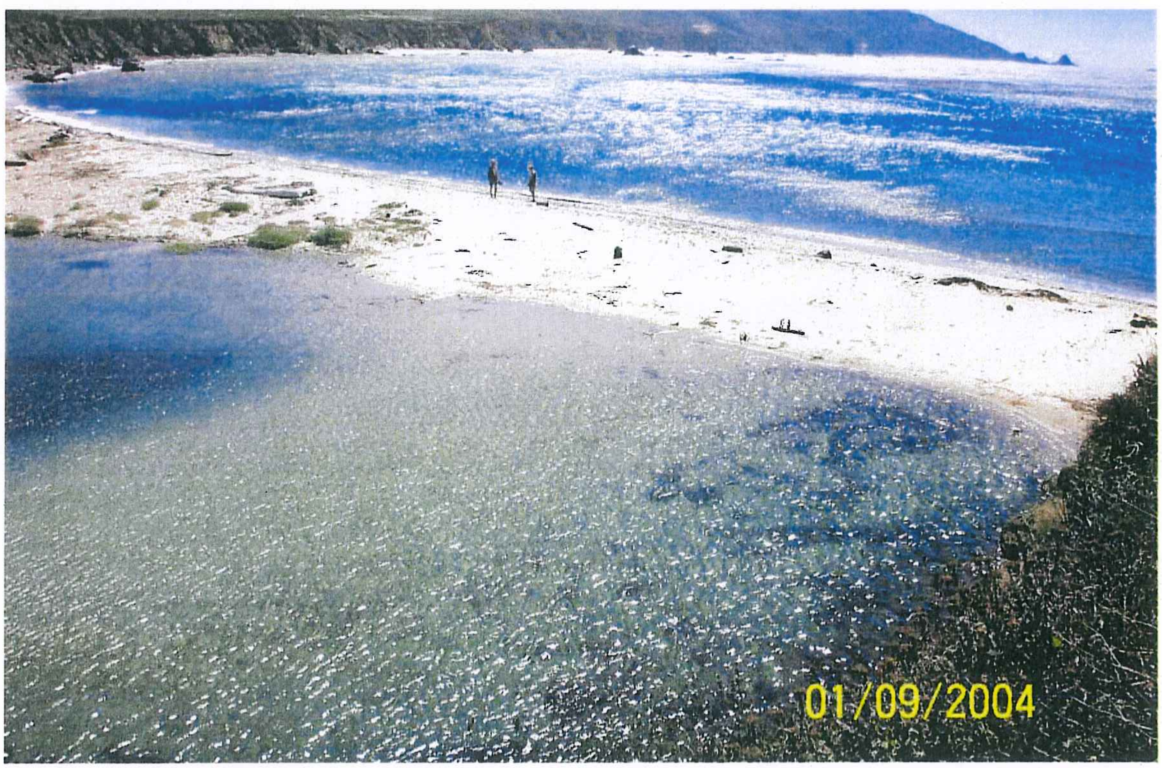

FIGURE 16. Lagoon pool outflow blocked by sand bar deposited during high tide combined with extreme large surf event.

FIGURE 17. Alternate view of lagoon pool outflow blocked by sand bar deposited during high tide combined with extreme large surf event. Alternate angle shows lagoon pool habitat.

FIGURE 18. Sand bar breached after large storm event caused high velocity flows.

FIGURE 19. Lagoon pool connecting to wide upstream channel.

FIGURE 20. Lagoon pool habitat and upstream channel (alternate view) at temperature station CT-1.

FIGURE 21. Big Sur River habitat 200 ft upstream of lagoon pool. Water depth approximately 6 feet.

FIGURE 22. River habitat downstream of water quality transect WQ-8. Water depth approximately 2-5 feet.

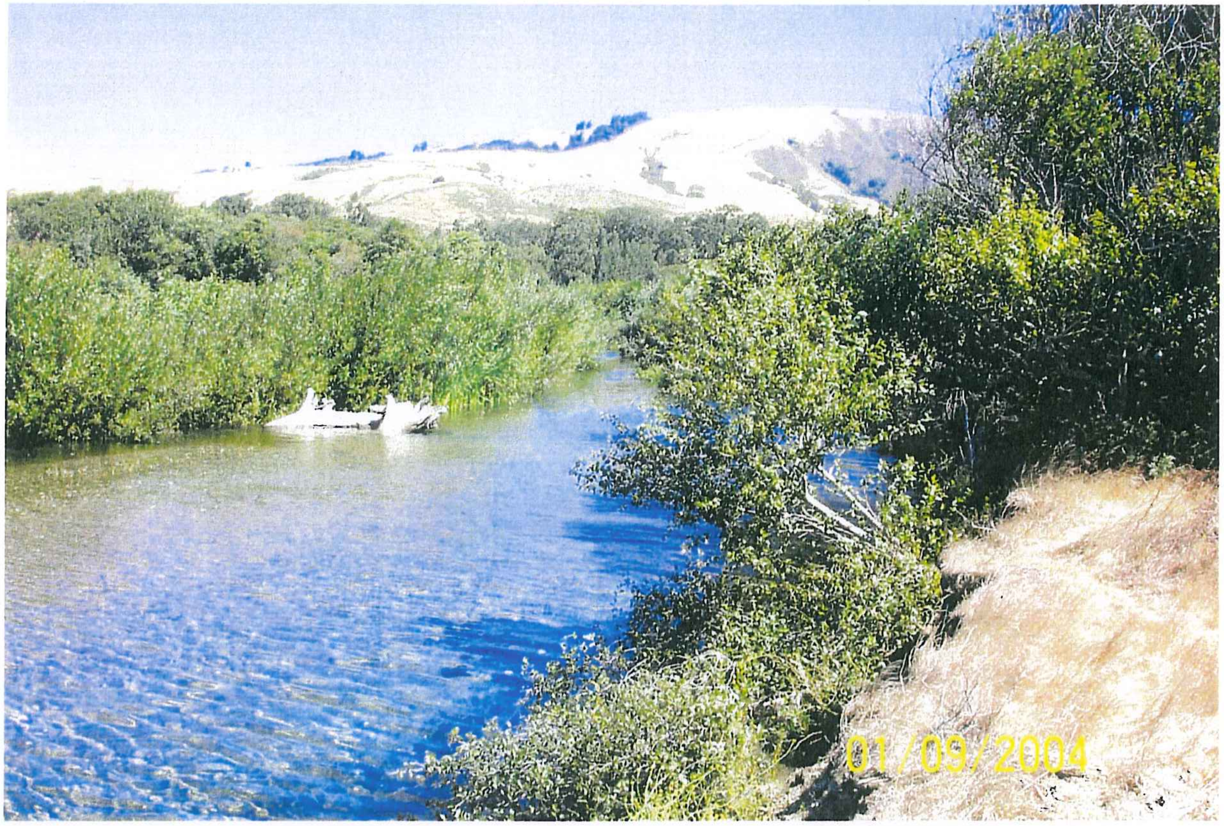

FIGURE 23. River habitat at water quality transect WQ-8 where groundwater upwelling (accretions) was detected.

FIGURE 24. River habitat at VT-1 upstream reference point location.

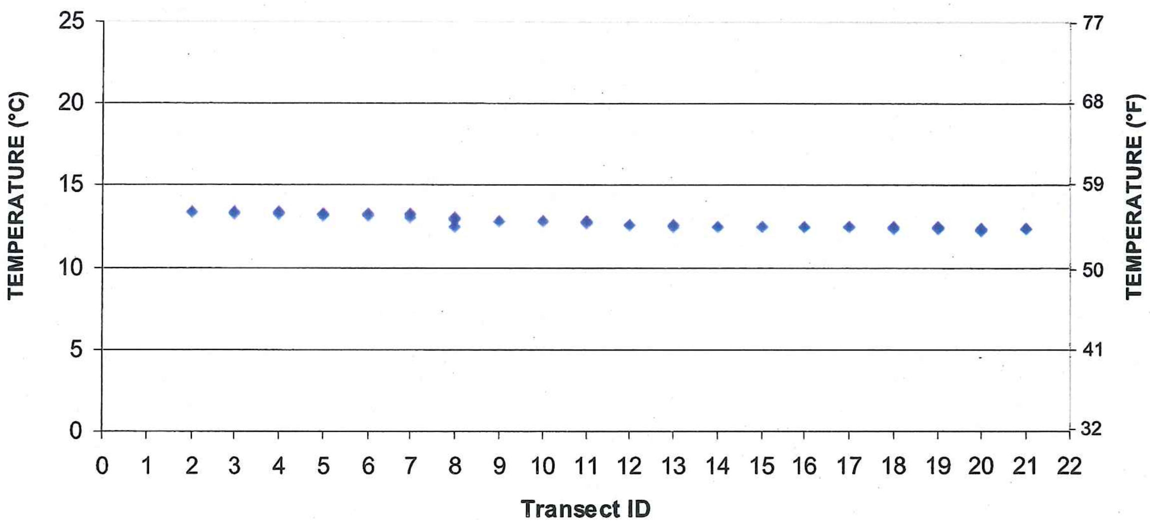

FIGURE 25. Results of water temperature measurements within the lower river and lagoon on April 18, 2004.

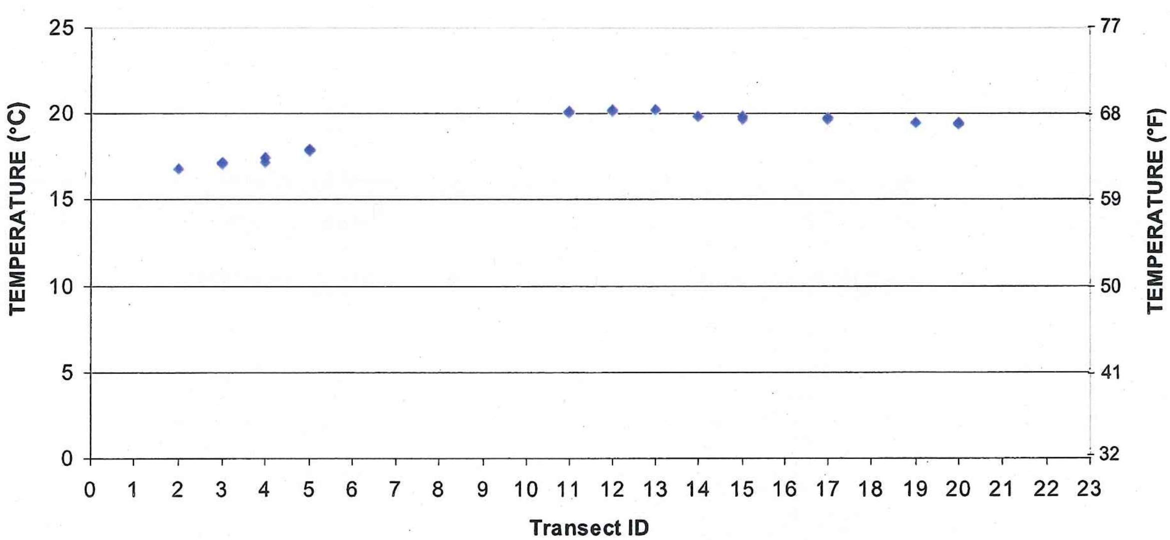

FIGURE 26. Results of water temperature measurements within the lower river and lagoon on July 12, 2004.

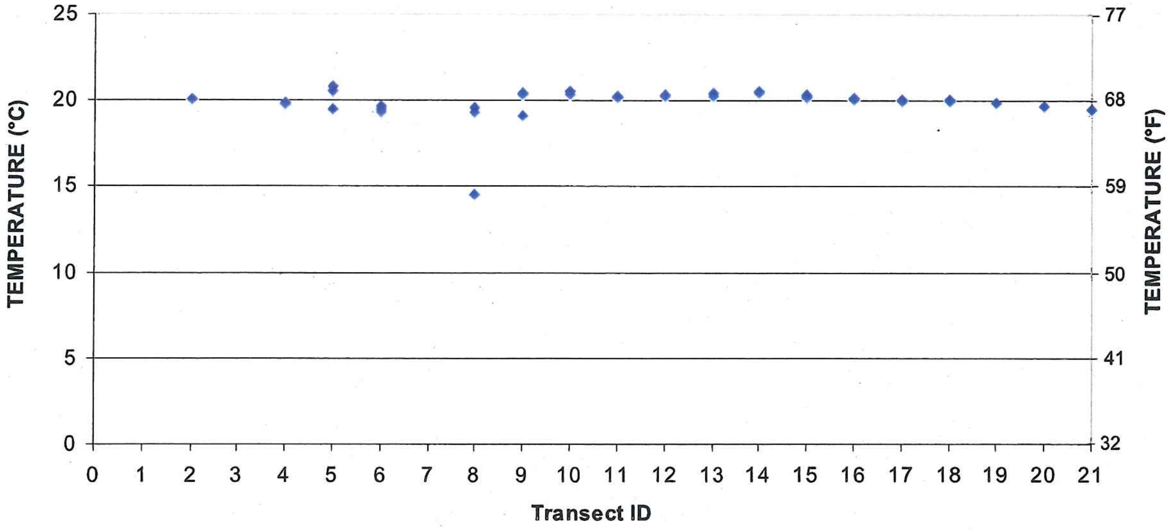

FIGURE 27. Results of water temperature measurements within the lower river and lagoon on July 23, 2004.

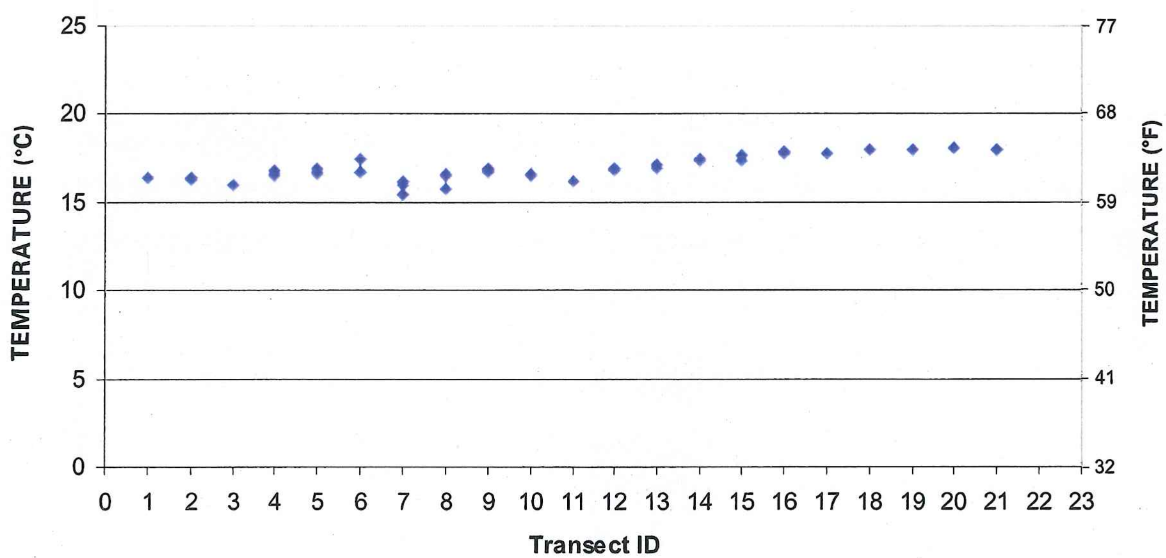

FIGURE 28. Results of water temperature measurements within the lower river and lagoon on August 6, 2004.

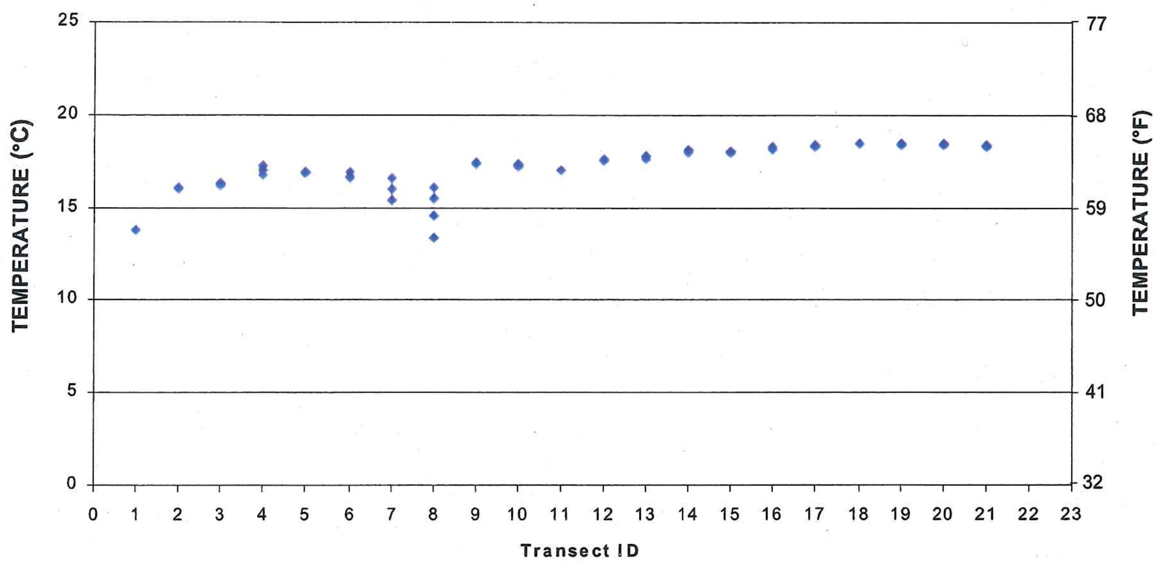

FIGURE 29. Results of water temperature measurements within the lower river and lagoon on August 19, 2004.

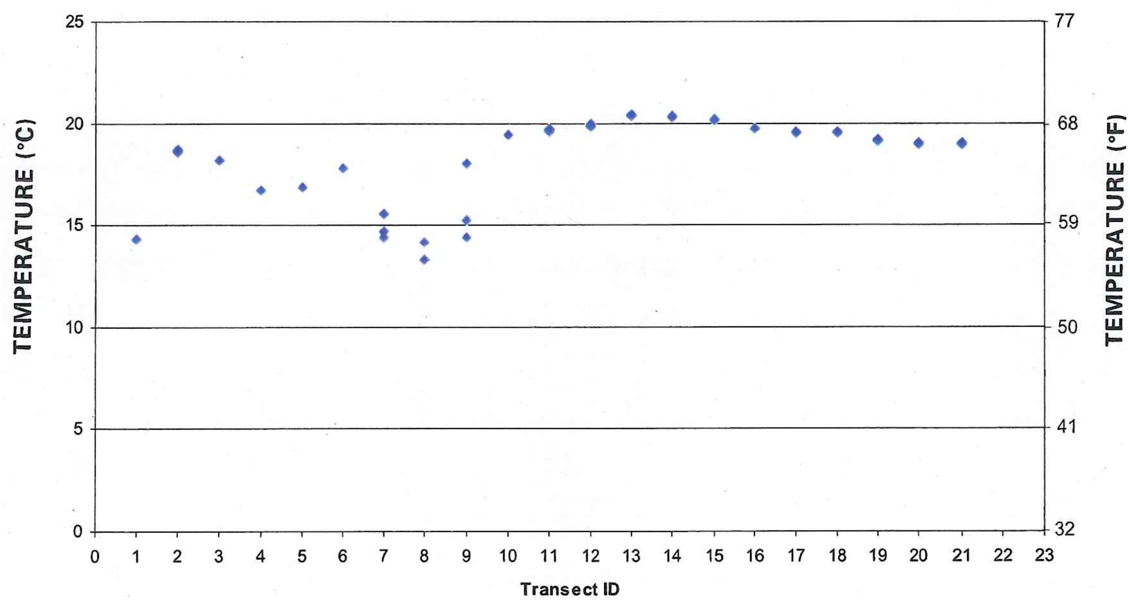

FIGURE 30. Results of water temperature measurements within the lower river and lagoon on September 2, 2004.

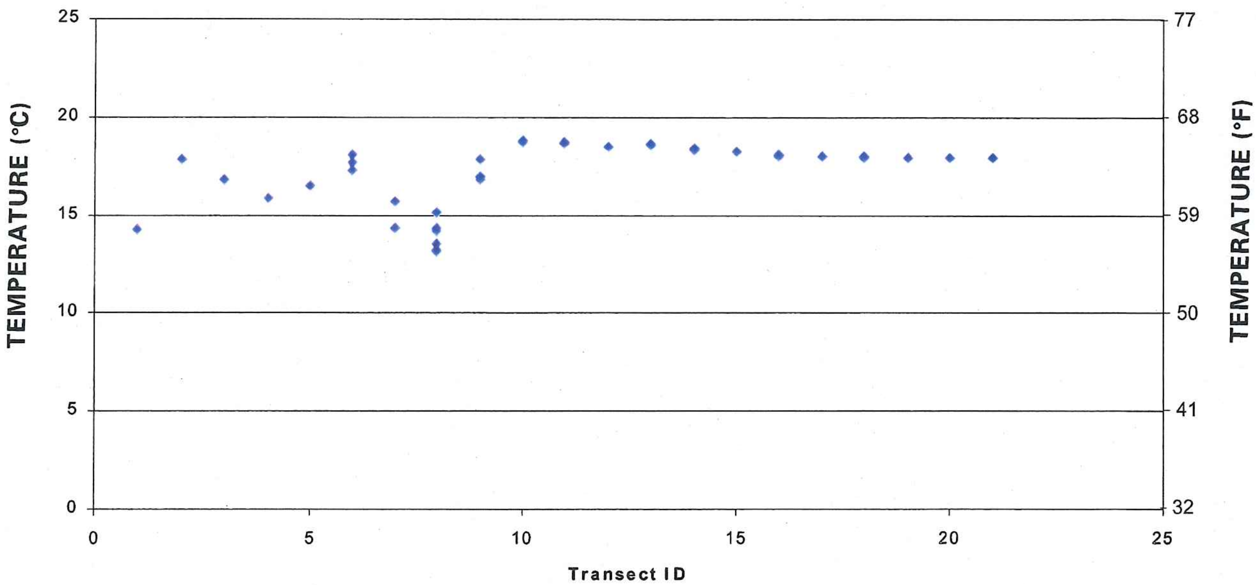

FIGURE 31. Results of water temperature measurements within the lower river and lagoon on September 15, 2004.

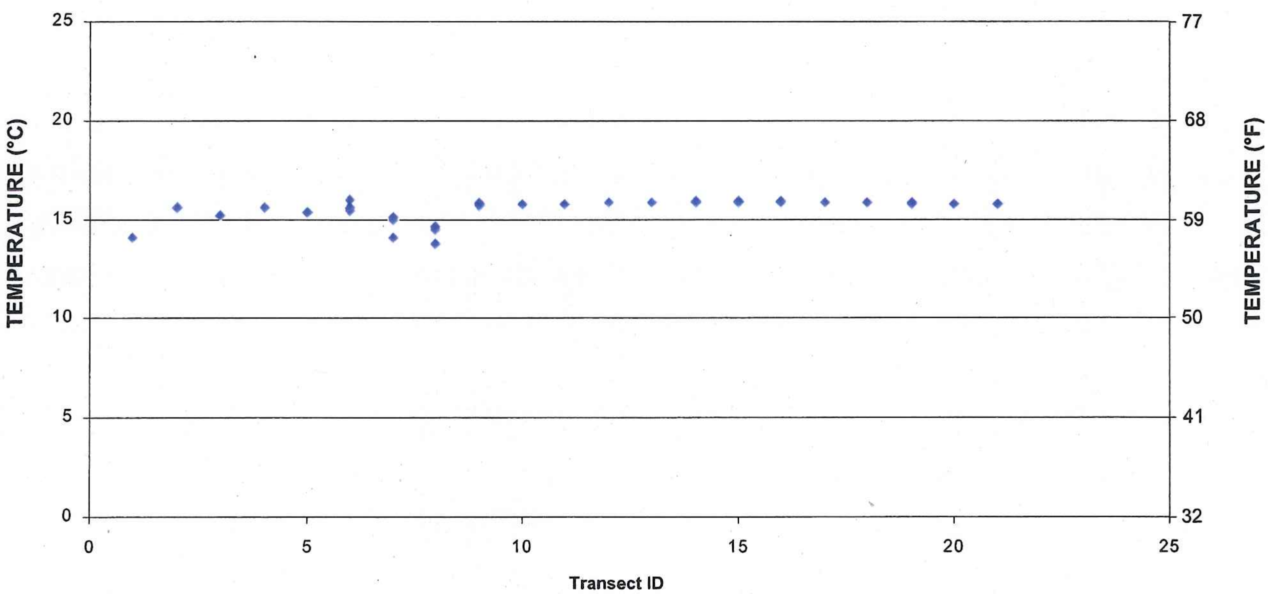

FIGURE 32. Results of water temperature measurements within the lower river and lagoon on September 30, 2004.

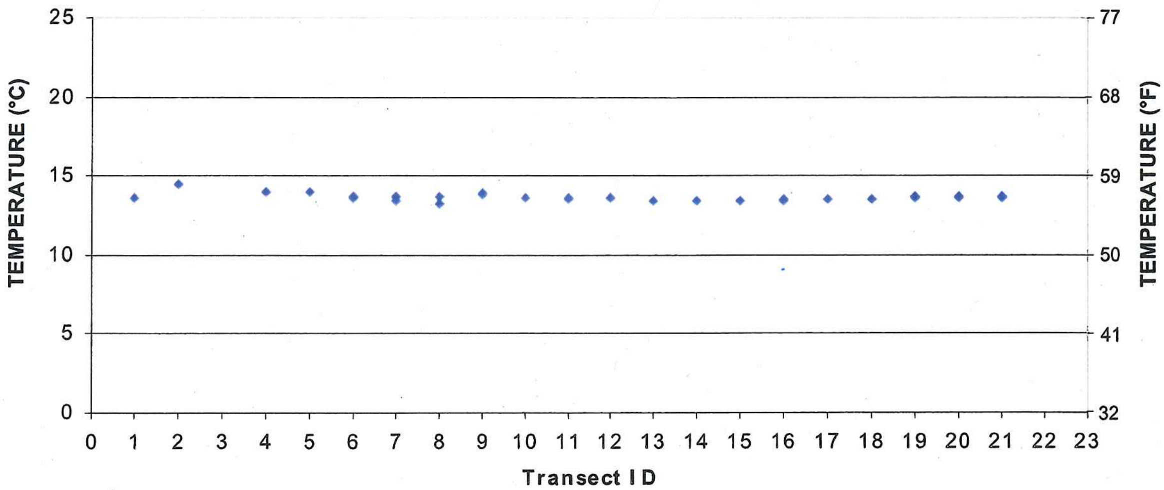

FIGURE 33. Results of water temperature measurements within the lower river and lagoon on October 15, 2004.

