**D. W. KELLEY** & Associates aquatic biology

# THE FEASIBILITY OF INCREASING FISH POPULATIONS IN LAGUNITAS CREEK BY PLACING BOULDERS AND LOGS IN THE CREEK CHANNEL

Prepared for the

Marin County Resource Conservation District

Point Reyes Station, California

by

D. W. Kelley & Associates

November 1989

• P.O. **BOX** 634 • NEWCASTLE. CA 95658 • [916] 1663-2535

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

# THE FEASIBILITY OF INCREASING FISH POPULATIONS IN LAGUNITAS CREEK BY PLACING BOULDERS AND LOGS IN THE CREEK CHANNEL

## INTRODUCTION AND SUMMARY

On July 8, 1986, biologists David H. Dettman and William T. Mitchell of D. W. Kelley & Associates, William Cox of the California Department of Fish and Game, Landon Waggoner of the Department of Parks and Recreation, and Liza Prunuske of Prunuske-Chatham, selected 12 sites for the possible placement of large boulders in the Lagunitas Creek channel between Samuel P. Taylor State Park headquarters and the Shafter Bridge. This is a broad, aggraded reach with limited water deep enough for the rearing of steelhead beyond their first summer and for coho salmon juveniles during their first summer. Michael E. Bird of the California Department of Fish and Game recommended that log structures also be tested. Six sites were subsequently treated four with clusters of boulders and two with logs.

Such "stream improvement" has been popular for more than 50 years in the East and North Central United States, where the seasonal changes in flows are much less and the channels more stable. In the West, this approach has always been controversial. The Lagunitas Creek project was strictly experimental and our objective was to evaluate its results.

Lagunitas Creek is an important salmon and steelhead stream. It supports small runs of a few hundred spawning coho salmon and steelhead trout each fall and winter. Eggs are buried in the gravel of the stream bottom where they incubate and hatch in late winter and spring. In many years there are large losses of eggs or fry because of high scour in the soft bottom. Some of the surviving juveniles emigrate to Tomales Bay during their first spring, but the evidence from studies on other streams suggests that these do not survive well in the saltwater environment and contribute little or nothing to the subsequent adult runs.

The magnitude of adult coho runs depends upon the survival of coho salmon that remain in the stream, feeding and growing throughout their first summer and the following winter to emigrate the following spring. Increasing the pool-like habitat used by these small coho is important.

Because the steelhead spawn later in the winter or even in the early spring, their nests are less subjected to destruction by high winter flows that scour. There are nearly always large populations of young-of-the-year steelhead in

Lagunitas Creek throughout the first summer. Some of those steelhead that survive the first summer and their first winter emigrate to Tomales Bay the following spring. But many remain in Lagunitas Creek throughout their second summer and winter to emigrate as yearling fish 5-7 inches long. The survival of these yearlings in the ocean is much greater, and the deeper water habitat needed by these larger fish is lacking in Lagunitas Creek.

The project was intended to provide deeper water with some cover, as habitat for these young-of-the-year coho and the yearling or older steelhead.

We found that this effort to improve habitat in Lagunitas Creek has so far not succeeded. The boulder clusters probably caused scour of the soft, sandy bottom and created deeper water during storms, but those storms also move a large amount of sand and small gravel along the bottom. As the storm declines and flows decrease, this sand simply fills in the holes created by the boulders. The logs also accomplished nothing.

Unless evaluation after a wet winter demonstrates much improvement, we do not recommend further attempts of this kind of stream improvement in Lagunitas Creek. We believe that the answer to improving habitat there lies primarily in watershed and streambank erosion control to reduce the amount of sand in the stream bottom. Trees that naturally fall into the stream should be left, but the placement of boulders or logs in the stream channel is not likely to provide more habitat so long as the substrate is so soft and mobile.

## TREATMENT OF SITES

On October 31, 1986, under the supervision of Prunuske-Chatham, three clusters of four or five 3- to 4-foot diameter boulders were placed in long, shallow riffles of finer substrate that provide no habitat for yearling or older steelhead, young-of-the-year coho, and very little for even young-of-the-year steelhead. These sites offered the greatest likelihood of achieving net scour around the boulders. Ward and Slaney (1979) tested the effectiveness of different boulder cluster designs in the Ceogh River on Vancouver Island, BC, and found that groupings of boulders in a triangular configuration along a riffle or very shallow run resulted in the highest standing populations of juvenile steelhead trout and coho salmon.

A single redwood log was chained to the bank in each of two sites to provide both deeper water through scour and overhead cover. The location of five treated and two control sites is described in Table 1.

Table 1 is missing from this
KRIS edition
of this document.
We are sorry for the inconvenience, and working
to rectify the problem.

## METHOD OF EVALUATION

Evaluating the success of stream improvement is very difficult to do well, especially in a stream whose principal value is to provide juvenile rearing habitat for salmon or steelhead. There are three large problems.

1. A measurement of the fish population before treatment with one after treatment is misleading because it assumes that the reach was equally well seeded with fry or young juveniles both before and after the project. In Lagunitas Creek the numbers of spawners vary greatly from year to year, and in some years most of the eggs and fry are washed away during high winter storms. Equal seeding of the habitat cannot be assumed and, because of that, measurement of fish population is not a valid way to evaluate.

2. Changes in the stream channel which occur during winter flows may be unrelated to the structures themselves. The two control sites were included to help here.

3. A structure placed in the stream may cause the beneficial scouring of sand from the stream bottom immediately under it but may cause sand deposition with detrimental results upstream or downstream.

Our approach to evaluation was to (a) define physical conditions that we believe necessary for rearing juvenile coho throughout their first summer and for rearing steelhead through their second summer, (b) to measure the amount of habitat fitting this criteria in a 50-ft reach of creek whose center was the planted boulders or log before the treatment and again after the improvement devices had been in place and subjected to winter flows. The 1986 pretreatment measurements were made at a flow of 7.3 cfs and the 1989 post treatment measurements at a flow of 8.1 cfs. Flows of at least 200 cfs are needed to cause substantial bedload movement in Lagunitas Creek and such flows occurred for only 5 days during the winter of 1986-87 (Table 2), never in 1987-88 (Table 3), and for 5 days during the winter of 1988-89 (Table 4). Evaluation in the future, after a winter of higher flows sustained for a longer time, may be desirable.

## MEASUREMENT OF PHYSICAL CONDITIONS

Physical condition relevant to habitat was measured in each 50-foot reach whose center was the boulder clusters or the log. A reference chain marked at 5-foot intervals was strung tightly between end stakes along each side of the stream. At right angles to this chain, transects were established across the stream at the zero, 15, 20, 25, 30, and 50-foot markers with the zero foot mark located at the downstream end of the section. Beginning at the right bank (looking downstream) we recorded the presence of cover in the form of overhanging vegetation and

Table 2.
Mean daily Lagunitas Creek streamflow in cubic feet per second at USGS Samuel P. Taylor State Park gage; water year October 1986 to September 1987.

