Smith, J.J. 1984. Liddell Creek Baseline and Watershed Study: Fisheries Section. Prepared for Lonestar Industries by Creegan & D'Angelo, Consulting Engineers and Harvey and Stanley Associates.

I. SUMMARY

The following report presents a baseline of information concerning San Vicente - Mill Creek Watersheds and the Liddell Creek Watershed. These watersheds drain a total of 13.15 square miles of the western slope of the Santa Cruz Mountains. This report is based on and summarized approximately one year of flow and quality analysis as well as an inventory and assessment of fishery and vegetative patterns within the yea. The data was collected predominantly during the year extending form October 1981 through September 1982. Some data was collected from the fall of 1980 through the spring of 1983 to provide a more complete picture of the watershed and its changing facets.

Flow measurements were recorded at 13 different locations within the watershed. These records provide a composite and detailed picture of the behavior of the various hydrographic sub-units of the watershed.

The strong influence of ground water recharge and discharge was observed throughout both the watersheds. Its impact was most notable in the Liddell Creek drainage resulting in an estimated 10 percent greater annual yield.

The water quality data collected for these watersheds indicate that overall water quality within these watersheds is of similar quality to other streams draining the Santa Cruz Mountains. The presence of quarry operations is detectable within the watershed but is strictly local in nature and does not detract from the overall water quality or restrict the established beneficial uses of the surface streams.

The stream beds of San Vicente, Mill and Liddell Creeks were carefully reviewed for migration, spawning, rearing and overwintering habitats for steelhead and silver salmon. Steelhead were found in Liddell Creek, while steelhead, silver salmon, three-spine stickleback, prickly sculpin and coastrange sculpin were found in San Vicente and Mill Creeks. The major limitations that were identified on the creeks was the relatively poor pool development. The reason for the condition can not be identified but may be related to the very high flows that occurred during the 1982 and 1983 winter season.

An extensive inventory of riparian vegetation was conducted along the banks of the creeks within the study. The initial inventory was conducted in 1981 and comments are included as to changes to the vegetation associated with the extreme flows of the 1982 and 1983 winters.

VI. FISH RESOURCES

Background: Steelhead and Salmon Ecology

Steelhead and silver salmon populations in the small coastal streams of central California are affected by problems in 1) migration, 2) spawning, 3) summer rearing habitat for young-of-the-year and yearling fish, and 4) overwintering habitat. The overall importance of the individual factors varies from stream to stream and year to year, but in most small streams, summer rearing habitat for yearling fish appears to determine steelhead production. Summer rearing habitat is also the factor most likely to be impacted by stream diversions.

Migration. Adult steelhead in small coastal streams of central California tend to migrate upstream after several prolonged storms; the migration seldom begins earlier than December and may extend through April. Many of the earliest migrants tend to be smaller than those migrating later in the season. Salmon tend to migrate earlier, often entering the stream in October, if flows are adequate. Adult fish may be blocked in their upstream migration by barriers, such as log jams, bedrock falls, and shallow riffles. Man-made objects, such as culverts, bridge abutments, and dams are often significant barriers. Some barriers may completely block upstream migration, but many barriers in coastal streams are passable at certain (usually higher) stream flows. If the barrier is not absolute, some adult steelhead are usually able to pass in most years, since they can time their upstream movements to match peak flow conditions. Silver salmon, however, often have severe migration problems, because their migration period is usually prior to the peak flows needed to pass shallow riffles and partial logjam barriers. Access is also a greater problem for salmon, because they die at maturity and cannot wait in the ocean an extra year if access is poor.

Smolts (young steelhead and salmon which have physiologically transformed in preparation for ocean life) in local coastal streams tend to migrate downstream in March through June. In streams with a lagoon, they may spend several months in the lagoon. In some small coastal streams downstream migration can occassionally be blocked or restricted by low flows (due to heavy streambed percolation or early stream diversions), flashboard dams, or closure of the stream mouth or lagoon by sand bars. For most local streams, downstream migration does not appear to be a major problem.

Spawning. Both salmon and steelhead require spawning sites with gravels (from 1/4" to 3" diameter) having a minimum of fine material (sand and silt) mixed in them and with good flows of clean water moving over and through them. Increases in fine materials, or cementing of the gravels with fine materials, restrict water and oxygen flow through the redd (nest) to the fertilized eggs and reduce hatching success. In many local streams steelhead appear to be successfully utilizing substrates for spawning with percentages of coarse sand which should be reducing hatching success. Unless hatching success has been severely reduced, however, spawning success is still sufficient to saturate the limited available rearing habitat in most small coastal streams.

Rearing Habitat. Except in streams with high summer flow volumes (greater than .2 to .4 CFS per foot of stream width), steelhead require two summers of residence before reaching smolt size. Silver salmon, however, smolt after one year, despite their small size. The slow growth and two year residence time of most local steelhead means that the year class can be adversely affected by low flows or other problems during either of the two years of residence.

Young-of-the-year salmon and steelhead appear to be regulated by available insect food, although cover (hiding areas, provided by undercut banks, large rocks which are not buried or "embedded" in finer substrate, etc.) and pool and riffle depth are also important, especially for larger fish. Where they occur together, young steelhead are most abundant in riffles, while silver salmon are in pools.

Density of yearling steelhead is usually regulated by depth and cover. In most small coastal streams, availability of this "yearling maintenance habitat" provided by depth and cover appears to determine smolt production.

Yearling steelhead growth usually shows a large increment in March through June, but summer growth is very small (or even negative in terms of weight) as flow reductions eliminate fast-water feeding areas and reduce insect production. The "yearling growth habitat" provided by high flows in spring (or in summer for streams with high flows) is very important, since ocean survival and rate of return as adults increases exponentially with the size of the smolts that the stream produces.

Overwintering Habitat. Deeper pools, undercut banks, side channels, and especially large, unembedded rocks provide shelter for fish against the high flows of winter. In some years, such as in 1982, extreme floods may make overwintering habitat the critical factor in steelhead production. In most years, however, the pools and cover which provided the summer rearing habitat for yearling fish are sufficent to protect them against winter flows.

Methodology

Migration Conditions. Liddell Creek, San Vicente Creek (up tp the tunnel) and Mill Creek (up to the diversion dam) were surveyed for barriers in September of 1981, June of 1982, and June of 1983 by Don Alley and Jerry Smith. Barriers were evaluated by determining presence and/or abundance of young-of-the-year steelhead above the barrier and by estimating conditions which would provide passage for adult steelhead.

Spawning Conditions. Eight sites on San Vicente Creek and five sites on Liddell Creek (see figures 8 and 9 for locations of spawning and rearing investigation sites) were evaluated for suitability of spawning substrates in 1981 by examining abundance of steelhead spawning substrate, its particle size percentages, and its degree of compaction. Sites on each stream were also rechecked in 1982 and 1983. Presence and abundance of young-of-the-year fish was also considered in evaluating whether spawning conditions were limiting; young-of-the-year populations were sampled with an electroshocker in 1981 and were visually evaluated in spring of 1982 and 1983.

No spawning redds (steelhead spawning sites, with eggs buried in gravel depressions) were located in any of the years. Bed movement, especially of smaller particles, apparently occurs with late spring storms and obscures redds. No ideal spawning substrate was located at any of the sites, and it appears that high redd sand content and redd destruction from scouring are common. In some years (1983) late spring storms may either destroy redds or cause severe mortality among recently emerged fry and be a major factor in spawning success.

Fish Censusing and Rearing Habitat Conditions. Fish populations at 9 representative sites on San Vicente and Mill creeks and 5 representative sites on Liddell Creek were sampled by backpack electroshocker in 1981. A two-pass "diminishing returns" method was used to estimate density of both young-of-the-year and yearling steelhead. Length versus frequency analysis was used to distinguish yearlings from young-of-the-year; sizes of the two age classes were also similar to sizes found in investigations conducted on other Santa Cruz County streams in 1981.

At each site the following environmental data were also taken: flow volume, pool, run, and riffle width and depth, escape cover (ratio of suitable undercut banks, unembedded rocks, etc., for hiding compared to habitat perimeter), overhead cover, substrate composition and embeddedness, and shade (and % evergreen shade). The same data were taken, along with fish population estimates, for sites on 13 other Santa Cruz County streams during other 1981 investigations. This extensive data base was then used to construct a rearing habitat model based upon the relationship of environmental variables to density of yearling steelhead. Silver salmon were found at only 1 site on San Vicente Creek (and 4 additional sites in Santa Cruz County) so the rearing model is based upon steelhead habitat requirements.

Testing of the model for 1982 stream conditions was not possible because severe flooding in January 1982 severely depressed yearling steelhead populations. Limited testing (during other investigations) in 1983 showed no change in fish response to model variables.

Overwintering Habitat Conditions. Normally, overwintering habitat is not limiting for steelhead, but because of the severity of the January 1982 storms, we checked fish populations in both San Vicente and Liddell creeks in June 1982 by backpack shocker to see if yearling populations were affected by peak winter flows.

Habitat Problems. Potential sources of sediment, future barriers, and other habitat problems were noted during field surveys in each of the three years. In some cases, instream sediments could be traced to general sources because of their composition (granite, marble, etc.).

Relationship of Flow to Rearing Habitat. Pool, run, and riffle habitats evaluated in 1981 were resurveyed in 1982 and 1983 at higher flows. For habitats which had not changed in general streambed configuration, substrate, or cover characteristics, the effect of increased flow upon depth and cover was used to determine the relationship of incremental flow volume changes to rearing potential of portions of the streams for yearling steelhead. This approach was similar to Fish and Wildlife Service IFG methods, except that we used single values for mean depth and escape cover in each habitat segment, rather than transect measurements.

Effects of Diversions Upon Steelhead Populations. The effects of present and potential diversions upon steelhead populations were evaluated for low flow and high flow years based upon flow data for 1981 and for 1982 (in the hydrology sections of this report) and curves developed relating rearing habitat for yearling steelhead to incremental changes in flow.

Fish Habitat Conditions on Liddell Creek

The only fish species encountered in sampling on Liddell Creek (including sampling done during other investigations on the West Fork and at one site downstream of the West Fork) was steelhead (rainbow trout).

Conditions for Migration. Adult steelhead access to portions of the potential spawning and rearing habitat on the East Fork of Liddell Creek may be a problem in some years. In 1981 two partial barriers (B3, B4), and one complete barrier (B6) were present; in 1983 two additional partial barriers (B1, B5) and one potential (severe) barrier (B2) were present (see Figure 7 and Table 14).

In 1981, yearling and young-of-the-year steelhead were present up to the uppermost barrier (B6); the rearing habitat appeared to be saturated. Barrier B6 may be a complete block to upstream migration, but very limited spawning and rearing habitat is present above the barrier. In spring of 1982 and spring of 1983 no steelhead fry were observed above barriers B3 and B4. In many years, adult fish might be blocked from about 1/3 mile of habitat by either of the two barriers; both require high flows and probably multiple jump attempts for passage. Barrier B5, immediately upstream of the two, is a fairly solid log jam in the bend of the stream; it may worsen and become an additional serious obstacle. Barrier B2 is presently an open log jam, which does not block upstream migration. However, the large trees present have the potential to become a severe log jam, which would block or restrict access to an additional 0.6 miles of presently accessible habitat.

Spawning Conditions. In 1981, spawning success was sufficient to saturate the rearing habitat available, despite very limited spawning substrate. In nearly all riffles the gravels present were mixed with more than thirty percent fine and coarse sand (see Appendix C). Most of the gravels were in a thin armouring layer, too shallow for good redd construction. Because of the high percentage of sand, oxygenation of redds and hatching success were probably poor. The worst conditions were found upstream of the Middle Fork, where substrate other than sand was extremely rare, even in riffles.

In 1982, spawning substrate significantly improved. Spawning-sized gravels (mostly 1/2 to 2 inches in diameter), primarily of marble, greatly increased in and downstream of the Middle Fork. Upstream of the Middle Fork there was a lesser increase in gravels of granitic origin. In 1983 there was a slight further increase in granitic gravels, especially in several of the riffles between barriers B5 and B6. From near barrier B5, downstream to the Middle Fork, there was gully erosion in 1983 associated with small-scale 1982 logging (see Figure 7); substrate conditions deteriorated slightly, rather than improving, as in other portions of the stream.

At the present time, spawning gravels downstream of the Middle Fork appear to ensure adequate spawning success in any year with winter flows sufficient to provide adult access. Upstream of the Middle Fork, spawning gravels are rarer and may vary in quality, year to year, depending upon silt inputs from logging and recruitment of granitic gravels from upstream.

Storms during late spring, 1983, apparently scoured redds or flushed young fry in many coastal streams. Few fry were seen in Liddell Creek, despite the improved conditions of spawning gravels.

Summer Rearing Habitat Conditions. In 1981 late summer streamflows were very low in Liddell Creek (near or below 0.1 CFS), and densities of young-of-the-year and yearling steelhead were quite low throughout the stream (see Figure 8). For most years the major restriction on steelhead production from Liddell Creek is summer rearing habitat, especially for yearling fish. Hiding cover is limited; large rocks are rare on the stream bottom, and most that are present are relatively flat (shale) and easily embedded within the generally sandy stream substrate. Many of the undercut banks are exposed if summer streamflows drop to very low levels. Pool development is generally limited throughout the stream. Most pools are shallow, except where bedrock outcrops or logs increase scour; in low flow years, a large portion of the yearlings are probably restricted to the relatively few, deep pools. Water quality and water temperatures are very good.

From near the confluence with the West Fork, upstream to about channel mile 0.65, Liddell Creek has almost no deep pools. The substrate of sand and gravels provides little hiding cover, and there are few undercut banks. At the fish census station upstream of the West Fork, watercress did provide hiding cover, but its availability is strongly seasonal and restricted to portions of the stream with open canopy.

From channel mile 0.65, upstream to the ford, moderately deep pools were fairly common. Most pools were at bends, partial log jams, or where bedrock or boulders provided scour. The importance of deeper pools in providing summer rearing habitat was strikingly evident in fish sampling results from a single large (65 feet long), deep (to 2 feet) pool, formed by the gravel ford constructed at channel mile 0.9 in 1981 (see Figure 8). The "artificial" pool contained more yearling fish than would be expected in a tenth of a mile of typical Liddell Creek habitat.

Upstream of the pool formed by the ford, pools were extremely shallow in 1981. However, several of the pools were deepened considerably by high flows in the winters of 1982 and 1983. Winter scour also increased hiding cover substantially by deeply undercutting tree roots and banks. Although the reach from the ford, upstream to the Middle Fork, provided the poorest rearing habitat in 1981, the rearing capacity of the habitat is now similar to the remainder of the stream.

Upstream from the Middle Fork (channel mile 1.2), the percentage of sand in the substrate increased substantially (see Appendix C). Above channel mile 1.7 sand dominated pools and most riffles, but limestone bedrock was also fairly common, contributing to pool formation. Woody debris and larger logs, which increased pool frequency and depth, greatly increased in 1982 and 1983.

Algae growth is extremely limited in Liddell Creek, because of dense summer shade and lack of larger, stable rocks for periphyton attachment. Low summer flows, lack of algae growth, and sandy substrate were responsible for low aquatic insect populations and poor fish growth rates in 1981. Most yearling fish were less than 4 inches long (total length) in October. The high spring flows of 1982, however, did provide for the usual, early season growth spurt found in coastal stream yearlings; in June 1982 most yearlings were already 4 to 5 inches long.

Overwintering Habitat Conditions. Despite the relatively limited pool development found on Liddell Creek, overwintering habitat does not appear to be a problem. Yearling fish were not flushed from the stream by the severe January 4th, 1982 storm, as did occur on several other coastal streams (including San Vicente Creek). The small watershed is probably responsible for the lack of severe flood peaks.

Habitat Problems. Steelhead habitat is affected by water diversions, barriers, and sedimentation. In June, 1983, some logging sites were gullied despite being reseeded with grass. The road which parallels the stream also suffered some gullying (especially at the mouth of logging roads) (Figure 7). Stream substrate in the logged area (between the Middle Fork and channel mile 1.8) appeared to have been slightly degraded by sedimentation when observed in June, 1983; substrate on the remainder of the stream improved. The road paralleling the stream was eroded by the stream at four locations, and a landslide blocked the road downstream of the Middle Fork. Care must be taken during restoration of the road so that no additional sediment is added to the stream (such as if soil from the slide is bulldozed into the streambed directly adjacent to the road). Restoration of washed out sections of the road should be done so as to prevent future erosion.

Fish Habitat Conditions on San Vicente and Mill Creeks

Besides steelhead and a small population of silver salmon, San Vicente Creek contains threespine stickleback, prickly sculpin, and coastrange sculpin. Sculpins were encountered upstream to channel mile 2.0 (the second bridge), while sticklebacks were present upstream to channel mile 1.0 (the conveyor) in 1981. Populations of the three species were low and probably do not influence steelhead and salmon populations.

Conditions for migration. Exclusive of the San Vicente Tunnel and the Mill Creek diversion dams, three barriers to salmon and steelhead migration are now present on San Vicente and Mill creeks (Table 15).

Barrier B1 is an earthen dam on Coast Dairy & Land property (below the downstream boundary of Lonestar Property), which is used for water diversion.

Because the dam is removed or washed out in winter, it probably does not affect steelhead migration in most years. However, in September 1981, juvenile silver salmon were collected only at our one sampling site downstream of the barrier. It is likely that the earlier migration of adult silver salmon often begins before storms strong enough to wash out the dam. In many years salmon spawning might be restricted to the 0.7 miles of stream below the dam. Early migration access is apparently a severe problem for silver salmon in other Santa Cruz County streams; we collected them only in Fall and Bean creeks among 18 other Santa Cruz County streams sampled in 1981.

An abandoned concrete fish hatchery structure at channel mile 2.45 on San Vicente Creek (B2) probably did not restrict adult steelhead access in 1981 or 1983, but we judged it to have been a significant barrier in 1982. Undercutting of the stream bank and riprap on the west side of the stream caused a slide which blocked passage around the concrete walls. The concrete apron downstream prevented development of a jump pool, necessary to clear the lower wall at low flows. At high flows (50-70 CFS) the barrier was probably passable on the west side; juvenile steelhead (possibly produced by early spawners) were abundant above the barrier in 1982. The channel on the west side was again passable in 1983, but could be blocked in the future. The structure is a complete barrier to sculpins.

In 1982, fine and coarse sediment eroded from a gully in an old quarry overburden site on the north side of Mill Creek (channel mile 0.2), producing a delta which caused undercutting and landsliding of the hillside south of the stream. The 12 to 15 foot high landslide and log jam which resulted, is now a complete barrier to adult steelhead migration (no fry were present in 1983). The presence of some steelhead fry above the barrier in 1982 indicates that the slide occurred after some steelhead successfully spawned.

Spawning Conditions. At every station investigated in 1981, spawning substrate was judged to be poor enough to reduce maximum potential hatching success. Sand made up at least 25% of the substrate of almost all riffles (Appendix C), and in most riffles the percentage of sand was even greater below a thin surface armour of gravels. However, most of the sand, except in Mill Creek, was coarse granitic sand, which should permit greater water and oxygen movement. Despite the relatively low quality of spawning substrate, rearing habitat at all sites appeared to be saturated with young-of-the-year and yearling fish in 1981.

In 1982, spawning substrate improved at all sites (Appendix C). Although the amount of sand present is still sufficient to have some effect on hatching success, especially in Mill Creek, spawning success is not likely to be a limiting factor for steelhead production in San Vicente Creek.

In 1983, late spring storms apparently scoured redds or flushed recently emerged fry in some sections of San Vicente Creek. Fry were rare in the steeper portion of San Vicente Creek, above its confluence with Mill Creek. Other sites had sufficient fry to saturate available rearing habitat.