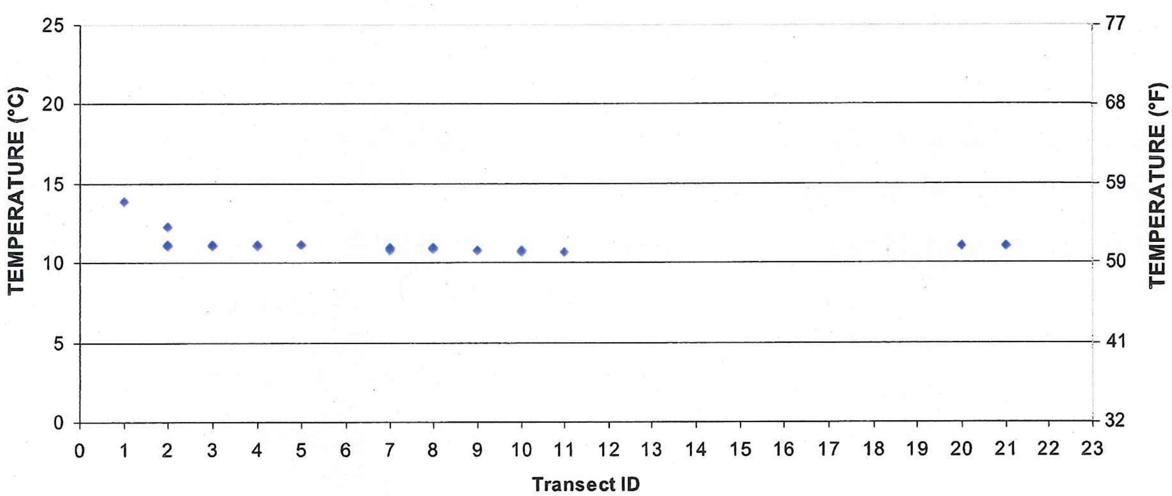

FIGURE 34. Results of water temperature measurements within the lower river and lagoon on October 28, 2004.

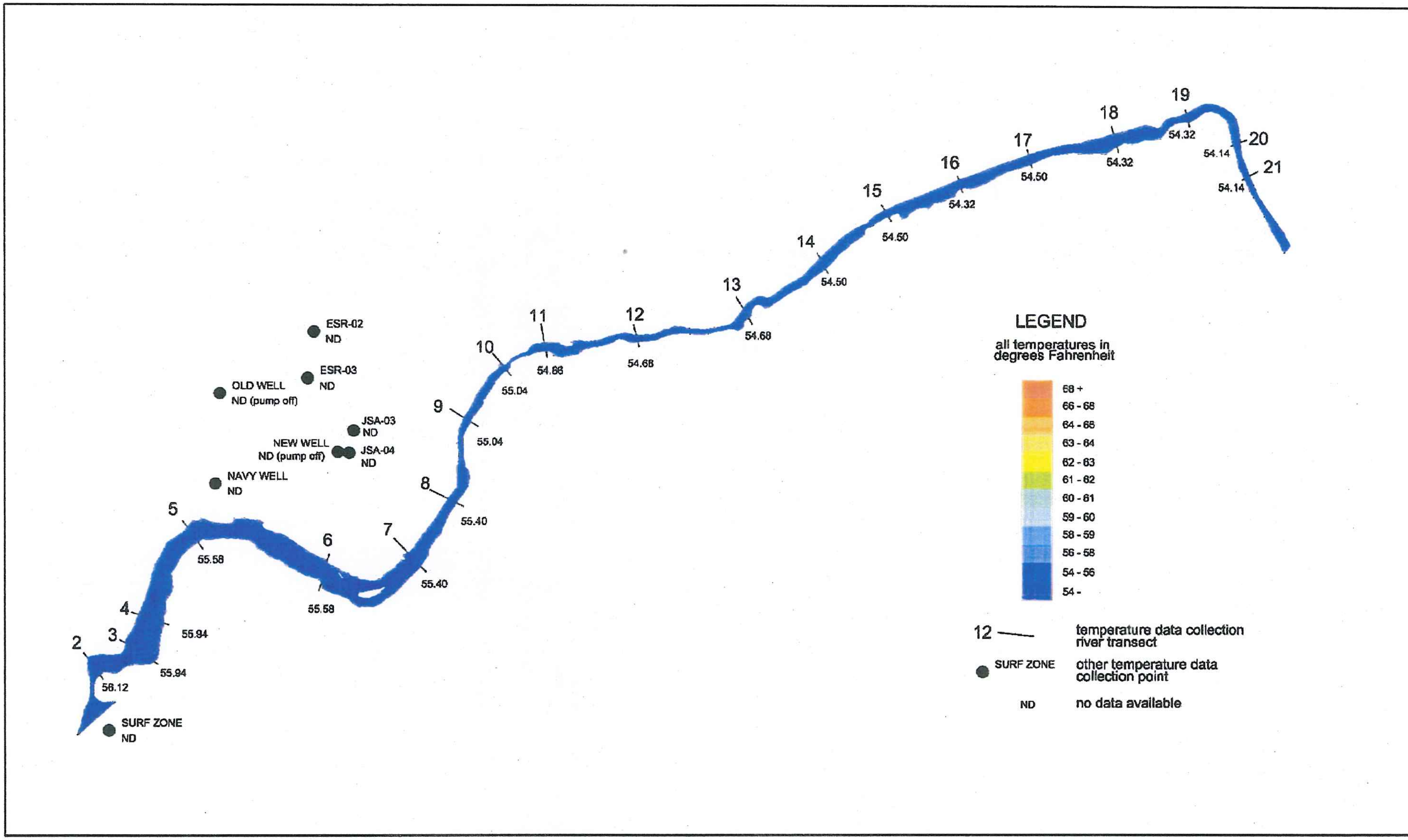

FIGURE 35. Geographic distributions of water temperature for April 18th water quality survey.

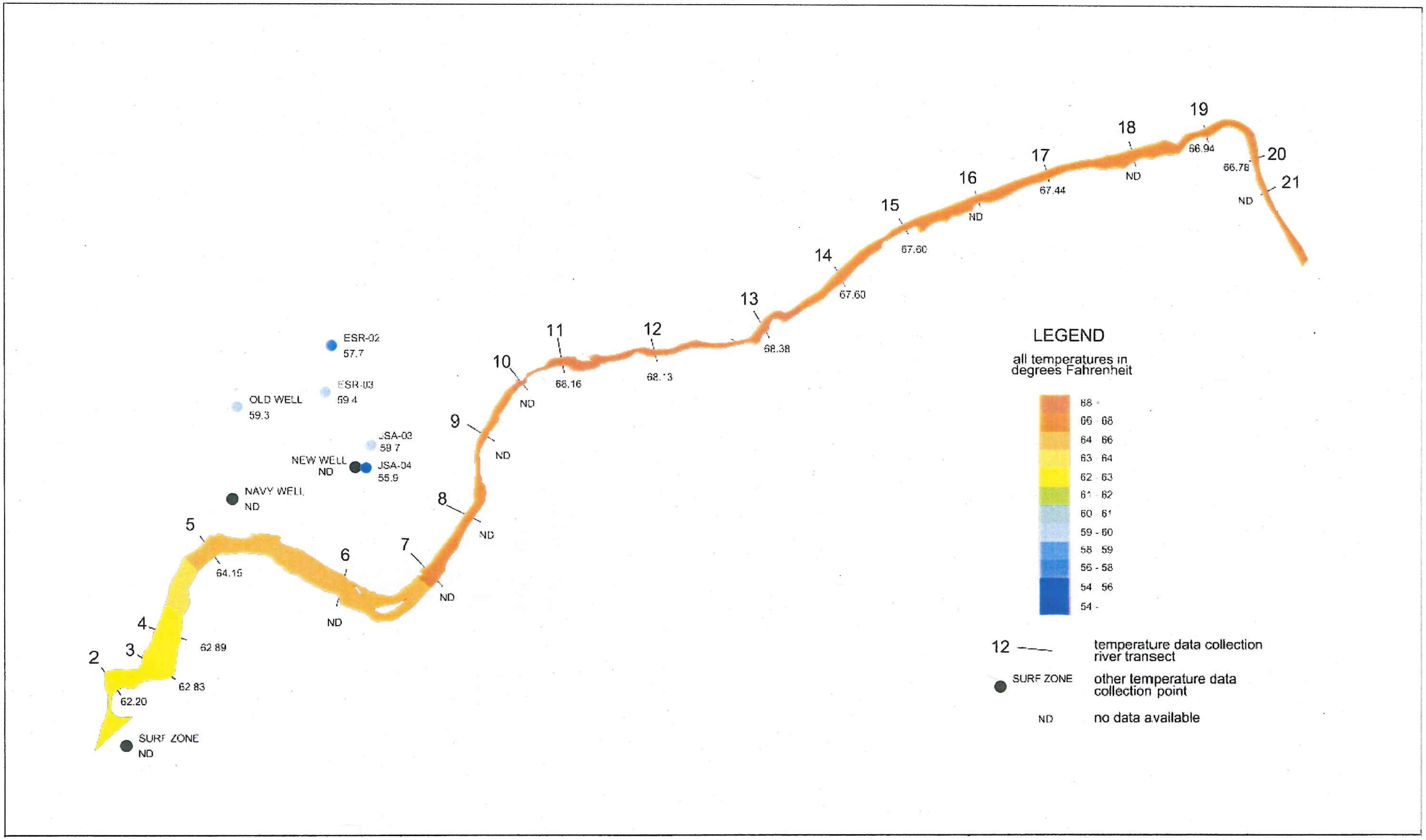

FIGURE 36. Geographic distributions of water temperature for July 12th water quality survey.

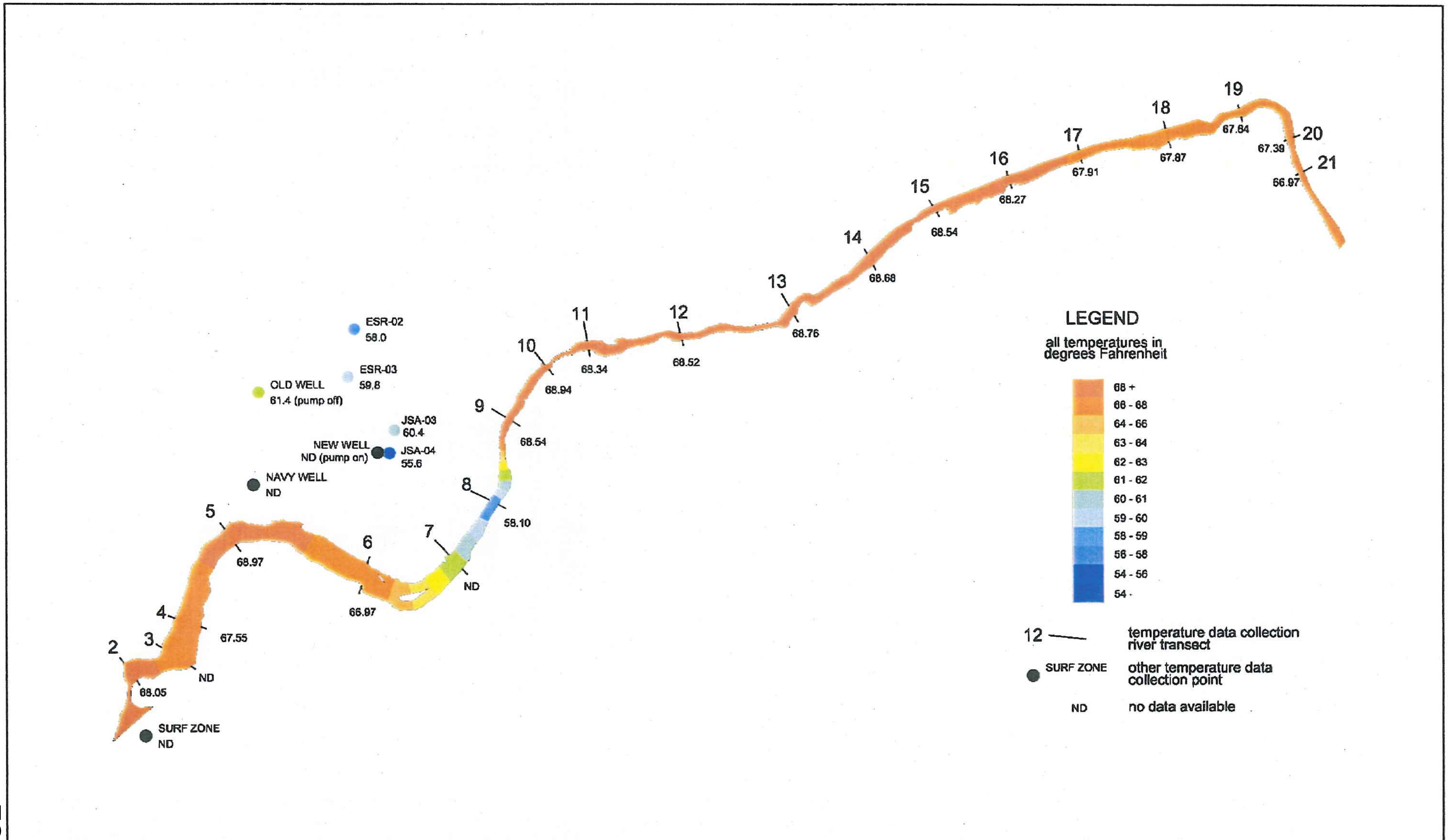

FIGURE 37. Geographic distributions of water temperature for July 23rd water quality survey.

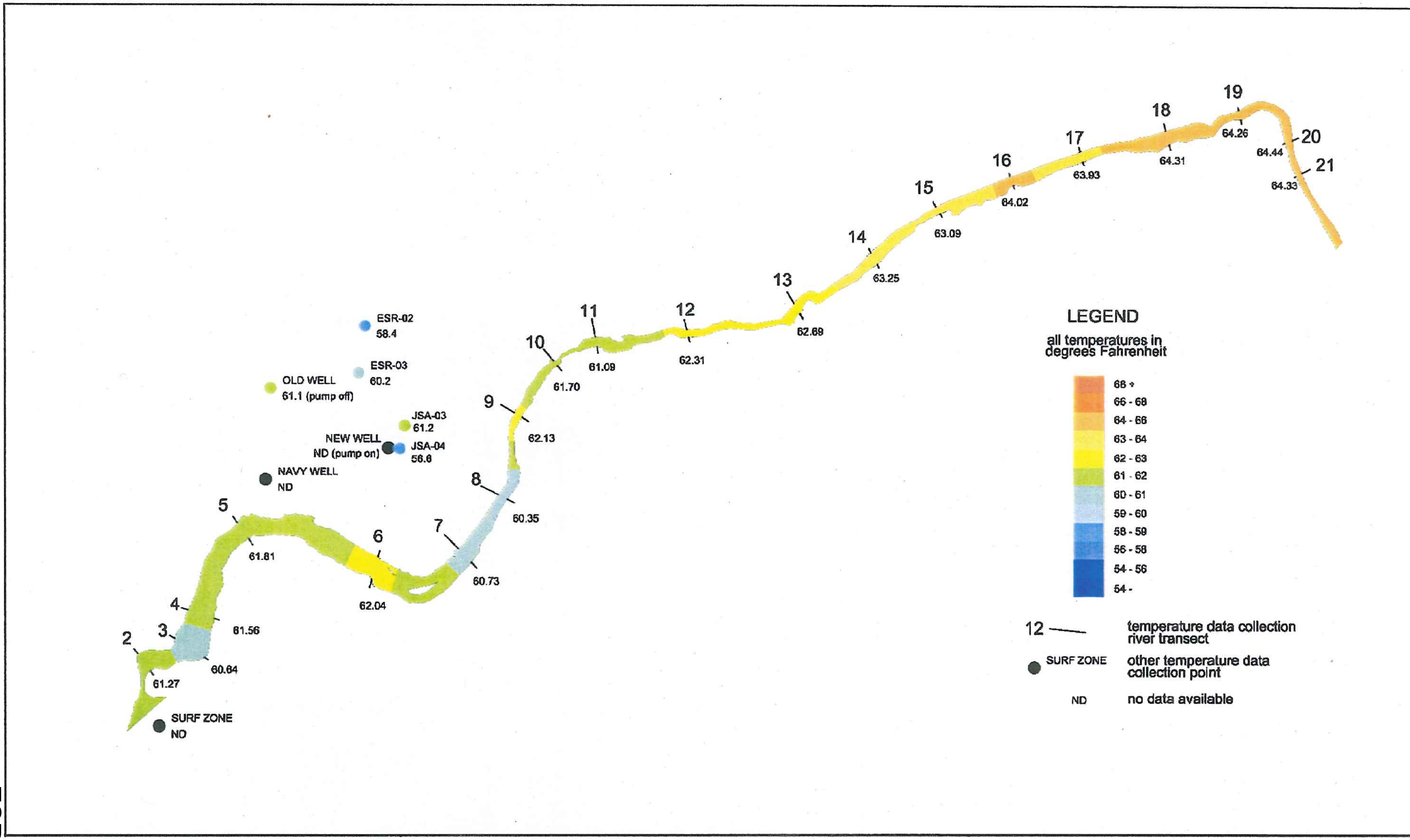

FIGURE 38. Geographic distributions of water temperature for August 6th water quality survey.

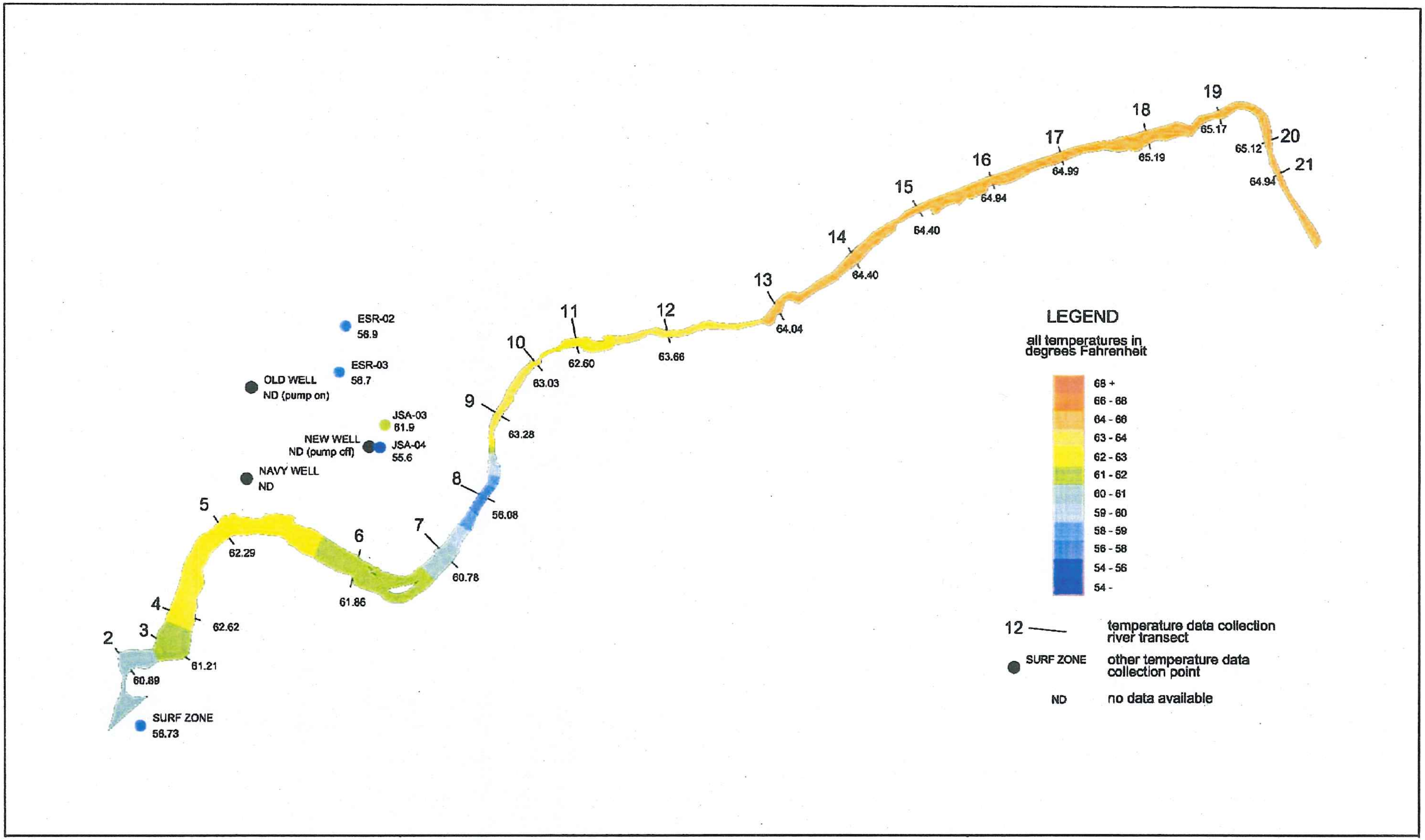

FIGURE 39. Geographic distributions of water temperature for August 19th water quality survey.

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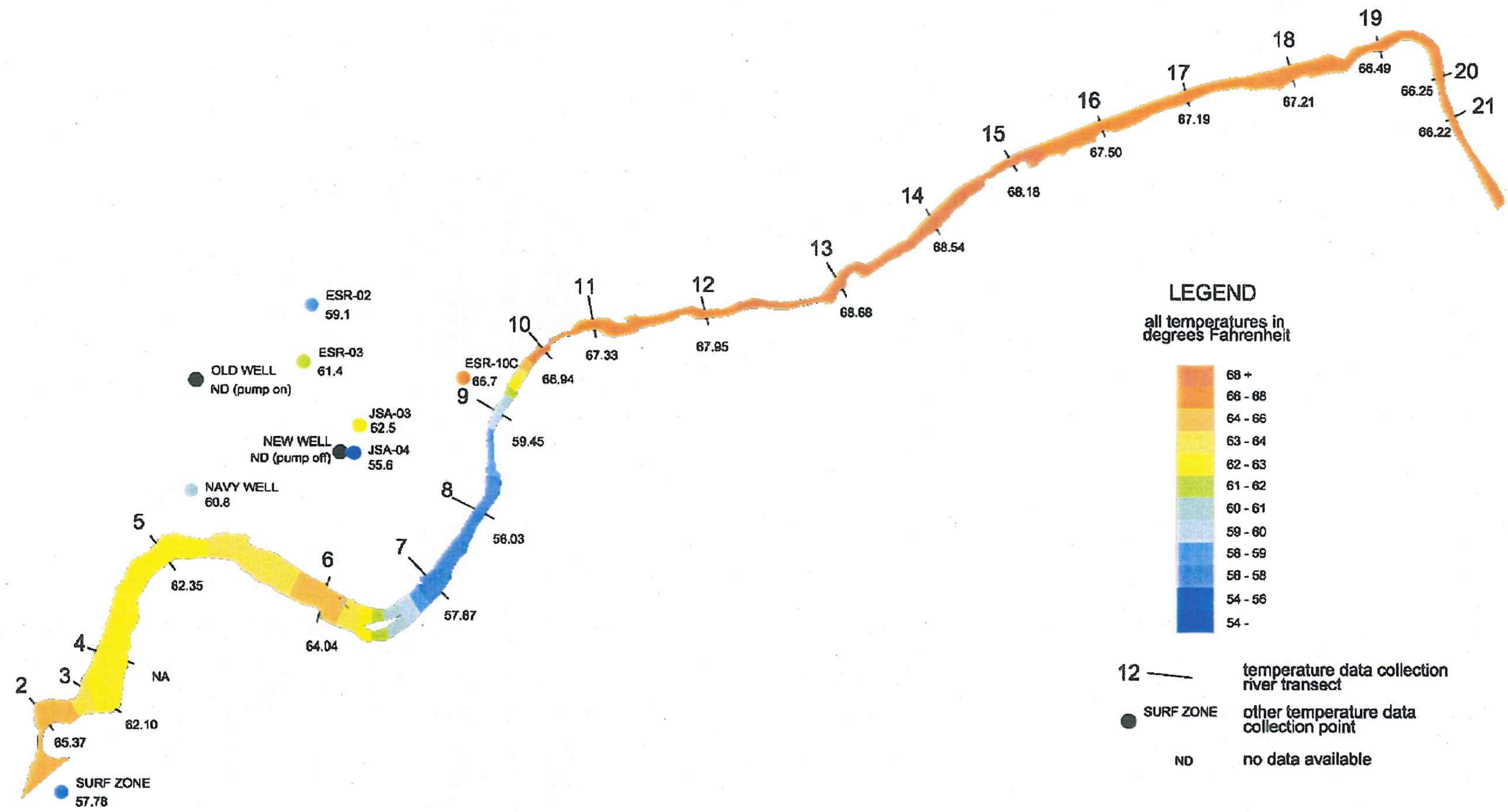

FIGURE 40. Geographic distributions of water temperature for September 2nd water quality survey.

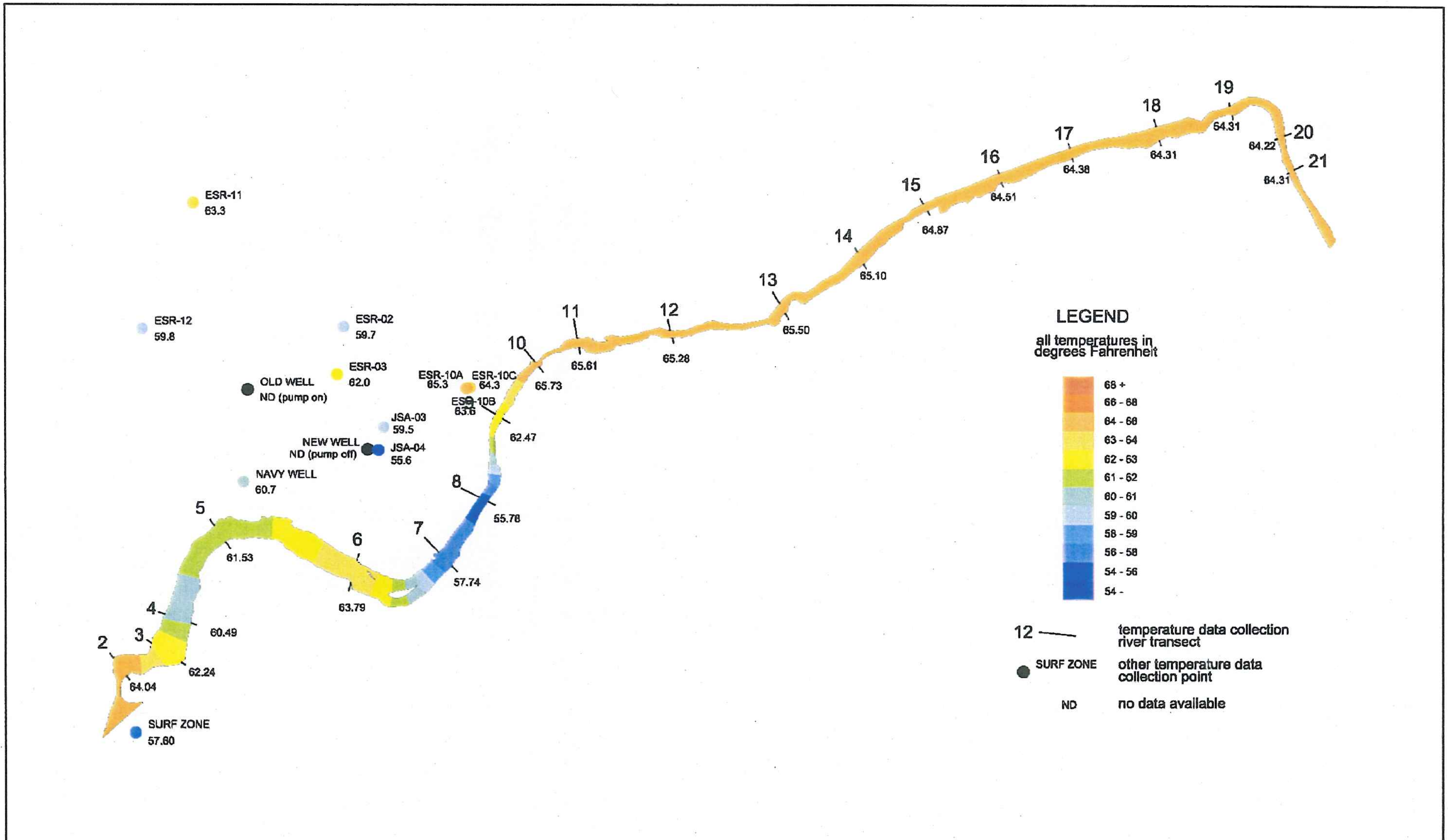

FIGURE 41. Geographic distributions of water temperature for September 15th water quality survey.