| DAY | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.9 | 5.0 | 4.6 | 9.1 | 22.0 | 10.0 | 12.0 | 7.9 | 6.1 | 8.2 | 5.7 | 5.6 |
| 2 | 4.7 | 4.9 | 4.6 | 9.4 | 81.0 | 10.0 | 11.0 | 8.9 | 6.1 | 7.8 | 5.5 | 5.6 |
| 3 | 4.6 | 4.9 | 4.6 | 54.0 | 55.0 | 10.0 | 11.0 | 8.6 | 6.5 | 6.9 | 5.3 | 5.6 |
| 4 | 4.6 | 4.9 | 5.1 | 24.0 | 28.0 | 11.0 | 11.0 | 8.6 | 6.1 | 6.7 | 5.3 | 5.6 |
| 5 | 4.6 | 4.9 | 7.0 | 15.0 | 19.0 | 139.0 | 9.9 | 8.6 | 5.8 | 6.7 | 5.3 | 5.6 |
| 6 | 4.6 | 4.9 | 5.5 | 15.0 | 15.0 | 67.0 | 9.5 | 8.6 | 5.6 | 6.7 | 5.3 | 5.9 |
| 7 | 4.6 | 4.9 | 5.2 | 17.0 | 13.0 | 41.0 | 9.0 | 8.6 | 5.7 | 6.6 | 5.3 | 6.3 |
| 8 | 4.6 | 4.9 | 5.0 | 16.0 | 12.0 | 31.0 | 8.3 | 8.6 | 5.8 | 6.3 | 5.3 | 6.1 |
| 9 | 4.6 | 4.9 | 4.9 | 15.0 | 10.0 | 24.0 | 8.3 | 8.6 | 5.8 | 6.1 | 5.5 | 5.9 |
| 10 | 4.6 | 4.9 | 4.9 | 15.0 | 11.0 | 20.0 | 8.9 | 8.1 | 5.8 | 6.1 | 5.8 | 5.8 |
| 11 | 4.4 | 4.9 | 7.3 | 15.0 | 33.0 | 20.0 | 8.9 | 7.9 | 5.8 | 6.1 | 5.8 | 5.8 |
| 12 | 4.4 | 4.9 | 9.7 | 15.0 | 359.0 | 92.0 | 8.5 | 7.9 | 5.8 | 6.1 | 5.8 | 5.8 |
| 13 | 4.4 | 4.9 | 9.7 | 15.0 | 617.0 | 102.0 | 8.2 | 7.9 | 6.0 | 6.4 | 5.8 | 5.8 |
| 14 | 4.3 | 4.9 | 9.7 | 15.0 | 107.0 | 94.0 | 7.9 | 7.9 | 6.1 | 6.4 | 5.8 | 5.8 |
| 15 | 4.1 | 4.9 | 8.3 | 15.0 | 133.0 | 71.0 | 7.7 | 7.9 | 6.1 | 6.4 | 5.8 | 5.8 |
| 16 | 3.8 | 4.9 | 6.4 | 16.0 | 68.0 | 50.0 | 7.8 | 7.7 | 6.1 | 6.4 | 5.8 | 5.8 |
| 17 | 3.8 | 4.6 | 6.4 | 15.0 | 46.0 | 39.0 | 8.2 | 7.3 | 6.1 | 6.2 | 5.8 | 5.6 |
| 18 | 3.8 | 4.4 | 8.3 | 14.0 | 35.0 | 32.0 | 8.2 | 7.2 | 6.1 | 5.5 | 6.0 | 5.6 |
| 19 | 4.0 | 4.4 | 8.7 | 14.0 | 27.0 | 27.0 | 7.9 | 6.9 | 6.1 | 5.3 | 5.8 | 5.6 |
| 20 | 4.2 | 4.4 | 8.7 | 14.0 | 22.0 | 23.0 | 7.9 | 6.9 | 6.4 | 5.3 | 5.8 | 5.5 |
| 21 | 4.1 | 4.6 | 6.9 | 14.0 | 19.0 | 35.0 | 7.9 | 7.0 | 6.4 | 5.3 | 5.8 | 5.3 |
| 22 | 4.0 | 4.6 | 8.9 | 14.0 | 17.0 | 26.0 | 7.6 | 6.9 | 6.4 | 5.3 | 5.8 | 5.2 |
| 23 | 4.0 | 4.6 | 8.3 | 17.0 | 15.0 | 30.0 | 7.5 | 6.5 | 6.4 | 5.0 | 5.8 | 5.1 |
| 24 | 4.0 | 4.6 | 7.1 | 76.0 | 14.0 | 26.0 | 7.3 | 6.1 | 6.4 | 4.9 | 5.8 | 5.1 |
| 25 | 4.0 | 4.6 | 6.8 | 42.0 | 13.0 | 23.0 | 7.3 | 6.1 | 6.5 | 4.9 | 5.8 | 5.1 |
| 26 | 4.0 | 4.6 | 6.7 | 28.0 | 11.0 | 21.0 | 6.8 | 6.1 | 6.7 | 4.8 | 5.8 | 5.0 |
| 27 | 4.0 | 4.6 | 6.7 | 34.0 | 10.0 | 18.0 | 6.7 | 6.1 | 6.7 | 4.9 | 5.8 | 4.8 |
| 28 | 4.1 | 4.6 | 6.5 | 59.0 | 10.0 | 17.0 | 6.7 | 6.1 | 6.9 | 5.2 | 5.8 | 4.9 |
| 29 | 4.6 | 4.6 | 6.4 | 26.0 | — | 15.0 | 6.7 | 6.4 | 8.4 | 6.3 | 5.7 | 4.9 |
| 30 | 5.1 | 4.6 | 6.4 | 43.0 | — | 14.0 | 7.2 | 6.4 | 8.4 | 5.8 | 5.6 | 4.7 |
| 31 | 5.1 | — | 6.8 | 29.0 | — | 13.0 | — | 6.1 | — | 5.8 | 5.6 | — |

MONTHLY MEAN CFS

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.3 | 4.6 | 6.8 | 23.2 | 58.8 | 37.1 | 8.1 | 7.4 | 6.1 | 6.0 | 5.7 | 6.0 |

Table 3.
Mean daily Lagunitas Creek streamflow in cubic feet per second at USGS Samuel P. Taylor State Park gage; water year October 1987 to September 1988.

| DAY | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.9 | 5.8 | 37.0 | 26.0 | 17.0 | 15.0 | 12.0 | 12.0 | 8.0 | 7.0 | 5.5 | 5.0 |
| 2 | 4.9 | 5.8 | 76.0 | 23.0 | 16.0 | 15.0 | 12.0 | 12.0 | 8.0 | 7.0 | 5.4 | 5.0 |
| 3 | 4.9 | 5.8 | 34.0 | 109.0 | 16.0 | 15.0 | 12.0 | 12.0 | 8.0 | 7.0 | 5.4 | 5.1 |
| 4 | 4.9 | 5.8 | 33.0 | 477.0 | 16.0 | 15.0 | 12.0 | 12.0 | 8.0 | 6.9 | 5.4 | 5.0 |
| 5 | 4.9 | 5.8 | 38.0 | 180.0 | 16.0 | 15.0 | 12.0 | 12.0 | 8.0 | 6.8 | 5.4 | 5.0 |
| 6 | 4.9 | 5.8 | 132.0 | 84.0 | 16.0 | 15.0 | 12.0 | 13.0 | 8.4 | 6.9 | 5.5 | 5.0 |
| 7 | 5.0 | 5.9 | 49.0 | 59.0 | 16.0 | 15.0 | 12.0 | 14.0 | 9.4 | 6.7 | 5.4 | 5.0 |
| 8 | 5.3 | 6.1 | 215.0 | 50.0 | 15.0 | 15.0 | 12.0 | 13.0 | 8.9 | 6.5 | 6.1 | 5.0 |
| 9 | 5.3 | 6.7 | 227.0 | 39.0 | 15.0 | 14.0 | 12.0 | 13.0 | 8.8 | 6.5 | 5.4 | 5.2 |
| 10 | 5.5 | 6.7 | 121.0 | 38.0 | 15.0 | 14.0 | 12.0 | 13.0 | 8.8 | 6.5 | 5.2 | 5.2 |
| 11 | 5.8 | 6.5 | 58.0 | 61.0 | 15.0 | 14.0 | 12.0 | 13.0 | 8.7 | 6.5 | 5.5 | 5.2 |
| 12 | 5.8 | 6.4 | 36.0 | 46.0 | 15.0 | 14.0 | 12.0 | 13.0 | 8.6 | 6.5 | 5.6 | 5.1 |
| 13 | 5.8 | 9.3 | 25.0 | 37.0 | 15.0 | 14.0 | 12.0 | 13.0 | 8.6 | 6.3 | 5.5 | 5.0 |
| 14 | 5.8 | 7.4 | 20.0 | 31.0 | 14.0 | 14.0 | 12.0 | 13.0 | 8.6 | 6.6 | 5.4 | 5.0 |
| 15 | 5.9 | 6.5 | 20.0 | 60.0 | 14.0 | 13.0 | 12.0 | 12.0 | 8.6 | 7.5 | 5.4 | 4.9 |
| 16 | 6.0 | 6.3 | 56.0 | 103.0 | 15.0 | 13.0 | 12.0 | 11.0 | 8.6 | 7.5 | 5.3 | 4.8 |
| 17 | 5.8 | 12.0 | 73.0 | 206.0 | 16.0 | 13.0 | 12.0 | 9.6 | 8.4 | 7.5 | 5.2 | 5.0 |
| 18 | 5.6 | 8.4 | 40.0 | 103.0 | 16.0 | 13.0 | 12.0 | 9.4 | 7.5 | 7.5 | 5.2 | 5.0 |
| 19 | 5.6 | 5.9 | 29.0 | 63.0 | 16.0 | 13.0 | 19.0 | 9.3 | 7.2 | 7.7 | 5.2 | 5.0 |
| 20 | 5.6 | 9.3 | 23.0 | 45.0 | 16.0 | 13.0 | 16.0 | 9.0 | 7.2 | 7.5 | 5.5 | 5.1 |
| 21 | 5.6 | 9.1 | 20.0 | 35.0 | 16.0 | 13.0 | 13.0 | 8.8 | 7.2 | 7.3 | 5.5 | 5.0 |
| 22 | 5.6 | 7.2 | 18.0 | 28.0 | 16.0 | 13.0 | 13.0 | 8.8 | 7.2 | 6.5 | 5.4 | 5.1 |
| 23 | 5.7 | 6.8 | 18.0 | 24.0 | 16.0 | 13.0 | 14.0 | 8.8 | 7.1 | 6.3 | 5.4 | 5.2 |
| 24 | 5.8 | 6.4 | 20.0 | 21.0 | 15.0 | 13.0 | 13.0 | 8.8 | 7.0 | 6.3 | 5.3 | 5.2 |
| 25 | 5.8 | 6.1 | 19.0 | 19.0 | 15.0 | 13.0 | 13.0 | 8.7 | 7.0 | 6.2 | 5.4 | 5.3 |
| 26 | 5.7 | 6.1 | 18.0 | 18.0 | 15.0 | 13.0 | 13.0 | 8.6 | 6.9 | 6.3 | 5.4 | 5.1 |
| 27 | 5.9 | 6.1 | 19.0 | 16.0 | 15.0 | 13.0 | 13.0 | 8.6 | 6.8 | 6.4 | 5.4 | 5.0 |
| 28 | 8.4 | 6.1 | 90.0 | 15.0 | 17.0 | 13.0 | 13.0 | 8.7 | 6.8 | 5.5 | 5.4 | 5.0 |
| 29 | 6.6 | 6.0 | 98.0 | 24.0 | 16.0 | 12.0 | 13.0 | 8.9 | 6.8 | 5.3 | 6.3 | 5.0 |
| 30 | 6.0 | 40.0 | 47.0 | 21.0 | — | 12.0 | 12.0 | 8.4 | 7.0 | 5.2 | 6.9 | 5.0 |
| 31 | 5.8 | — | 33.0 | 18.0 | — | 12.0 | — | 8.0 | — | 5.2 | 4.4 | — |