Summer Rearing Habitat Conditions. Summer rearing habitat for yearling fish limits steelhead production in San Vicente Creek. Pools are generally shallow and stream substrate is weakly segregated. It appears that large amounts of sediment are moved during frequent, extreme flood peaks, filling pools. Scouring at lesser flows is often insufficient to recut deep pools in the relatively coarse substrate, except at bends, downed trees, boulders, or exposed bedrock. Although large cobbles are common, they are usually quite embedded in coarse granitic sand, reducing available hiding cover. Undercut banks provide some escape cover, but many are exposed at very low summer streamflows.

Fish populations downstream of the diversion pond on Coast Dairy and Land property (channel mile 0.7) were very low in 1981 (see Figure 9). Occassional high water temperatures or reduced streamflows, due to the diversion pond, were possibly responsible for the low densities encountered; however, at the time of sampling in late September, both water temperature (58 degrees at 11:45) and streamflows were suitable to support considerably more fish. The apparent impacts of the diversion are on silver salmon as well as on steelhead; young-of-the-year silver salmon (outnumbered 5 to 1 by steelhead) were present in the pool at the sampling site.

The diversion pond, itself, provided excellent rearing habitat for young-of-the-year and yearling steelhead in 1981 (Figure 9). Although water temperature in the pond was higher than in the creek upstream (67 degrees versus 60 degrees), the pond provided the security of both depth and good escape cover (algae and floating water fern). Fish collected from the pond showed excellent growth rates also. Young-of-the-year fish were "yearling-sized" (3 1/2 to 5 inches long) and yearlings were 5 to 7 inches long; all fish were probably large enough to smolt the following spring. Smolt production from the pond was probably equivalent to over 1/2 mile of creek habitat in 1981.

The sampling site at the conveyor (channel mile 1.0) had the highest density of young-of-the-year steelhead that we found among over 100 Santa Cruz County sites in 1981. Lack of dense shading and increased algae probably increased insect food for the fish, and large cobbles present in the shallow riffles and runs at the site provided good escape cover for the small fish. However, yearling fish were only found in association with the deeper water and undercut bank and tree stump of a large pool at the site. The pool was eliminated by floods in 1982.

Upstream of the first bridge (channel mile 1.3) the stream is heavily shaded and both density and size of yearling steelhead are slightly lower than elsewhere on San Vicente Creek. Cobbles were present in the pools, but were embedded sufficiently to reduce their value as escape cover. Many of the pools had undercut banks, and bank undercutting and pool depth both increased in 1983. However, at the low summer flows observed in 1981 many of the undercut banks were exposed or too shallow to provide cover for fish. Yearling fish in this reach, and upstream, were associated with pools and deeper run habitats; shallow runs and riffles tended to have only young-of-the-year fish. Both coastrange and prickly sculpins were abundant in the pools in 1981.

Below the second bridge (channel mile 1.9) both yearling and young-of-the-year steelhead slightly increased, compared to the heavily shaded site near the first bridge (Figure 9). In some open areas, watercress provided limited escape cover, primarily for young-of-the-year fish. Pools were rare in the reach, and one large one, located at a bend in the stream, was lost in 1982, when the stream straightened and by-passed the pool. Only a few prickly and coastrange sculpins were present this far upstream in 1981.

At channel mile 2.5, downstream of the mouth of Mill Creek, young-of-the-year density again dropped, possibly due to very dense shading. Yearling density and habitat preference did not change, however.

On San Vicente Creek upstream of Mill Creek (channel mile 2.7) yearling density did not decrease, despite reduced streamflows. The steeper gradient and improved pool development above Mill Creek provide some of the best rearing habitat on San Vicente Creek. The streambed in this reach was radically scoured by storms in 1982, but had returned to its original character in 1983.

Pool development on Mill Creek was the most limited in the watershed in 1981. Mill Creek also contained the highest percentages of substrate sand and lowest streamflows. The stream was severely scoured in January 1982, but by 1983 pool development and substrate had improved. Fish densities in 1981 were low compared to other sites (Figure 9).

All sites appeared to have slight reductions in pool development in 1982, due to the severe January 1982 storm. However, in 1983 pool frequency throughout San Vicente and Mill creeks increased. Most new pools and increased depth for established pools were due to downed trees or partial log jams. At about channel mile 1.5 one new, large pool was created when a concrete wall beside the road collapsed into the stream. The structure's location at a bend and at the base of a long riffle provided exactly the right conditions for scouring of a pool; removal of the concrete when the road was restored resulted in partial loss of the new pool.

<u>Overwintering Habitat Conditions.</u> Extremely high flood peaks were generated in San Vicente Creek by the January 1982 storm. Logs and sand were piled more than 5 feet above the bank tops at some locations. Similar displays were common at sites on Corralitos and Browns creeks, which we studied in spring of 1982. On those streams all pools were eliminated by the flood peak, but lesser high flows in April 1982 restored pools to near their previous condition. A similar chain of events probably occurred on San Vicente Creek, and accounts for the near elimination of yearling fish from the stream in 1982. In most years the pools, utilized by larger fish in summer, are probably adequate to provide overwintering habitat. The large size and high potential rainfall of the San Vicente Watershed suggests, however, that heavy winter mortality can occasionally occur.

<u>Habitat Problems.</u> The major habitat question on San Vicente and Mill creeks is why pool frequency and pool depth are so limited. The watershed may be producing very large amounts of sediment, due to erosion or landslide

conditions; the watershed may frequently experience peak flows which move bed materials and fill the pools; or both processes may be operating. During the three years of observations on the watershed, we have observed the disappearance and reappearance of pools, and the formation new of pools. However, at no time were deep pools common, even prior to the heavy rainfalls experienced in 1982 and 1983. No data are available on streambed morphology prior to 1981, so it is not known whether present conditions are "typical." The winters of 1977-78 and 1979-80 produced large storm and erosion events in several Santa Cruz mountain watersheds, including Zayante Creek. The sediment problems produced on Zayante had not improved by 1981. It is possible that conditions may gradually improve in the San Vicente Creek watershed in the absence of severe peak flow events. However, recovery may be very slow.

The substrate in Mill and San Vicente creeks is of primarily granitic origin. However, in 1982 an increased percentage of marble was found in the stream bed at all sites. One major source of the marble is gully erosion of slopes at an old quarry overburden site, above channel mile 0.2 on Mill Creek; marble was present only downstream of the site, and showed a progressive reduction downstream. Erosion at the site is also responsible for the landslide which produced the impassible barrier on Mill Creek. Lesser amounts of marble are also present in San Vicente Creek above the mouth of Mill Creek, so some sediment may be coming from the abandoned quarry, upstream on San Vicente Creek.

Because of the large size of the San Vicente Watershed, some sediment sources may lie far outside the study area. Roads, quarries, and homesite developments (including Bonnie Doon) in the upper watershed may be contributing the majority of the sediment present in this relatively "undisturbed" study area.

In 1982 some small-scale logging took place along Mill Creek, near the diversion dam.

Although the stream is closed to fishing by Fish and Game regulations and is posted as private property, sport fishing probably occurs, especially at the diversion pond. Because of the few barriers to adult steelhead migration, poaching is probably not a problem.

Relationship of Flow to Rearing Habitat

Rearing habitat for yearling steelhead appears to be the most critical factor in steelhead production on Liddell, Mill and San Vicente creeks (as well as for most streams that we studied in 1981), and concerns about impacts upon stream habitat should focus upon yearling density and growth rate. The ability of small coastal streams to provide habitat for juvenile steelhead is certainly dependent upon flow volume, especially during the critical minimum flows of August, September, and October. Reductions in flow would reduce pool and riffle depth, escape and overhead cover, and fast-water feeding areas, so any late summer diversion would have some adverse effects on steelhead. However, when diverse sites are observed, the loose positive relationship seen between yearling steelhead density and minimum flow (Figure

10) implies that other factors or the indirect effects of flow are also very important.

Habitat depth, which is closely related to yearling steelhead density (Figure 11) is affected by flow volume, but is also even more dependent upon channel morphology; habitat depth will be greater in a stream with low flows, but good pool development, than it will be in a stream with high flow volume, but with few pools. Escape cover (crevices under unembedded rubble, undercut banks, submerged logs, etc.) is also an important determinant of yearling steelhead density (Figure 12), especially in moderately shallow water.

We analyzed the relationships between yearling steelhead densities and habitat depth and cover estimates for riffle, run, and pool habitats on San Vicente, Mill, and Liddell creeks, and on thirteen other Santa Cruz County streams. The relationships were used to produce an empirical rearing index model, which predicts yearling steelhead densities for streams where two years are required to reach smolt size (Figure 13). We found that depth and cover are not strictly additive, and interact in a non-linear manner; in shallow water (less than 0.5 feet) the effect of large increases in cover is minimal, but in deeper water, increases in either depth or escape cover contribute to increased yearling steelhead densities. The relationship is similar over a wide variety of Santa Cruz County streams (Figure 13), having greatly differing summer streamflows, channel morphologies, and substrate compositions.

We next used data (from 1982 and 1983) on the effects of flow increases upon habitat depth and escape cover, to develop curves which relate minimum summer flow volume to yearling steelhead rearing indices at our sites on Liddell, San Vicente, and Mill creeks (Figures 14, 15). Because channel width and morphology are so important in determining depth, we found the greatest rearing habitat response to flow increases in stream sections where channels were narrow and pool development was poor.

Liddell Creek has narrow channels and limited pool development, and the curves (Figure 14) indicate that little habitat should remain at very low flows (such as we found in 1981), but that habitat sharply increases at higher flows. Site 4, which has better pool development than other sites, shows higher rearing values at all flows; the relative difference is greatest at very low flows, when pools at site 4, but not at other sites, still have sufficient depth to provide yearling steelhead rearing habitat.

San Vicente Creek sites (Figure 15) show higher rearing capacity at low flows than Liddell Creek sites, because of better escape cover and greater pool development. The sites vary considerably in low-flow rearing capacity, however, because of variations in pool frequency and depth. Because San Vicente Creek sites do have greater pool development and wider channels than Liddell Creek sites, increases in rearing capacity with increased flows are less pronounced.

<u>Effects of Present Diversions Upon Rearing Habitat</u>

Liddell Creek. The city of Santa Cruz presently diverts water at Liddell Spring #1. The approximate effect of this diversion can be estimated for average and wet years, using hydrologic data on stream flows and diversion rates for 1981 and 1982 and flow/rearing index curves (Figure 14). There is presently a small riparian diversion at Spring #2, but it is apparently used irregularly for very small amounts of water.

In October, 1981 the diversion from Spring #1 was 0.4 CFS, at a time when remaining stream flows were only .09 to .14 CFS. Based upon our flow/rearing index curves (Figure 14), this resulted in very heavy reductions in yearling rearing capacity in Liddell Creek (Table 17), due to reduced pool depth and escape cover. Average habitat reduction at the five sites was 58 percent, with ranges of 40 to 85 percent reduction (depending upon pool frequency and depth). The apparently large impact of the diversion in 1981 was because, in a dry year, most of the stream flow originates at the spring, and accretion downstream is minimal.

In September, 1982 the diversion from Spring #1 was 0.64 CFS, but stream flows were .73 to 1.17 CFS, even with the diversion. The estimated reduction in yearling rearing capacity was 31 percent (Table 17).

In addition to the effect of the diversion upon density of yearling steelhead, there would probably be a negative effect upon steelhead growth rate. In a dry year, diversion during May and June would eliminate some fastwater feeding areas and might slightly reduce the growth spurt that young-of-the-year and yearling steelhead normally show in spring.

San Vicente and Mill creeks. Lonestar presently diverts water from the upper portions of both San Vicente and Mill creeks. In October 1981 the diversion rate was 0.78 CFS on San Vicente Creek and 0.29 CFS on Mill Creek. Estimated rearing habitat reductions ranged from 13 percent on San Vicente Creek above the Mill Creek confluence (with good pool development) to 35 percent below the second bridge; average reduction was about 20 percent (Table 18).

In September 1982 the diversion rate was 0.75 CFS on San Vicente Creek and 0.33 CFS on Mill Creek. Estimated average rearing habitat reduction was about 14 percent.

As indicated for Liddell Creek, there may also be a slight effect of the diversions upon young-of-the-year and yearling growth rates.

Effects of the Proposed Liddell Spring #2 Diversion

The flow from Liddell Spring #2 fluctuates directly with yearly rainfall, and does not show the high "dry year" flows that Spring #1 does. Because of this, there is little divertable water during dry years; in October of 1981 flow at the Spring was as low as .05 CFS. Based upon flow/rearing index relationships (Figure 14), if all available flow at the spring had been diverted in October 1981, there would have been an estimated average yearling rearing habitat reduction of 15 percent (Table 19). The greatest effect would have been in the reach above the ford, where the scarcity of pools would have resulted in a habitat capacity reduction of 60 percent.

In a wetter year, the diversion rate would increase to the proposed 0.4 CFS. If the proposed diversion had taken place in September of 1982, the larger percentage reduction in streamflow would have reduced yearling steelhead rearing potential by an estimated 38% (Table 19).

Although the proposed diversion would be expected to have significant impacts upon steelhead rearing, the impacts would be relatively small in critical dry years, and would be largest in those years when available rearing habitat is quite high.

This study was designed to address only the question of summer disversion, however, observations on this and other coastal streams indicate that a diversion of 0.4 CFS during December through April could probably take place (except in driest years) without affecting steelhead density or growth rates.

Potential Mitigations

On the East Fork of Liddell Creek, removal of barrier B5 (logjam) and modification of barriers B3 and B4 (limestone bedrock falls) would provide improved access to channel mile 1.75 through 2.1. It appears that these barriers presently can restrict adult steelhead access, especially in dry years. On Mill Creek, removal of the barrier at mile 0.2 (landslide and logjam) would reopen access through mile 0.45 (abandoned diversion dam). Removal of the abandoned dam would open up access through mile 0.7 to the present diversion dam.

San Vicente, Mill, and Liddell creeks have relatively limited pool development and high percentages of fine sediment. A reduction in stream sediments and an improvement in pool frequency and depth could sharply increase rearing habitat depth and escape cover, and thus yearling steelhead rearing capacity. Such improvements would reduce the impacts of water diversions, and they also would make the streams less sensitive to drought impacts. However, the reasons for the high amounts fine sediment and lack of pool development are not fully known. Smallscale logging appears, presently, to be a source of sediment, but roads and clearcuts are reseeded with grass. The abandoned quarry and overburden sites in the San Vicente watershed are contributing sediment; the absolute amounts and their percentage contributions are not known, but revegetation, especially above Mill Creek, should significantly reduce sediment inputs.

It is clear, from our observations in 1982 and 1983, that downed trees, logs, and boulders produce new and deeper pools, which greatly enhance steelhead rearing habitat. A program, in which large boulders or trees are placed in the stream, could be used to increase pool development. Large pools could also be created by constructing temporary flashboard dams in summer at strategic locations, such as at bridge crossings. Table 20 contains sample estimates for the extent of habitat improvement necessary to mitigate the impacts of the proposed Liddell Creek diversion. The estimates are based upon the relationship between rearing indices and stream depth for Liddell Creek sites. The estimates assume no change in escape cover, although most improvements in pool development will also improve escape cover. As shown, dry year diversion could probably be fully mitigated if stream depth were increased by 50% (using flashboard dams, pool construction with boulders, etc.) on 20% of the stream length. Alternatively, a more radical depth increase of 350% would be required on only 5% of the stream. Mitigating the more extensive impacts of wet year diversion would require more extensive stream modifications (Table 20). The number and types of structures necessary to achieve these modifications is unknown; it would depend upon materials available, upon conditions at the chosen sites, and upon monitoring of pilot attempts at improving pool development.

Since groundwater at the mouth of Liddell Creek may also be a potential source of appropriated water, construction of ponds for diversion or percolation there may provide additional rearing habitat.

Spawning conditions above the Middle Fork could be improved by periodicially adding spawning-sized gravels to the stream at the upper road crossing.

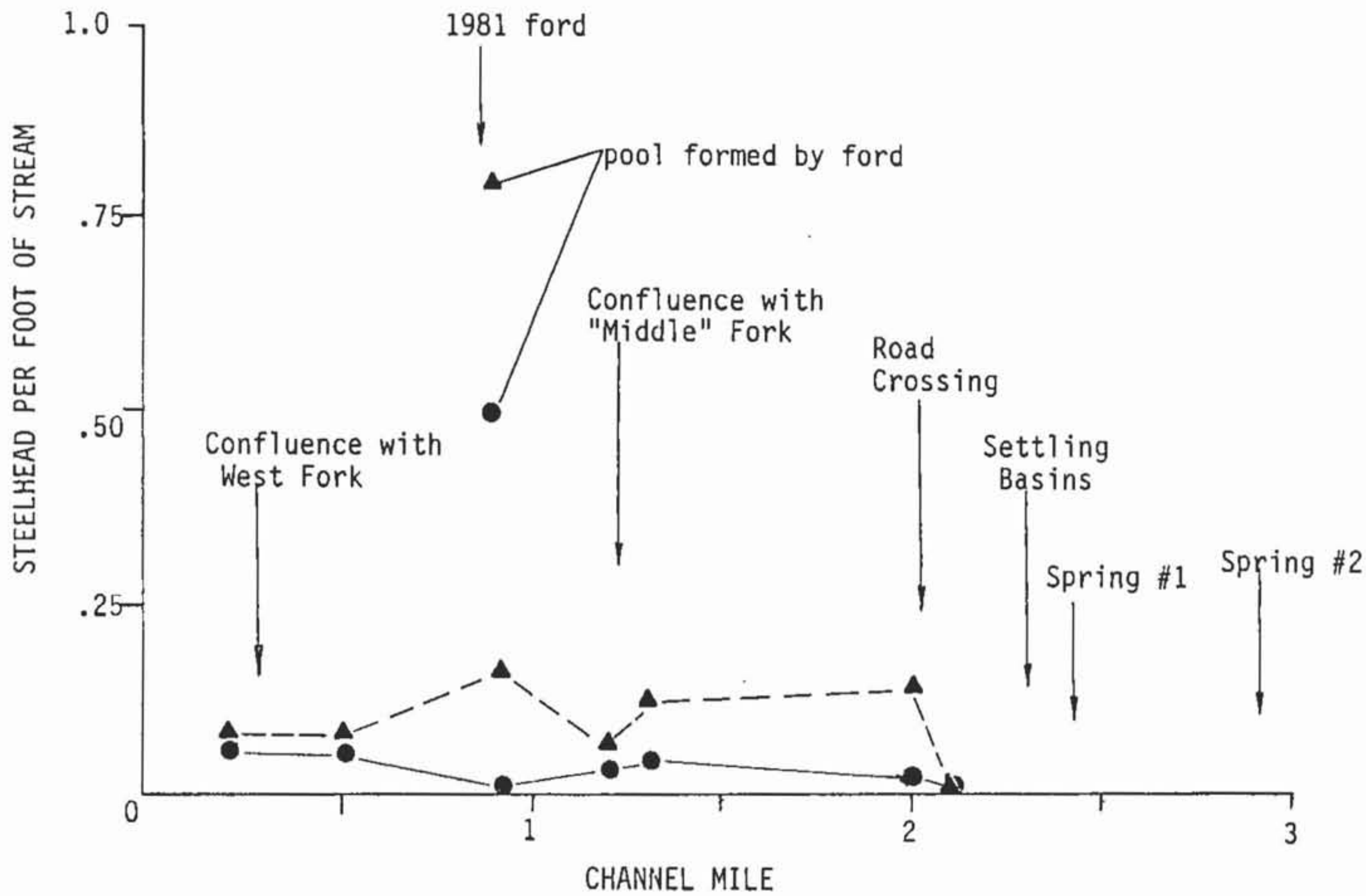


FIGURE 1. Density of young-of-year (▲) and yearling (●) steelhead by channel mile in Liddell Creek, 1981.