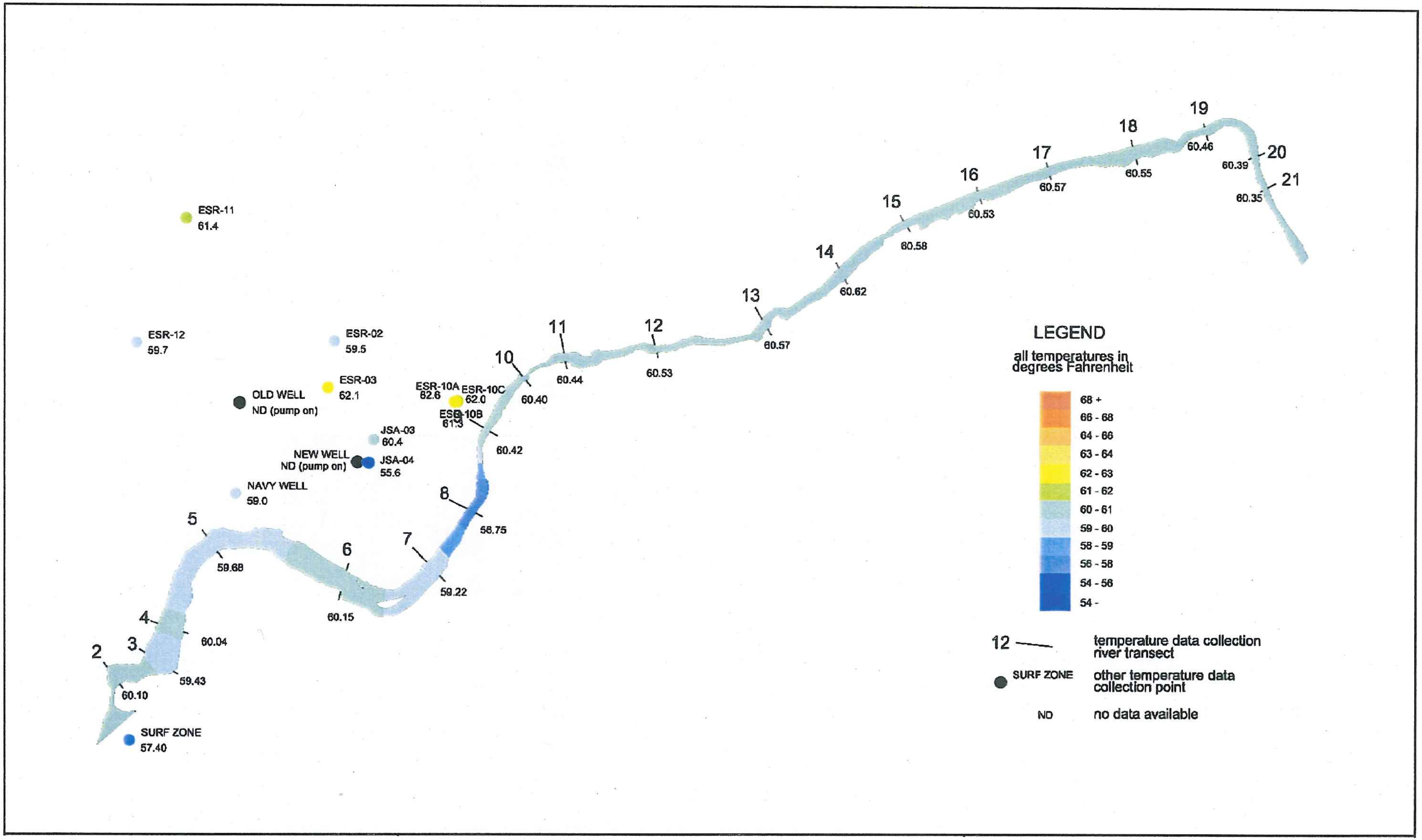

FIGURE 42. Geographic distributions of water temperature for September 30th water quality survey.

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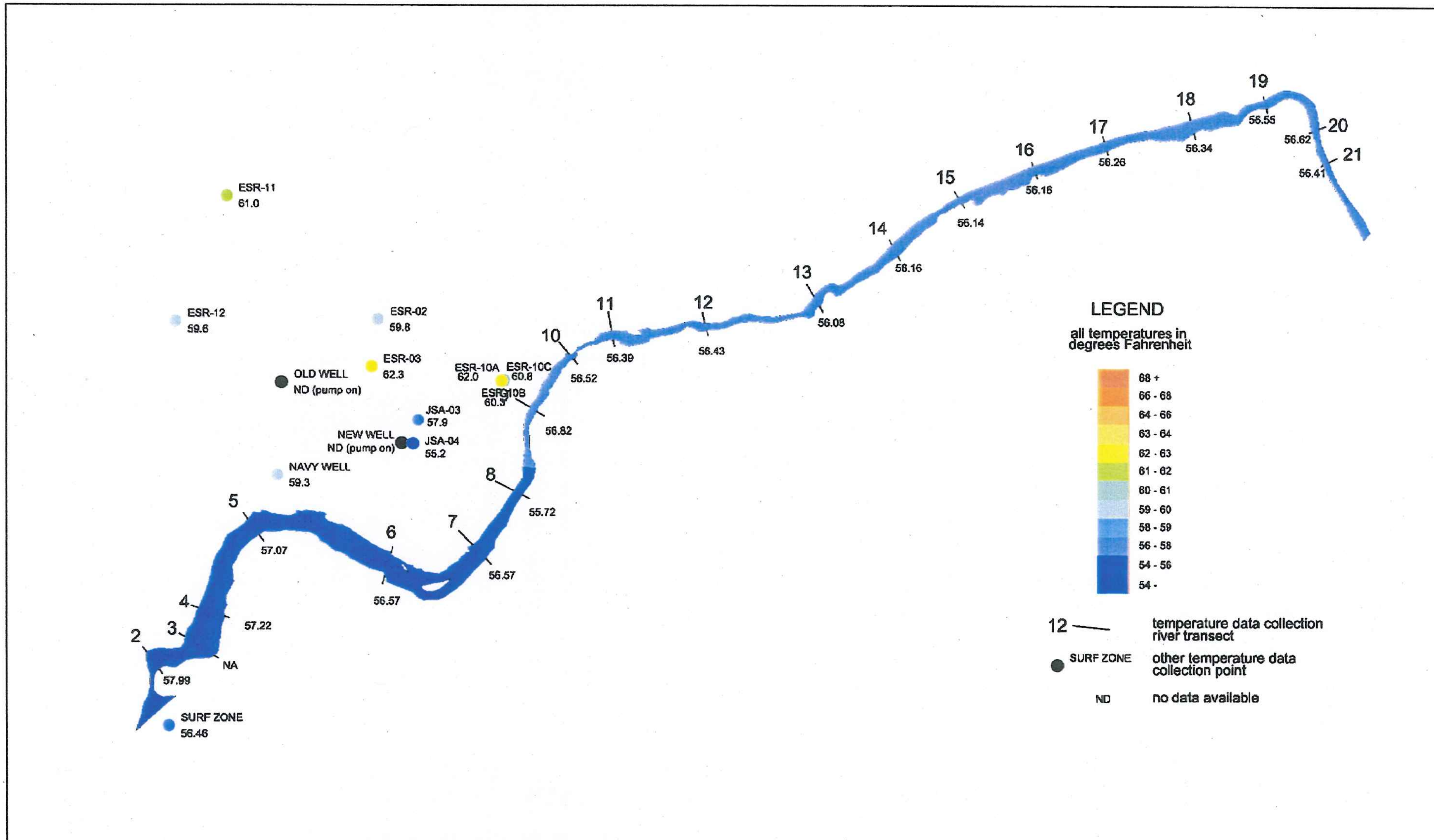

FIGURE 43. Geographic distributions of water temperature for October 15th water quality survey.

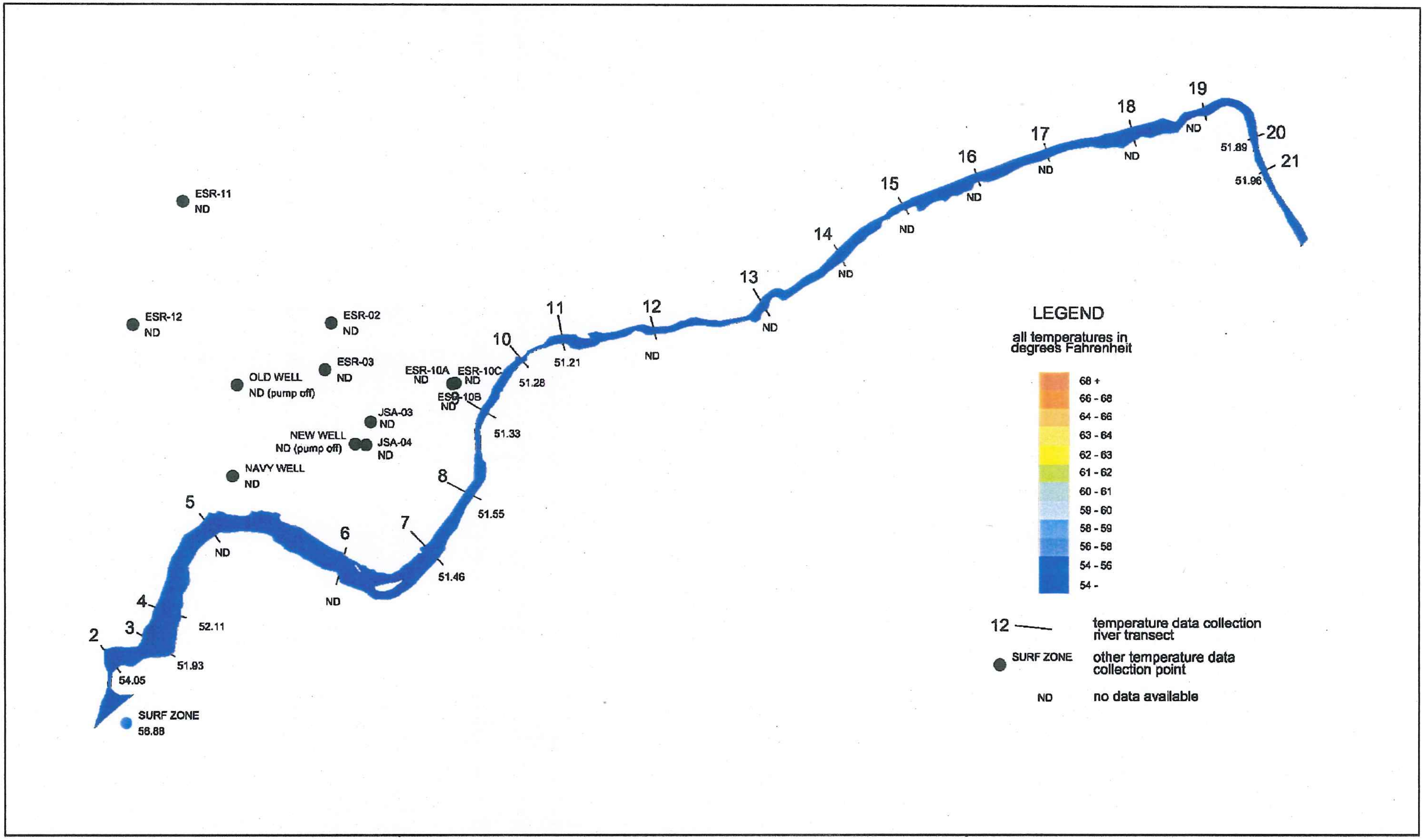

FIGURE 44. Geographic distributions of water temperature for October 28th water quality survey.

ESR--22

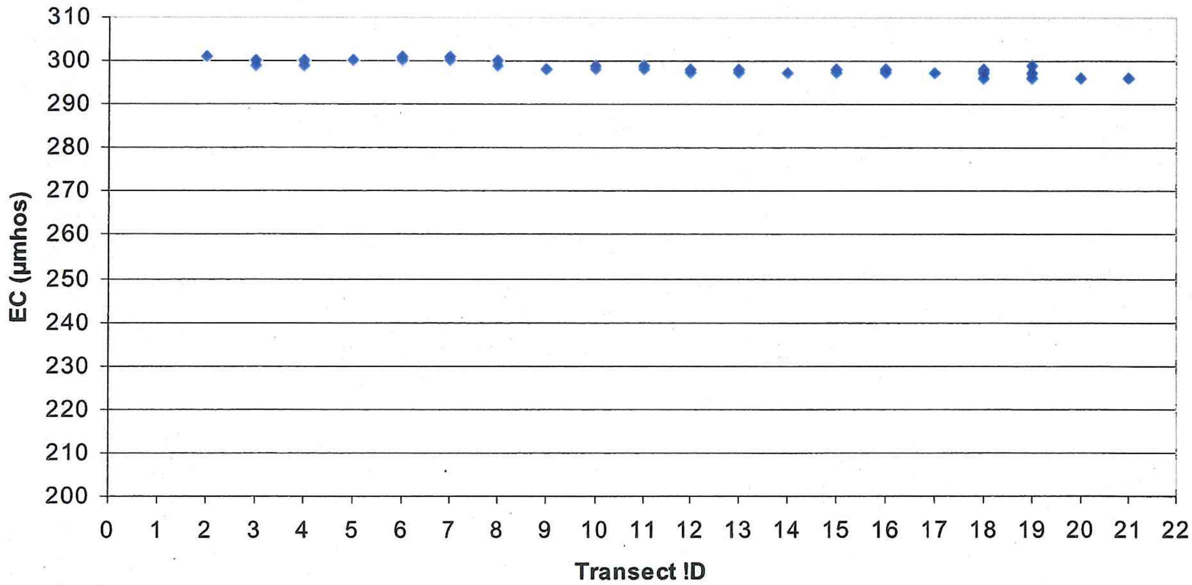

FIGURE 45. Results of electrical conductivity measurements within the lower river and lagoon on April 18, 2004.

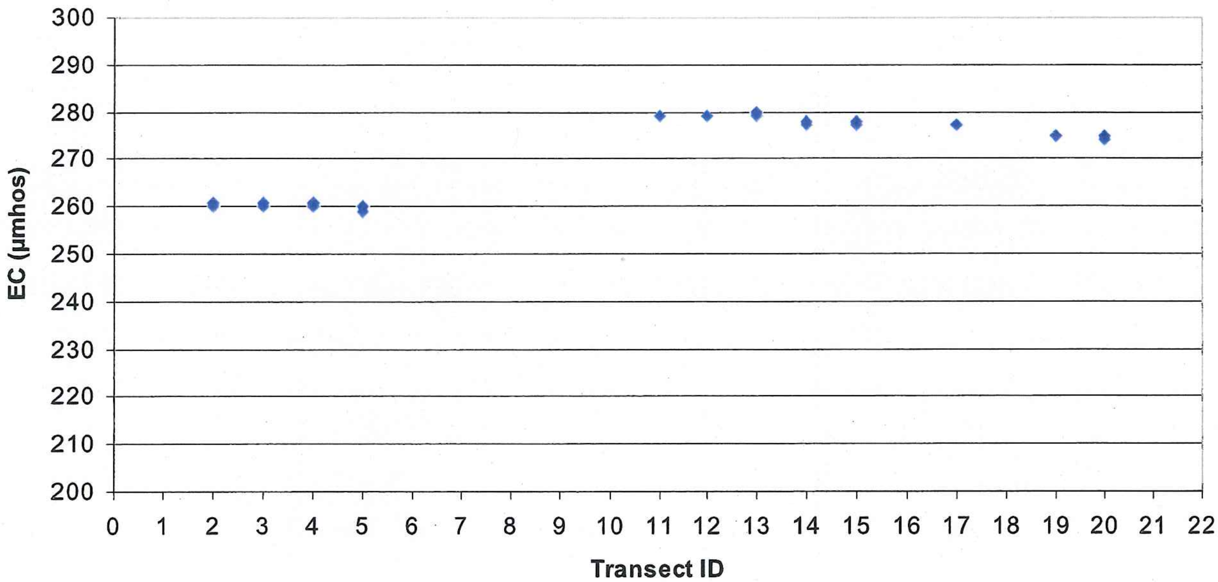

FIGURE 46. Results of electrical conductivity measurements within the lower river and lagoon on July 12, 2004.

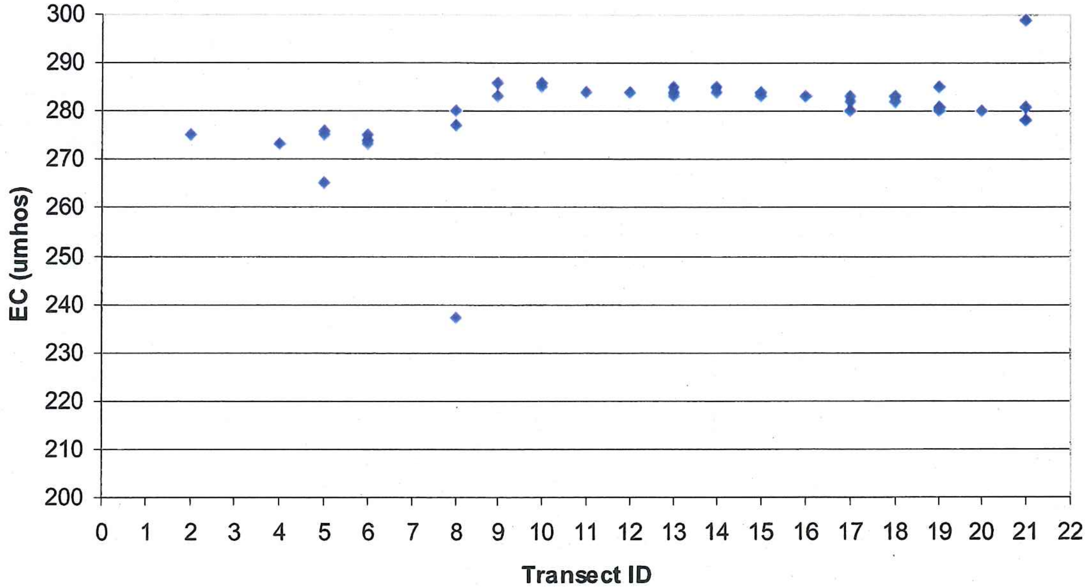

FIGURE 47. Results of electrical conductivity measurements within the lower river and lagoon on July 23, 2004.

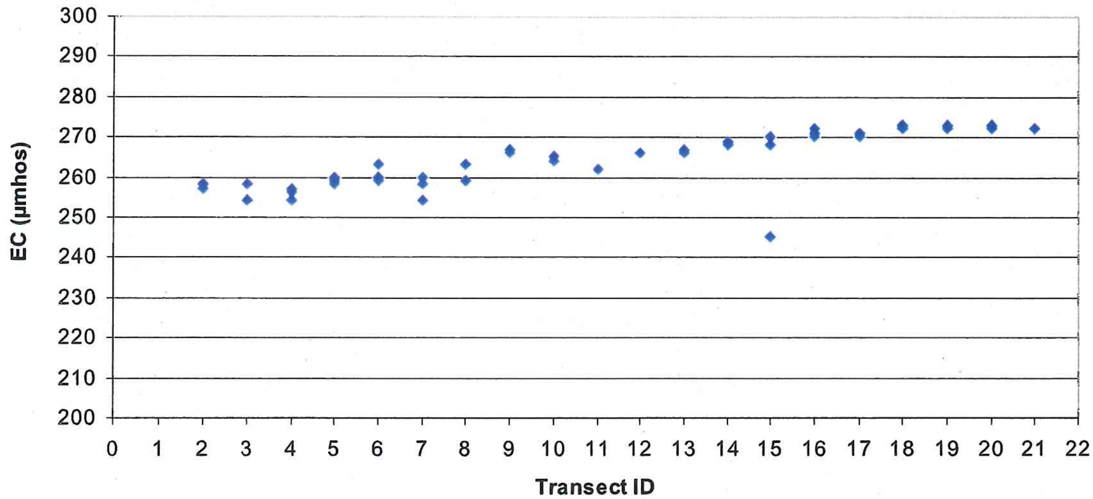

FIGURE 48. Results of electrical conductivity measurements within the lower river and lagoon on August 5, 2004.

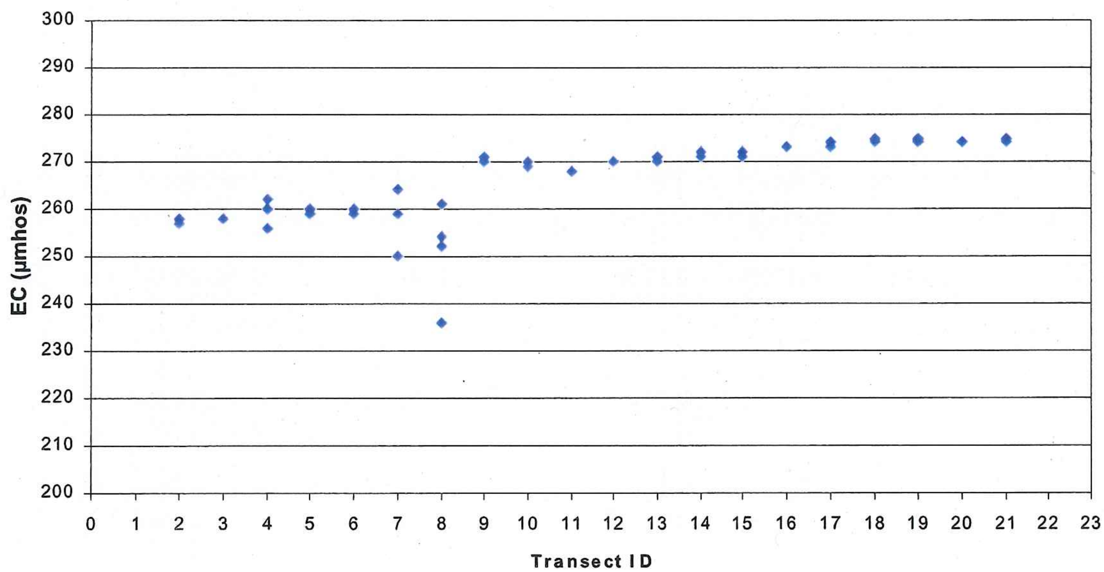

FIGURE 49. Results of electrical conductivity measurements within the lower river and lagoon on August 19, 2004.

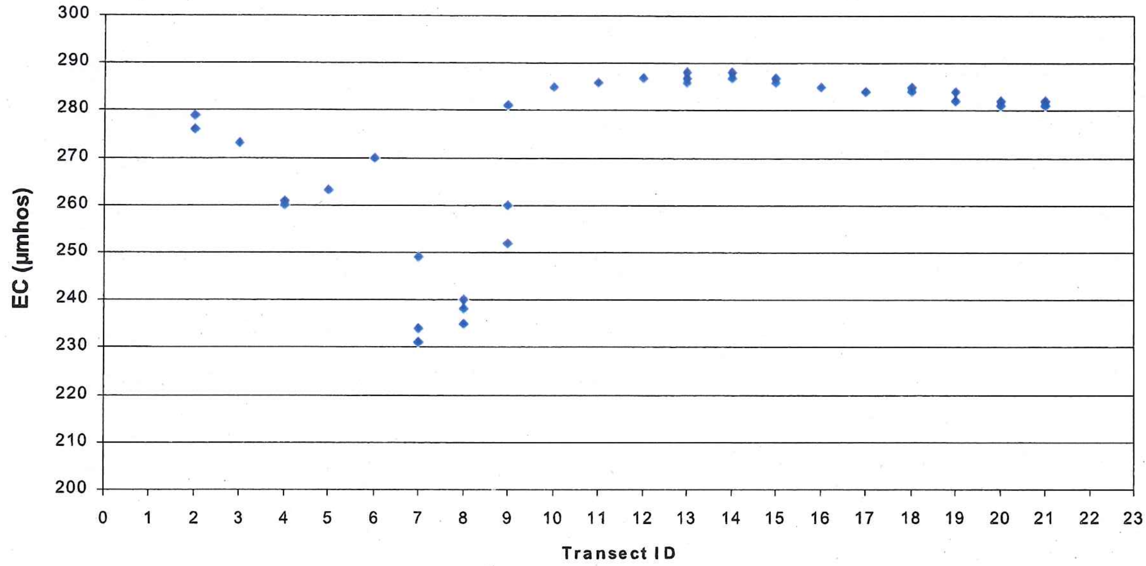

FIGURE 50. Results of electrical conductivity measurements within the lower river and lagoon on September 2, 2004.

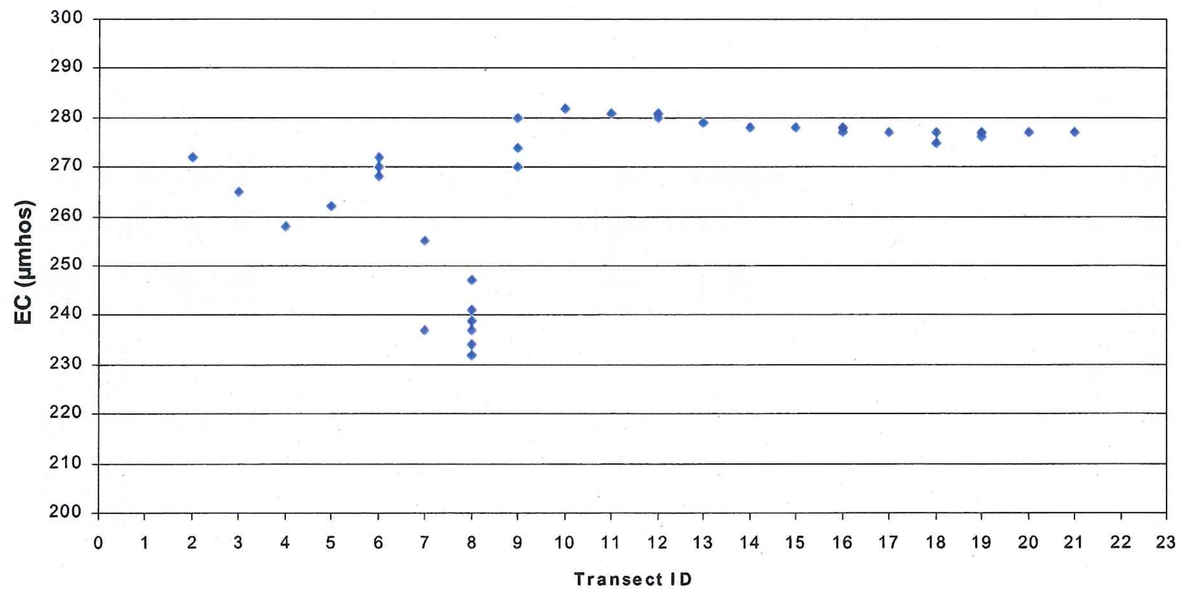

FIGURE 51. Results of water temperature measurements within the lower river and lagoon on September 15, 2004.