MONTHLY MEAN CFS

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.65 | 7.94 | 56.20 | 67.10 | 15.60 | 13.60 | 12.70 | 10.80 | 7.87 | 6.63 | 5.46 | 5.05 |

Table 4.
Mean daily Lagunitas Creek streamflow in cubic feet per second at USGS Samuel P. Taylor State Park gage; water year October 1988 to June 1989.

| DAY | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 5.6 | 17.0 | 34.0 | 11.0 | 11.0 | 25.0 | 10.0 | 7.9 |
| 2 | 5.0 | 6.8 | 18.0 | 26.0 | 11.0 | 405.0 | 23.0 | 10.0 | 7.8 |
| 3 | 5.0 | 7.3 | 18.0 | 21.0 | 12.0 | 98.0 | 21.0 | 11.0 | 7.8 |
| 4 | 5.0 | 6.9 | 18.0 | 18.0 | 13.0 | 53.0 | 19.0 | 11.0 | 7.8 |
| 5 | 5.0 | 6.7 | 18.0 | 83.0 | 11.0 | 43.0 | 17.0 | 11.0 | 8.3 |
| 6 | 5.0 | 6.5 | 18.0 | 43.0 | 14.0 | 57.0 | 16.0 | 11.0 | 8.0 |
| 7 | 5.2 | 6.5 | 18.0 | 30.0 | 11.0 | 40.0 | 15.0 | 11.0 | 8.0 |
| 8 | 5.2 | 6.4 | 17.0 | 22.0 | 12.0 | 42.0 | 14.0 | 12.0 | 7.8 |
| 9 | 5.2 | 6.5 | 17.0 | 20.0 | 21.0 | 96.0 | 13.0 | 13.0 | 7.8 |
| 10 | 5.2 | 11.0 | 18.0 | 18.0 | 16.0 | 264.0 | 13.0 | 13.0 | 7.8 |
| 11 | 5.8 | 7.5 | 17.0 | 18.0 | 14.0 | 337.0 | 13.0 | 13.0 | 7.8 |
| 12 | 5.6 | 7.1 | 17.0 | 18.0 | 13.0 | 103.0 | 12.0 | 13.0 | 7.8 |
| 13 | 5.8 | 9.7 | 17.0 | 18.0 | 12.0 | 61.0 | 12.0 | 13.0 | 7.7 |
| 14 | 6.4 | 9.0 | 17.0 | 18.0 | 11.0 | 42.0 | 12.0 | 13.0 | 7.5 |
| 15 | 5.8 | 8.2 | 17.0 | 18.0 | 11.0 | 33.0 | 11.0 | 12.0 | 7.5 |
| 16 | 5.5 | 10.0 | 17.0 | 18.0 | 11.0 | 49.0 | 11.0 | 11.0 | 7.5 |
| 17 | 5.4 | 11.0 | 16.0 | 18.0 | 11.0 | 42.0 | 11.0 | 10.0 | 7.4 |
| 18 | 5.3 | 9.8 | 16.0 | 19.0 | 11.0 | 146.0 | 11.0 | 9.5 | 7.2 |
| 19 | 5.2 | 9.9 | 17.0 | 20.0 | 12.0 | 142.0 | 11.0 | 9.4 | 7.2 |
| 20 | 5.2 | 9.9 | 36.0 | 21.0 | 11.0 | 81.0 | 10.0 | 9.4 | 7.2 |
| 21 | 5.2 | 10.0 | 35.0 | 21.0 | 11.0 | 55.0 | 10.0 | 9.4 | 7.2 |
| 22 | 5.2 | 24.0 | 140.0 | 21.0 | 12.0 | 41.0 | 10.0 | 8.6 | 7.0 |
| 23 | 5.4 | 34.0 | 41.0 | 28.0 | 12.0 | 60.0 | 14.0 | 7.9 | 7.2 |
| 24 | 5.4 | 18.0 | 72.0 | 17.0 | 12.0 | 273.0 | 12.0 | 7.8 | 7.8 |
| 25 | 5.4 | 26.0 | 47.0 | 14.0 | 13.0 | 379.0 | 17.0 | 7.7 | 7.8 |
| 26 | 5.4 | 18.0 | 26.0 | 14.0 | 13.0 | 146.0 | 13.0 | 7.6 | 7.8 |
| 27 | 5.4 | 16.0 | 25.0 | 13.0 | 12.0 | 81.0 | 12.0 | 8.0 | — |
| 28 | 5.4 | 15.0 | 21.0 | 13.0 | 11.0 | 56.0 | 11.0 | 8.0 | — |
| 29 | 5.4 | 15.0 | 18.0 | 12.0 | — | 42.0 | 11.0 | 8.0 | — |
| 30 | 5.4 | 15.0 | 30.0 | 12.0 | — | 34.0 | 10.0 | 8.0 | — |
| 31 | 5.4 | — | 60.0 | 11.0 | — | 28.0 | — | 8.0 | — |

MONTHLY MEAN CFS

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN |
|---|---|---|---|---|---|---|---|---|
| 5.35 | 13.4 | 28.4 | 21.8 | 12.3 | 108.0 | 13.7 | 10.2 | — |

undercut bank or "roughness" associated with bedrock or boulders on the bottom. Measurements of depth, mean column velocity, substrate composition, and cobble embeddedness were then taken at 3-, 5-, or 6-foot intervals along the measuring tape depending upon the homogeneity of the habitat. Photographs were taken at each site. The substrate composition and the degree to which cobble was embedded was measured as a fraction of the height of the cobble buried in the stream bottom.