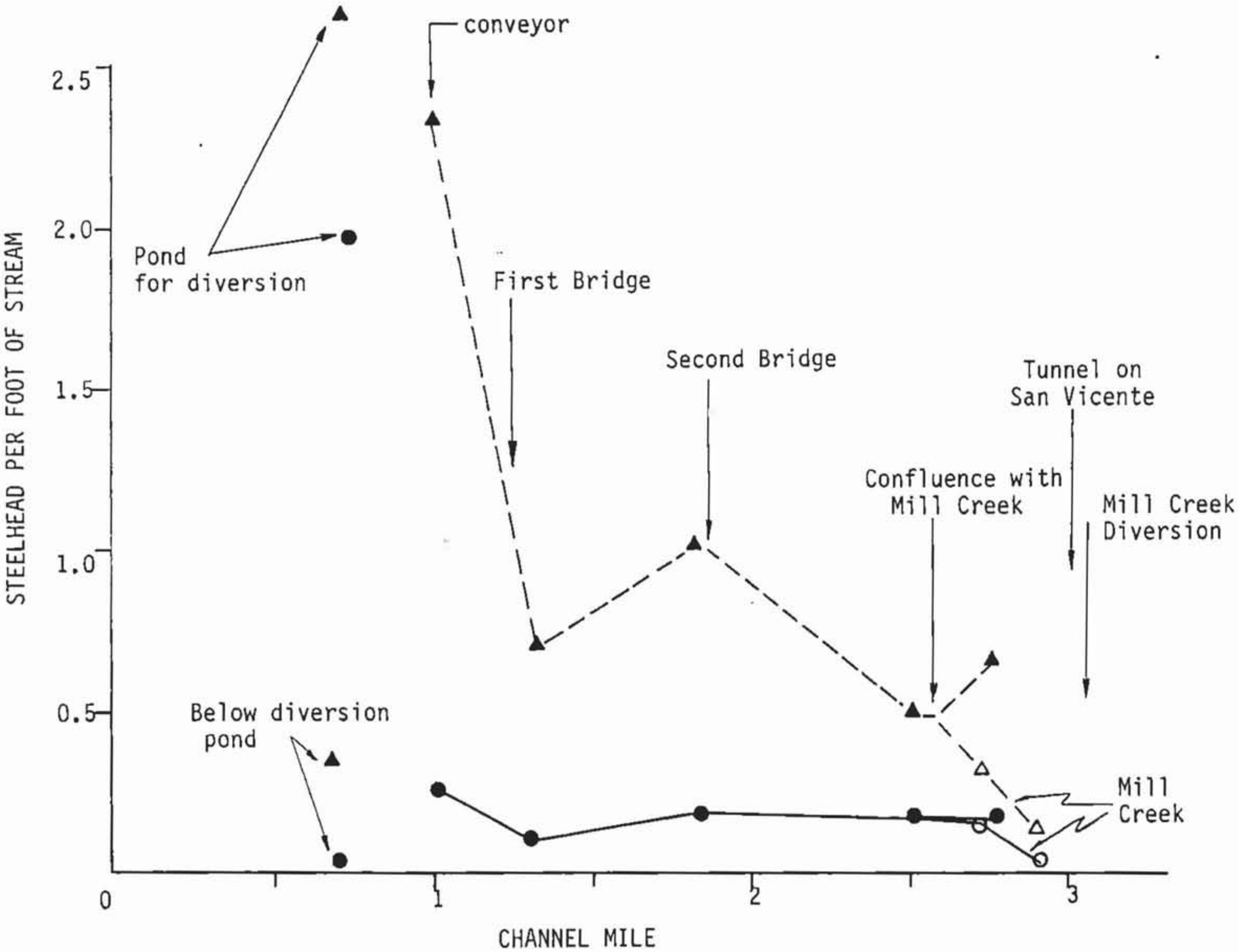


FIGURE 2. Density of young-of-year (▲) and yearling (●) steelhead by channel mile in San Vicente and Mill creeks in 1981.

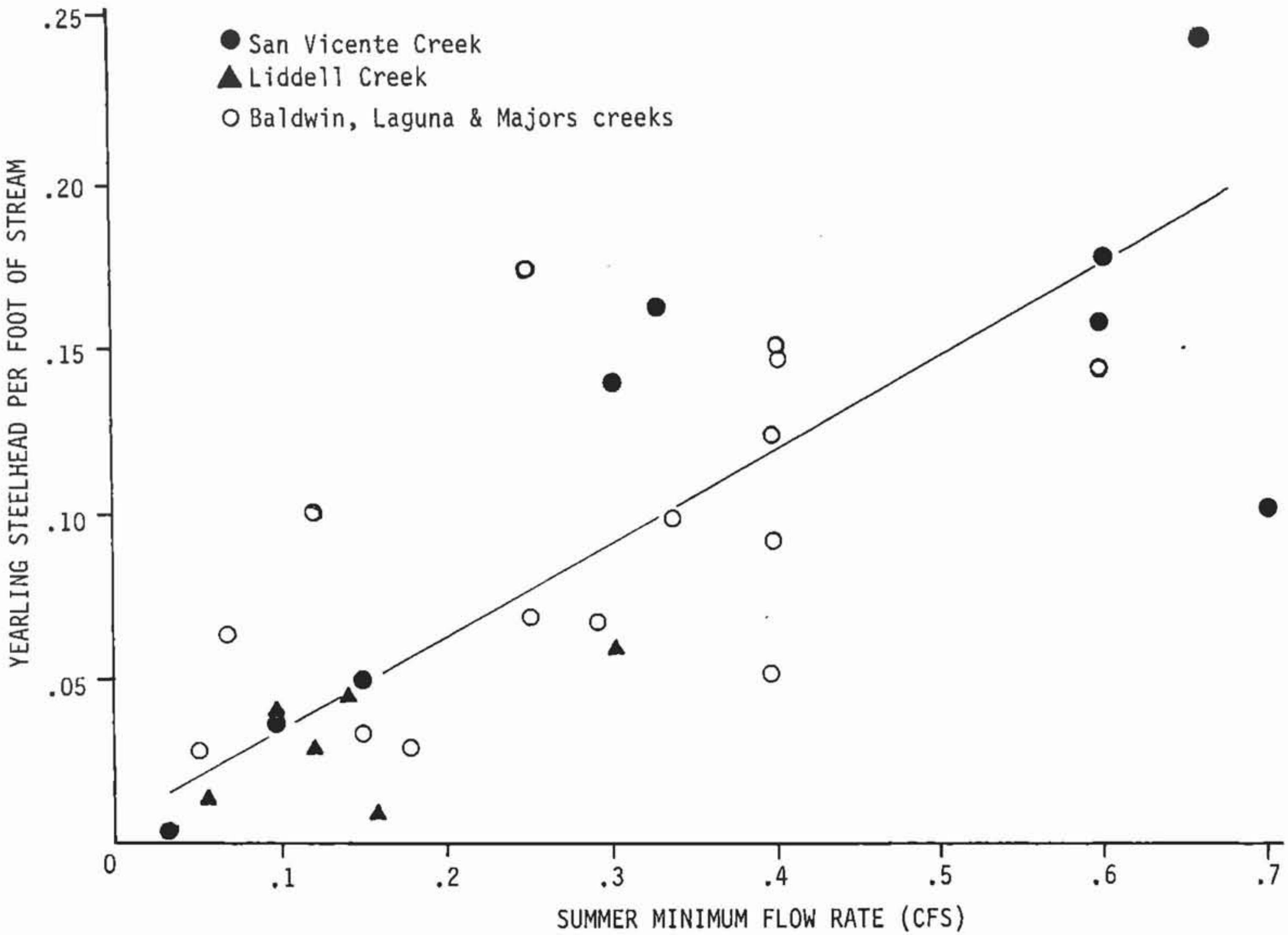


FIGURE 3. Relationship of yearling steelhead density to summer minimum flow rate.

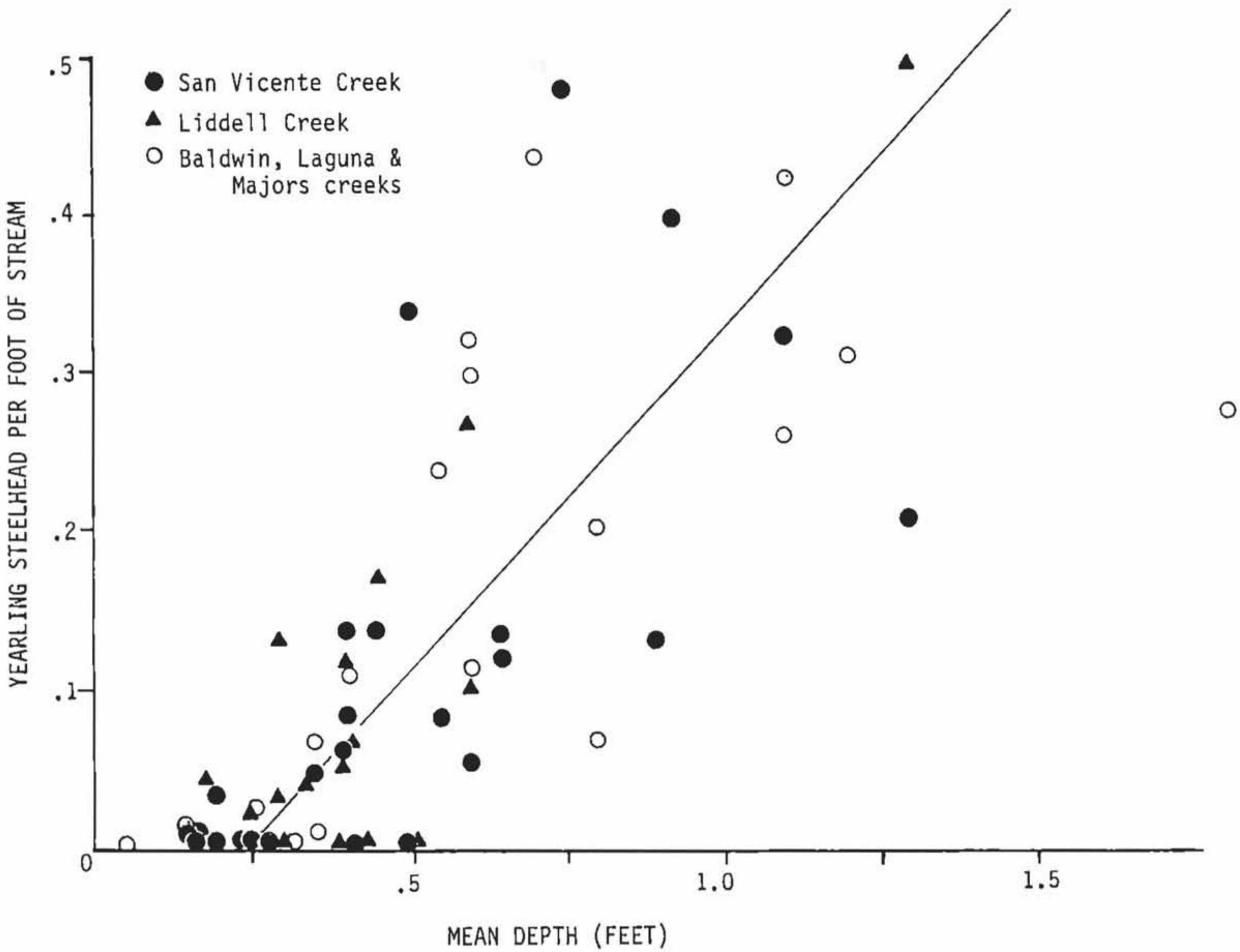


FIGURE 4. Relationship of yearling steelhead density to habitat mean depth.

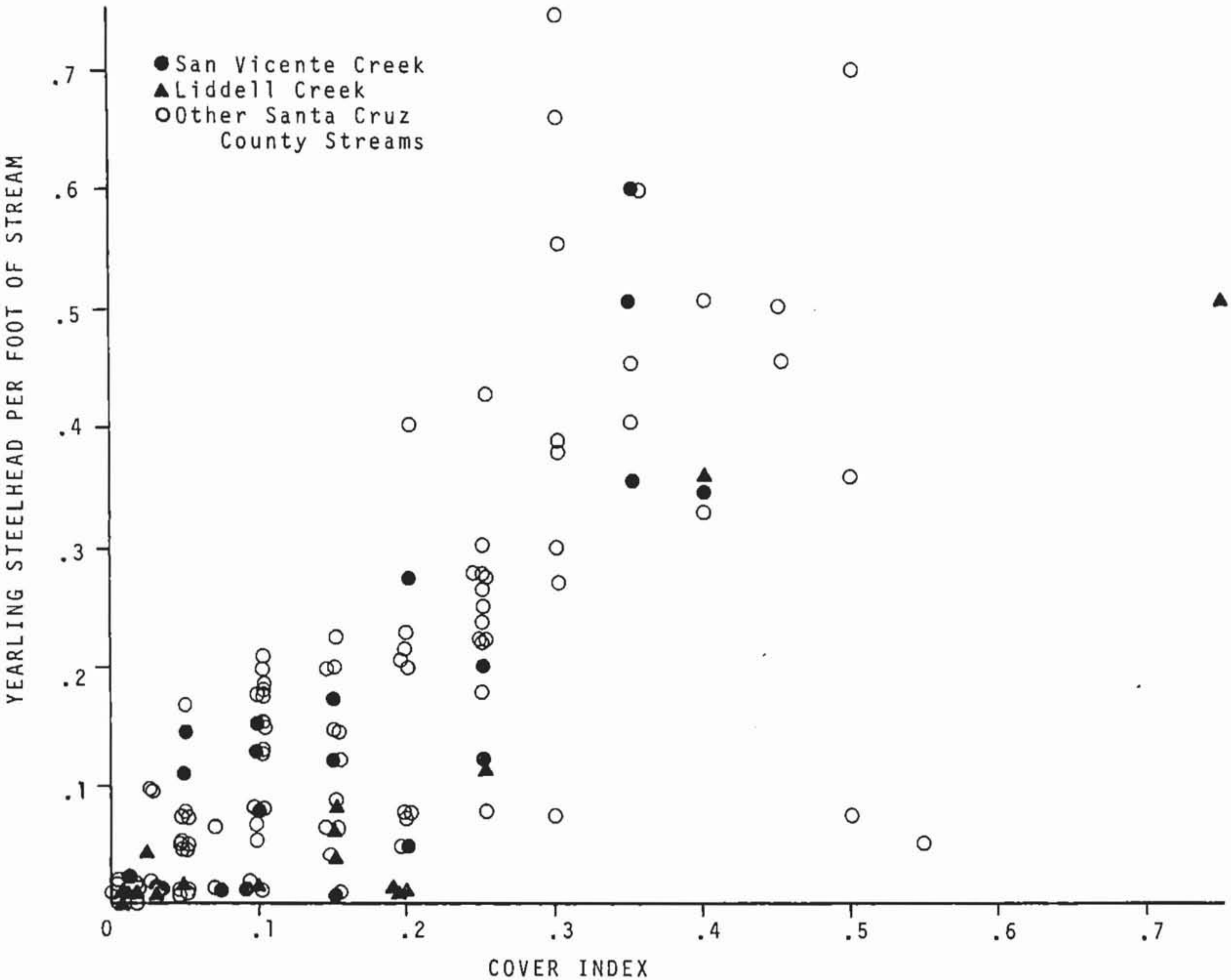


FIGURE 5. Relationship of yearling steelhead density to cover index for small Santa Cruz County streams.

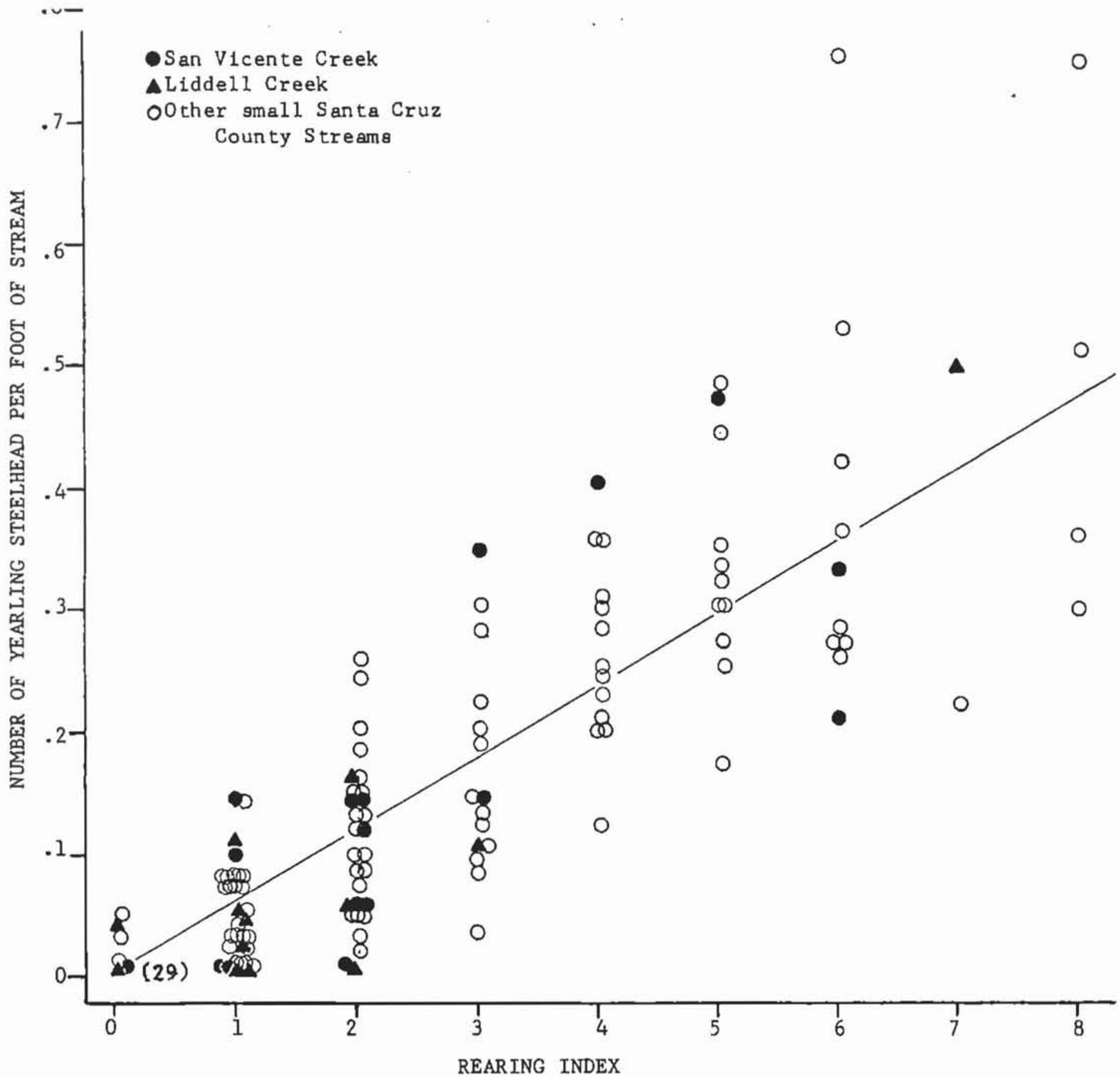


FIGURE 6. Relationship between rearing index and actual yearling steelhead densities for sixteen small Santa Cruz County streams.