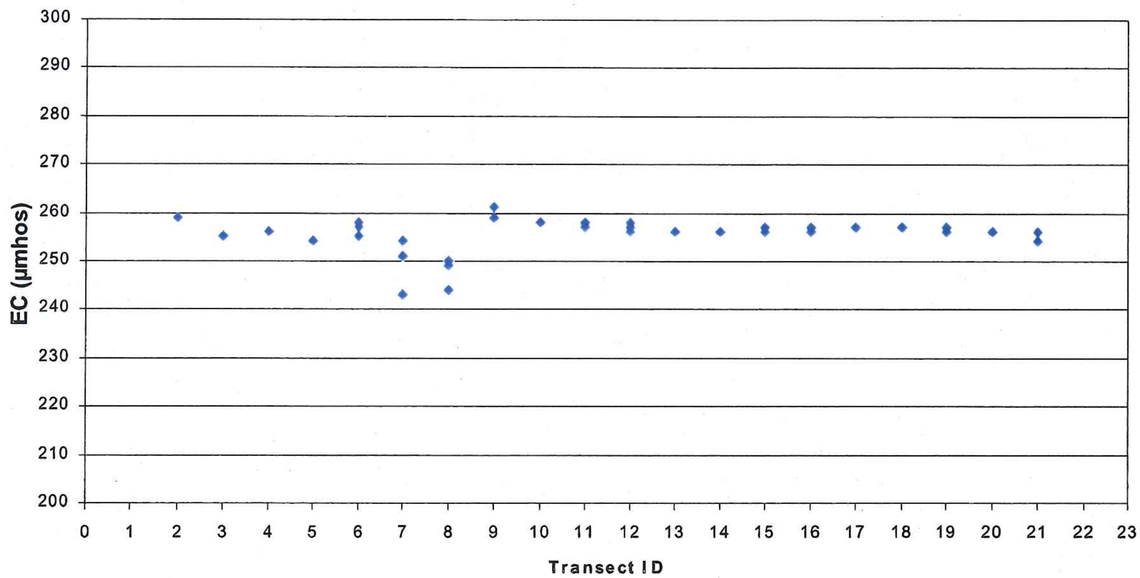

FIGURE 52. Results of electrical conductivity measurements within the lower river and lagoon on September 30, 2004.

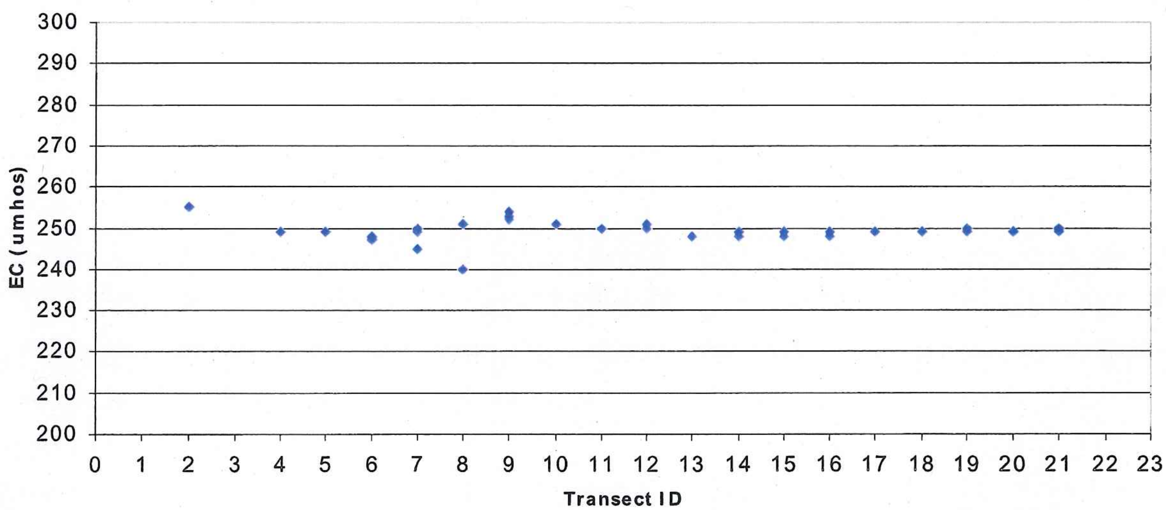

FIGURE 53. Results of electrical conductivity measurements within the lower river and lagoon on October 15, 2004.

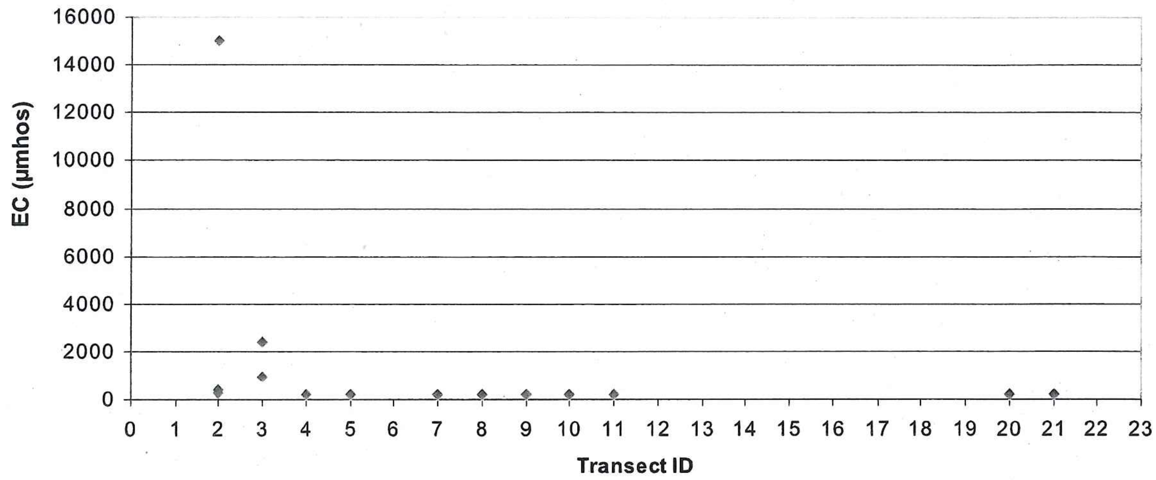

FIGURE 54. Results of electrical conductivity measurements within the lower river and lagoon on October 28, 2004.

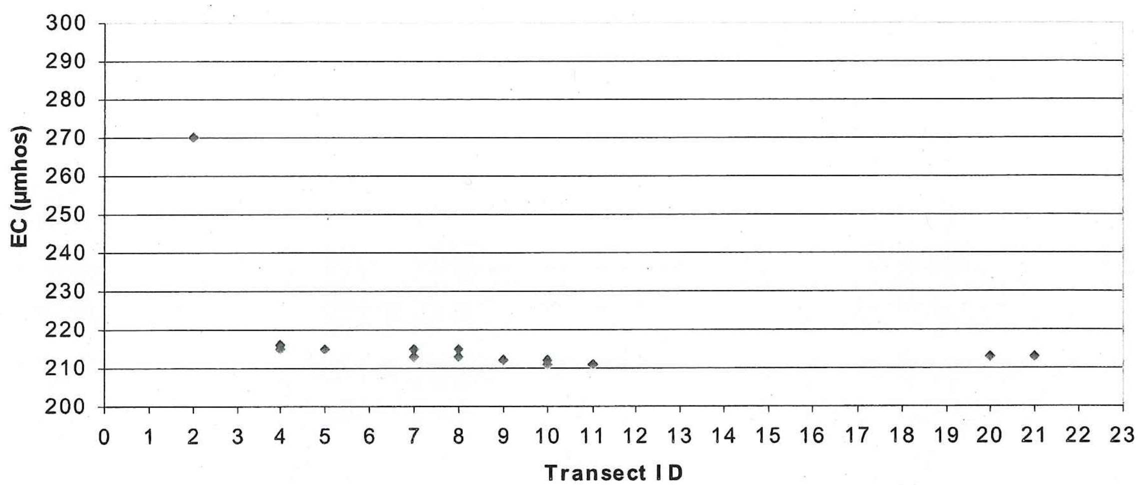

FIGURE 55. Results of electrical conductivity measurements within the lower river and lagoon on October 28, 2004 (scale modified and EC at site WQ-1 and WQ-3 not shown).

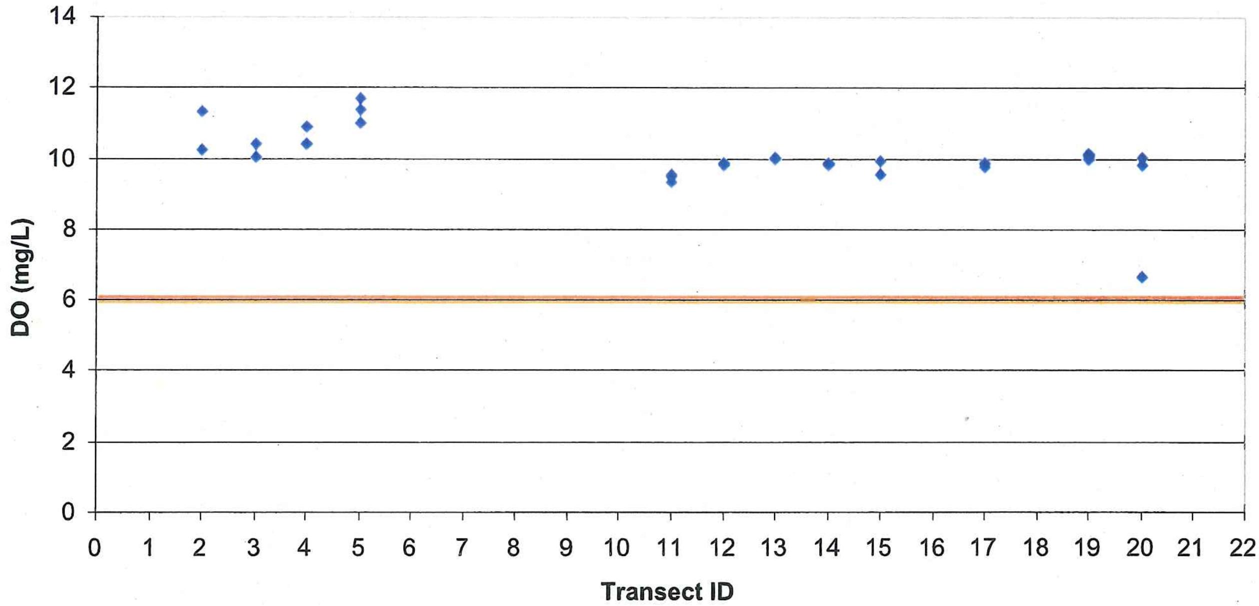

FIGURE 56. Results of dissolved oxygen measurements within the lower river and lagoon on July 12, 2004.

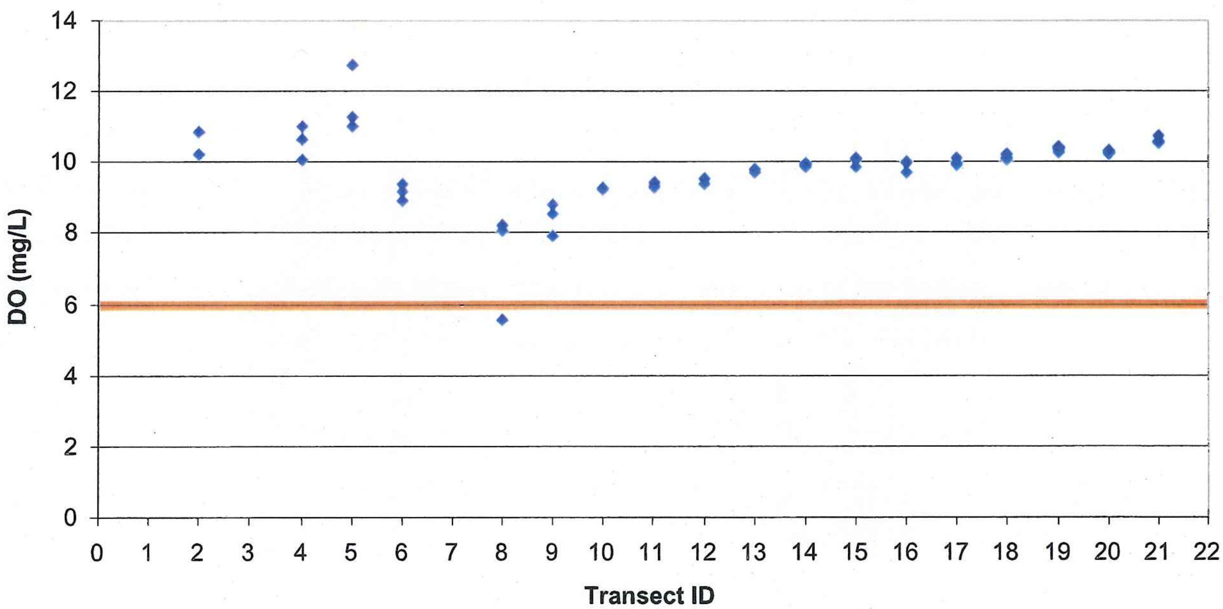

FIGURE 57. Results of dissolved oxygen measurements within the lower river and lagoon on July 23, 2004.

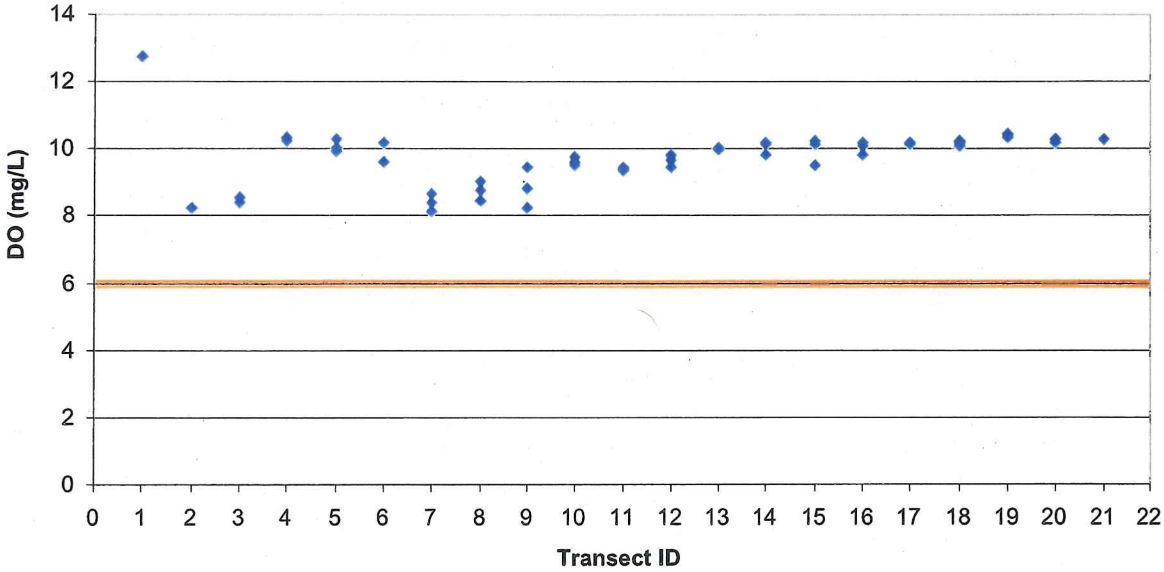

FIGURE 58. Results of dissolved oxygen measurements within the lower river and lagoon on August 5, 2004.

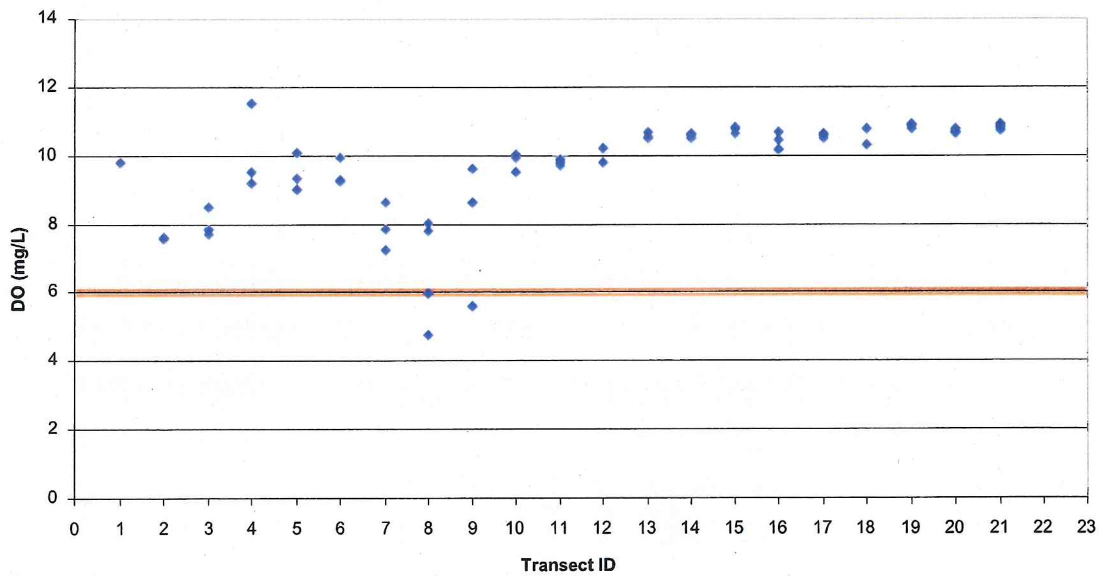

FIGURE 59. Results of dissolved oxygen measurements within the lower river and lagoon on August 19, 2004.

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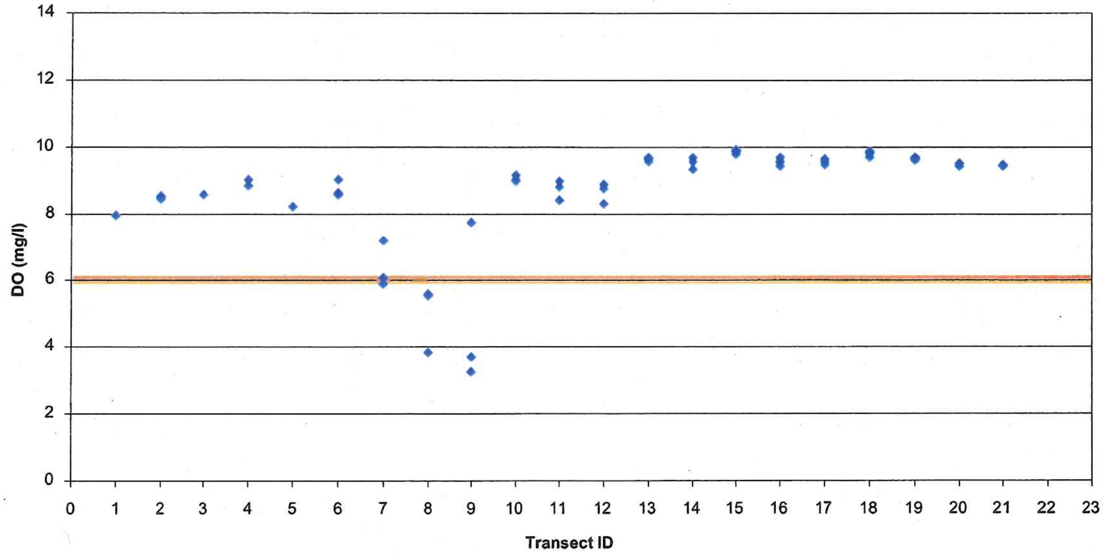

FIGURE 60. Results of dissolved oxygen measurements within the lower river and lagoon on September 2, 2004.

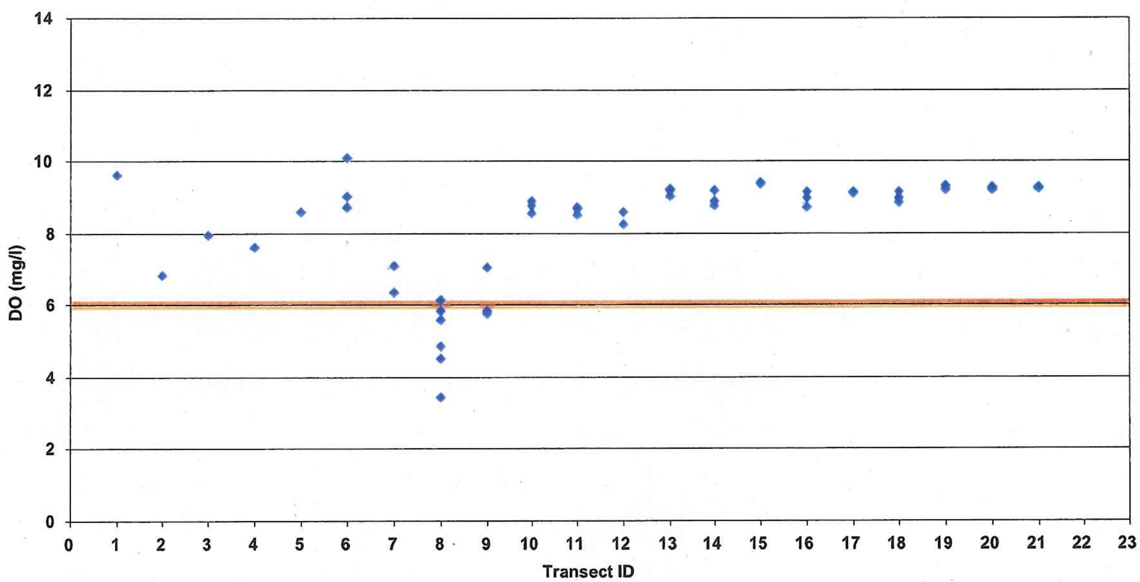

FIGURE 61. Results of dissolved oxygen measurements within the lower river and lagoon on September 15, 2004.

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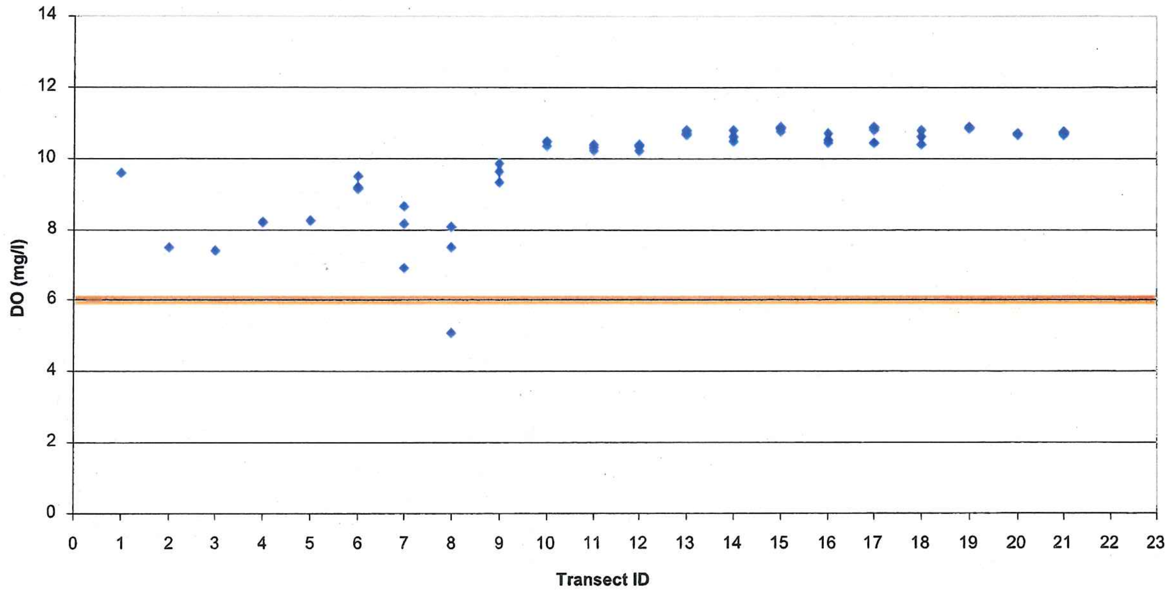

FIGURE 62. Results of dissolved oxygen measurements within the lower river and lagoon on September 30, 2004.

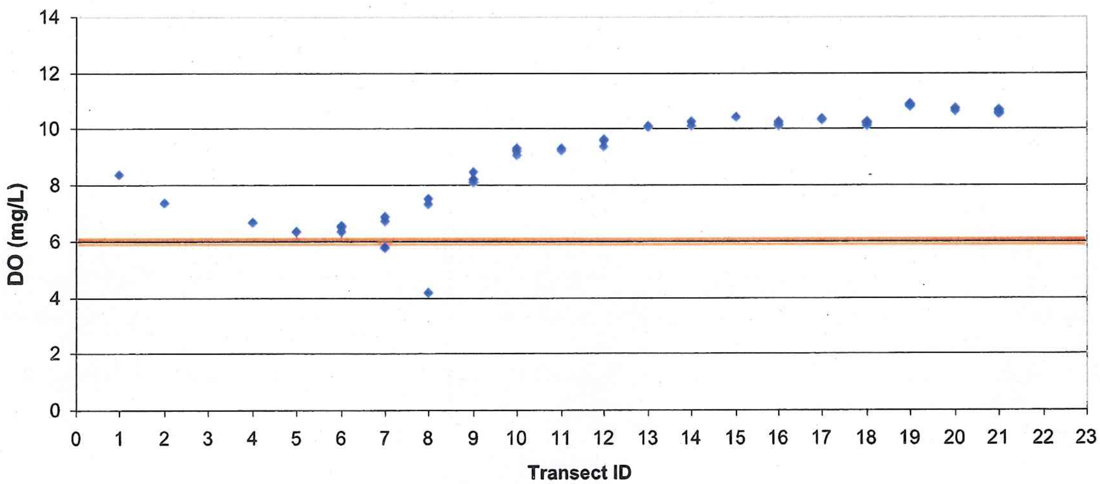

FIGURE 63. Results of dissolved oxygen measurements within the lower river and lagoon on October 14, 2004.