These measurements were first made on July 9-11, 1986 before the boulders and logs were installed. In September 1987, they were made for the second time on a limited number of transects. We found that no significant changes had occurred and requested an extension of our contract until after a wetter winter. The winter of 1987 was even drier, and we requested a further extension. Five days of modestly high flows occurred in March of 1989 and, on July 18 and 19, 1989, we remeasured the physical characteristics of the stream along the original transects established in 1986.

## FISH POPULATIONS

An attempt was made to measure the fish populations of each reach in late October 1987, and again in mid-July of 1989. Each 50-ft reach was segregated with small-mesh block nets and subject to repeated passes of a Smith-Root backpack electrofishing unit. The success of such efforts depends upon catching diminishing numbers of fish in subsequent passes—and this requires a larger population than existed in either year. The populations of yearling or older steelhead and young-of-the-year coho in these reaches of poor habitat were always too small to estimate, except to say that there were only a few there. In 1989 when the numbers were somewhat higher, we captured only 11 yearling steelhead and 17 young-of-the-year coho in 2 days of electrofishing.

## EVALUATION CRITERIA

Work done on Lagunitas Creek over the years has made it clear to us and to biologists of the California Department of Fish and Game that the stream *is* deficient in the pool-type habitat utilized by coho juveniles during their first and only summer in the creek and by the juvenile steelhead during their second summer in the creek. There is plenty of the shallow habitat utilized by young-of-the-year steelhead during their first summer, and first summer populations of steelhead are usually reasonably high. The need is for deeper waters with cover, and the installation of boulders and logs with this project was designed to provide more of this deeper water.

### Definition of Yearling Steelhead Habitat

On the basis of underwater observations in the Carmel River, California, Dettman and Kelley (1986) developed a set of criteria that were subsequently validated and used to grade summer habitat for yearling steelhead. These criteria reflect their general observations that yearlings were nearly always utilizing areas of reduced current velocities behind boulders and submerged logs in water greater than or equal to 1.0 ft deep. Yearlings were most commonly associated with mean column water velocities from 0.6-2.0 ft/sec but typically held their position in currents between 0.6 and 1.0 ft/sec.

Similarly, Pearlstone (1976) observed in the Big Qualicum River, B.C. that most age I+ steelhead utilized greater than 1.0 ft and "focal point" velocities between 0.6 and 1.0 ft/sec. Yearlings were most often observed in areas with overhead cover in the form of logs and surface turbulence. Nickelson et al. (1979) developed a habitat model which explained 79% of the variation in standing crop of age I+ - III+ juvenile steelhead trout in four Oregon coastal streams. Cover, expressed as a combination of escape cover (e.g., undercut banks, rootwads, undercut boulders), overhanging cover, and surface turbulence, appeared to be the most important factor determining standing crop of juvenile steelhead. Depth and velocity were incorporated into Nickelson's model as a single factor based upon probability-of-use criteria developed by the Cooperative Instream Flow Service Group, US Fish and Wildlife Service. These criteria indicate that yearling and older steelhead are most frequently associated with depths between 1.0 ft and 6.0 ft and current velocities between 0.3 ft/sec and 1.6 ft/sec.

Biologist William Mitchell's underwater observations of yearling steelhead in Lagunitas Creek in July 1989 was consistent with the pattern of habitat utilization described in other streams.

For the evaluation of whether the steelhead habitat increased as a result of this project, we therefore define steelhead habitat as that water which is deeper than 1.0 ft, has a mean column velocity of between 0.6 - 2.0 ft/sec, and some overhead cover either in the form of logs, undercut bank, tree branches, or, if the depth is greater than 1.6 ft, some degree of surface turbulence (Table 5).

Coho Salmon Habitat

The importance of pools as rearing areas for juvenile coho salmon has been well documented (Ruggles 1966; Hartman 1965; Mason 1966). Ruggles (1966) demonstrated greatest coho smolt production in experimental stream channels with pool-like conditions (depth = 3.8 ft, mean water velocity = 0.1 ft/sec) versus channels with riffle-like (depth = 0.5 ft, mean water velocity = 1.2 ft/sec) and intermediate conditions (depth = 1.4 ft, mean water velocity = 0.6 ft/sec). Nickelson et al. (1979) found a strong correlation between standing crop of juvenile coho salmon and pool volume in small Oregon coastal streams. The amount of instream cover has also been shown to have a positive

Table 5.
Physical criteria used to define summer rearing habitat of juvenile steelhead trout (age I+) and coho salmon (age 0+).

| | STEELHEAD | COHO |
|---|---|---|
| DEPTH (ft) | >1.0 | >1.0 |
| MEAN COLUMN VELOCITY (ft/sec) | 0.6 - 2.0 | <0.5 |
| COVER | Overhead cover required (e.g., logs, surface turbulence) if depth <1.6 ft. | No cover requirement but if present, increases habitat quality. |

effect on coho numbers (Mason and Chapman 1965). Our own observations have been that juvenile coho are not common in habitat less than 1 ft deep or where mean column velocity is greater than 0.5 ft/sec.

For the evaluation of this project, we have described coho salmon habitat as that water which is deeper than 1.0 ft and has a mean column velocity less than 0.5 ft/sec. All water >1.0 ft deep is not, of course, coho habitat but that appears to be a key criteria for significant production.

## EVALUATION OF HABITAT CHANGES

According to this criteria, in the summer of 1986 none of the sites provided any habitat for yearling or older steelhead—which is why they were chosen (Table 6). By the summer of 1989 only one site had improved—and only very slightly. In 1986, there was a small amount of habitat for coho salmon in these sites, and in 1989 a slightly greater amount in two sites, one of which was a control without instream improvement devices. In the following pages the limited changes in depth or velocity in each of the sites are presented graphically. The shaded cells within the graphs represent measurements of total depth or mean column velocity along each of the transects. Darker shades represent deeper or faster water. Instream objects such as boulders, or dry areas, or gravel, or sandbars, within the channel are denoted by a letter. The photographs were taken during the physical measurements in 1989.

SITE 1 - Figure 1.

This reach was primarily occupied by a long riffle of gravel and well-embedded cobble (Table 7). None of it had the appropriate combination of depth, velocity, and overhead cover to qualify as yearling or older steelhead habitat, but 22.5 sqft along the right bank were judged to be suitable for coho salmon (Figures 2 and 3).

A redwood log was placed in the channel and cabled to the right bank in 1986 with the expectation that it would provide more cover and cause some scour to create deeper water. By 1989, this log had pivoted so that most of its length was outside the channel. The end of the log is visible on the left side of Figure 1 at the stream edge. In 1989 there was no significant yearling steelhead or coho habitat in this 50-ft section of stream.

Table 7.
Average cobble abundance (%) and embeddedness (%) at treatment and control sites on Lagunitas Creek, summer 1986 and 1989.

| | AVERAGE COBBLE ABUNDANCE | | AVERAGE COBBLE EMBEDDEDNESS | |
|---|---|---|---|---|
| SITE | 1986 | 1989 | 1986 | 1989 |
| 1 | 40 | 30 | 40 | 45 |
| 2 | 15 | 10 | 60 | 35 |
| 2 Control | 20 | 20 | 70 | 55 |
| 7 | 15 | 2 | 35 | 15 |
| 7 Control | 25 | 5 | 30 | 30 |
| 8 | 15 | 5 | 50 | 20 |
| 10 | 40 | 30 | 45 | 20 |