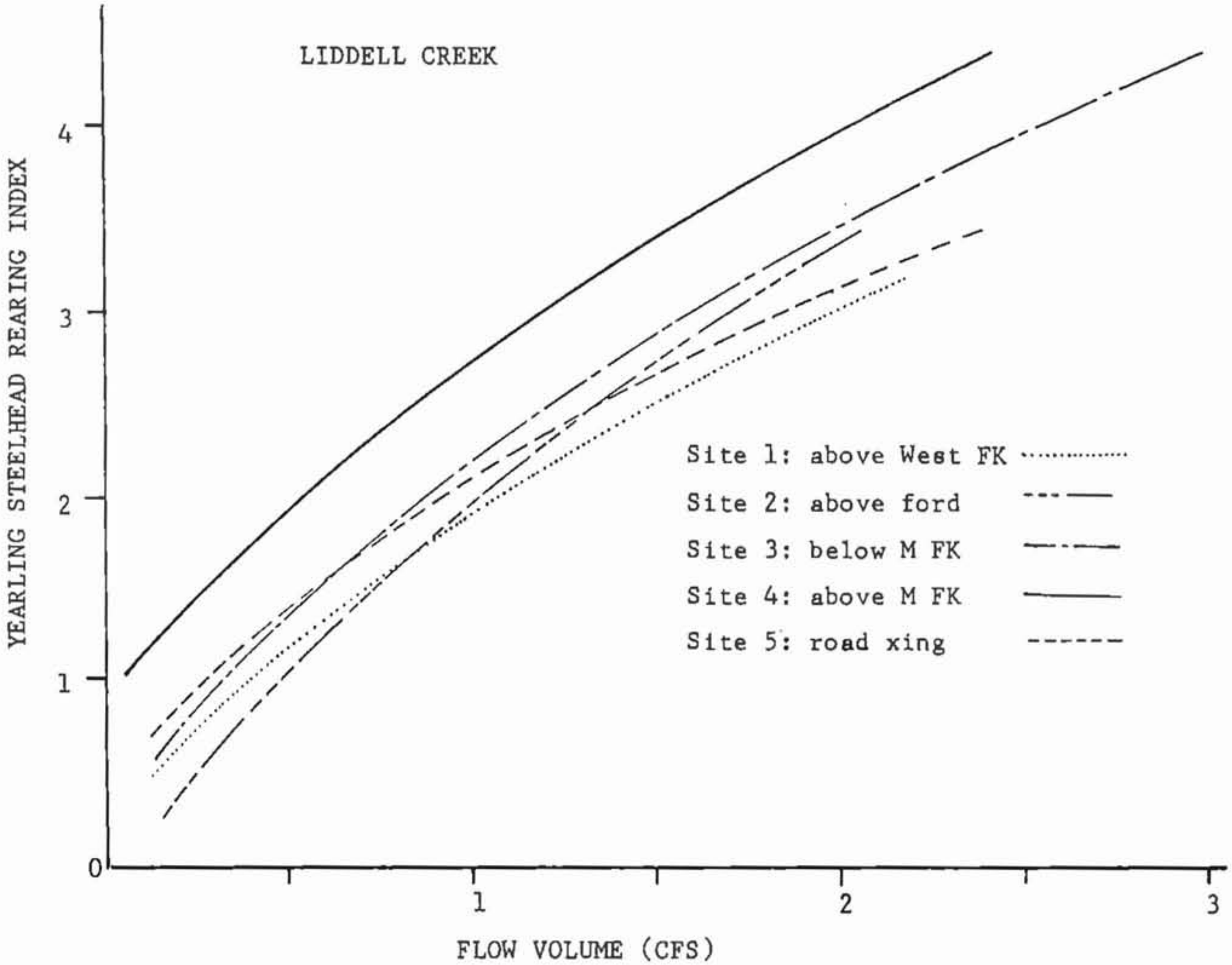


FIGURE 7. Relationship between yearling steelhead rearing index and flow volume.

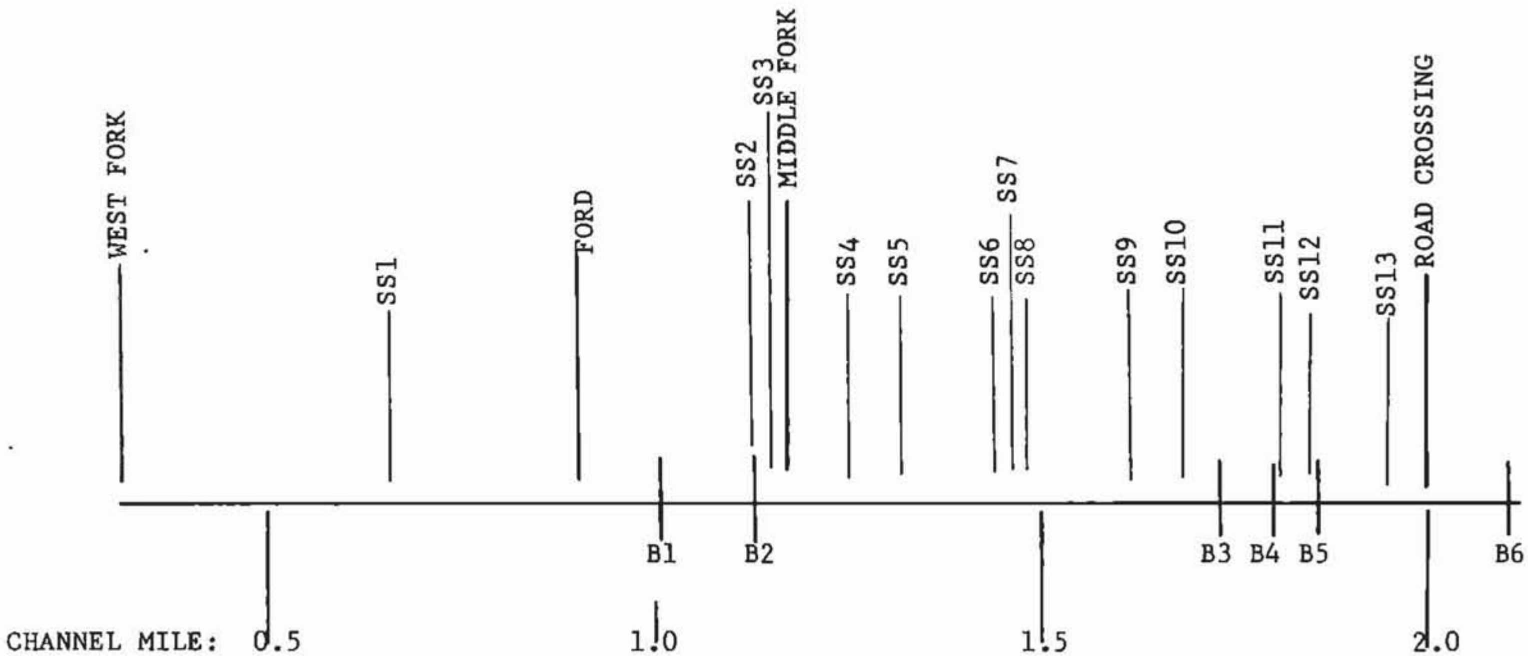


FIGURE 7. Migration barriers (B) and sediment sources (SS) on Liddell Creek, 1983.
See Tables 14 and 16 for descriptions.

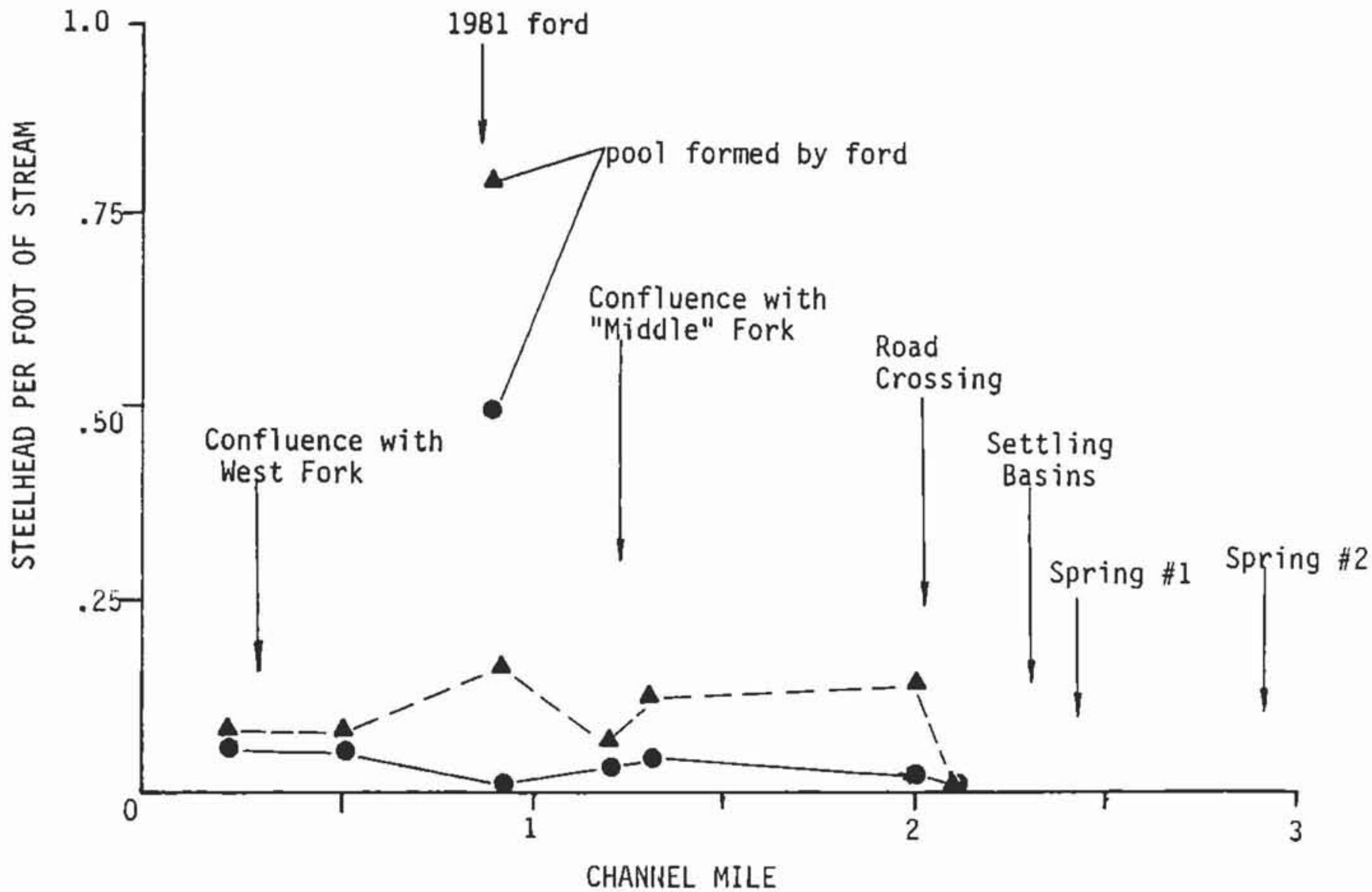


FIGURE 8. Density of young-of-year (▲) and yearling (●) steelhead by channel mile in Liddell Creek, 1981.

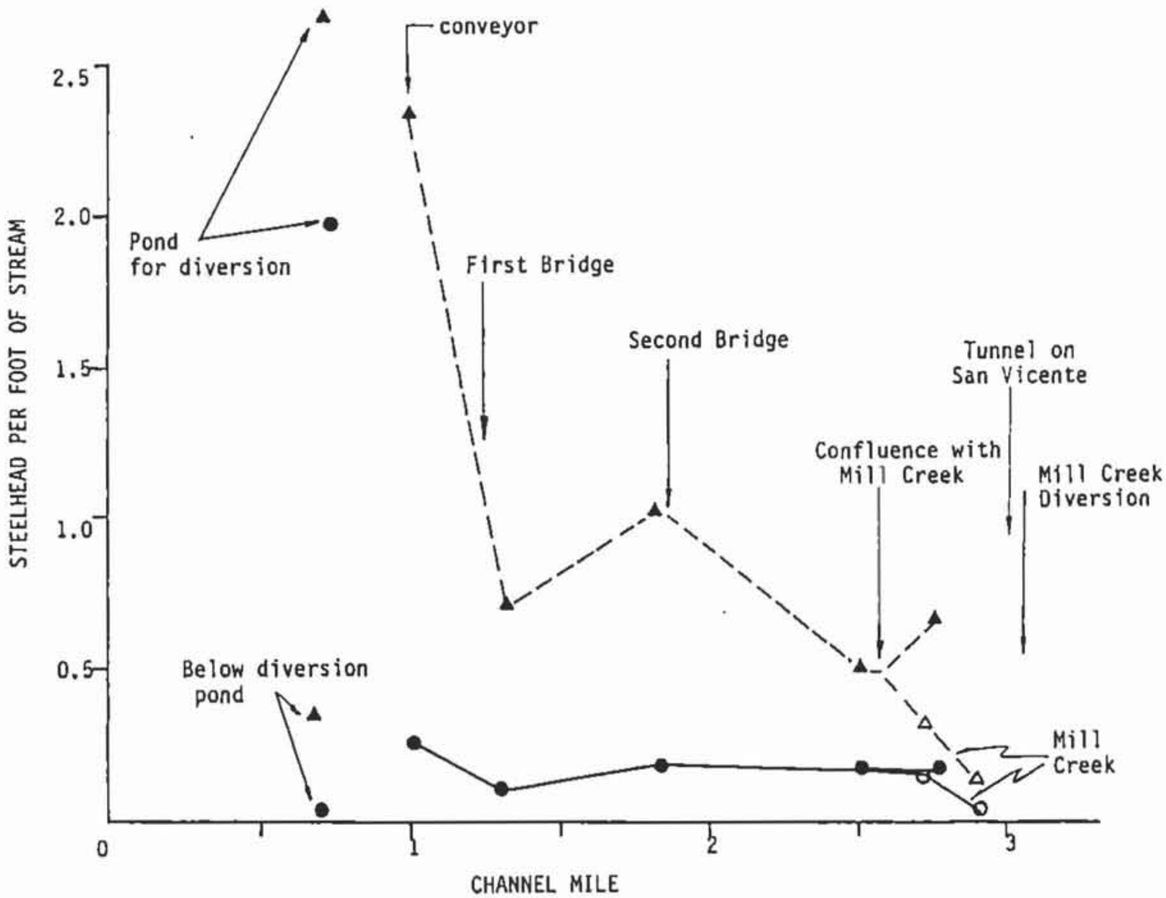


FIGURE 9. Density of young-of-year (▲) and yearling (●) steelhead by channel mile in San Vicente and Mill creeks in 1981.

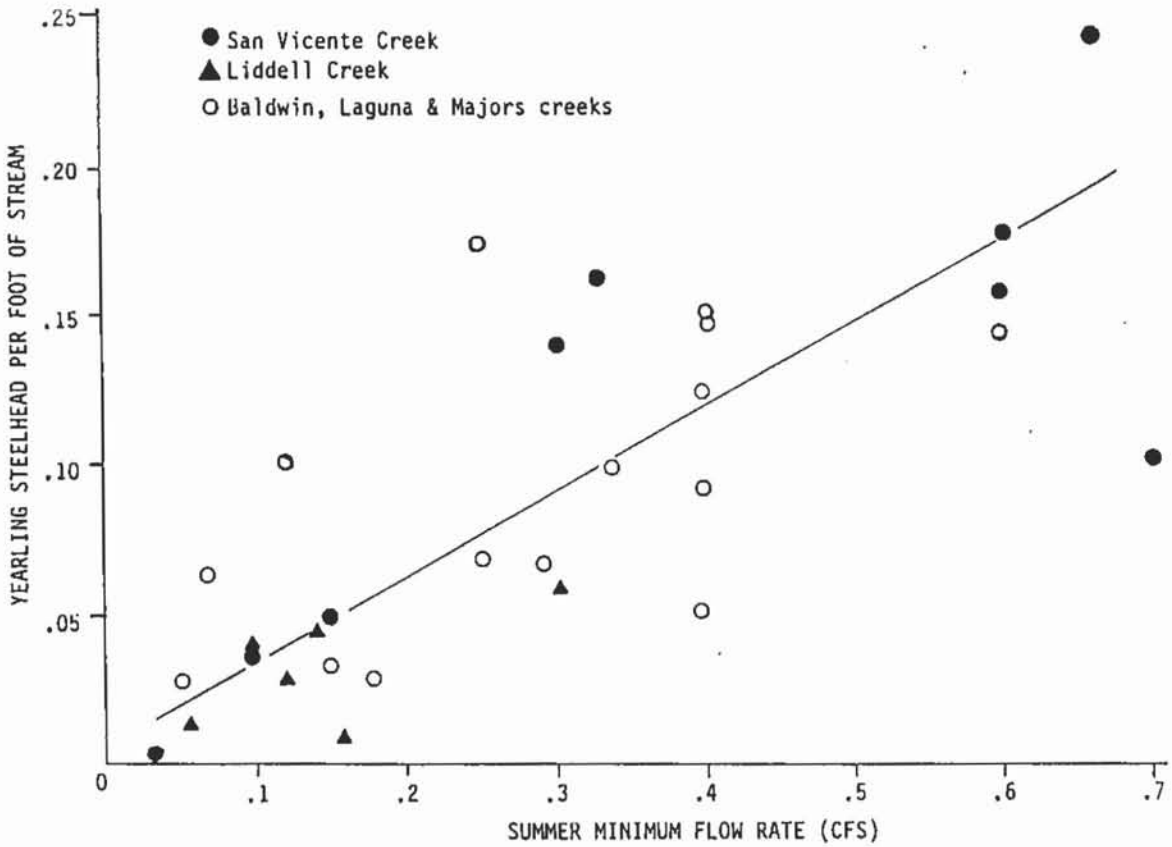


FIGURE 10. Relationship of yearling steelhead density to summer minimum flow rate.

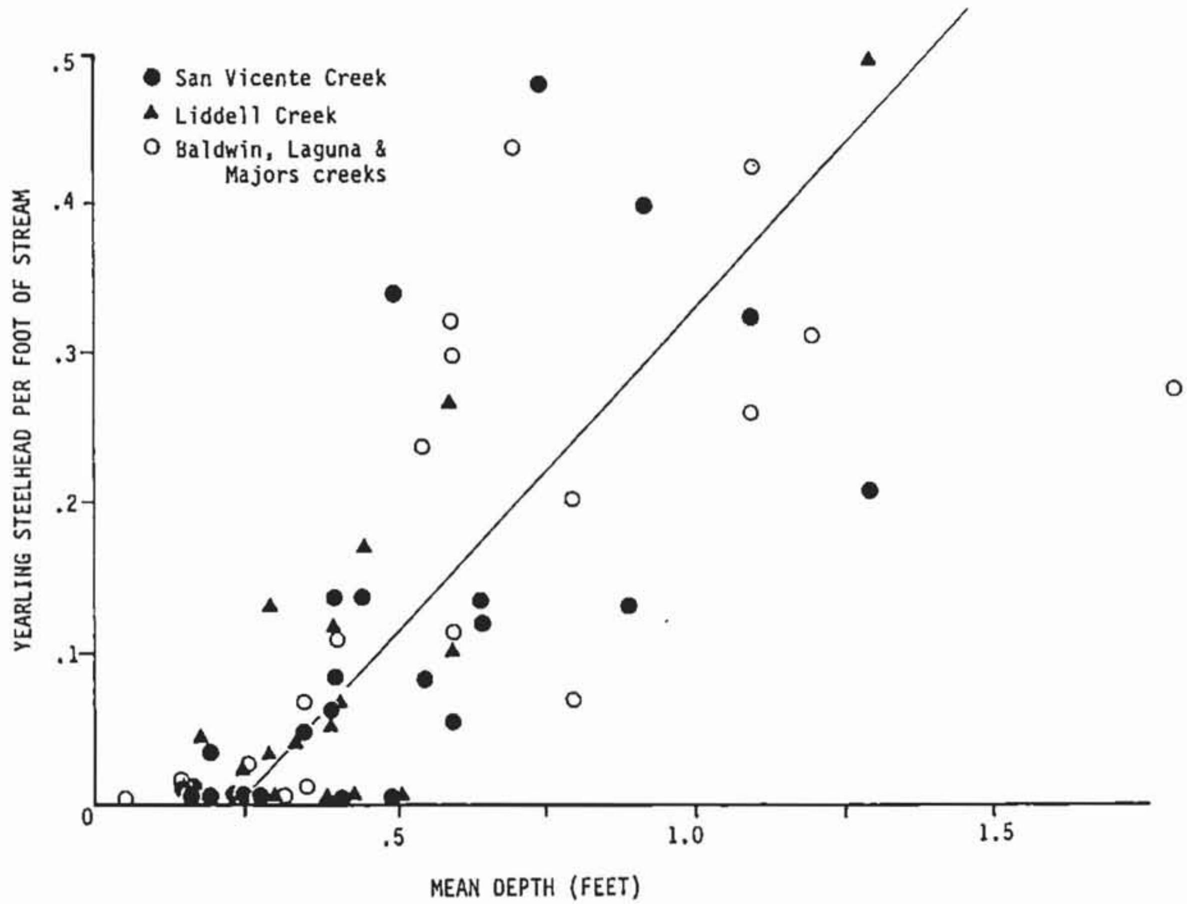


FIGURE 11. Relationship of yearling steelhead density to habitat mean depth.