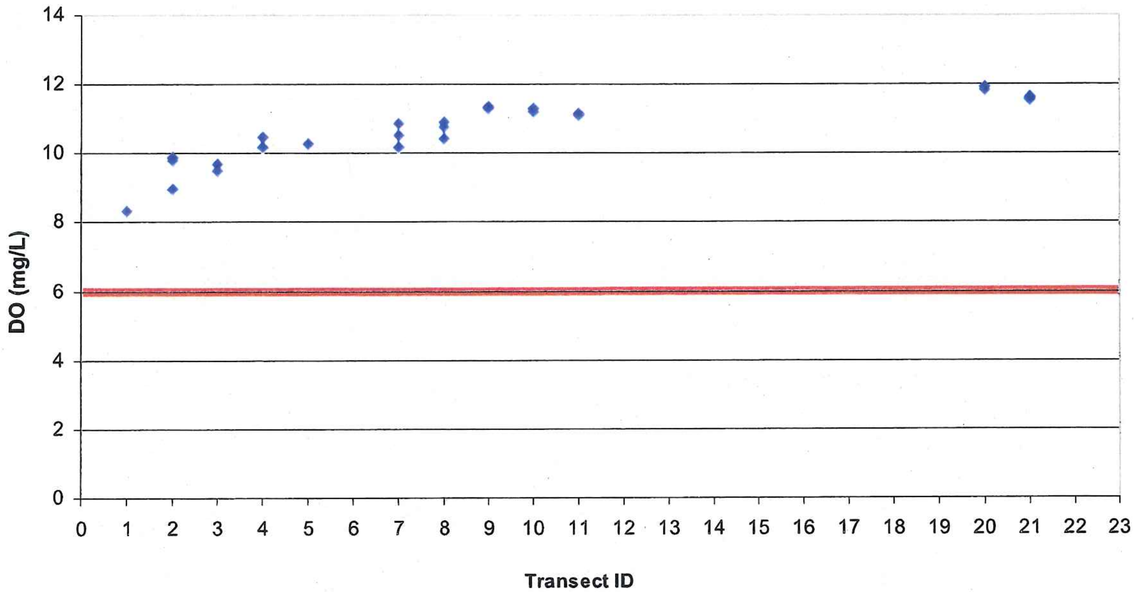

FIGURE 64. Results of dissolved oxygen measurements within the lower river and lagoon on October 28, 2004.

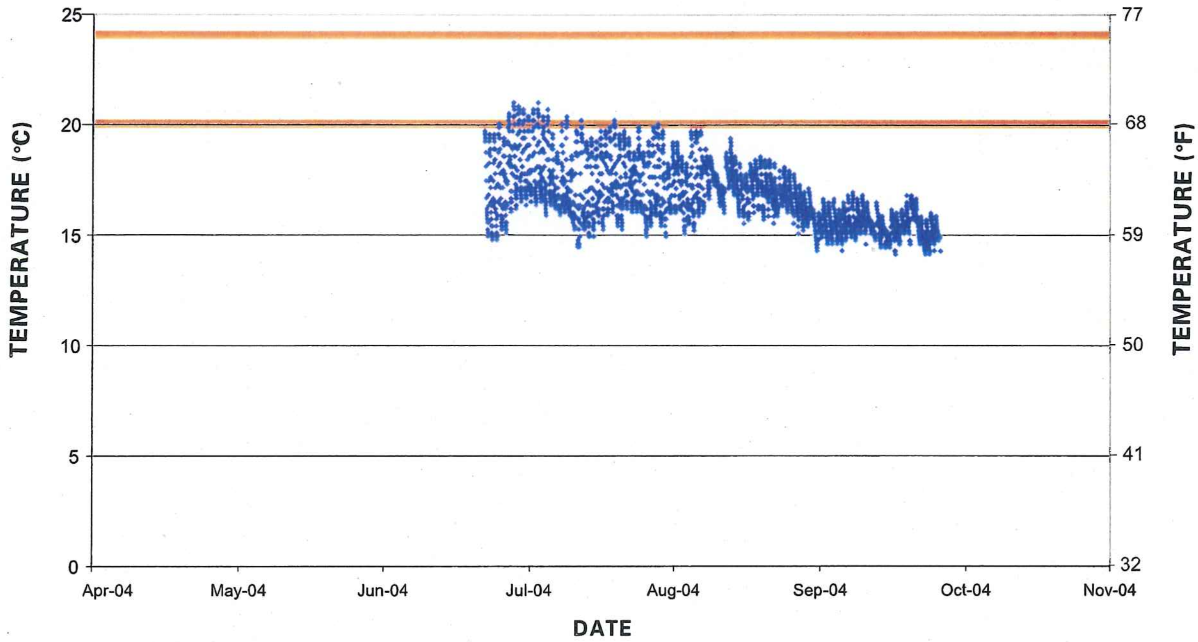

FIGURE 65. Results of hourly water temperature measurements at sampling station CT-1 (surface location at lagoon outfall).

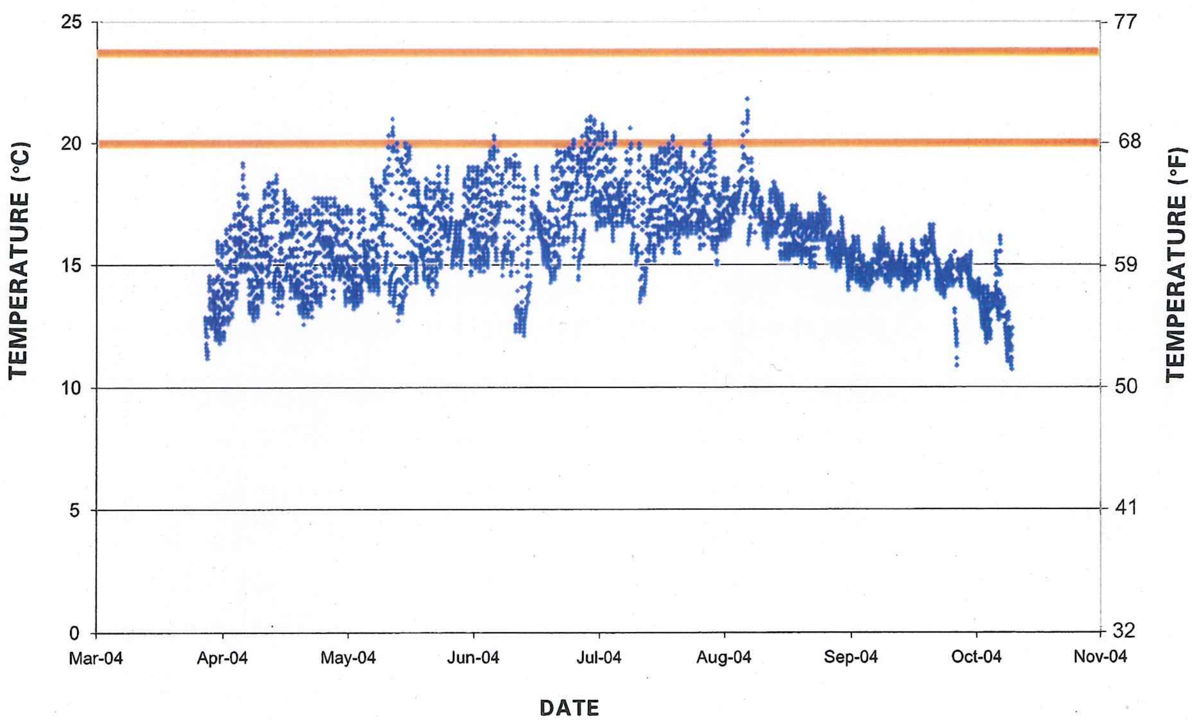

FIGURE 66. Results of hourly water temperature measurements at sampling station CT-1 (bottom location at lagoon outfall).

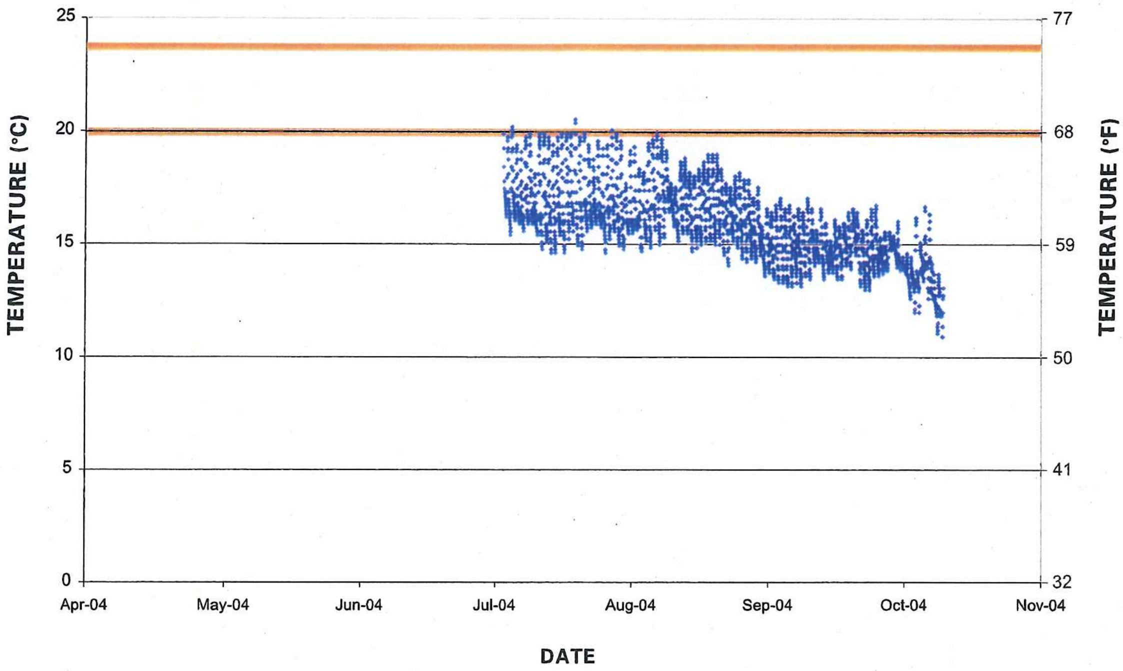

FIGURE 67. Results of hourly water temperature measurements at sampling station CT-2 (surface location at Creamery Meadow upstream of cutbank).

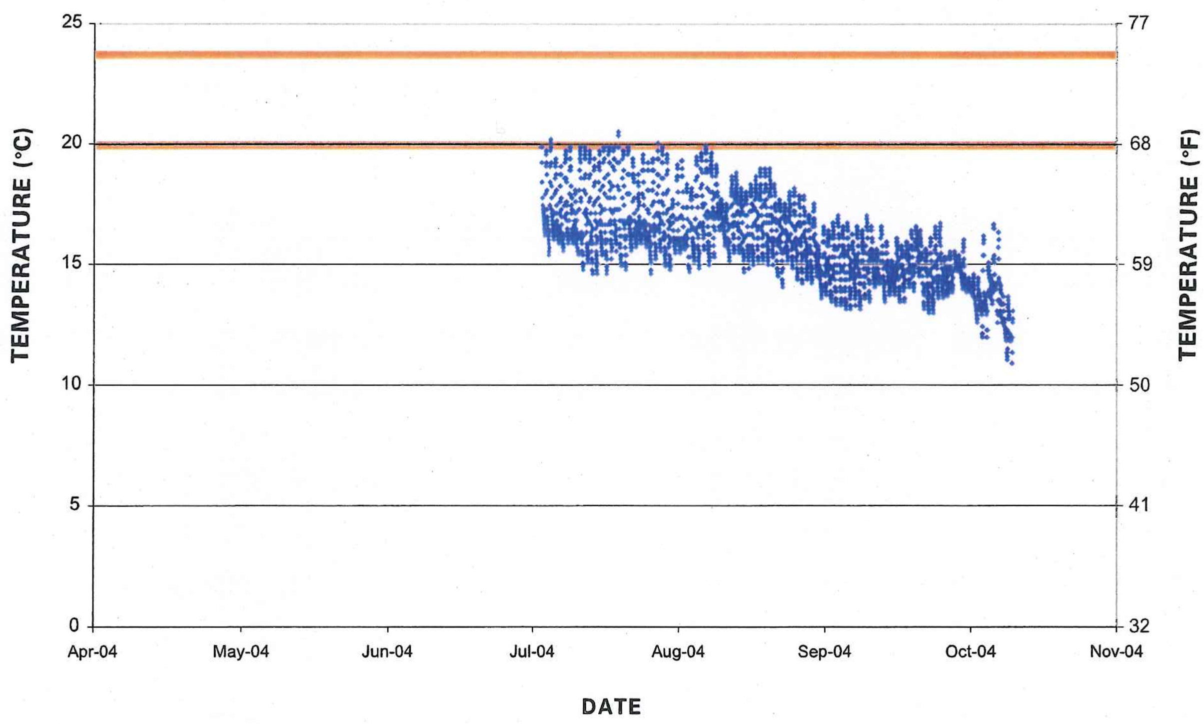

FIGURE 68. Results of hourly water temperature measurements at sampling station CT-2 (bottom location at Creamery Meadow upstream of cutbank).

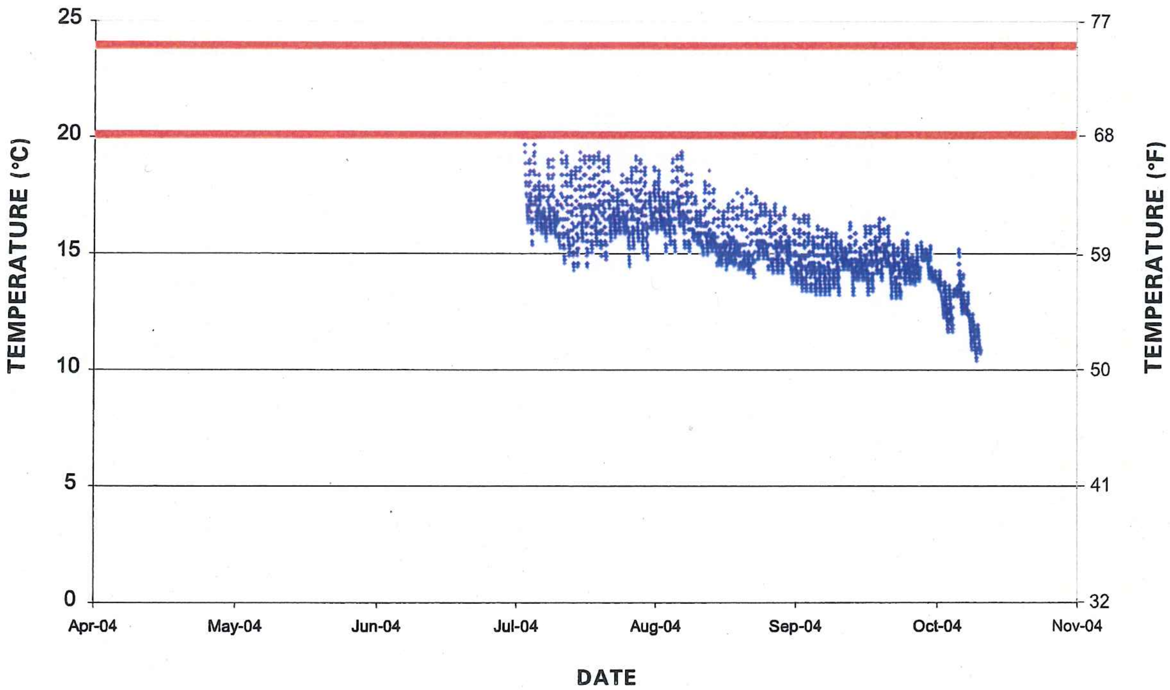

FIGURE 69. Results of hourly water temperature measurements at sampling station CT-3 (surface location at Creamery Meadow downstream of groundwater upwelling).

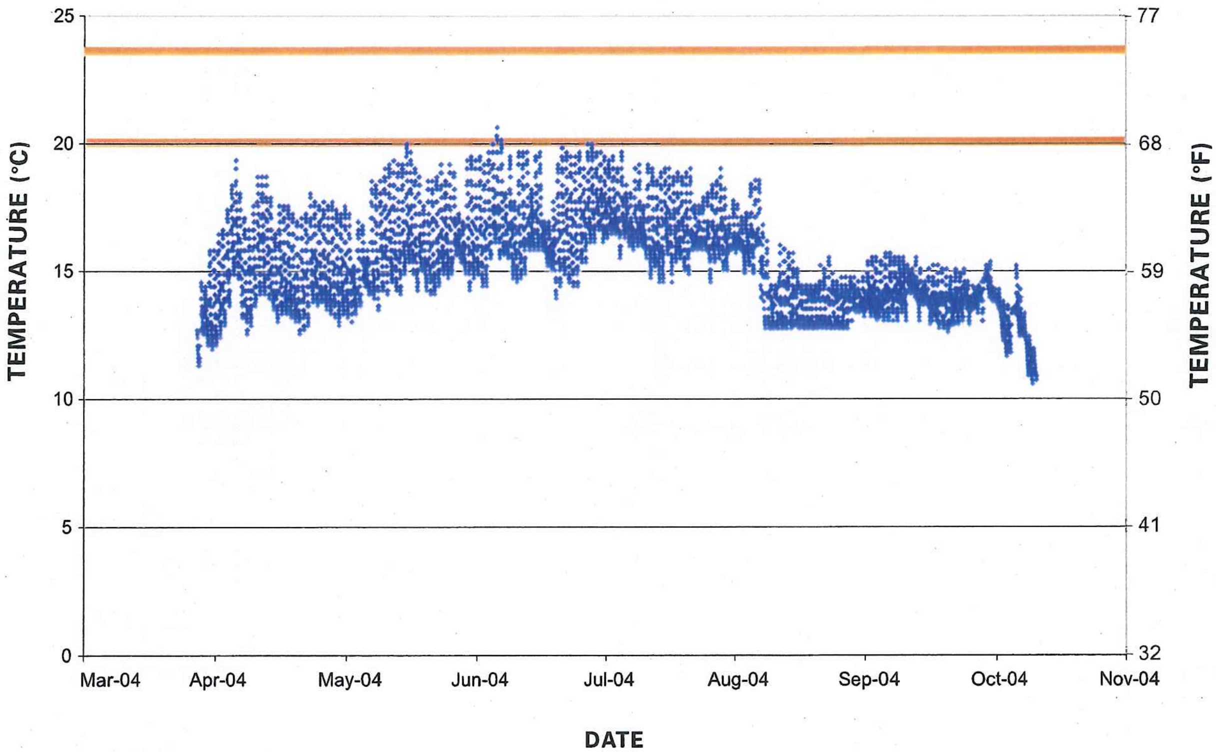

FIGURE 70. Results of hourly water temperature measurements at sampling station CT-3 (bottom location at Creamery Meadow downstream of groundwater upwelling).

NOTE: In early August there is a rapid drop in temperature and for the majority of the month of August there is an unusual temperature pattern with temperatures seemingly hitting a static "baseline". The factors contributing to this are unknown and the temperature conditions from late August to the end of the monitoring period resume a more regular pattern that corresponds with the temperature recorder on the surface at the same station.

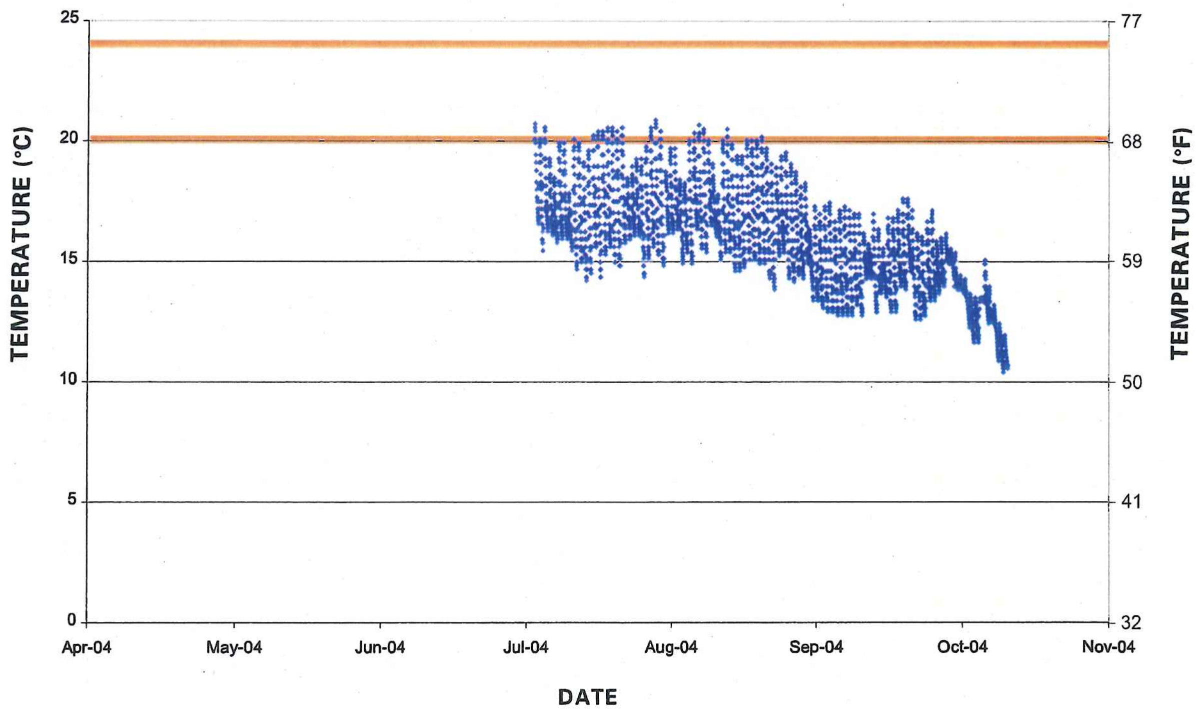

FIGURE 71. Results of hourly water temperature measurements at sampling station CT-4 (surface location at deep pool upstream of Creamery Meadow).

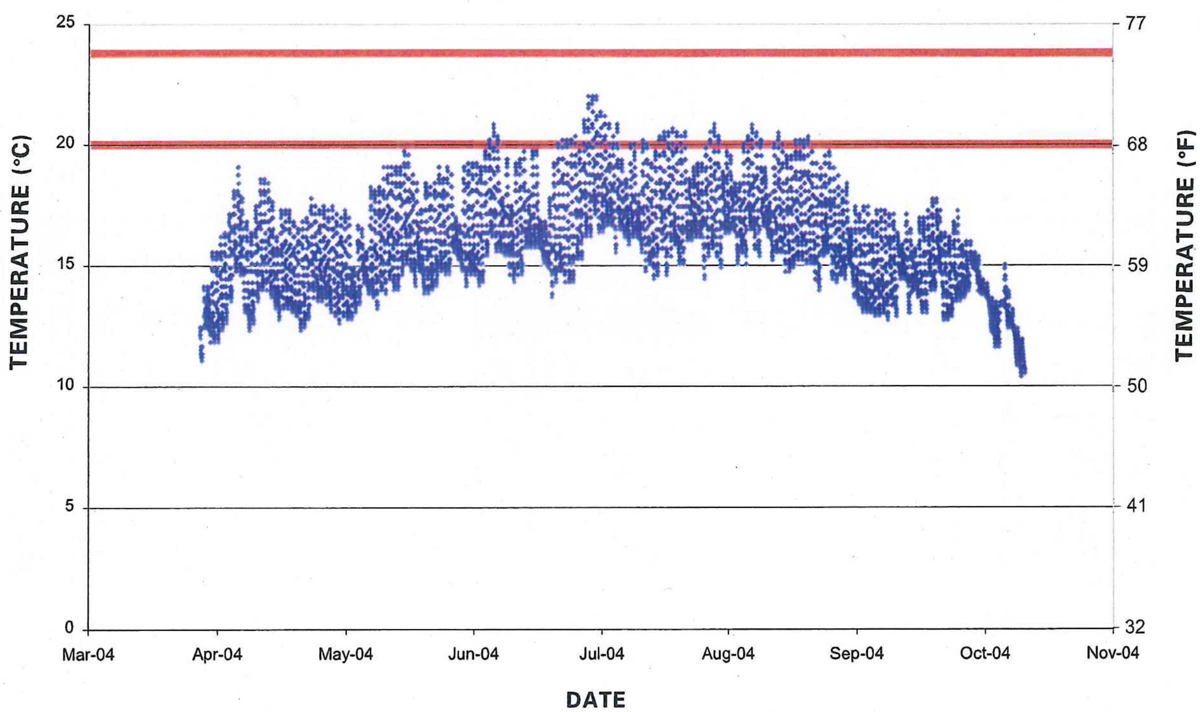

FIGURE 72. Results of hourly water temperature measurements at sampling station CT-4 (bottom location at deep pool upstream of Creamery Meadow).

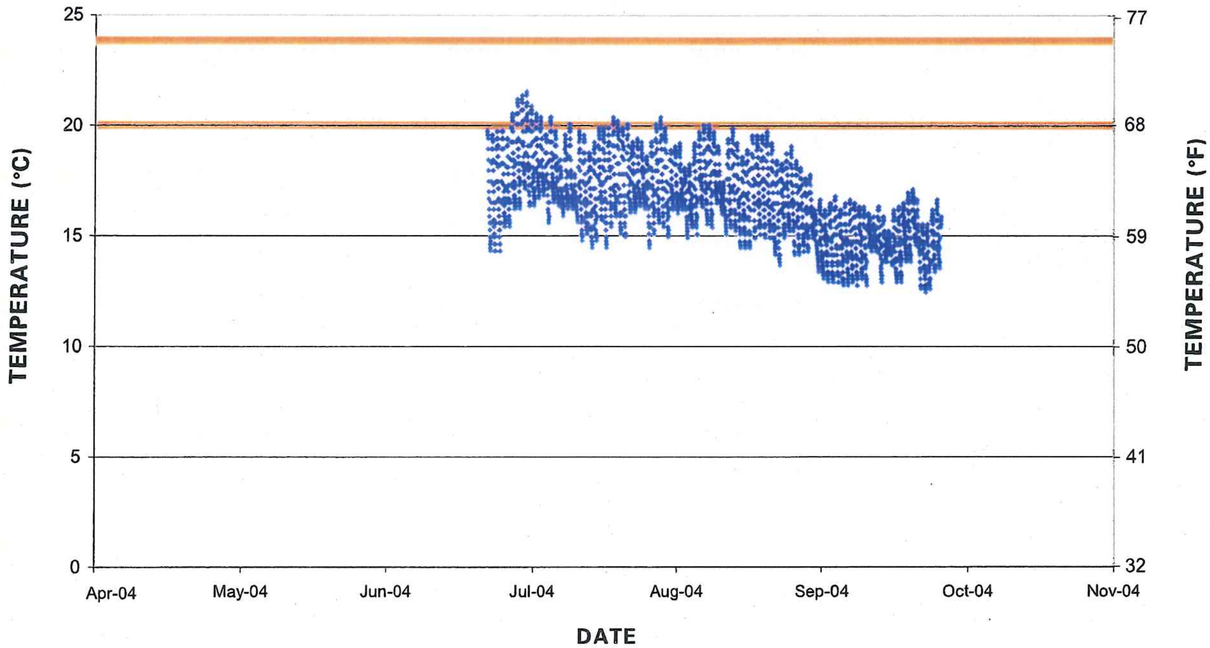

FIGURE 73. Results of hourly water temperature measurements at sampling station CT-5 (surface location at state park parking area).