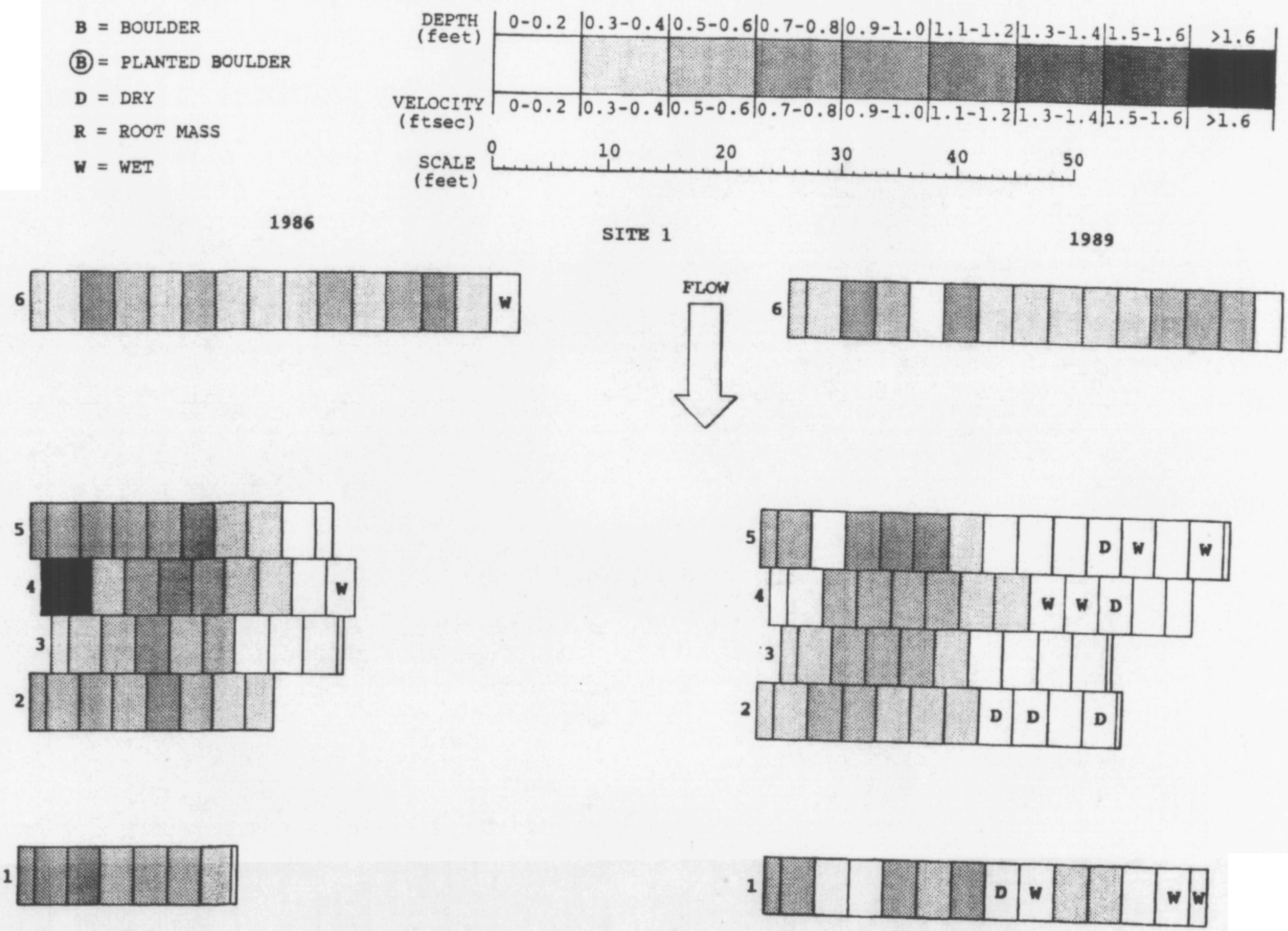



Figure 2. DEPTHS at Site 1 on Lagunitas Creek before (1986) and after (1989) treatment with log.

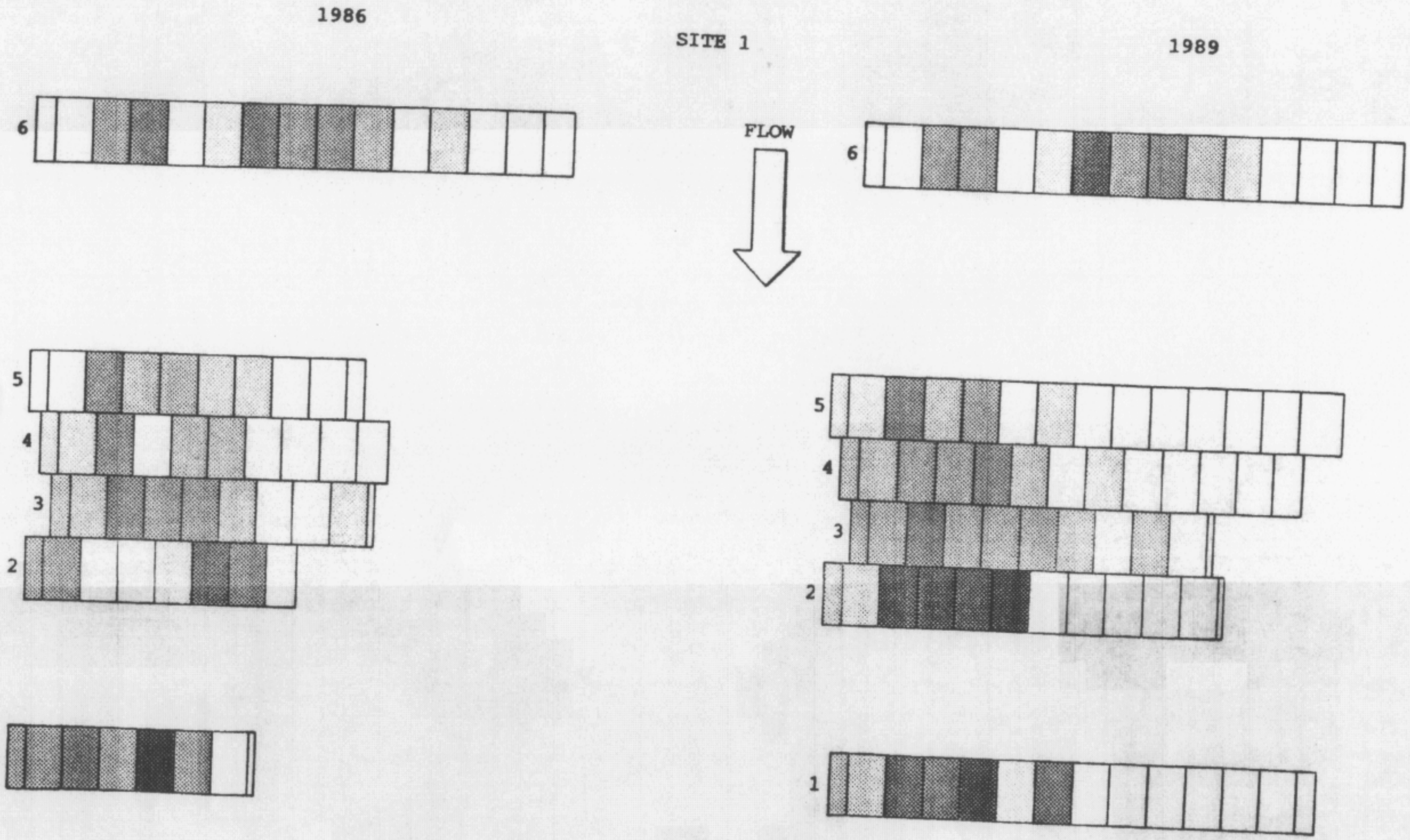



Figure 3. Mean column water VELOCITIES at Site 1 on Lagunitas Creek before (1986) and after (1989) treatment with log.

SITE 2 - Figure 4.

This broad, low gradient reach is pool-like. In 1986, nowhere in the reach were velocities high enough to qualify as yearling steelhead habitat, but nearly 42% of the 50-ft section was deep enough to qualify as coho habitat—although not of very high quality (Figures 5 and 6). A redwood log was cabled in place along the left bank in an attempt to provide more overhead cover and deeper water. In 1989 there was little change in the physical habitat associated with the log except for a small addition of overhead cover. The placement of the log in this part of the channel in an area of sand and gravel deposition proved to be of no value. The coho habitat was in deeper water near the other bank where some large natural boulders induce scour of the bottom.