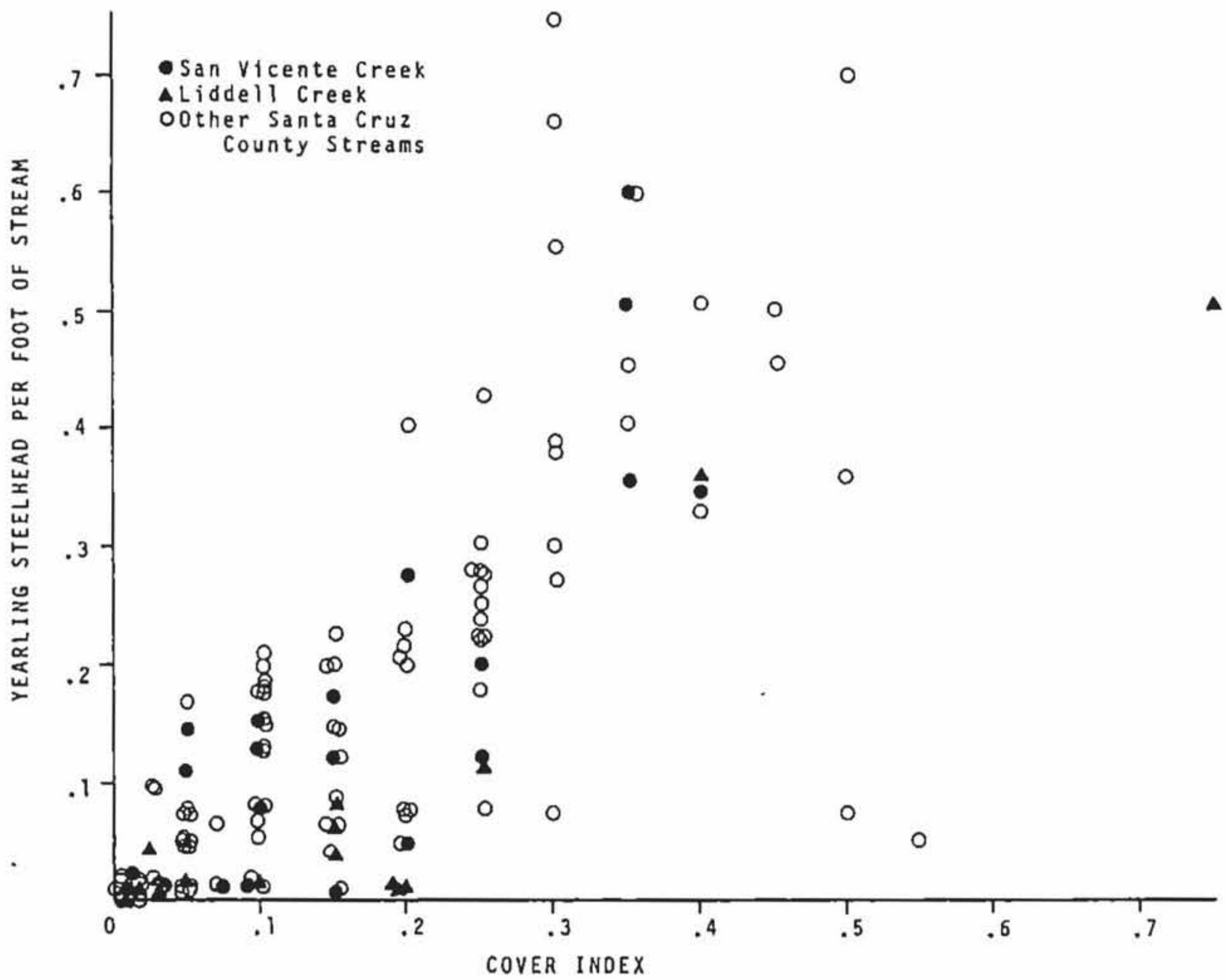


FIGURE 12. Relationship of yearling steelhead density to cover index for small Santa Cruz County streams.

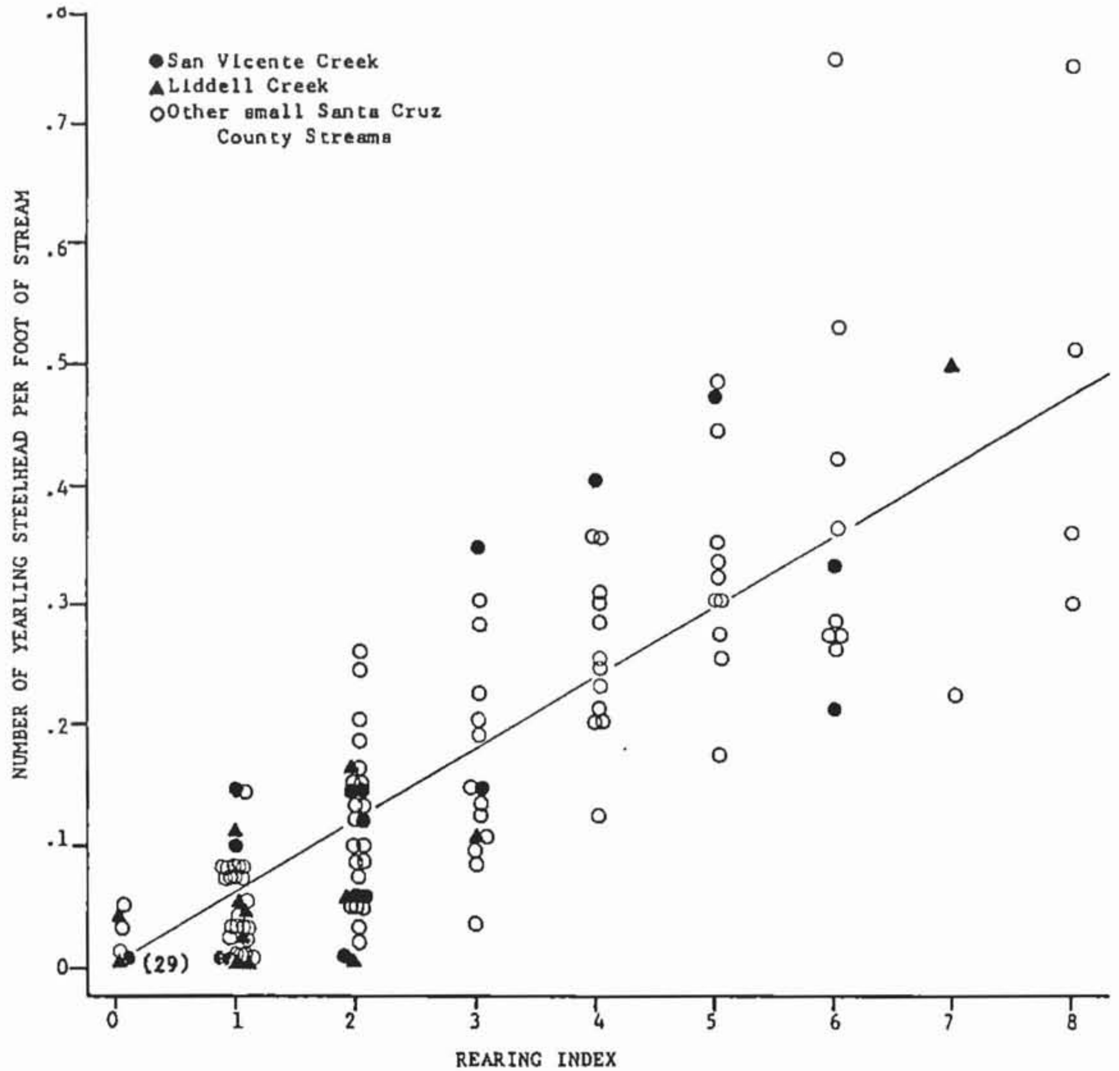


FIGURE 13 Relationship between rearing index and actual yearling steelhead densities for sixteen small Santa Cruz County streams.

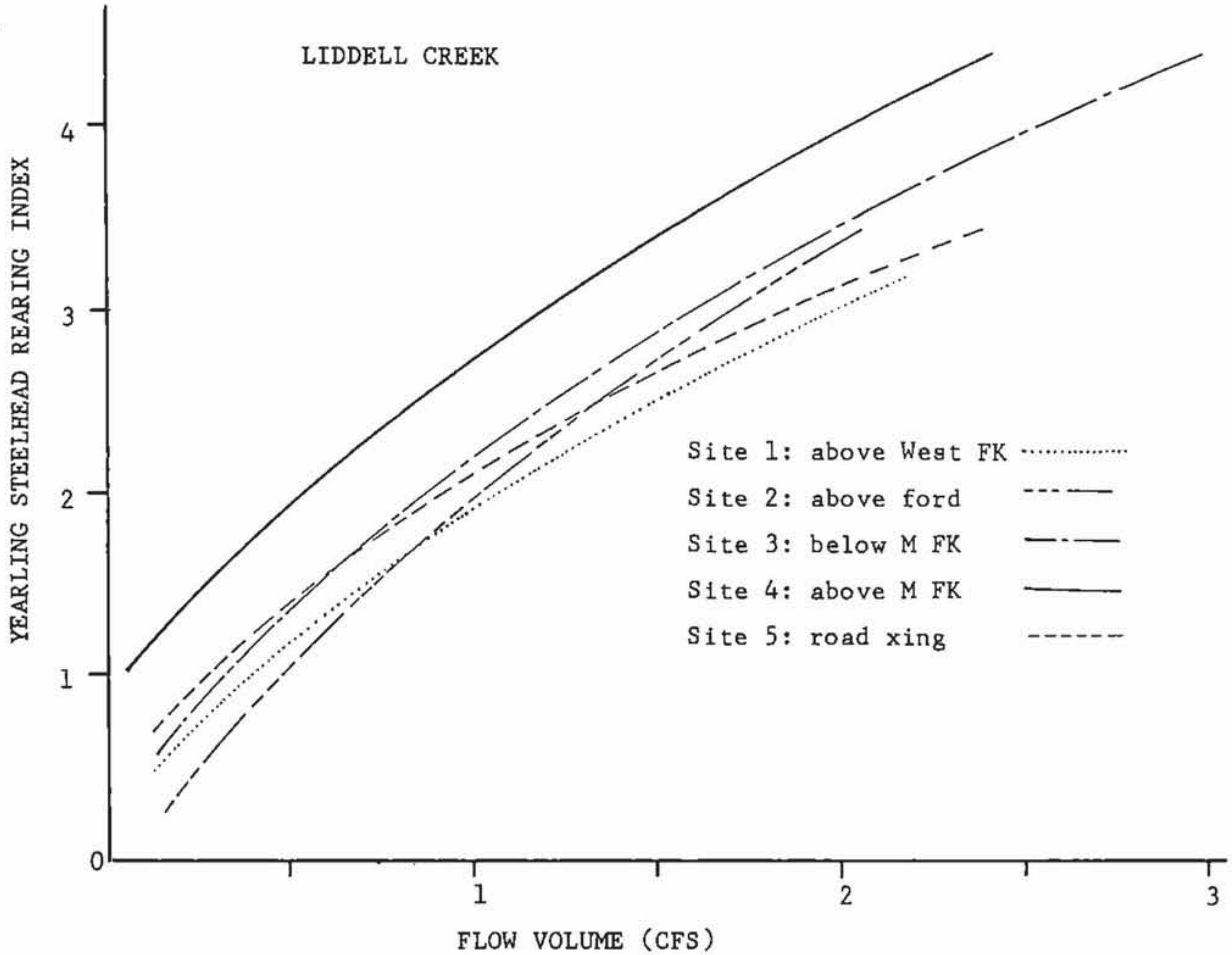


FIGURE 14. Relationship between yearling steelhead rearing index and flow volume.

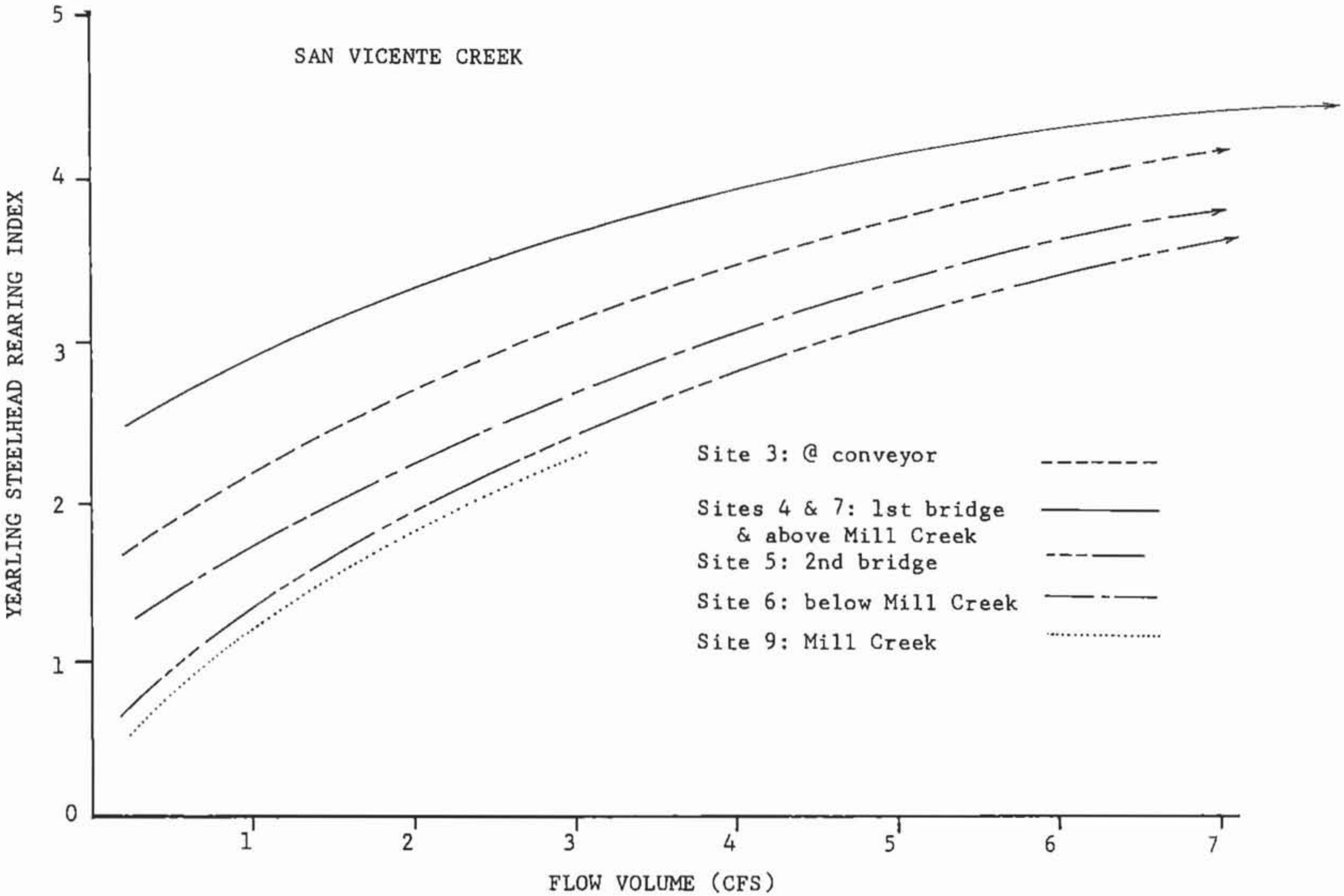


FIGURE 15. Relationship between yearling steelhead rearing index and flow volume.

APPENDIX C: SUBSTRATE CONDITIONS IN LIDDELL AND SAN VICENTE CREEKS, 1981-1983

Substrate Categories

1 = bedrock

2 = less than 2mm

3 = 2 - 5mm

4 = 5 - 25mm

5 = 25 - 50mm

6 = 50 - 100mm

7 = 100 - 250mm

8 = greater than 250mm

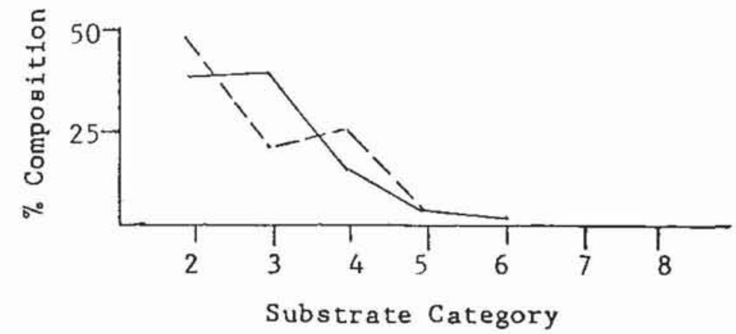
1981 ——————

1982 ----------

1983 ....