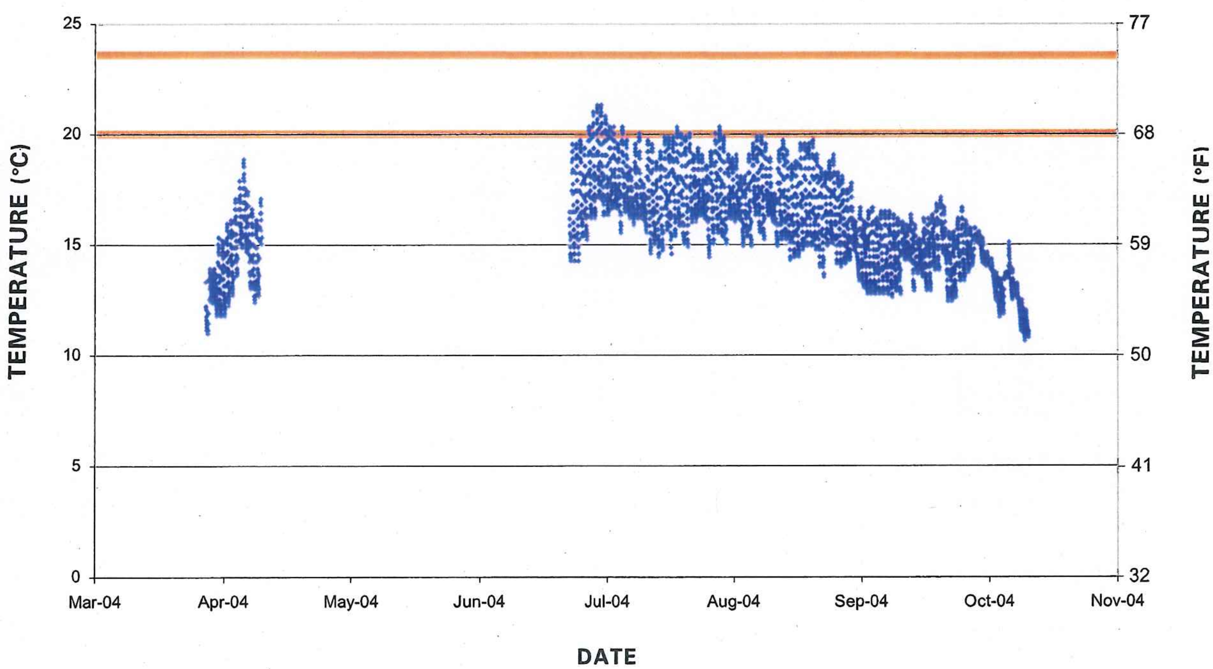

FIGURE 74. Results of hourly water temperature measurements at sampling station CT-5 (bottom location at state park parking area).

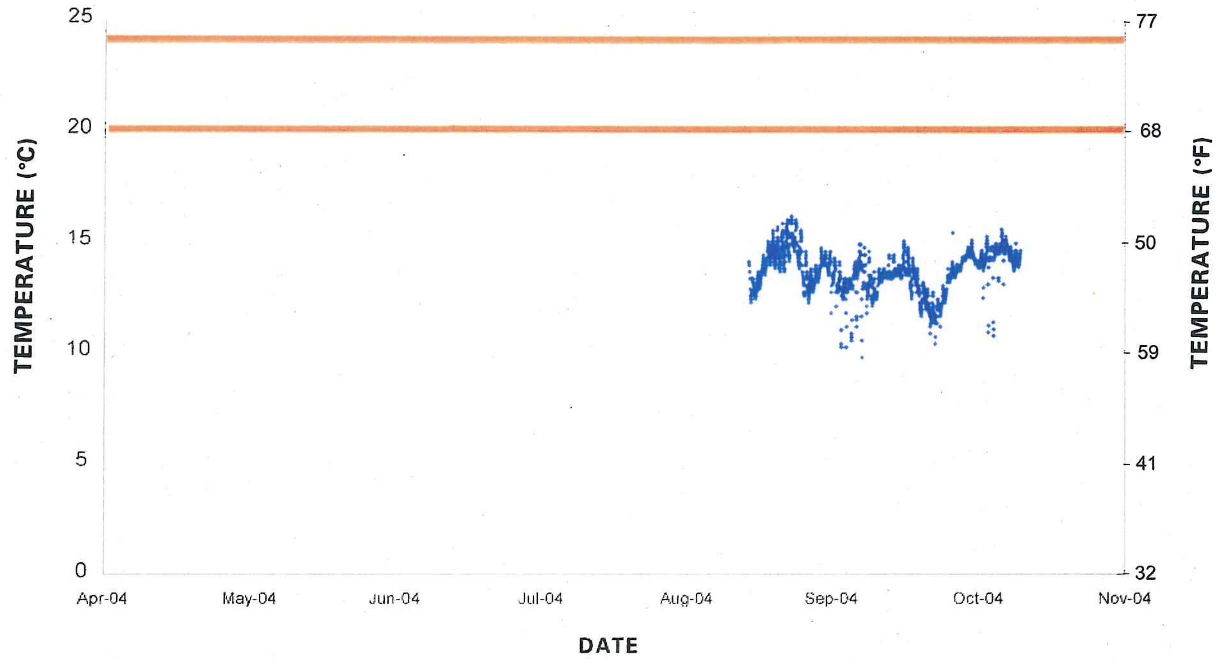

FIGURE 75. Results of hourly water temperature measurements at sampling station CT-6 (bottom location at surf zone).

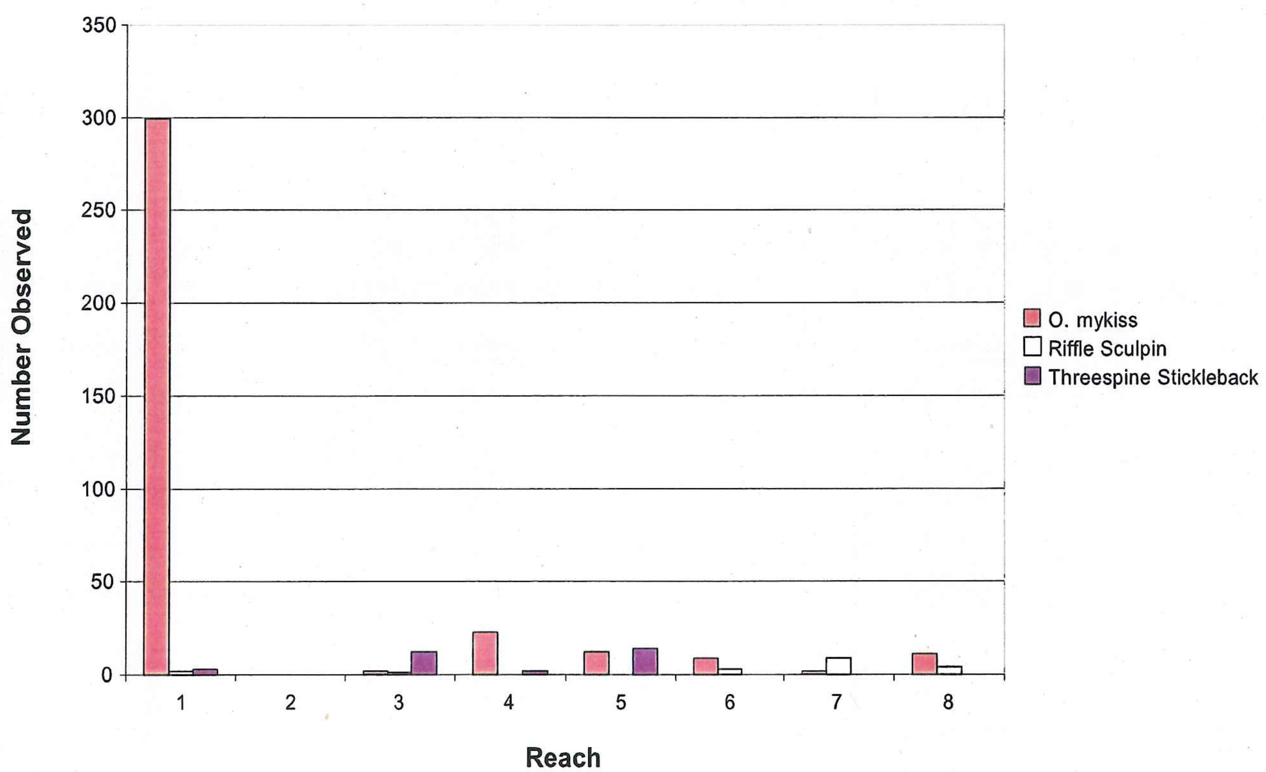

FIGURE 76. Geographic distribution and numbers of fish observed inhabiting the lower river and lagoon during the October snorkel survey.

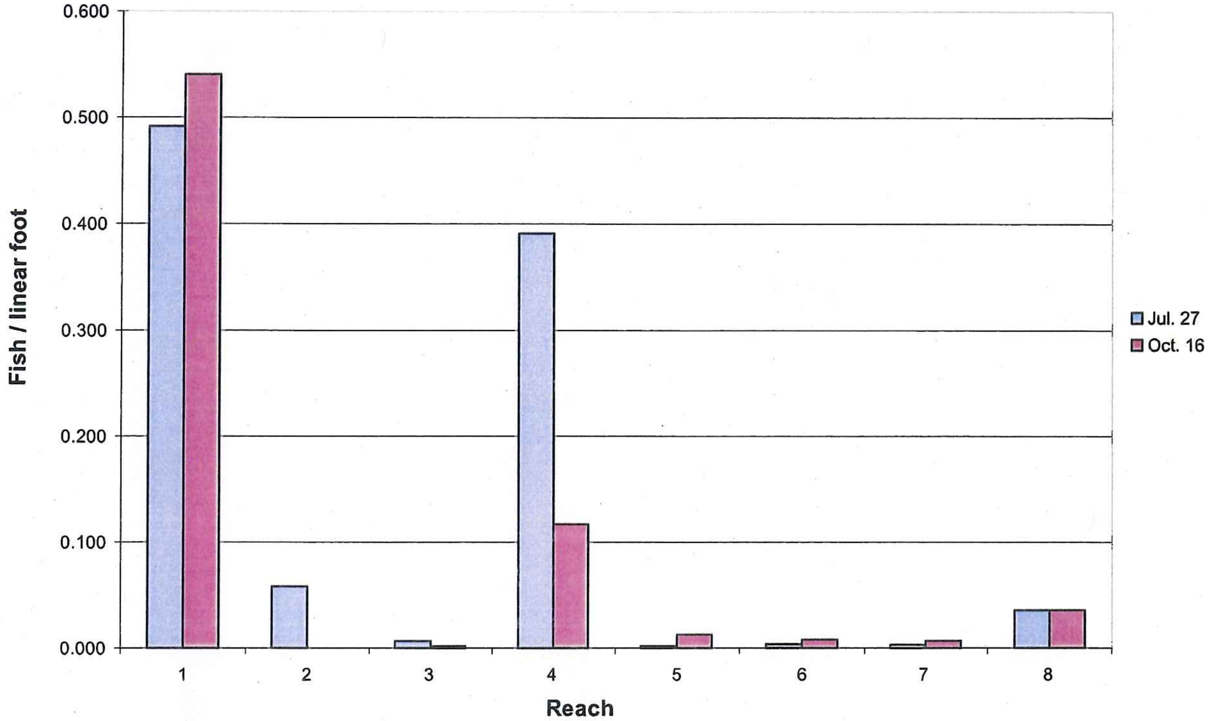

FIGURE 77. Density of juvenile steelhead/rainbow trout observed within various reaches of the lower river and lagoon during July and October snorkel surveys.

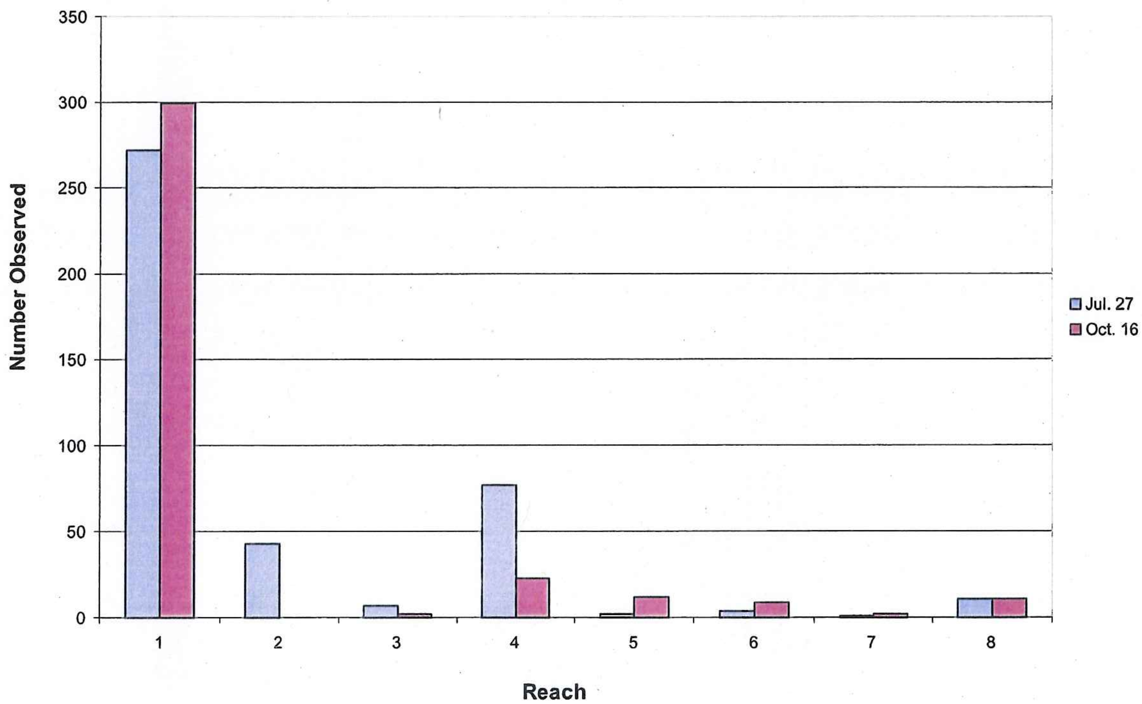

FIGURE 78. Actual number of juvenile steelhead/rainbow trout observed within various reaches of the lower river and lagoon during July and October snorkel surveys.

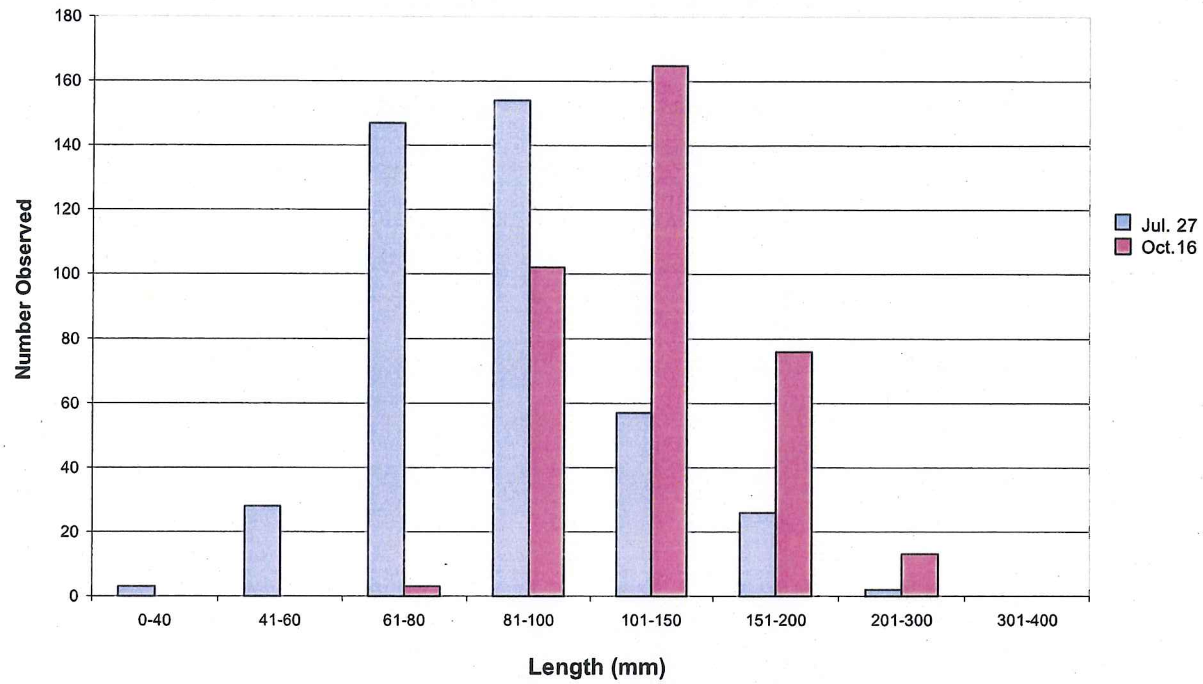

FIGURE 79. Length frequency distribution of juvenile steelhead/rainbow trout observed in the lower river and lagoon during the July and October snorkel surveys.

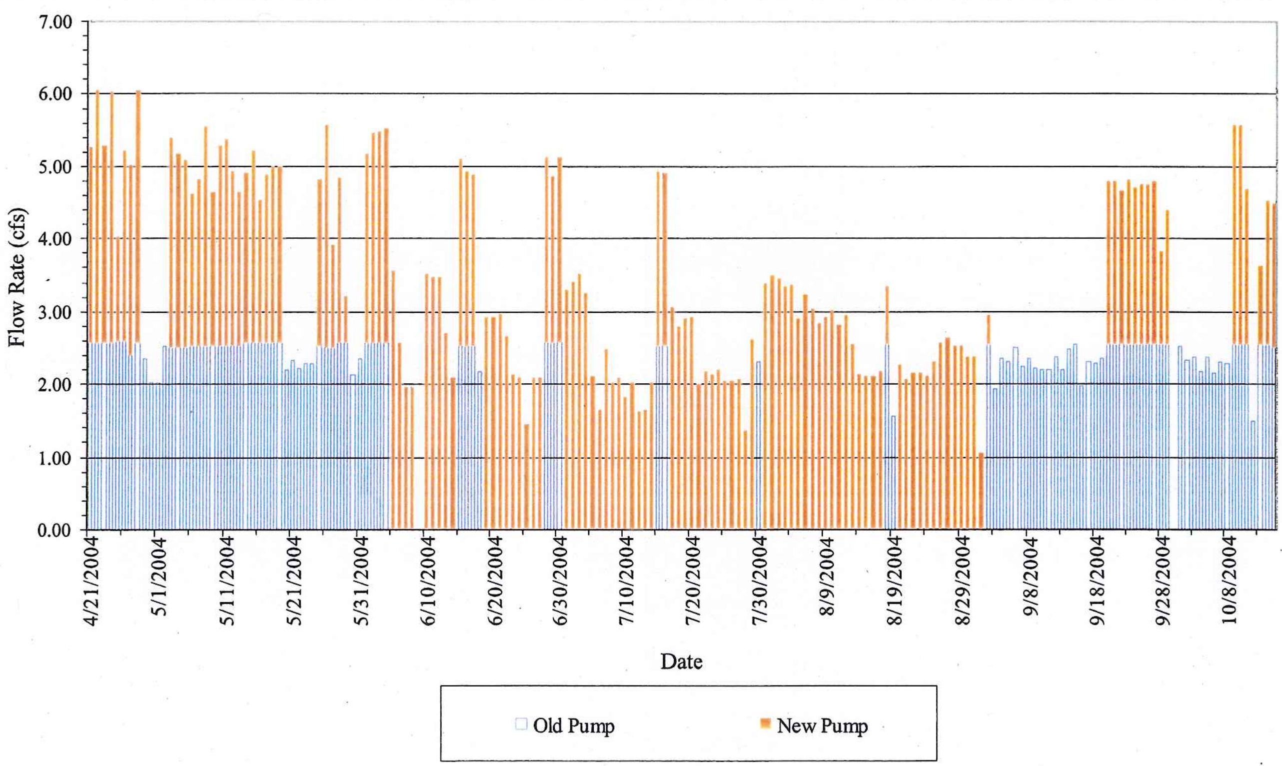

FIGURE 80. El Sur Ranch daily irrigation well operations during the spring, summer, and early fall 2004 (source: Natural Resources Consulting Engineers 2005).

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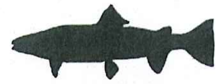
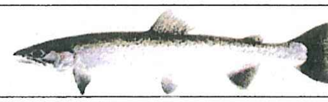
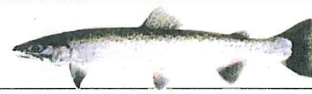
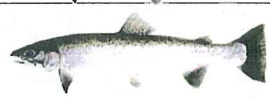
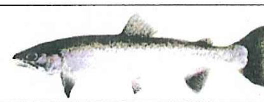
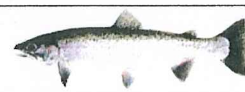
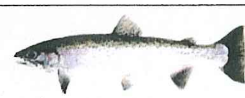
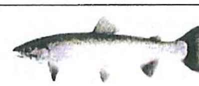
River System	Period	Growth Rate (mm/day) 
Lower Big Sur	*July-October*	
Navarro	*September-October*	
Navarro estuary	*July-September*	
Matole	*September-October*	
Artificial channel	*July-September*	
Navarro	*June-November*	
Matole	*July-October*	
Eel experiment	*June-August*	
Navarro	*July-August*	
Navarro tributaries	*July-September*	
Matole	*August-September*	

FIGURE 81. Side-by-side comparison of juvenile steelhead growth rates in coastal streams.

TABLE 1. Summary of the 2004 Big Sur River fishery habitat and water quality surveys.

Survey Date	Water Velocity and Streamflow	Habitat Conditions and Connectivity	Periodic Water Quality Measurements	Continuous Water Temperature Hourly measurements	Steelhead Snorkel Surveys
April 18		X	X	Continuous - hourly	
July 12		X	X	Continuous - hourly	
July 23	X	X	X	Continuous – hourly	
July 27				Continuous – hourly	X
August 5	X			Continuous - hourly	
August 6	X	X	X	Continuous – hourly	
August 19	X	X	X	Continuous - hourly	
August 30	X			Continuous - hourly	
August 31	X			Continuous - hourly	
September 1	X			Continuous - hourly	
September 2	X	X	X	Continuous - hourly	
September 15	X	X	X	Continuous – hourly	
September 16	X			Continuous - hourly	
September 30	X	X	X	Continuous - hourly	
October 1	X			Continuous – hourly	
October 14	X			Continuous - hourly	
October 15	X	X	X	Continuous – hourly	
October 16				Continuous – hourly	X
October 28	X	X	X	Continuous - hourly	

TABLE 2. Summary of water quality monitoring locations.

Transect ID	Location Description
WQ-1	Surf Zone
WQ-2	Lagoon Discharge - Velocity Transect VT-3
WQ-3	Lagoon Pool
WQ-4	Start of lagoon pool
WQ-5-7	Wide channel reach
WQ-8	Possible ground water upwelling
WQ-9	Low velocity pool
WQ-10	Velocity Transect VT-2
WQ-11	Deep water pool
WQ-12-17	Uniform shallower channel
WQ-18	Velocity Transect VT-1
WQ-19-20	Deeper water uniform channel
WQ-21	Parking Area Bridge

TABLE 3. Summary of water quality surveys conducted as part of the 2004 fishery habitat investigation.

Date	Water Temperature	Electrical Conductivity	Dissolved Oxygen
4/18/2004	X	X	
7/12/2004	X	X	X
7/23/2004	X	X	X
8/6/2004	X	X	X
8/19/2004	X	X	X
9/2/2004	X	X	X
9/15/2004	X	X	X
9/30/2004	X	X	X
10/14/2004	X	X	X
10/28/2004	X	X	X

TABLE 4. Snorkel survey reaches within the Big Sur River and lagoon.

Reach	Lower boundary(lat/long)		Upper boundary(lat/long)		Bottom (RM)	Top (RM)	Length (feet)
1	36 16.857	121 51.600	36 16.942	121 51.391	0.0	0.11	553
Comments: Reach SS-1, the lagoon, was characterized by deeper slow moving water and fine substrate (silt/clay/detritus). Thermal stratification was observed in the deeper areas and filamentous algae were abundant. Brushy instream cover was most abundant in this reach.							
2	36 16.942	121 51.391	36 17.017	121 51.300	0.11	0.24	738
Comments: Reach SS-2 was a glide/run complex with lateral scour and instream cover (brush) in many areas. Filamentous green algae were abundant in the margins and in the low velocity sections.							
3	36 17.017	121 51.300	36 17.105	121 51.237	0.24	0.43	1024
Comments: Reach SS-3 was a four tiered riffle glide series and contained the first potential spawning habitat. Particle size distribution looked good but there were substantial fines in the gravel. The reach was less than 2 feet deep for the most part with little cover.							
4	36 17.105	121 51.237	36 17.119	121 51.134	0.43	0.47	197
Comments: Reach SS-4 is a slow, mid stream pool with brush and LWD across the entire channel. Substrate consists of silt, sand, and detritus. Rearing habitat is abundant.							
5	36 17.119	121 51.134	36 17.183	121 50.990	0.47	0.65	950
Comments: Reach SS-5 is a three-tiered run/riffle series with small to medium substrate and no instream cover (brush). Velocity refugia were also lacking. Filamentous green algae are no longer abundant.							
6	36 17.183	121 50.990	36 17.256	121 50.778	0.65	0.87	1146
Comments: Reach SS-6 is a three-tiered glide riffle series with small to medium substrate. The river has widened in this reach and is less than 1 foot deep. There was little rearing habitat.							
7	36 17.256	121 50.778	36 17.273	121 50.695	0.87	0.93	312
Comments: Reach SS-7 was a medium gradient riffle with medium to large substrate. Depths greater than 3 feet were present in two lateral scour pools but there was no cover.							
8	36 17.273	121 50.695	36 17.235	121 50.660	0.93	1.04	306
Comments: Reach SS-8 was a glide/high-gradient riffle complex with predominately large substrate. Depth was greater than 3 feet below the high-gradient riffle but very little instream cover (brush) was present.							

TABLE 5. Summary of flow and channel measurements made at the upstream reference transect VT-1.

Date	Day			Night		
	Wetted Width (ft)	Mean Depth (ft)	Discharge (cfs)	Wetted Width (ft)	Mean Depth (ft)	Discharge (cfs)
7/23/2004	35.35	0.96	10.1			
8/5/2004	34.80	0.94	8.9			
8/6/2004				35.20	0.94	8.7
8/19/2004	34.65	0.87	7.2	34.85	0.92	7.9
8/30/2004	34.80	0.89	8.2			
8/31/2004	34.50	0.85	8.3	34.90	0.91	8.2
8/31/2004	34.50	0.87	8.8			
9/1/2004	34.30	0.86	10.2	34.70	0.90	8.4
9/1/2004	34.30	0.86	9.9			
9/2/2004	34.40	0.86	10.9	34.90	0.90	7.2
9/15/2004	34.50	0.86	6.3			
9/16/2004				34.40	0.89	7.2
9/30/2004	34.4	0.91	8.1			
10/1/2004				34.90	0.92	9.0
10/14/2004	34.40	0.89	9.8			
10/15/2004				34.40	0.91	11.7
10/28/2004	38.2	1.38	44.0	37.8	1.36	40.7

TABLE 6. Summary of flow and channel measurements made at the Creamery Meadow transect VT-2.