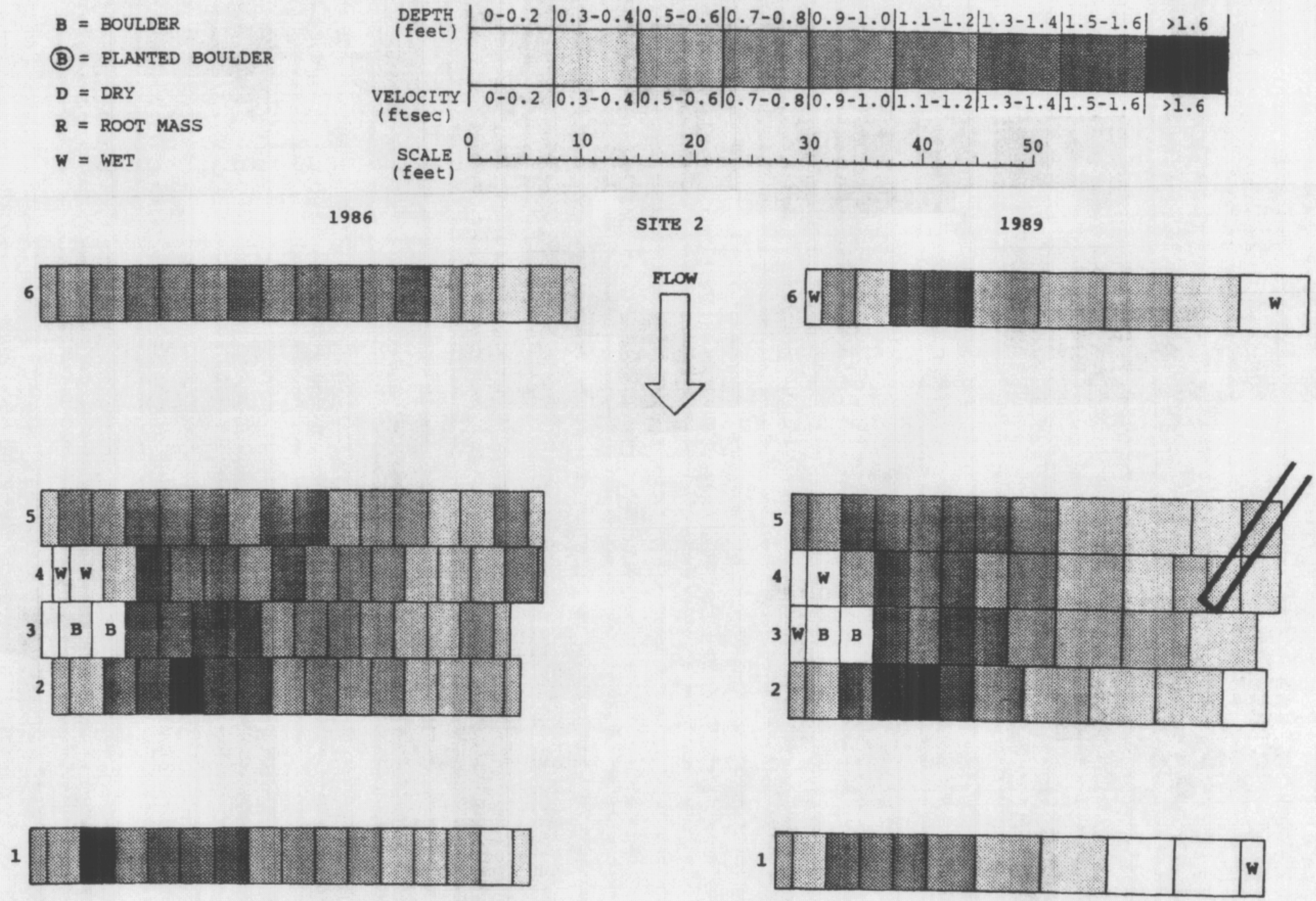



Figure 5. DEPTHS at Site 2 on Lagunitas Creek before (1986) and after (1989) treatment with log.

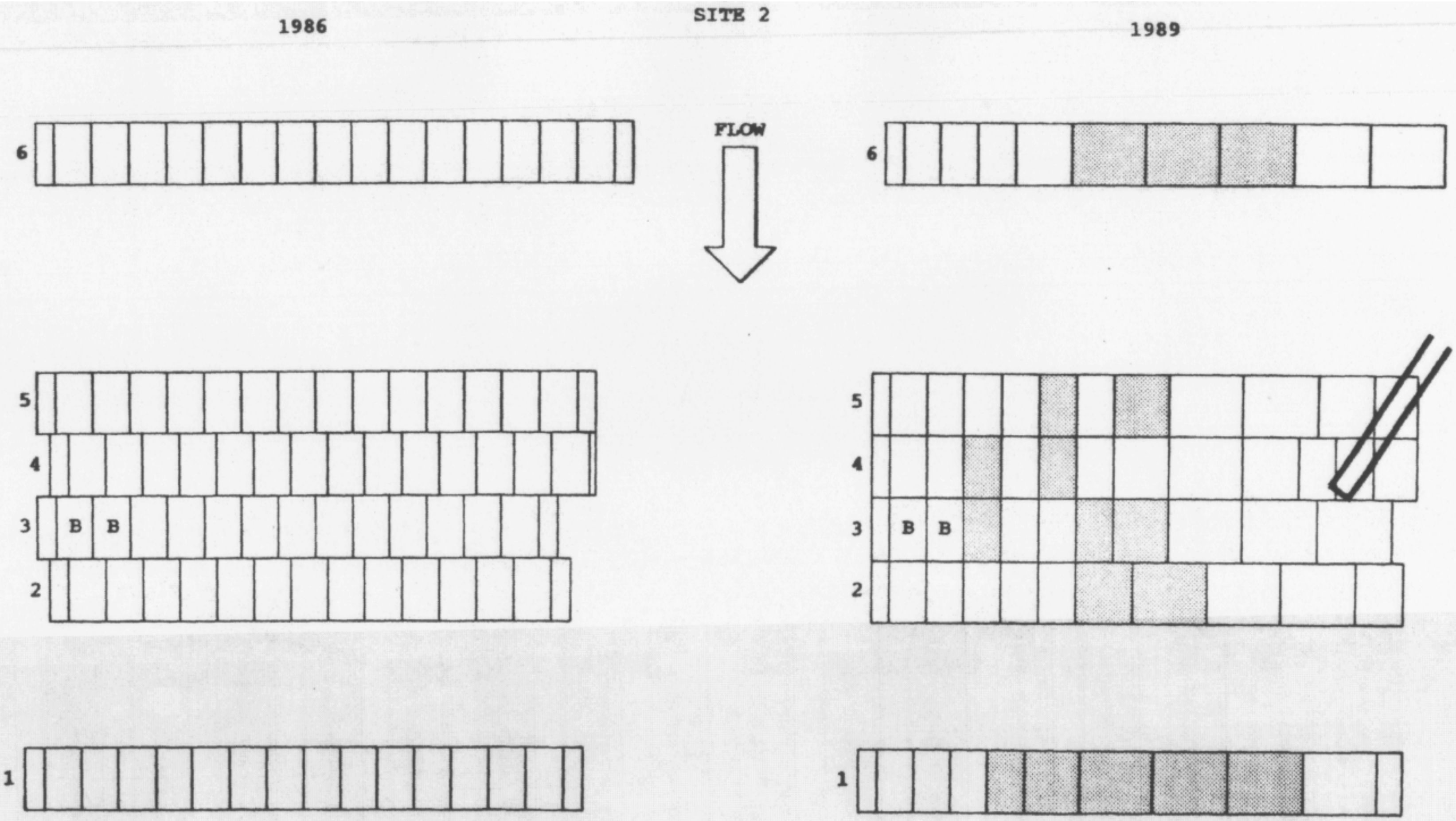



Figure 6. Mean column water VELOCITIES at Site 2 on Lagunitas Creek before (1986) and after (1989) treatment with log.

SITE 2 CONTROL - Figure 7.

Site 2 Control, located immediately upstream of Site 2 within the same pool, was similar in character to Site 2 except for being somewhat deeper and lacking the large boulders present along the right bank (Figures 8 and 9). Like Site 2, velocities were low and the bottom was composed largely of gravel and sand. Because of the low velocities, none of this site qualified as yearling or older steelhead habitat in either 1986 or 1989, but 50% of it qualified as coho habitat in 1986 and 49% in 1989. No major differences in depth or velocity characteristics were observed in the two summers.