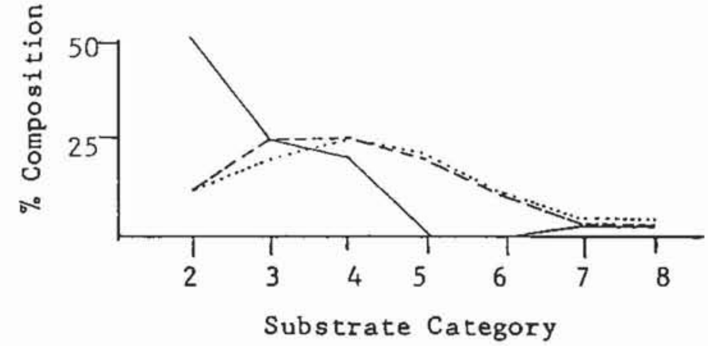
LIDDELL CREEK SUBSTRATE CONDITIONS: POOLS

1981 ——— 1982- - - - 1983 ··········



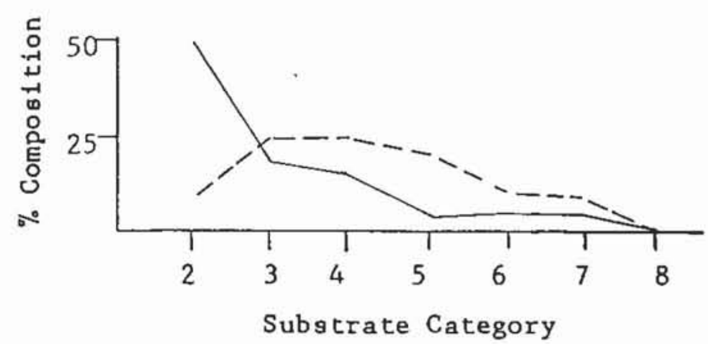
Site 1: above the West Fork

Pool



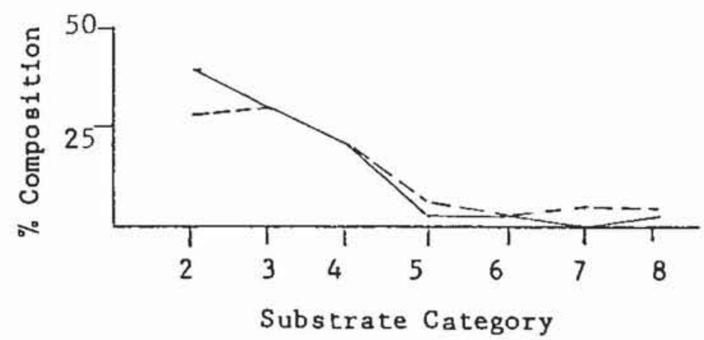
Site 2: above ford

Pool 1981, Run/pool 1982-3



Site 3: below "Middle" Fork

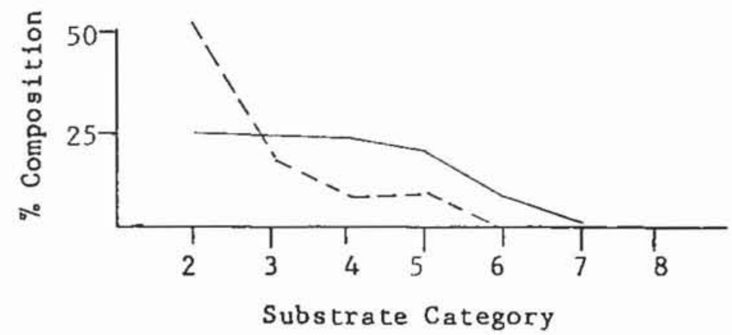
Pool/run 1981, Pool/run/riffle 1982



Site 3

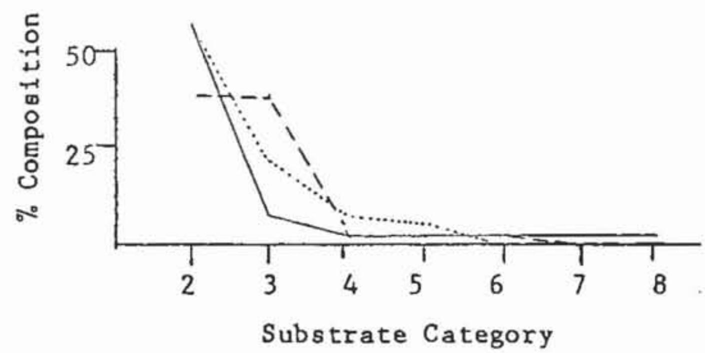
Pool 1981, Pool/run 1982

LIDDELL CREEK SUBSTRATE CONDITIONS: POOLS



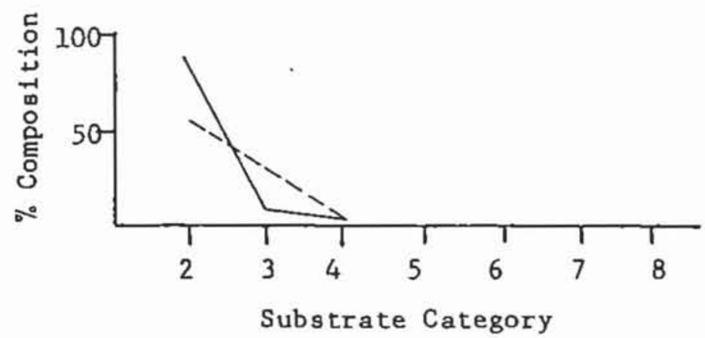
Site 4: above the "Middle" Fork

Run 1981, Pool/run 1982



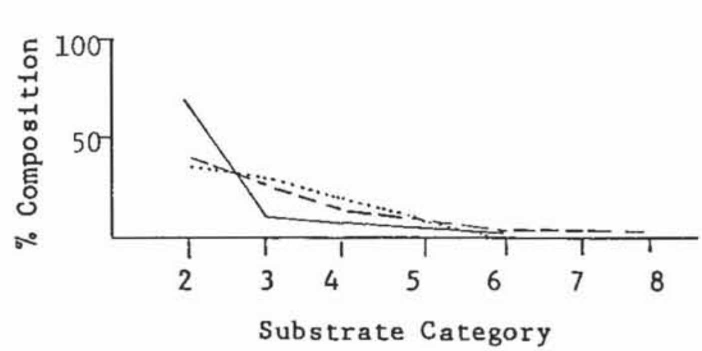
Site 4

Run 1981, Pool/run 1982-3



Site 5: Road Crossing

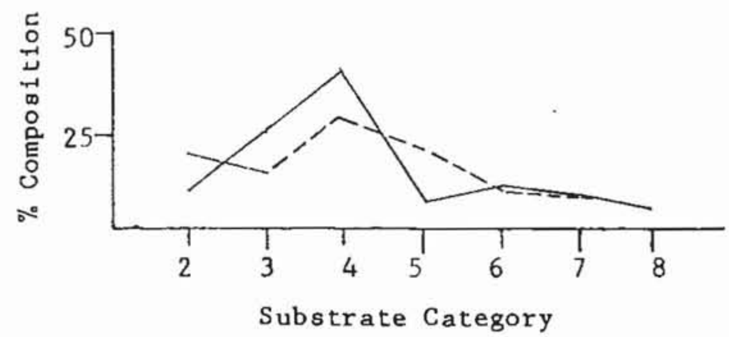
Pool/run



Site 5

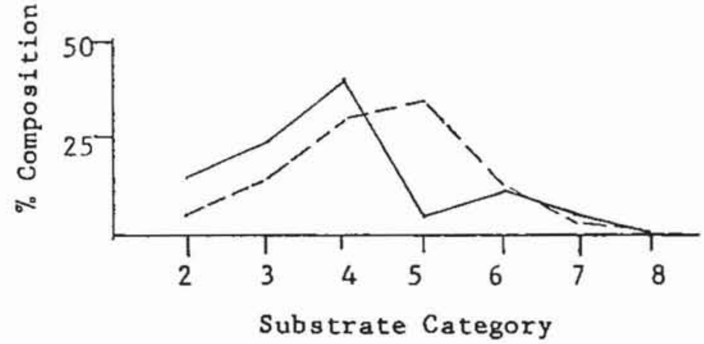
Pool/run

LIDDELL CREEK SUBSTRATE CONDITIONS: RIFFLES



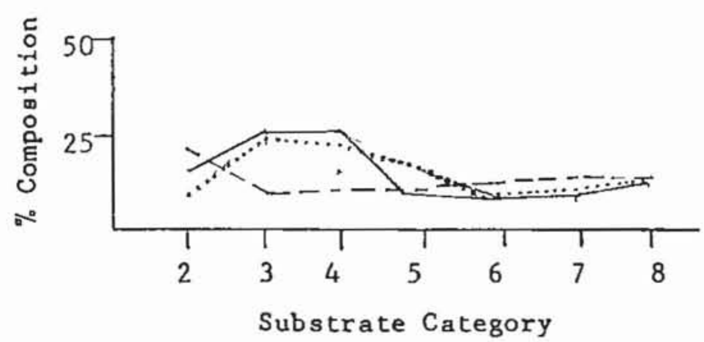
Site 1: above the West Fork

Riffle/run



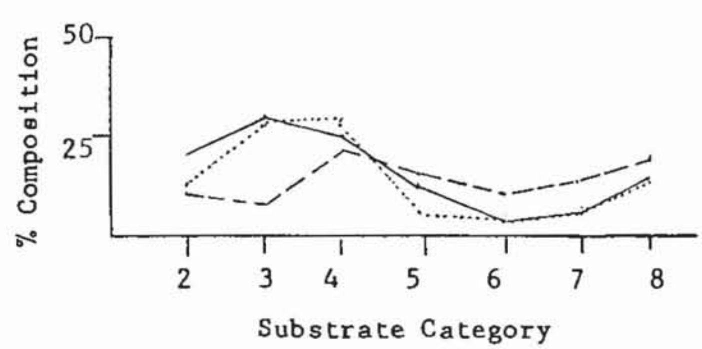
Site 1: above the West Fork

Riffle/run



Site 2: above ford

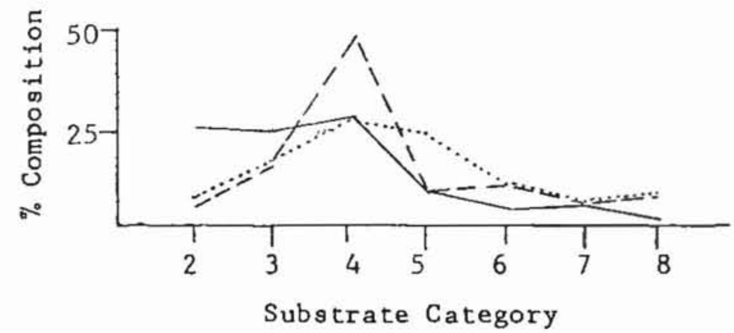
Riffle/run 1981
Riffle/run/pool 1982-3



Site 2

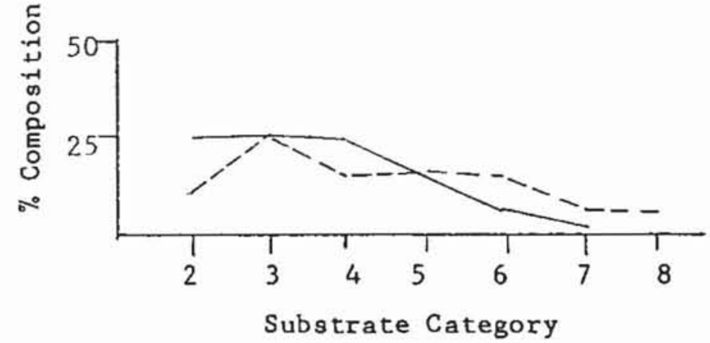
Riffle/run 1981
Riffle/run/pool 1982-3

LIDDELL CREEK SUBSTRATE CONDITIONS: RIFFLES



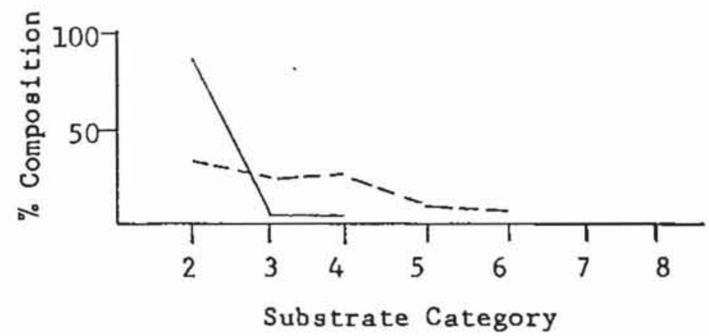
Site 3: below "Middle" Fork

Riffle/run



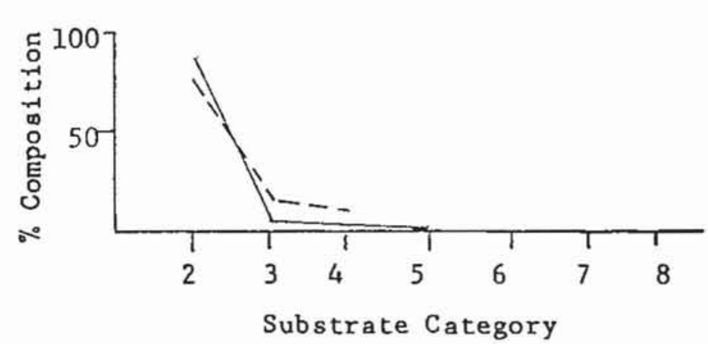
Site 4: above "Middle" Fork

Riffle



Site 5: Road Crossing

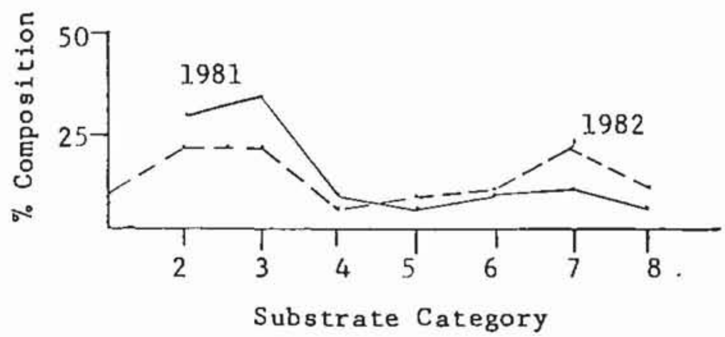
Riffle/run



Site 5

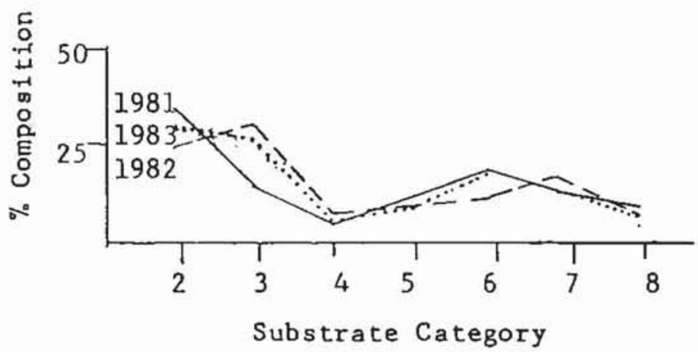
Riffle/run

SAN VICENTE CREEK SUBSTRATE CONDITIONS: POOLS



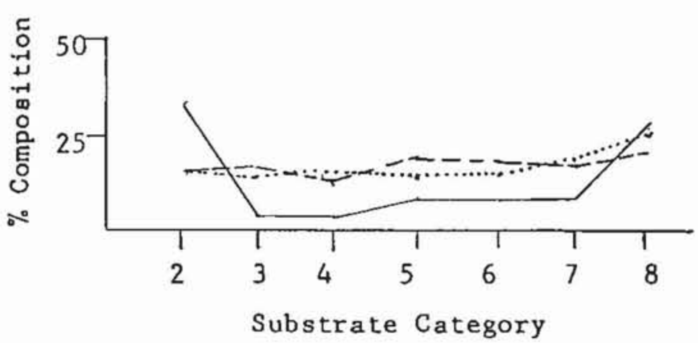
Site 4: 1st Bridge

Pool/run



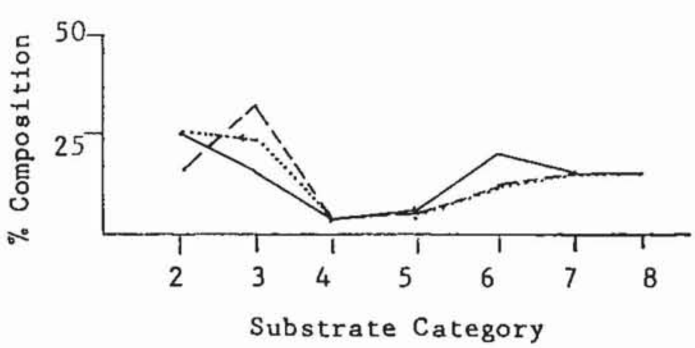
Site 6: below Mill Creek

Pool/run



Site 7: above Mill Creek

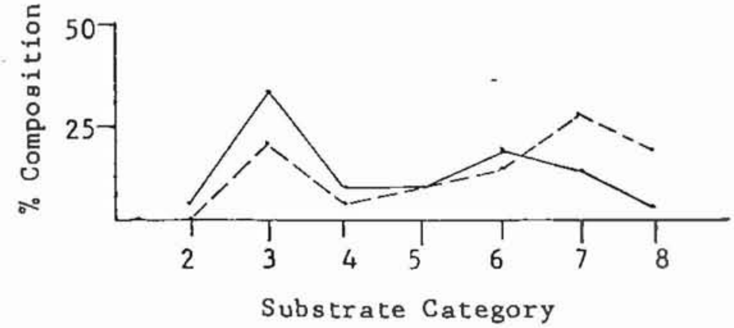
Pool 1981, Pool/run 1982, Pool/run 1983



Site 9: Mill Creek

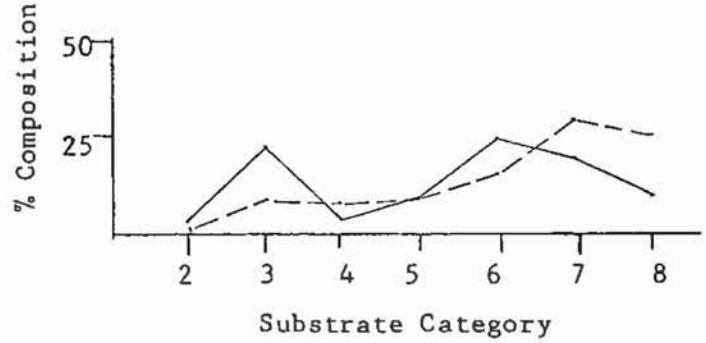
Shallow Pool/run

SAN VICENTE CREEK SUBSTRATE CONDITIONS: RIFFLES



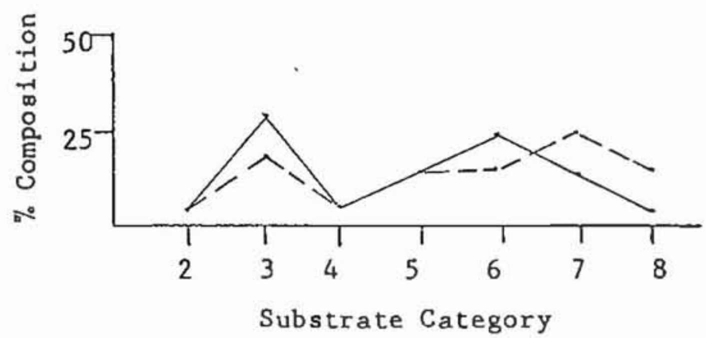
Site 3: @ Conveyor

Riffle/run 1981,
Riffle 1982



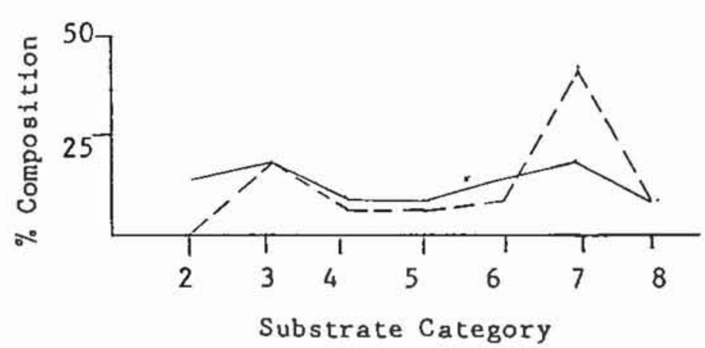
Site 4: 1st Bridge

Riffle/run 1981,
Riffle 1982



Site 5: 2nd Bridge

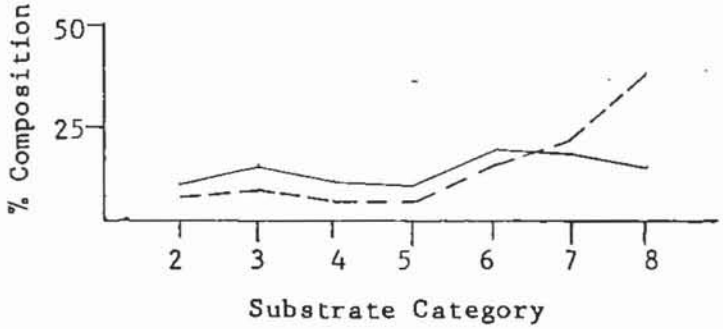
Riffle/run 1981,
Riffle 1982



Site 6: below Mill Creek

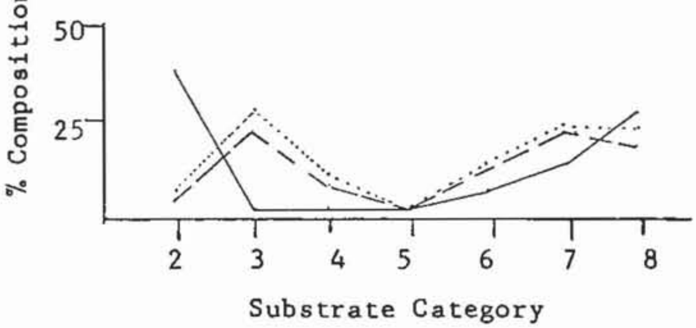
Riffle

SAN VICENTE CREEK SUBSTRATE CONDITIONS: RIFFLES



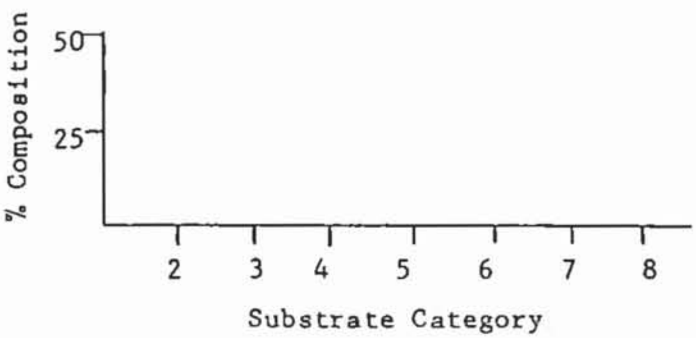
Site 7: above Mill Creek

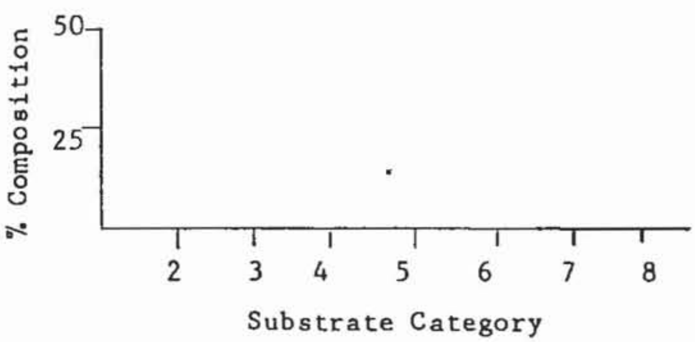
Riffle/run



Site 9: Mill Creek

Riffle/run





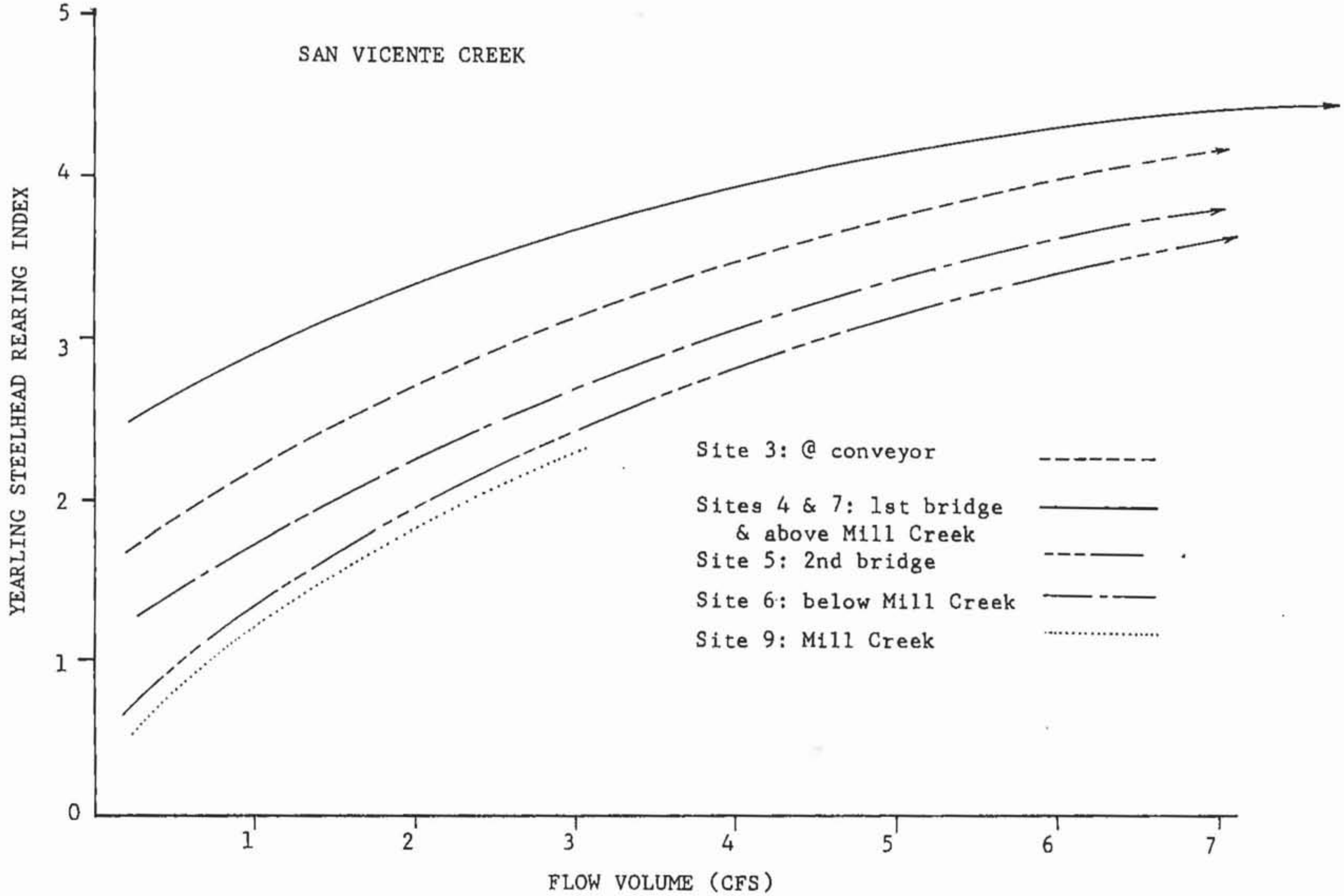


FIGURE 8. Relationship between yearling steelhead rearing index and flow volume.

APPENDIX C: SUBSTRATE CONDITIONS IN LIDDELL AND SAN VICENTE CREEKS, 1981-1983

Substrate Categories

1 = bedrock

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4 = 5 - 25mm

5 = 25 - 50mm

6 = 50 - 100mm

7 = 100 - 250mm

8 = greater than 250mm

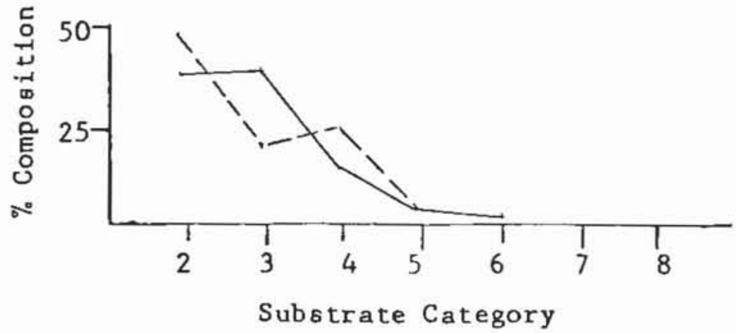
1981 ———————

1982 ----------

1983 ....