Date	Day			Night		
	Wetted Width (ft)	Mean Depth (ft)	Discharge (cfs)	Wetted Width (ft)	Mean Depth (ft)	Discharge (cfs)
7/23/2004	28.50	1.84	9.5			
8/5/2004	28.35	1.78	7.2			
8/6/2004				28.70	1.86	8.1
8/19/2004	28.15	1.75	7.0	28.45	1.79	5.8
8/30/2004	28.40	1.78	9.4			
8/31/2004	28.40	1.77	10.4	28.65	1.80	8.6
8/31/2004	29.00	1.73	8.9			
9/1/2004	28.45	1.78	14.6	28.65	1.75	8.8
9/1/2004	28.45	1.77	13.8			
9/2/2004	28.45	1.77	10.2	28.60	1.72	7.2
9/3/2004						
9/15/2004	28.50	1.72	6.1			
9/16/2004				28.40	1.77	5.9
9/30/2004	28.60	1.77	7.4			
10/1/2004				28.75	1.77	8.0
10/14/2004	28.6	1.75	12.1			
10/15/2004				28.6	1.77	11.8
10/28/2004	30	2.23	46.7	29.8	2.21	45.6

TABLE 7. Summary of flow and channel measurements made at the Big Sur lagoon outfall transect VT-3.

Date	Day			Night		
	Wetted Width (ft)	Mean Depth (ft)	Discharge (cfs)	Wetted Width (ft)	Mean Depth (ft)	Discharge (cfs)
7/23/2004	20.00	0.74	8.0			
8/5/2004	23.30	0.57	10.1			
8/6/2004				22.75	0.52	9.1
8/19/2004	22.85	0.52	9.9	22.1	0.49	8.7
8/30/2004						
8/31/2004						
9/1/2004						
9/2/2004						
9/3/2004						
9/15/2004						
10/28/2004	26.3	1.69	56.3			

TABLE 8. Summary of the numbers of fish observed within each survey reach of the lower river and lagoon during the October snorkel survey.

		Number observed		
Reach	River Mile	Steelhead	Riffle Sculpin	Threespine Stickleback
1	0.10	299	2	3
2	0.29	0	0	0
3	0.4	2	1	12
4	0.55	23	0	2
5	0.6	12	0	14
6	0.7	9	3	0
7	0.9	2	9	0
8	1	11	4	0

NOTE: See Figure 10 for reach locations.

TABLE 9. Number and density (number per foot) of juvenile steelhead/rainbow trout observed in each reach of the lower river and lagoon surveyed during July and October.

Number of steelhead observed								
Reach	1	2	3	4	5	6	7	8
July 27	272	43	7	77	2	4	1	11
October 16	299	0	2	23	12	9	2	11
Reach Length (ft)	553	738	1024	197	950	1146	312	306
Steelhead density (No./ft)								
July 27	0.492	0.058	0.007	0.391	0.002	0.003	0.003	0.036
October 16	0.541	0.000	0.002	0.117	0.013	0.008	0.006	0.036

NOTE: See Figure 10 for reach locations.

TABLE 10. Summary of length frequency distribution of juvenile steelhead/rainbow trout observed in the lower river and lagoon during the July and October snorkel surveys.

	Number observed	
Length (mm)	July 27	October 16
0-40	3	0
41-60	28	0
61-80	147	3
81-100	154	102
101-150	57	165
151-200	26	76
201-300	2	13
301-400		

TABLE 11. Summary of El Sur Ranch irrigation well operations during and prior to fishery habitat surveys in the Big Sur River.

Average Irrigation Well Deliveries (cfs)				
Survey Date	Survey Day	3 days prior (including survey day)	5 days prior (including survey day)	7 days prior (including survey day)
Jul. 12	1.63	1.8	1.9	2
Jul. 23	2.13	2.1	2.4	2.6
Aug. 5	2.91	3.2	3.3	3.2
Aug. 19	1.56	2.4	2.3	2.3
Sept. 2	2.95	2.1	2.3	2.4
Sept. 15	2.55	2.4	2.4	2.3
Sept. 30	0	2.7	3.6	3.9
Oct. 15	4.5	4.2	3.8	4.3

TABLE 12. Summary of juvenile steelhead growth rates in coastal streams.

River System	**Period**	**Growth Rate (mm/day)**	**Reference**
Lower Big Sur	July—October	0.48	This study
Navarro estuary	July—September	0.53	Bush undated
Navarro tributaries	July—September	0.09	Bush undated
Eel experiment	June—August	0.23(1)	Suttle *et al.* 2004
Artificial channel	July—September	0.34	Kelly 2001
Navarro	June—November	0.33	Cannata 1998
Navarro	September—October	0.61(2)	Cannata 1998
Navarro	July—August	0.13(3)	Cannata 1998
Matole	July—October	0.24	Zedonis 1992
Matole	September—October	0.40(2)	Zedonis 1992
Matole	August—September	-0.02(3)	Zedonis 1992

(1) Growth with no embedded substrate. As substrate embeddedness increased to 100% growth rates decreased to approximately 0.07 mm/day
(2) Peak observed growth rates
(3) Minimum observed seasonal growth rates – coincided with closure of the sand bar and blockage of flow through the estuary

TABLE 13. Summary of juvenile oversummering abundance observations within the lower reaches of the Big Sur River, 2004.

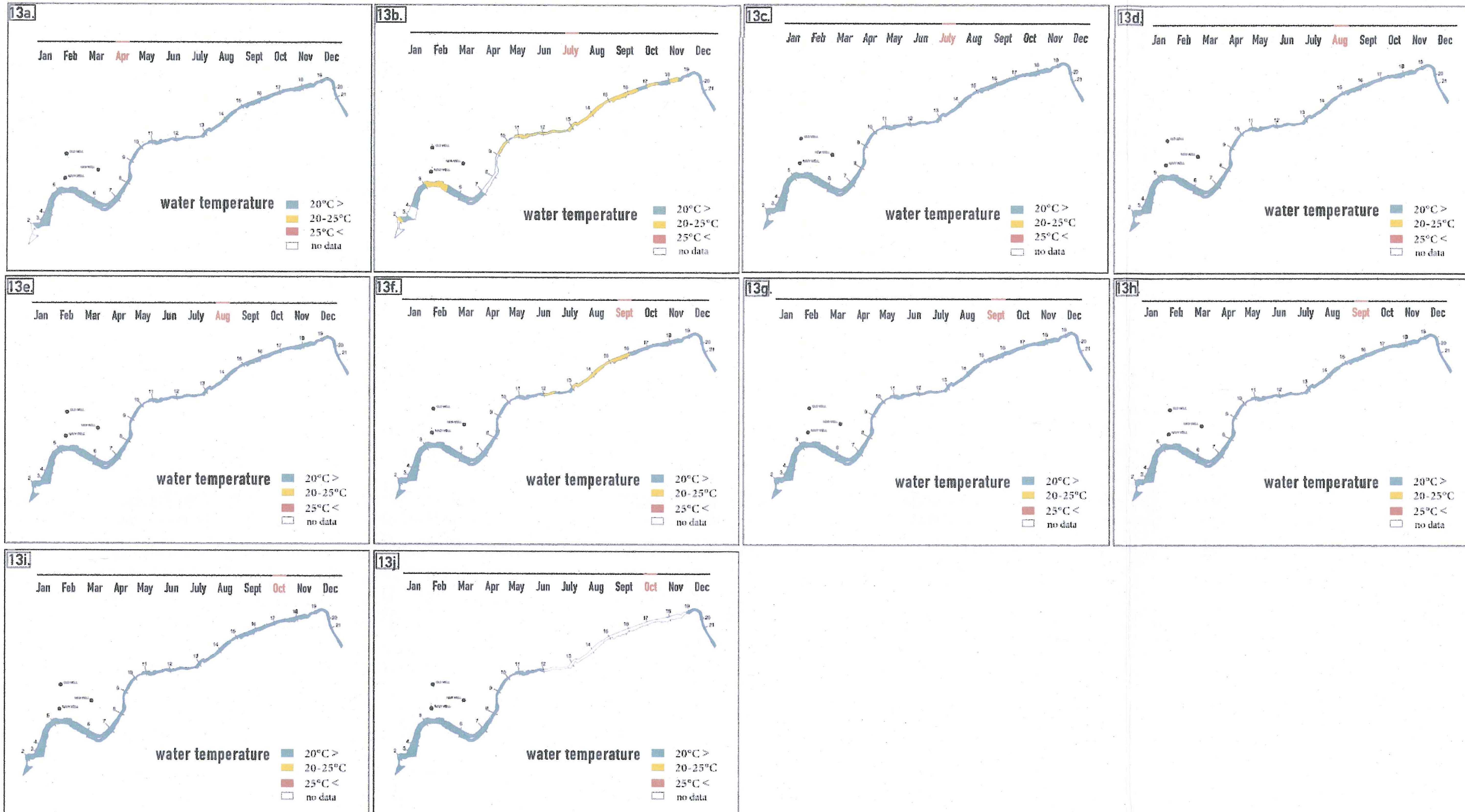
Survey Date	July 27, 2004	October 16, 2004
Number juvenile steelhead observed	417	358
Change in number observed		-59
Percentage change		-14

9.0 APPENDICES

9.1 APPENDIX A

Habitat Suitability Based on Water Temperature

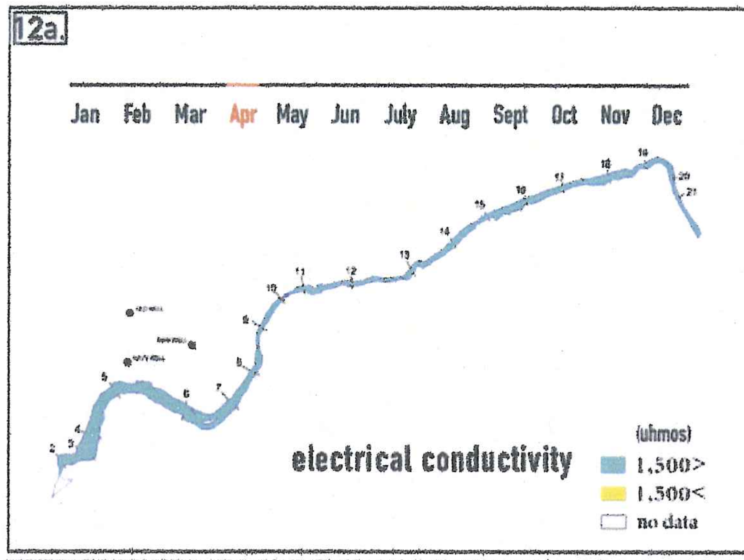
HABITAT SUITABILITY BASED ON WATER TEMPERATURE

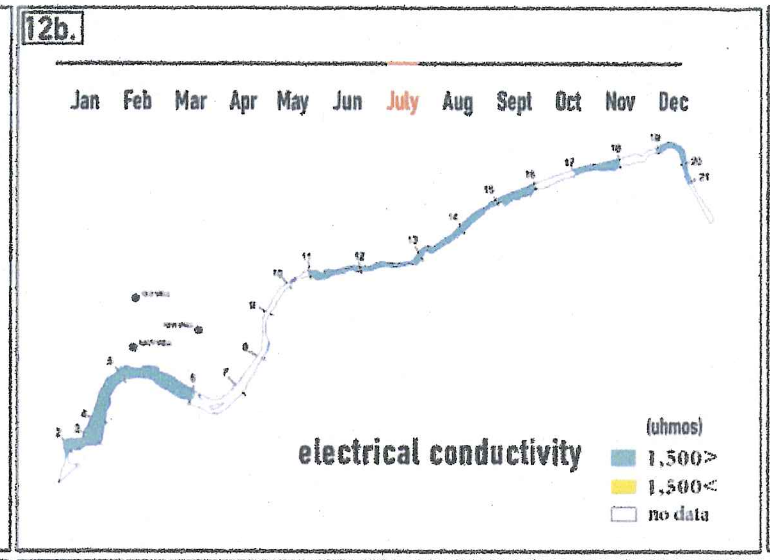


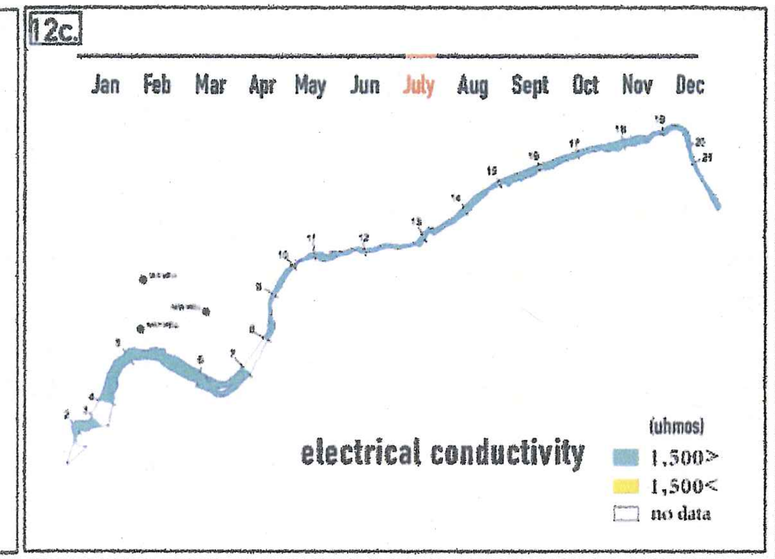
9.2 APPENDIX B

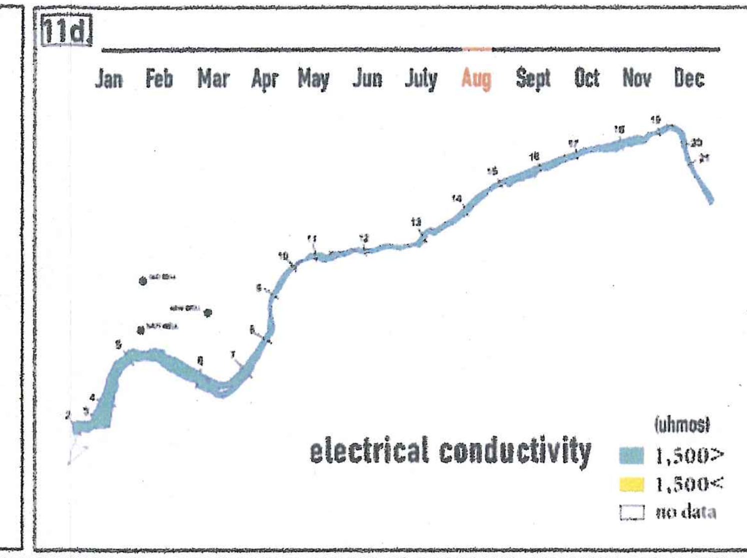
Habitat Suitability Based on Electrical Conductivity

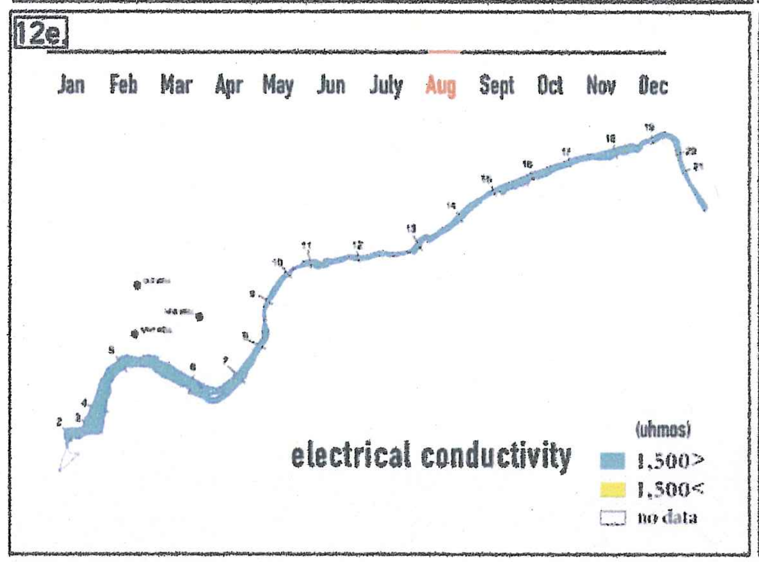
HABITAT SUITABILITY BASED ON ELECTRICAL CONDUCTIVITY

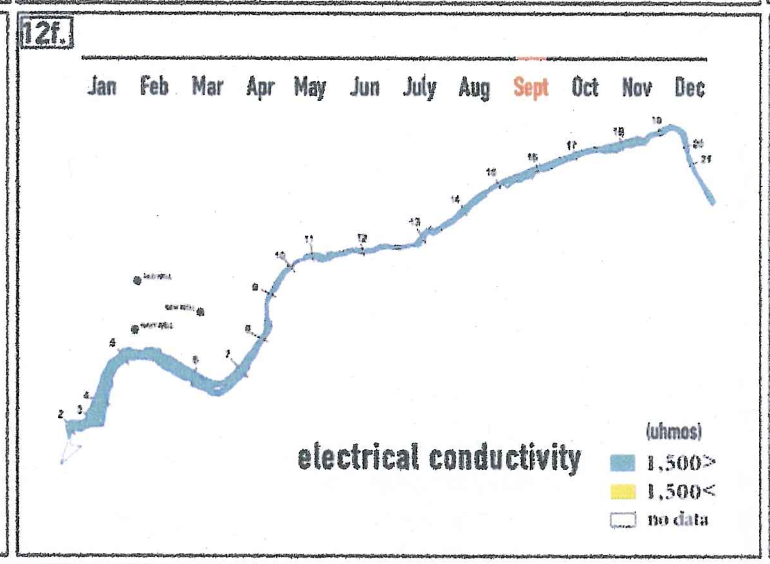


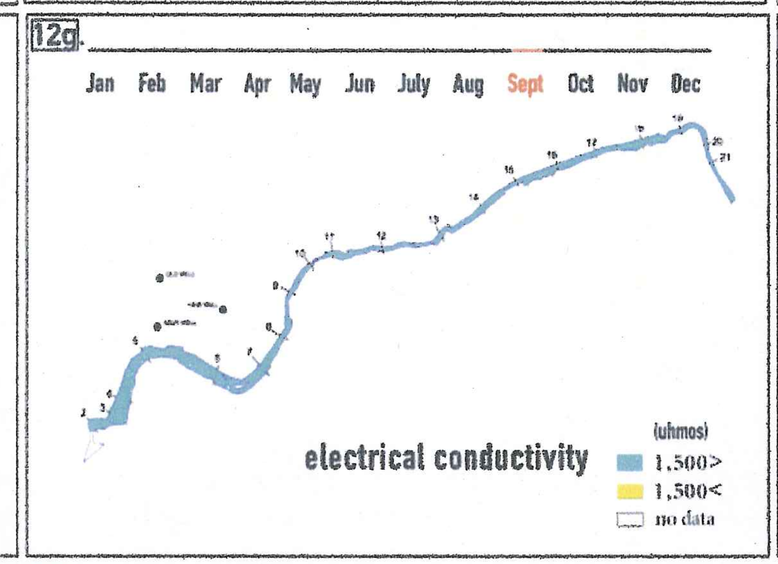


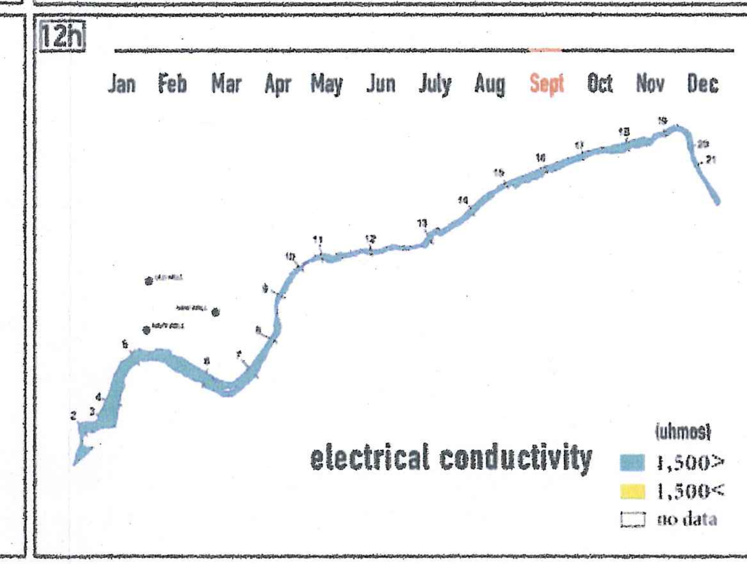


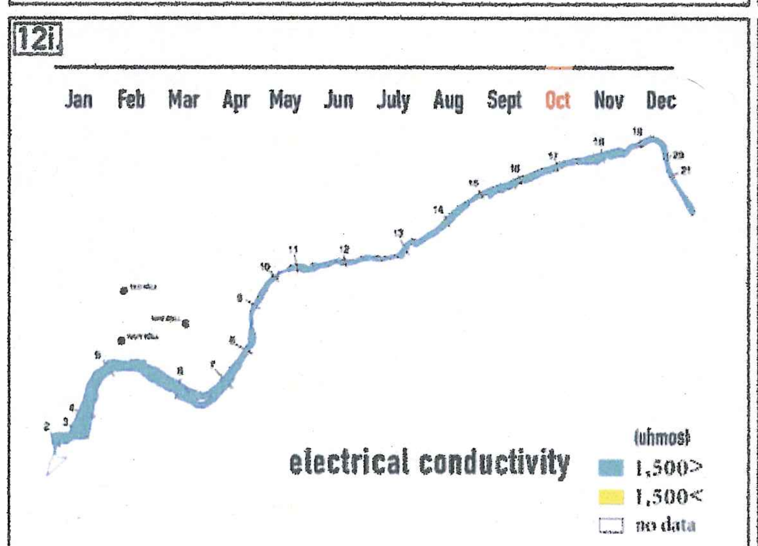


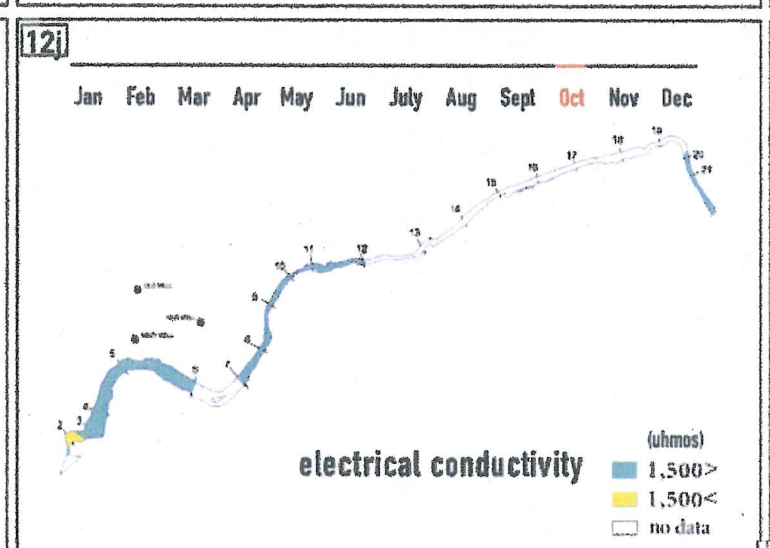


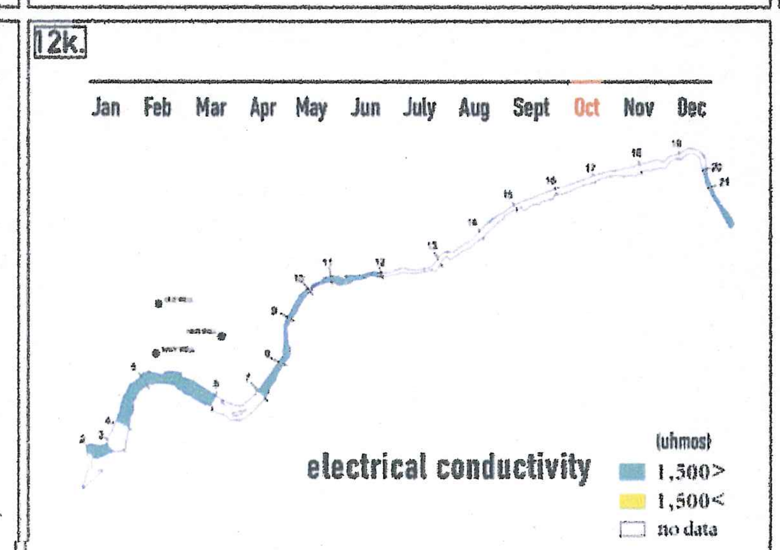








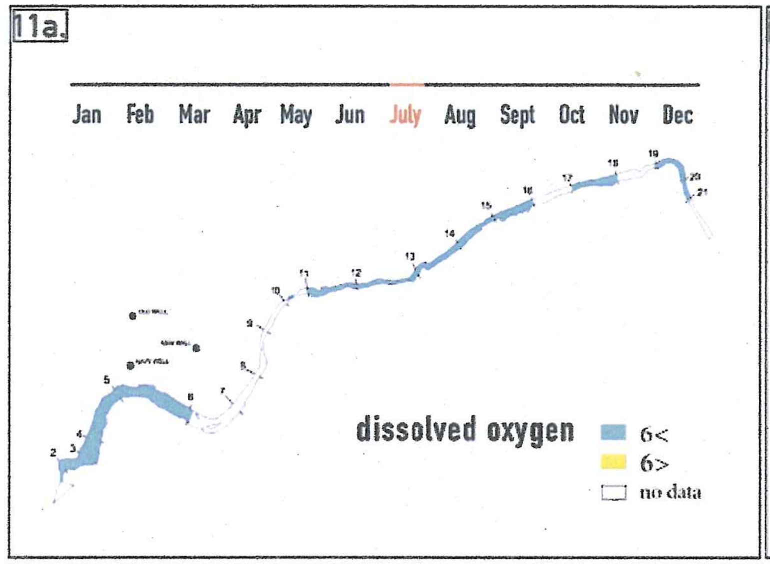


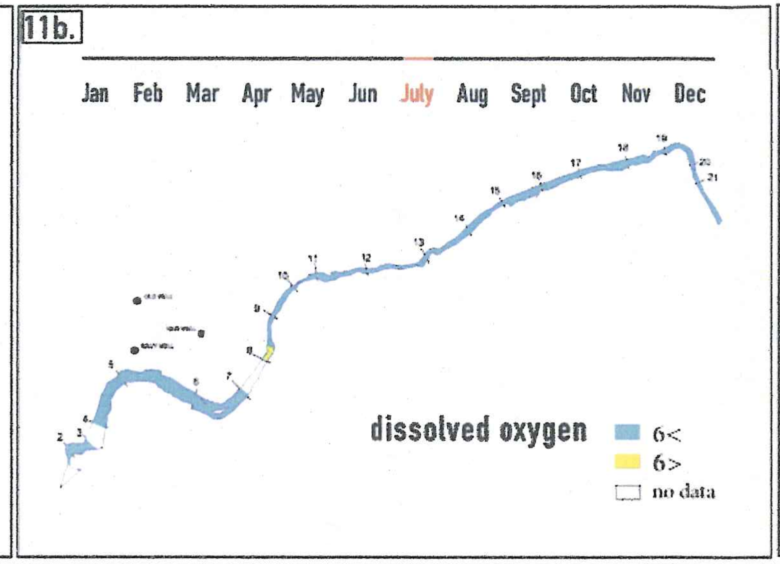


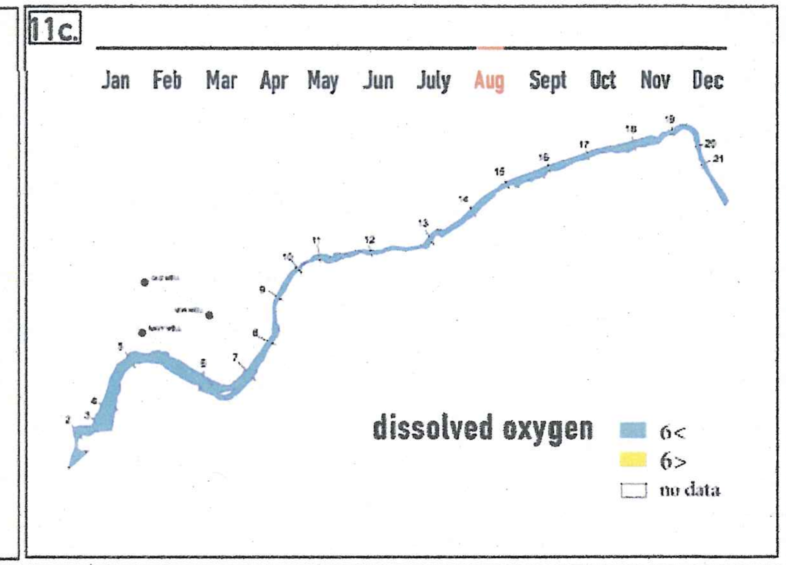
9.3 APPENDIX C

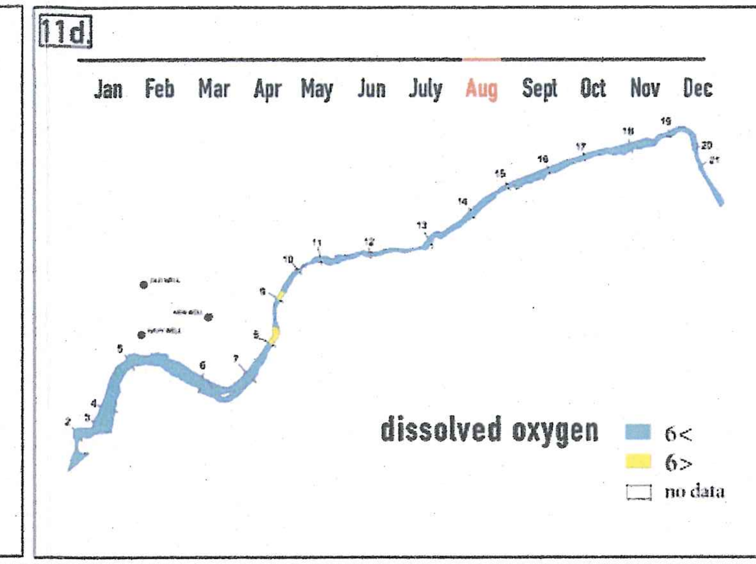
Habitat Suitability Based on River Drainage