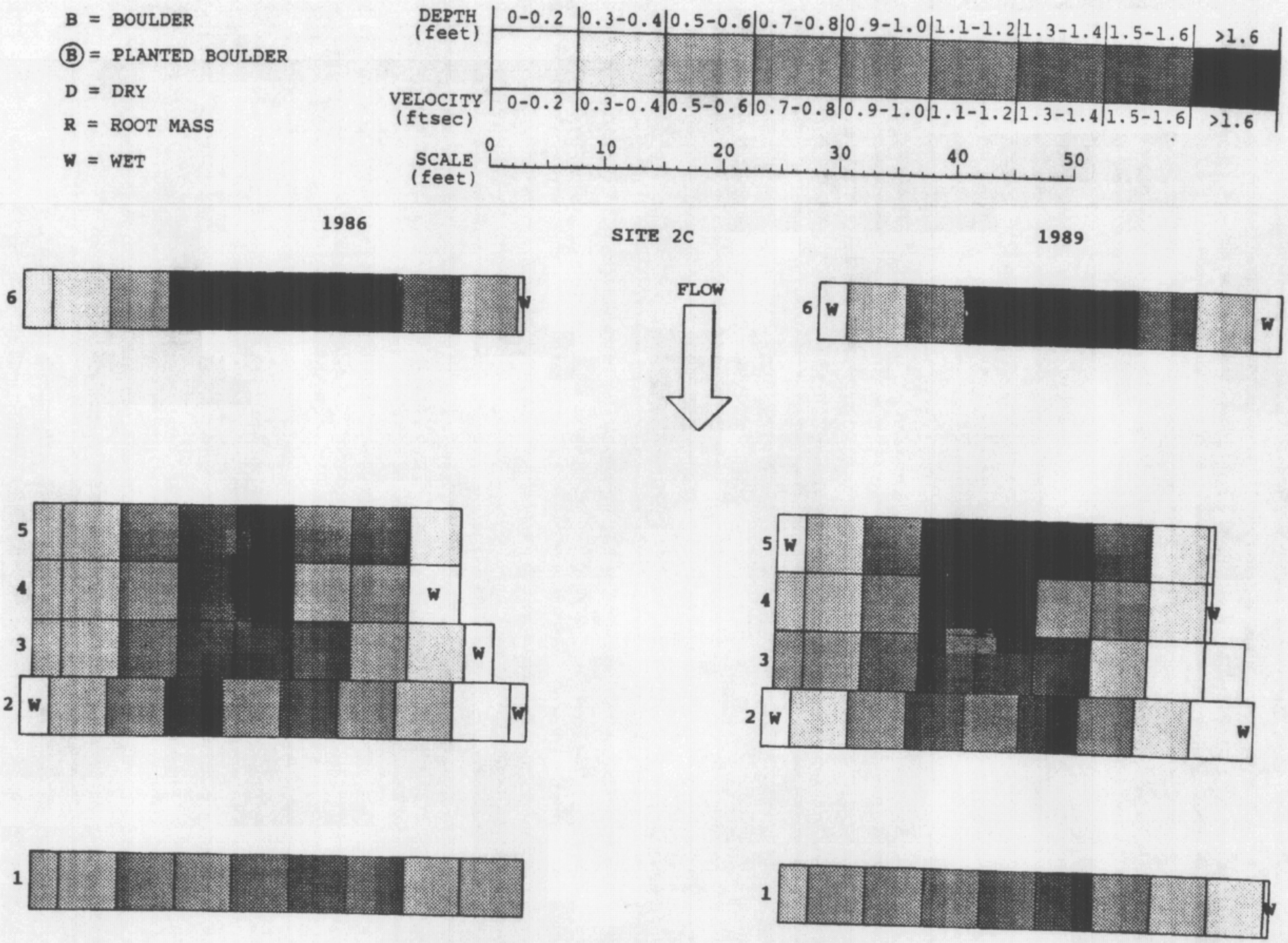



Figure 8. DEPTHS at Site 2C (control for Site 2) on Lagunitas Creek, July 1986 and 1989.

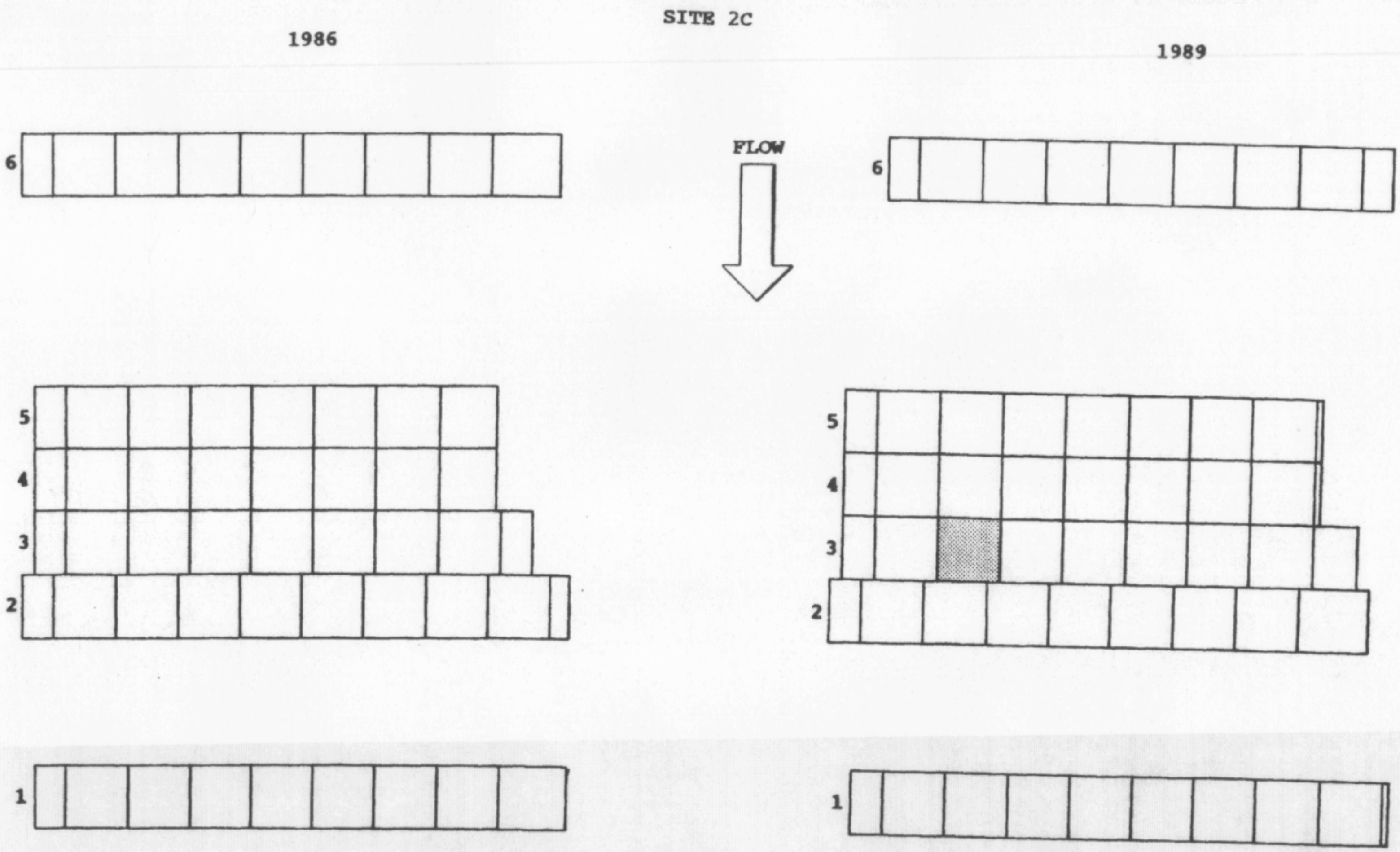



Figure 9. Mean column water VELOCITIES at Site 2C (control for Site 2) on Lagunitas Creek, July 1986 and 1989.

SITE 7 - Figure 10.

Site 7 is a sand and gravel bottom riffle. In 1986, only 15% of the bottom was covered with cobble. There was no habitat for yearling or older steelhead or for young-of-the-year coho. Five boulders 3-4 feet in diameter were placed in a V-shaped configuration pointing upstream. The boulders were 3-4 feet apart.

In 1989, depth adjacent to the boulders and along the right bank had roughly doubled (from 0.4 to 0.8 ft) with a maximum 1.3 ft (Figure 11). There was also a shift in the location of the faster velocities from the center of the channel to the right edge. Associated with the swifter water along the right bank in 1989 were greater depths in combination with an undercut bank and overhead cover in the form of roots.