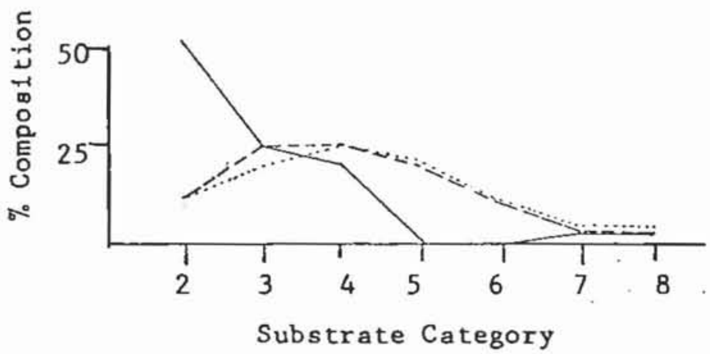
LIDDELL CREEK SUBSTRATE CONDITIONS: POOLS

1981 ——— 1982 – – – 1983 ·········



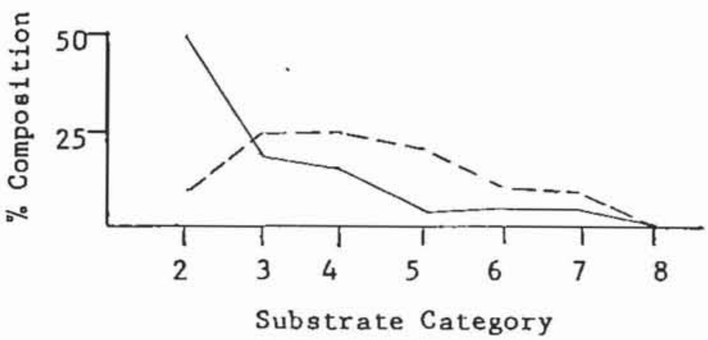
Site 1: above the West Fork

Pool



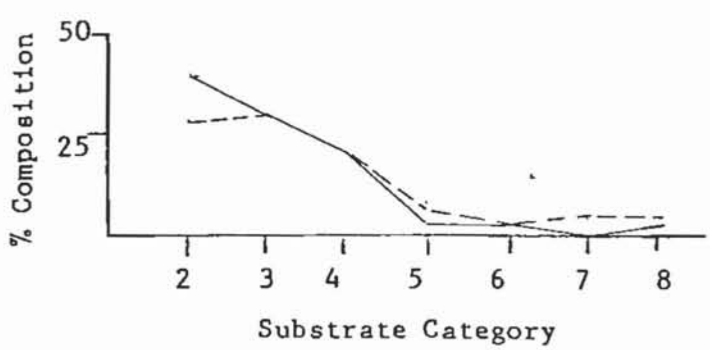
Site 2: above ford

Pool 1981, Run/pool 1982-3



Site 3: below "Middle" Fork

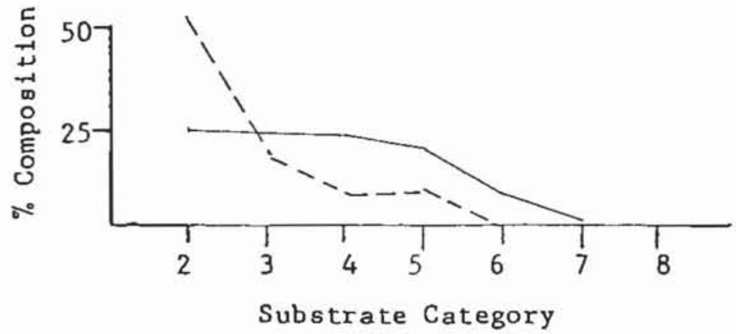
Pool/run 1981, Pool/run/riffle 1982



Site 3

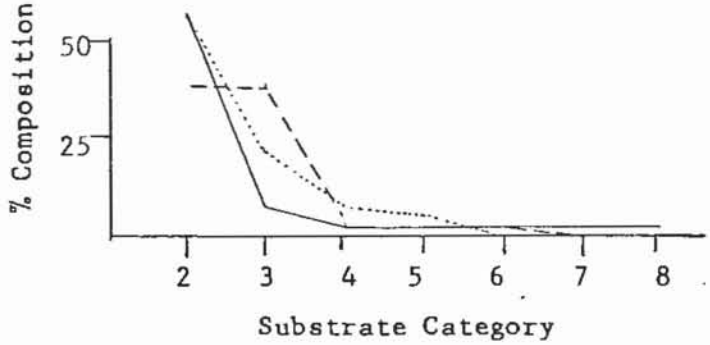
Pool 1981, Pool/run 1982

LIDDELL CREEK SUBSTRATE CONDITIONS: POOLS



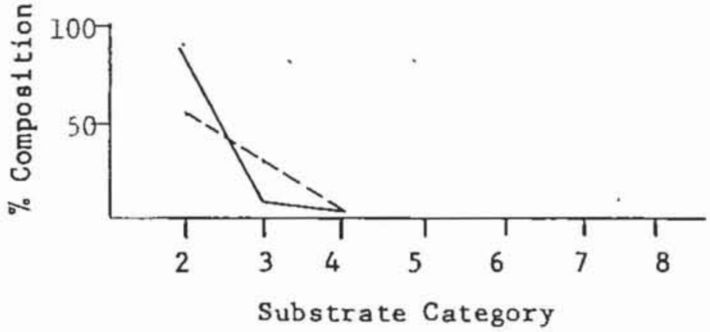
Site 4: above the "Middle" Fork

Run 1981, Pool/run 1982



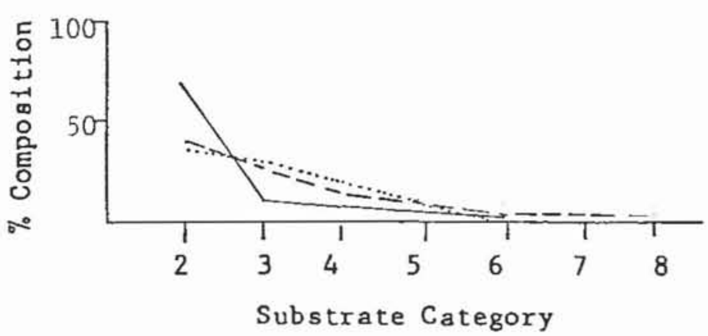
Site 4

Run 1981, Pool/run 1982-3



Site 5: Road Crossing

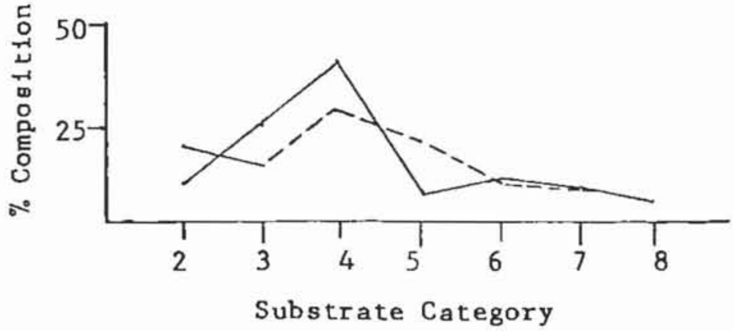
Pool/run



Site 5

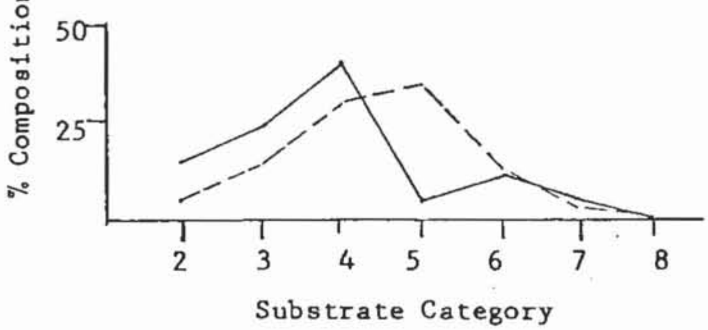
Pool/run

LIDDELL CREEK SUBSTRATE CONDITIONS: RIFFLES



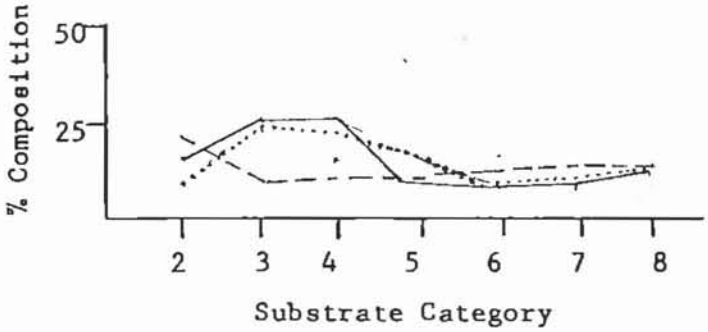
Site 1: above the West Fork

Riffle/run



Site 1: above the West Fork

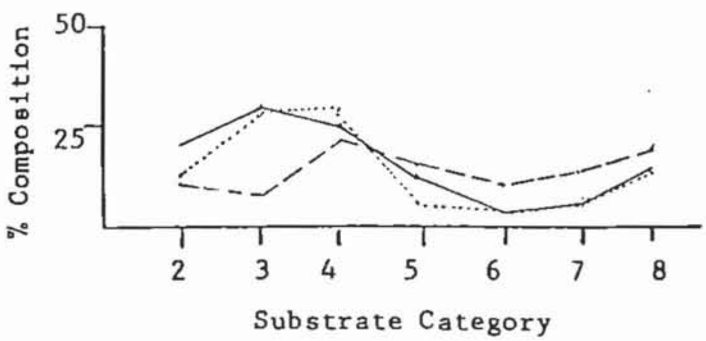
Riffle/run



Site 2: above ford

Riffle/run 1981

Riffle/run/pool 1982-3

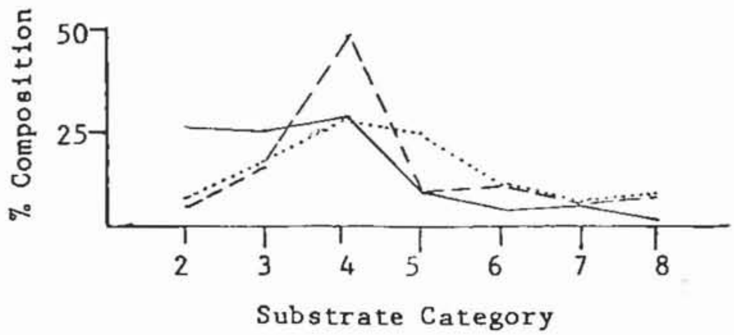


Site 2

Riffle/run 1981

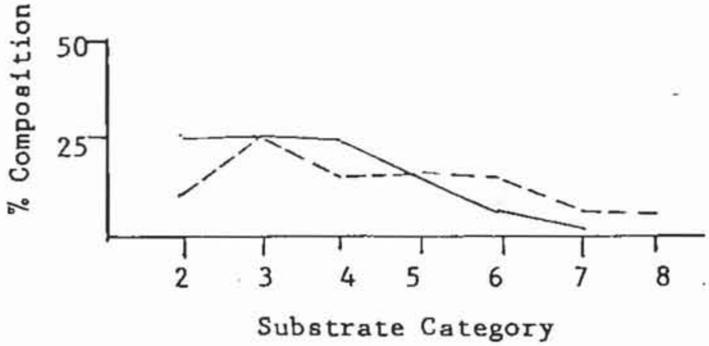
Riffle/run/pool 1982-3

LIDDELL CREEK SUBSTRATE CONDITIONS: RIFFLES



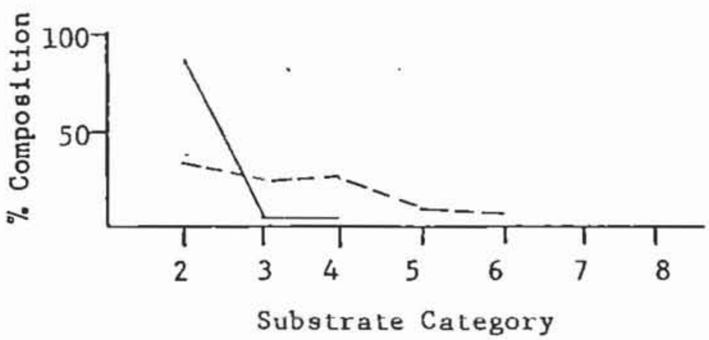
Site 3: below "Middle" Fork

Riffle/run



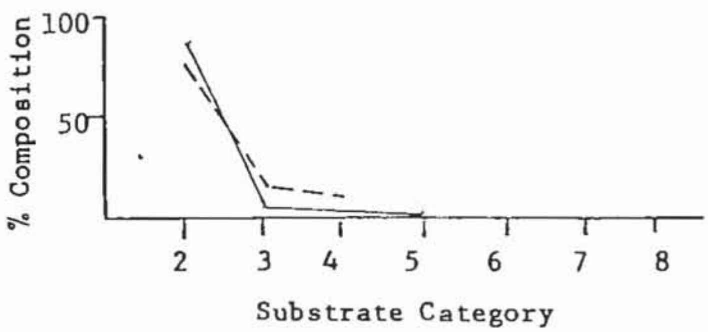
Site 4: above "Middle" Fork

Riffle



Site 5: Road Crossing

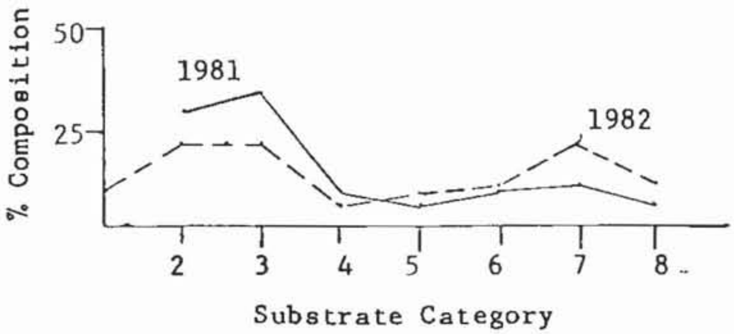
Riffle/run



Site 5

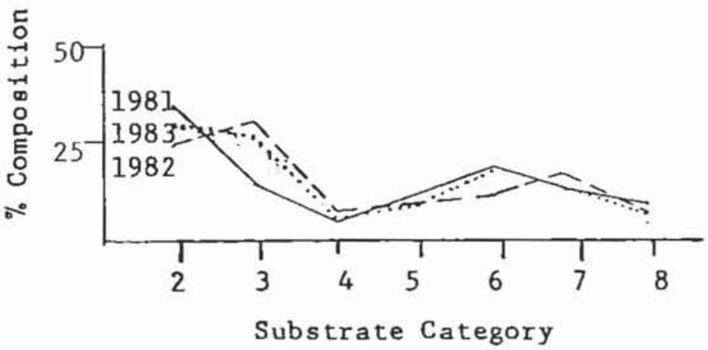
Riffle/run

SAN VICENTE CREEK SUBSTRATE CONDITIONS: POOLS



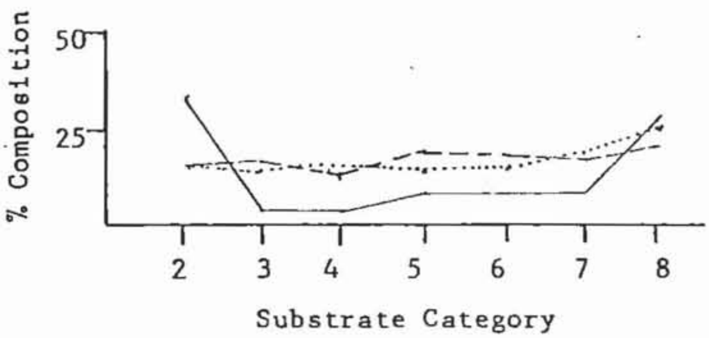
Site 4: 1st Bridge

Pool/run



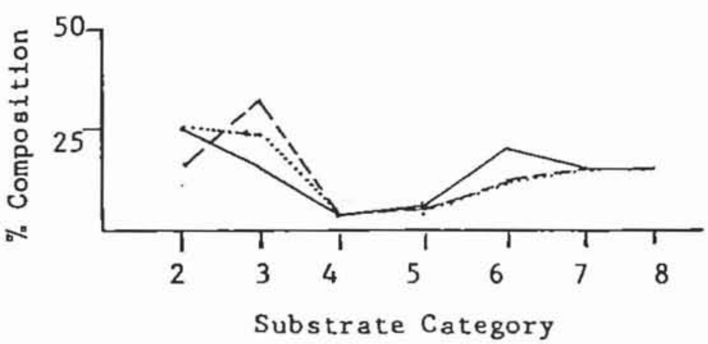
Site 6: below Mill Creek

Pool/run



Site 7: above Mill Creek

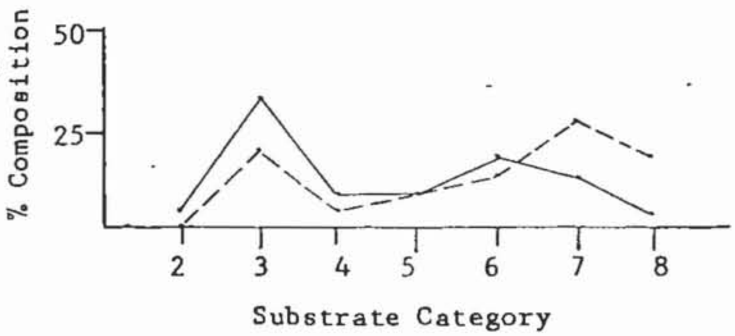
Pool 1981, Pool/run 1982, Pool/run 1983



Site 9: Mill Creek

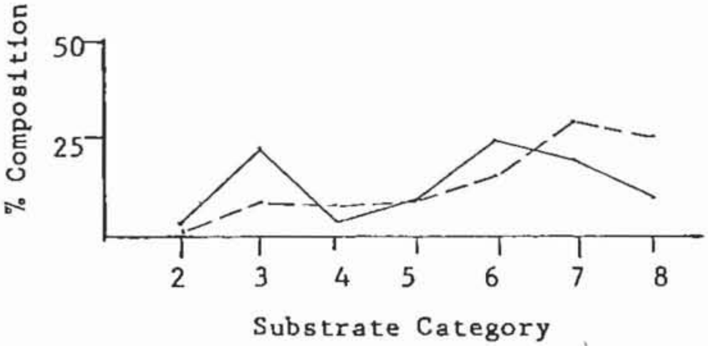
Shallow Pool/run

SAN VICENTE CREEK SUBSTRATE CONDITIONS: RIFFLES



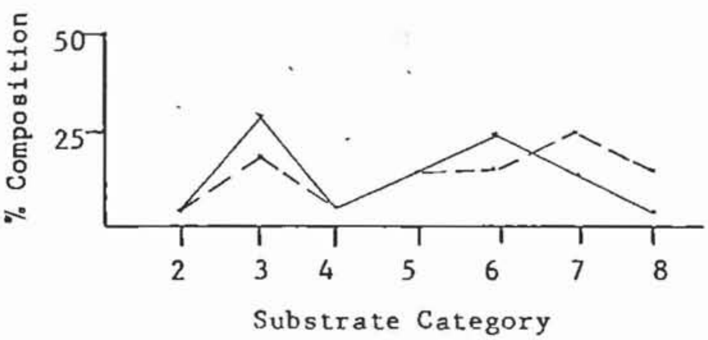
Site 3: @ Conveyor

Riffle/run 1981,
Riffle 1982



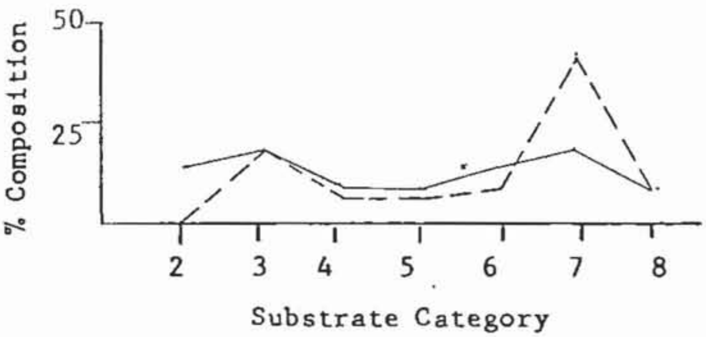
Site 4: 1st Bridge

Riffle/run 1981,
Riffle 1982



Site 5: 2nd Bridge

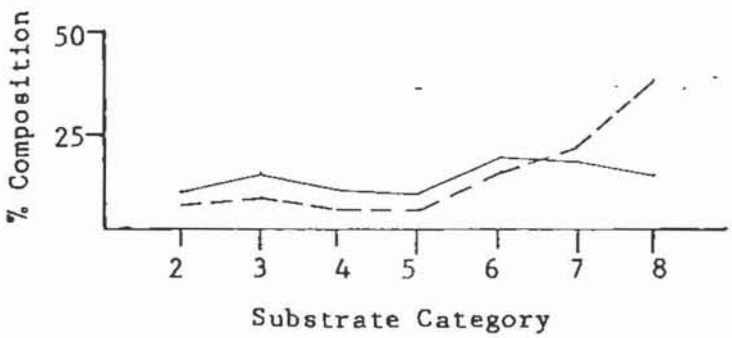
Riffle/run 1981,
Riffle 1982



Site 6: below Mill Creek

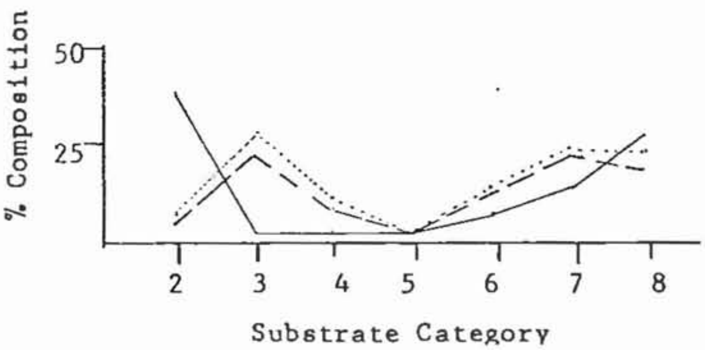
Riffle

SAN VICENTE CREEK SUBSTRATE CONDITIONS: RIFFLES



Site 7: above Mill Creek

Riffle/run



Site 9: Mill Creek

Riffle/run

Table 14. Barriers to fish migration on Liddell and East Liddell creeks.

ID #	Location and Description
B1	Located at channel mile 1 and slightly more than 0.1 mile upstream of a ford. Barrier is a log jam, formed in 1983, which creates a drop of about 2 1/2 feet. A relatively deep (2 foot) pool has formed below the jam, which allows migrating fish to successfully jump the barrier. The barrier may force fish to make several jump attempts but should not block upstream access during winter flows, except possibly in very dry years.
B2	Located at about channel mile 1.15 and about 100 yards downstream of the Middle Fork. In 1983 a large landslide blocked the road which parallels Liddell and carried seven douglas firs into the stream channel below the road. The trees do not presently completely block the channel, but their many branches are likely to catch log debris this winter and create a large, solid logjam. The channel downstream of the Middle Fork is narrow and steep-sided; a large logjam was present in 1982 immediately above the present landslide, but it washed out in 1983.
B3	Located at about channel mile 1.7. Barrier is a 2 foot high drop into a 2 foot high, narrow chute cut into limestone bedrock. The pool below is about 1 1/2 deep at low water, but because of the narrow channel, depth would increase sharply at higher flows. Upstream access requires high flows (10-15 CFS) sufficient to raise the pool level so the fish can clear the barrier with a 2 1/2 foot to 3 foot jump. Except at very high flows (25 CFS) the barrier is probably a major problem for migrating fish; multiple attempts are probably required.
B4	Located at about channel mile 1.76. Barrier is a 4 1/2 foot drop over limestone bedrock directly into a 2 foot deep pool. At higher flows, a large log at the tail of the pool would cause the pool depth to increase sharply. At flows of about 10 CFS or more, the jump required should be reduced to about 3 1/2 feet, and the barrier should be passable to some fish. At 20 CFS most fish should be able to pass (although multiple attempts are probably required).
B5	Located at about channel mile 1.8. First noticed in 1983, this barrier is a partial log jam with a 5 foot, multi-stepped drop, which stretches over 15-20 feet of stream. The barrier presently appears passable at about 5 CFS, but will likely worsen.
B6	Located at about channel mile 2.1 and immediately upstream of gaging station 4. Barrier is a drop of approximately 5 feet over limestone bedrock into a shallow (1 to 1 1/2 foot) pool. Barrier may be passable at very high flows, but channel is narrow above and offers limited rearing and spawning potential.

Table 15. Barriers to fish migration on San Vicente and Mill creeks.

ID #	Location and Description
B1	Located on San Vicente Creek at lower boundary of Lonestar property (channel mile 0.7) Barrier is a seasonal earth dam with culvert, used for water diversion. When the dam is in place it is a complete barrier to upstream fish migration. It is removed prior to, or washed out by, the first large winter storm.
B2	Located at channel mile 2.45 on San Vicente Creek, about .1 mile downstream of the mouth of Mill Creek. Barrier is a concrete-walled basin, in mid channel, with a 70 foot concrete apron downstream. The stream flowed around the barrier on the west side in 1981, allowing fish passage. In 1982, undercutting of the west side bank and road riprap caused the bank to slump and block the channel, forcing the streamflow over the 4 foot high walls of the concrete structure. Passage requirements under those conditions were estimated to be flows of at least 50-70 CFS. Channel on the west side was recut through riprap in 1983 and migrating fish should have been able to pass (probably with multiple attempts) at flows above 15 cfs.