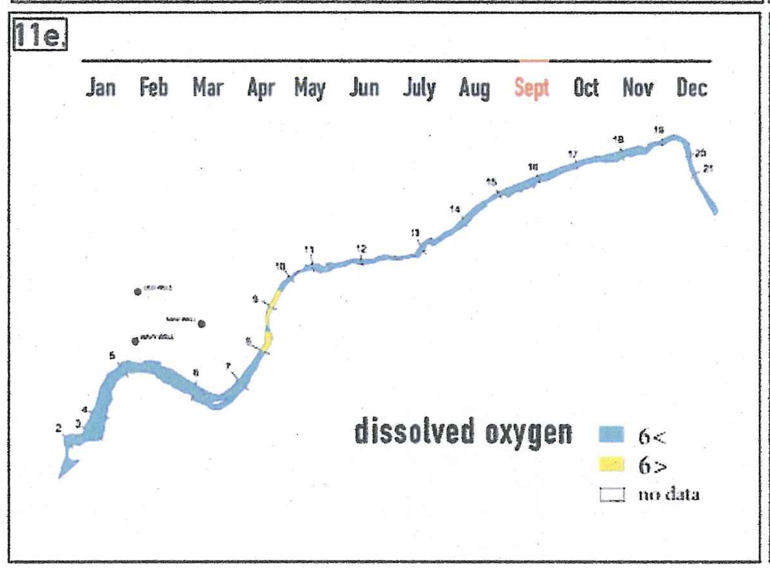
HABITAT SUITABILITY BASED ON RIVER DRAINAGE

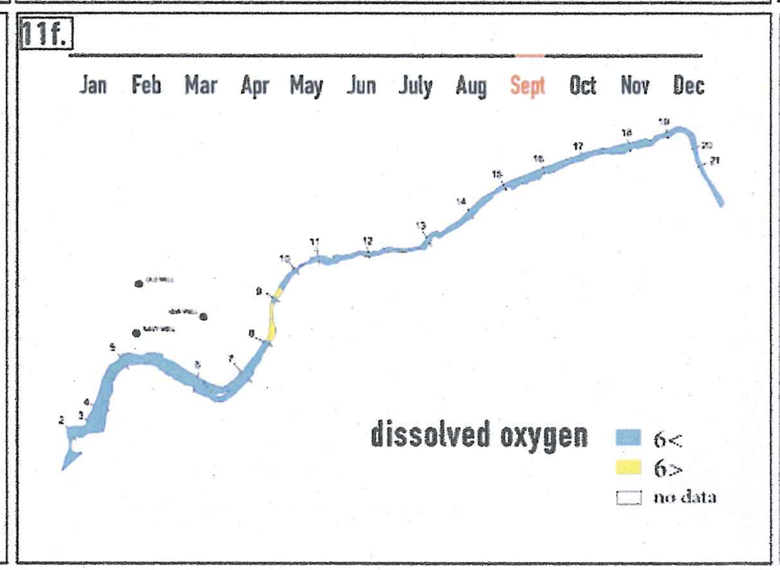


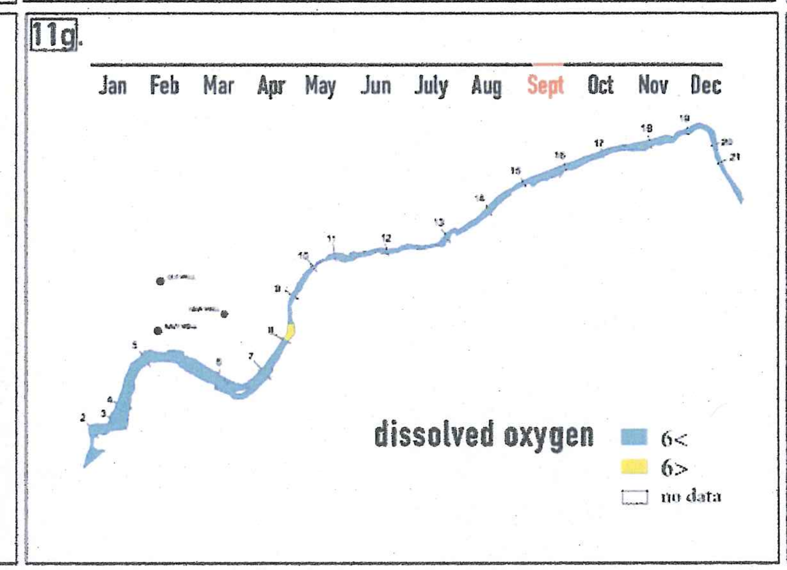


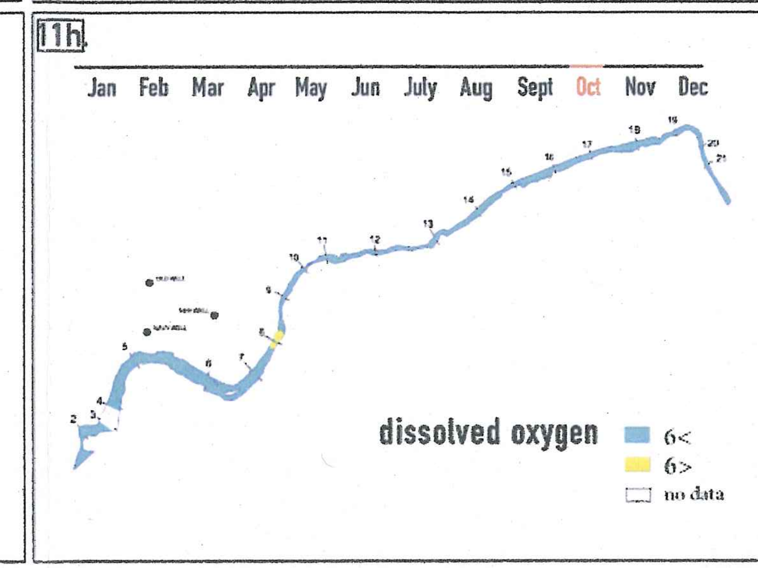


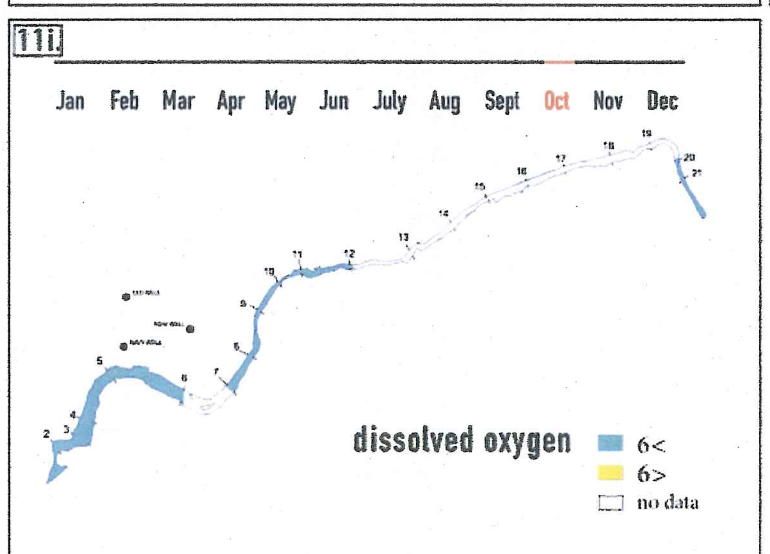






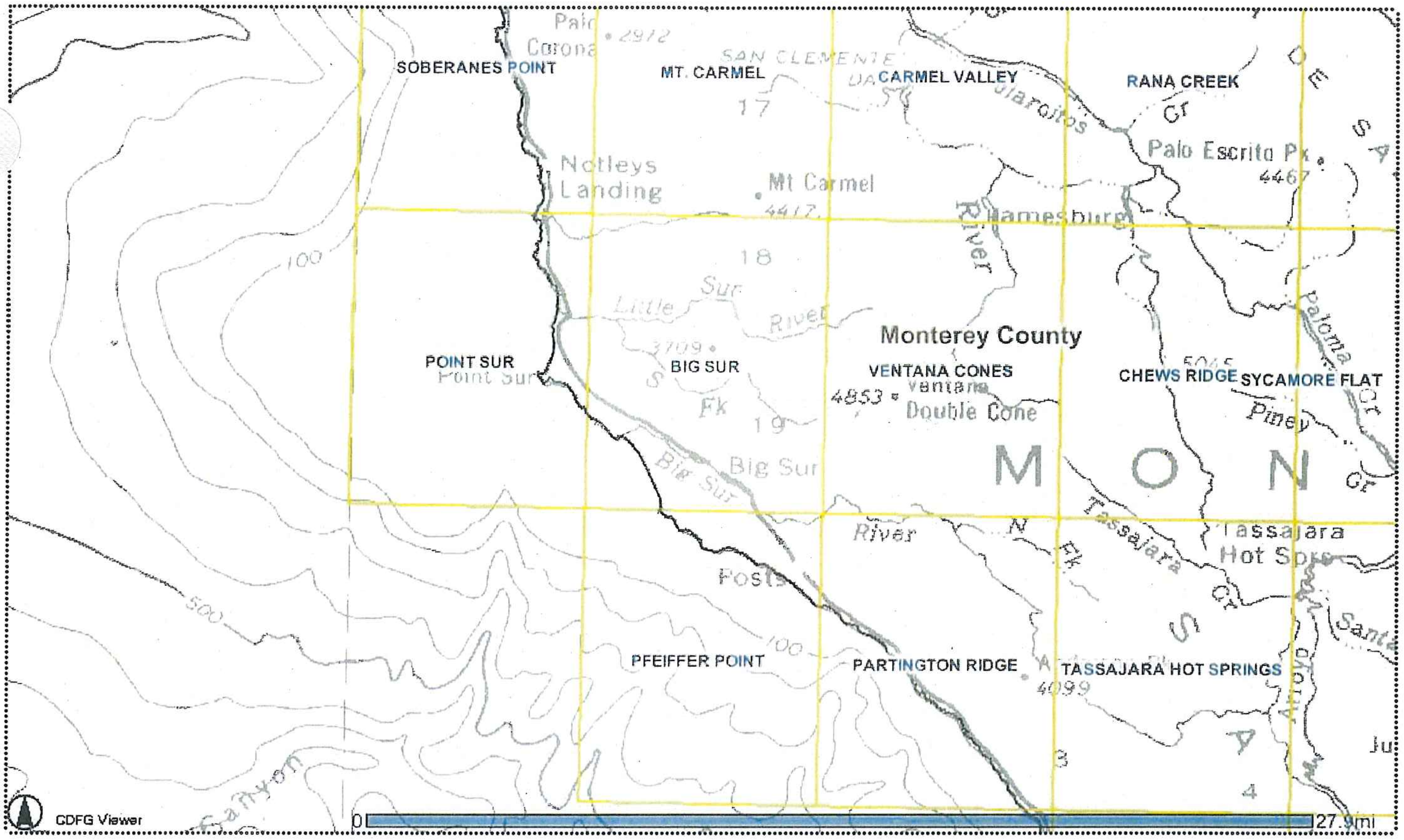






9.4 APPENDIX D

Results of the California National Diversity Database Search for the Big Sur 7.5 Minute Quadrangle



RESULTS FOR BIG SUR QUAD (3612137)

California Natural Diversity Database (CNDDB)

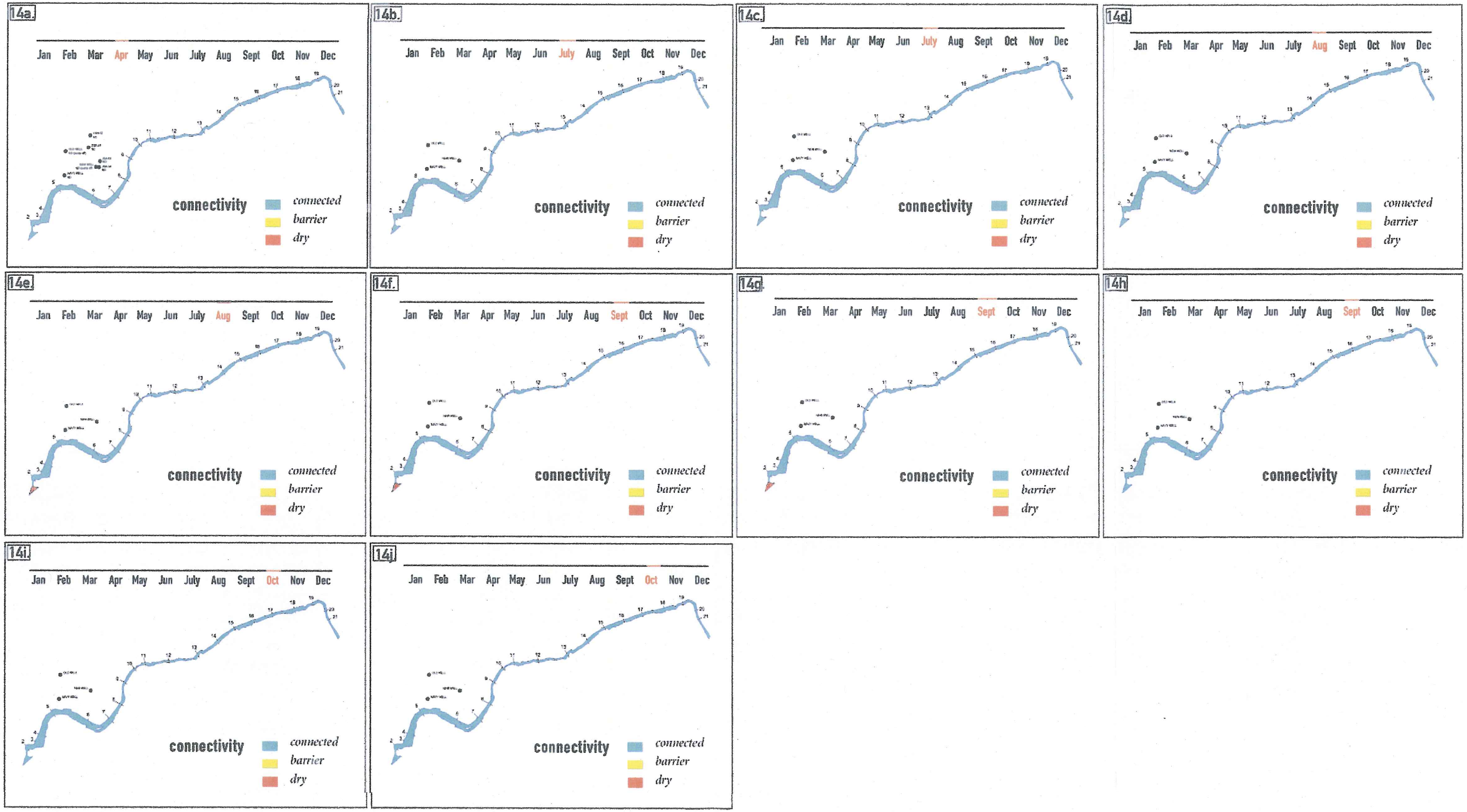
Record	QUADNAME	ELMCODE	SCINAME	COMNAME	FEDSTATUS	CALSTATUS	CDFG	CNPSLIST
1	Big Sur	ABNKD06090	*Falco mexicanus*	prairie falcon	None	None	SC	
2	Big Sur	ABNUA01010	*Cypseloides niger*	black swift	None	None	SC	
3	Big Sur	AFCHA0209H	*Oncorhynchus mykiss irideus*	steelhead - south/central California coast esu	Threatened	None		
4	Big Sur	AMAJF04010	*Taxidea taxus*	American badger	None	None	SC	
5	Big Sur	ARAAD02030	*Emys (=Clemmys) marmorata*	western pond turtle	None	None	SC	
6	Big Sur	CARA2631CA	*North Central Coast Fall-Run Steelhead Stream*	North Central Coast Fall-Run Steelhead Stream	None	None		
7	Big Sur	IILEPG2026	*Euphilotes enoptes smithi*	Smith's blue butterfly	Endangered	None		
8	Big Sur	IILEPP2010	*Danaus plexippus*	monarch butterfly	None	None		
9	Big Sur	ILARA17010	*Meta dolloff*	Dolloff Cave spider	None	None		
10	Big Sur	PDAPI1Z0D0	*Sanicula maritima*	adobe sanicle	None	Rare		1B
11	Big Sur	PDERI04260	*Arctostaphylos edmundsii*	Little Sur manzanita	None	None		1B
12	Big Sur	PDMAL0Q0B2	*Malacothamnus palmeri var. lucianus*	Arroyo Seco bush mallow	None	None		1B
13	Big Sur	PDMAL110E0	*Sidalcea malachroides*	maple-leaved checkerbloom	None	None		1B
14	Big Sur	PDONA050L0	*Clarkia jolonensis*	Jolon clarkia	None	None		1B
15	Big Sur	PDRAN0B0V0	*Delphinium hutchinsoniae*	Hutchinson's larkspur	None	None		1B
16	Big Sur	PDSCR1K0D0	*Pedicularis dudleyi*	Dudley's lousewort	None	Rare		1B
17	Big Sur	PGPIN01030	*Abies bracteata*	bristlecone fir	None	None		1B
18	Big Sur	PMLIL0V0C0	*Fritillaria liliacea*	fragrant fritillary	None	None		1B

(source: California Department of Fish and Game. 2004. http://www.dfg.ca.gov/whdab/html/cnddb.html)

9.5 APPENDIX E

Surface Water Connectivity Within the Lower Big Sur River

SURFACE WATER CONNECTIVITY WITHIN THE LOWER BIG SUR RIVER



10.0 GLOSSARY

abundance: Degree of plentifulness. The total number of fish in a population, stock, other group or on a fishing ground. Can be measured in absolute or relative terms and may be number per area or per unit fishing effort. (see also *relative abundance* and *oversummering abundance*)

adult: A sexually mature animal; a fish that has reached the length or age of first maturity.

anadromous: Fish that migrate from saltwater to fresh water to spawn.

barrier: Stakes, branches, reeds or netting temporarily or permanently fixed to the bottom in tidal waters arranged to trap fish.

biological monitoring: This is the periodic examination of biological specimens for the purposes of monitoring their exposure to or the effects of potentially toxic chemicals to the environment. This is normally done by analyzing the amounts of the toxic substances or their metabolites present in body tissues and fluids. The term is also used to mean assessment of the biological status of populations and communities of organisms at risk, in order to protect them and to gain an early warning of possible hazards to human health.

breaching: the breaking of waves or surf.

catch: The total number or poundage of fish captured from an area over some period of time. This includes fish that are caught but released or discarded instead of being landed. The catch may take place in an area different from where the fish are landed.

CDFG: California Department of Fish and Game.

CFS: Cubic feet per second; a measure of water velocity.

conductivity: The amount of electricity the water can conduct.

cover: Natural items such as weeds, logs, overhanging banks, boulders, roots, etc. providing shelter for fishes.

discharge: Flow of surface water in a stream or canal or the outflow of ground water from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.

dissolved oxygen (DO): The oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors. DO levels are considered a most important indicator of a water body's ability to support desirable aquatic life. Secondary and advanced waste treatment are generally designed to ensure adequate DO in waste-receiving waters.

disturbance: Any event or series of events that disrupt ecosystem, community, or population structure and alters the physical environment.

diversion: (1) Use of part ofia stream flow as water supply. (2) A channel with a supporting ridge on the lower side constructed across a slope to divert water at a non-erosive velocity to sites where it can be used and disposed of.

diversion rate: The percentage of waste materials diverted from traditional disposal such as landfilling or incineration to be recycled, composted, or re-used.

electrical conductivity: Ability ofiwater to conduct an electrical current, expressed as the electrical current per unit area divided by the voltage drop per unit length.

endangered animal species: A species of animal identified by official federal and/or state agencies as being faced with the danger of extinction.

environment: The sum of all external conditions and influences affecting the development and life of organisms.

Environmental Protection Agency (EPA): The U.S. agency responsible for efforts to control air and water pollution, radiation and pesticide hazards, ecological research, and solid waste disposal.

ESA: Endangered Species Act. Environmentally Sensitive Area.

ESU: Evolutionarily significant unit.

evapotranspiration: The loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil.

fishery: All the activities involved in catching a species of fish or a group of species.

flow: (1) A stream of water or other fluid; a current (2) The tidal setting in of the water from the ocean to the shore.

fry: (1) A young fish at the post-larval stage. May include all fish stages from hatching to fingerling. An advanced fry is any young fish from the start of exogenous feeding after the yolk is absorbed while a sac fry is from hatching to yolk sac absorption. In Salmonidae the stage from end of dependence on the yolk sac as the primary source of nutrition to dispersal from the redd.

GPS: Global positioning system/satellite.

ground water: Subsurface water occupying the saturated zone.

habitat: The place where a population (e.g. human, animal, plant, microorganism) lives and its surroundings, both living and non-living.

hydrology: Science that deals with the waters above and below the land surfaces of the Earth, their occurrence, circulation and distribution, both in time and space, their biological, chemical and physical properties, their reaction with their environment, including their relation to living beings.

juvenile: A young or sexually immature animal; relating to such a young animal.

lagoon: (1) A shallow pond where sunlight, bacterial action, and oxygen work to purify wastewater; also used for storage of wastewater or spent nuclear fuel rods. (2) Shallow body of water, often separated from the sea by coral reefs or sandbars.

length frequency: A breakdown of the different lengths of a kind of fish in a population or sample.

migration: A directed journey and return occurring regularly in a species, usually at a definite stage in the life cycle, e.g. anadromous, catadromous, diadromous, amphidromous, potamodromous, oceanodromous.

mortality: The death rate. The ratio of the total number of deaths to the total population.

outfall: The mouth or outlet of a river, stream, lake, drain or sewer.

oversummering abundance: Number of summer-run fish.

reach: An extended portion of land or water; a stretch; a straight portion of a stream or river, as from one turn to another; a level stretch, as between locks in a canal; an arm of the sea extending up into the land.

rearing: The amount of time that juvenile fish spend feeding in nursery areas of rivers, lakes, streams and estuaries before migration, or the care and support for young fish.

rearing habitat: Areas where larval and juvenile fish find food and shelter.

redd: Nest made in gravel, consisting of a depression dug by a fish for egg deposition (and then filled) and associated gravel mounds.

relative abundance: An index offfish population abundance used to compare fish populations from year to year. This does not measure the actual numbers of fish, but shows changes in the population over time.

riparian vegetation: Vegetation which occurs along watercourses, and is structurally or floristically distinct from nearby, non-streamside vegetation. Riparian vegetation is terrestrial vegetation that grows beside rivers, streams, and other fresh-water bodies and that depends on these water sources for soil moisture greater than would otherwise be available from local precipitation.

risk: A measure of the probability that damage to life, health, property, and/or the environment will occur as a result of a given hazard.

salinity: The percentage of salt in water.

salt marsh: An area where salt water from an ocean, bay, or gulf meets fresh water from a river.

sampling frequency: The interval between the collection of successive samples.

sedimentation: Deposition of material suspended in a stream system, whether in suspension (suspended load) or on the bottom (bed load).

sensitive species: Plant or animal species which are endangered species, or candidate species, protected bird species under endangered species laws and regulations, plant protection laws and regulations, Fish and Game codes, or species of special concern listings and policies, or species recognized by national, state, or local environmental organizations.

spawning: Laying (and fertilizing) eggs in the process of reproduction.

streamflow: General term for water flowing in a stream or river channel.

substrate: Bottom or bottom materials:- large boulders (>1024 mm), small boulders (256-1024 mm), stone (256-600 mm), rubble or large cobble (128-256 mm), cobble or small cobble (64-128 mm), pebble (2-64 mm), coarse gravel (32-64 mm), fine gravel (2-32 mm), sand (0.062-2.0 mm), silt (0.004-0.062) and clay (<0.004).

summer-run: Anadromous fish that migrate to fresh water in summer, overwinter there and spawn in spring.

surf: Wave activity between the shore line and the outermost limit of breakers; a habitat for certain fishes.

surface water: All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.)

survival rate: Number of fish alive after a specified time interval, divided by the initial number. Usually on a yearly basis.

transect: A line on the ground along which sample plots or points are established for collecting vegetation data and in many cases, soil and hydrology data as well.

trap: Fish trap (a spring-loaded trap made of netting on a frame that closes over a fish. The two rectangular halves of the trap are spread apart from the central spring mechanism. The fish is attracted by bait or a dummy fish that the fish sought tries to fight, e.g. a wooden male salmon painted in spawning colors).

USFWS: United States Fish and Wildlife Service.

velocity: The time rate of motion; the distance traveled divided by the time required to travel that distance.

velocity transect: A line on the ground along which sample plots or points are established for collecting vegetation data and in many cases, soil and hydrology data as well.

water monitoring: The process of constant control of a body of water by means of sampling and analyses.

water quality: The condition of water with respect to the amount of impurities in it.

well monitoring: Measurement by on-site instruments or laboratory methods of well water quality.