B3	Located at about channel mile 3 on San Vicente Creek. Vertical tunnel under abandoned limestone quarry is an absolute barrier to upstream migration.
B4	Located at about channel mile 0.2 on Mill Creek. Barrier is a multi-stepped landslide and log jam, with a total height of 12 to 15 feet. Individual drops exceed 5 feet. The barrier completely blocks upstream migration.
B5	Located at about channel mile 0.45 on Mill Creek. The abandoned diversion dam on Mill Creek is 10 feet high and silted in behind; it is a complete barrier to upstream fish migration.
B6	Located at about channel mile 0.7 on Mill Creek. The present diversion dam on Mill Creek would be a complete barrier to upstream fish migration.

Table 16. Sediment Sources on Liddell and East Liddell creeks (1983). See Figure 7 for locations.

ID #	Location and Description
SS1	Located at channel mile 0.7. Bend in stream has eroded 2 foot deep by 5 foot notch in road. Bank is 9 feet high.
SS2	Located at about channel mile 1.15 and about 100 yards downstream of the Middle Fork. In 1983 a landslide 125 feet wide blocked the road and carried sediment and trees (barrier B2) into the stream channel 75 feet below. Hillside above is steep and is likely to slump again when slide is removed.
SS3	Immediately downstream of Middle Fork. 20 foot long by 8 foot wide section of road washed away in 1983. Stream occupies former road site.
SS4	Located at channel mile 1.25. Stream ford to cleared landing on east side of stream. Road and landing reseeded to grass, with little apparent erosion. Extensive logging on steep hillside to the east of the stream. No slash debris in the stream. Substrate conditions about the same as in 1982; no obvious evidence of erosion into stream.
SS5	Located at channel Mile 1.3. Road pullout for logging operation. Reseeded to grass. No evidence of erosion into stream.
SS6	Located at channel mile 1.4. Limited logging along west side of road.
SS7	Located at channel mile 1.45. Small landslide partially blocking road in 1983.
SS8	Located at channel mile 1.50. Limited logging along west side of road.
SS9	Located at channel mile 1.6. Logging along road.
SS10	Located at channel mile 1.7. Logging road and large clearcut on west side of main road. Road reseeded to grass, but logging road and main road gullied.
SS11	Located at channel mile 1.77. Logging road and large clearcut on west side of main road. Although reseeded to grass, logging road is gullied and gully extends across main road. Gully is undercutting redwood clone along stream. Fine sediment dominates streambed above and below, but less granitic gravels are present below the erosion source.

Table 16 (continued).

SS12	Located at channel mile 1.8. Logging and road on west side of main road. Reseeded to grass but some gully erosion present.
SS13	Located at channel mile 1.9. 20 foot long by 8 foot wide notch eroded into road. slump angle in notch is about 45 degrees; notch is 7 feet deep.

TABLE 17. Estimated effects of Spring # 1 diversions upon yearling steelhead rearing capacity of Liddell Creek.

AVERAGE YEAR (1981)

Location	Min Oct 1981 Flow	Rearing Index	Flow Without Diversion	Rearing Index	Percent Rearing Reduction
Below Upper Road Xing	.09CFS	0.7	.49CFS	1.3	45
Above Middle Fork	.12	1.1	.52	1.9	40
Below Middle Fork	.12	0.5	.52	1.3	65
Above Ford	.12	0.15	.52	1.05	85
Above West Fork	.14	0.4	.54	1.3	65
Mean	.12	0.6	.52	1.4	58

WET YEAR (1982)

Location	Min Sept 1982 Flow	Rearing Index	Flow Without Diversion	Rearing Index	Percent Rearing Reduction
Below Upper Road Xing	.73	1.75	1.37	2.6	30
Above Middle Fork	.81	2.5	1.45	3.4	25
Below Middle Fork	.84	1.9	1.48	2.8	30
Above Ford	.84	1.6	1.48	2.8	45
Above West Fork	1.17	2.1	1.81	3.0	30
Mean	.88	2.0	1.52	2.9	31

TABLE 18. Estimated effects of San Vicente and Mill Creek diversions upon yearling steelhead rearing capacity of San Vicente and Mill creeks.

AVERAGE YEAR (1981)

Location	Min Oct 1981 Flow	Rearing Index	Flow Without Diversion	Rearing Index	Percent Rearing Reduction
Mill Creek	.15CFS	0.6	0.44CFS	0.7	17
Above Mill Creek	.68	2.7	1.46	3.1	13
Below Mill Creek	.87	1.6	1.94	2.15	26
Below 2nd Bridge	.92	1.25	1.99	1.9	35
Above 1st Bridge	.98	1.85	2.05	2.35	27
At Conveyor	.98	2.15	2.05	2.65	19
Mean	.76	1.7	1.66	2.2	20

WET YEAR (1982)

Location	Min Sept 1982 Flow	Rearing Index	Flow Without Diversion	Rearing Index	Percent Rearing Reduction
Mill Creek	0.45	0.8	0.78	1.0	20
Above Mill Creek	1.70	3.15	2.45	3.45	9
Below Mill Creek	2.15	2.25	3.23	2.75	18
Below 2nd Bridge	2.24	2.0	3.32	2.5	20
Above 1st Bridge	2.50	2.5	3.58	2.8	11
At Conveyor	2.70	3.0	3.78	3.35	10
Mean	1.96	2.3	2.86	2.6	14

TABLE 19. Estimated effects of proposed Spring # 2 diversions upon yearling steelhead rearing capacity of Liddell Creek.

AVERAGE YEAR (1981)

Location	Min Oct 1981 Flow	Rearing Index	Flow w/Proposed Diversion	Rearing Index	Percent Rearing Reduction
Below Upper Road Xing	.09CFS	0.7	.04CFS	0.62	12
Above Middle Fork	.12	1.1	.07	1.05	5
Below Middle Fork	.12	0.5	.07	0.43	14
Above Ford	.12	0.15	.07	0.06	60
Above West Fork	.14	0.4	.09	0.35	12
Mean	.12	0.6	.07	0.5	15

WET YEAR (1982)

Location	Min Sept 1982 Flow	Rearing Index	Flow w/Proposed Diversion	Rearing Index	Percent Rearing Reduction
Below Upper Road Xing	0.73	1.75	0.33	1.1	37
Above Middle Fork	.81	2.5	.41	1.5	40
Below Middle Fork	.84	1.9	.44	1.1	42
Above Ford	.84	1.6	.44	0.8	50
Above West Fork	1.17	2.1	.77	1.6	24
Mean	0.88	2.0	0.48	1.2	38

Table 20. Estimated extent of habitat improvement (depth increase) on Liddell Creek necessary to mitigate the proposed summer diversion.

AVERAGE YEAR (1981)

Mean Stream Depth	Changes Required to Mitigate 15% Streamflow Reduction: % Depth Increase	% of Stream Modified
0.30 feet	-- (present condition*)	--
.45	50	20
.75	150	10
1.35	350	5
2.25	650	3.5

WET YEAR (1982)

Mean Stream Depth	Changes Required to Mitigate 38% Streamflow Reduction: % Depth Increase	% of Stream Modified
.45	-- (present condition*)	--
.75	67	40
1.35	200	20
2.25	400	10

*Present condition: no streambed modification, and no additional diversion.