The boulder cluster failed, however, to create the yearling or older steelhead habitat as defined by our criteria because the deeper water that was created lacked sufficient velocity (Figure 12). A very slight amount of coho habitat (45 sqft) was created.

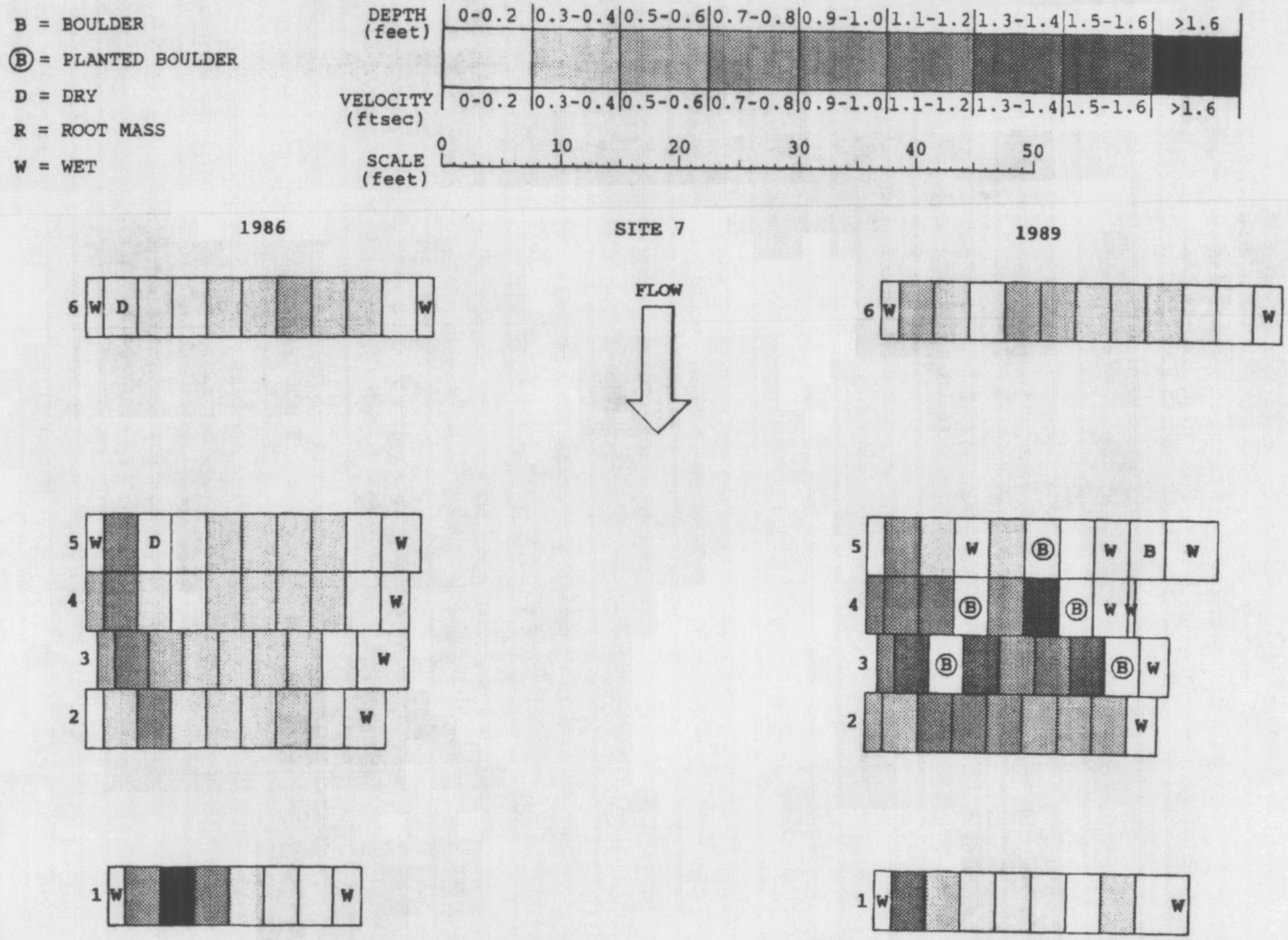



Figure 11. DEPTHS at Site 7 on Lagunitas Creek before (1986) and after (1989) treatment with boulder cluster.

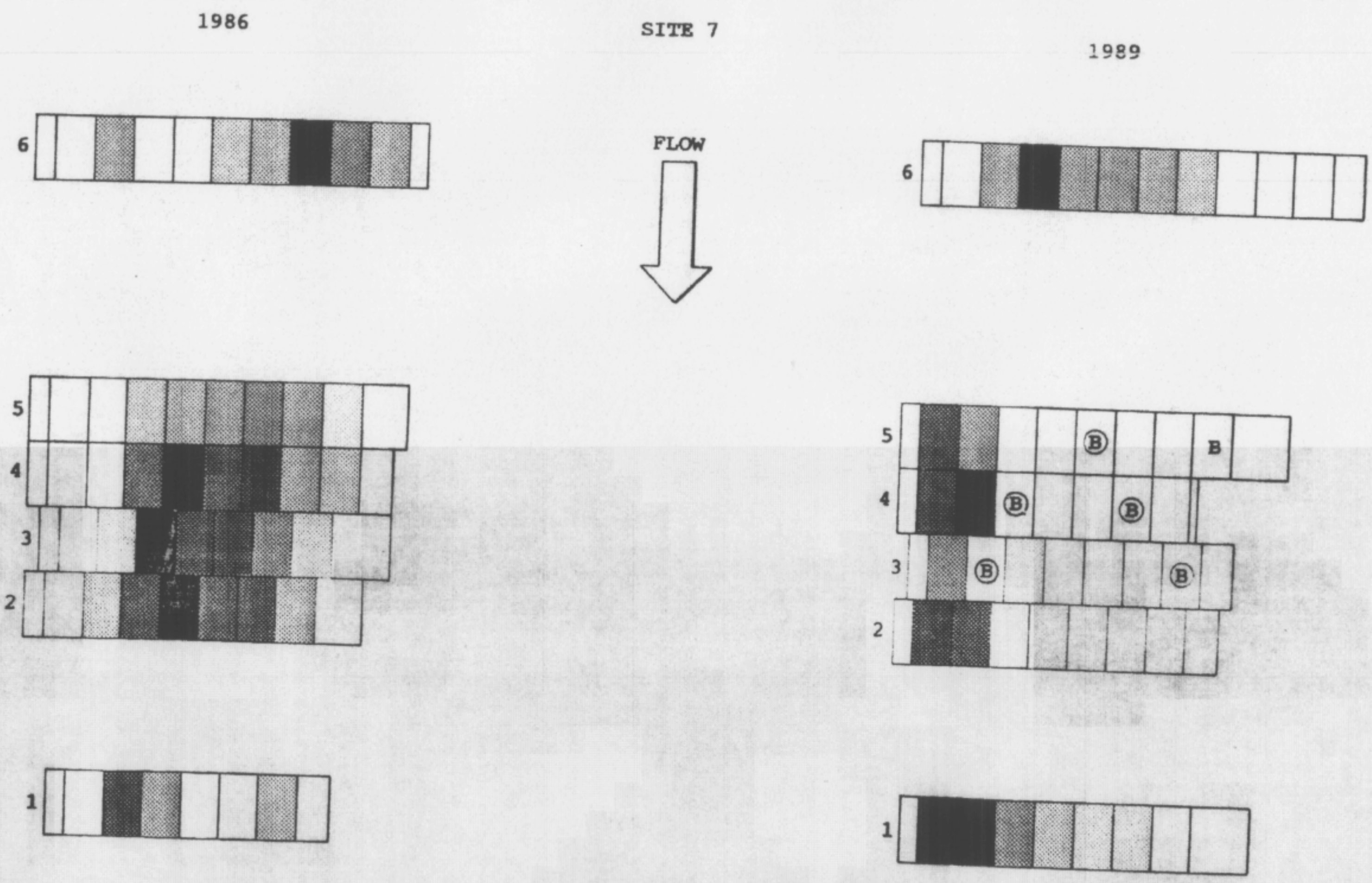
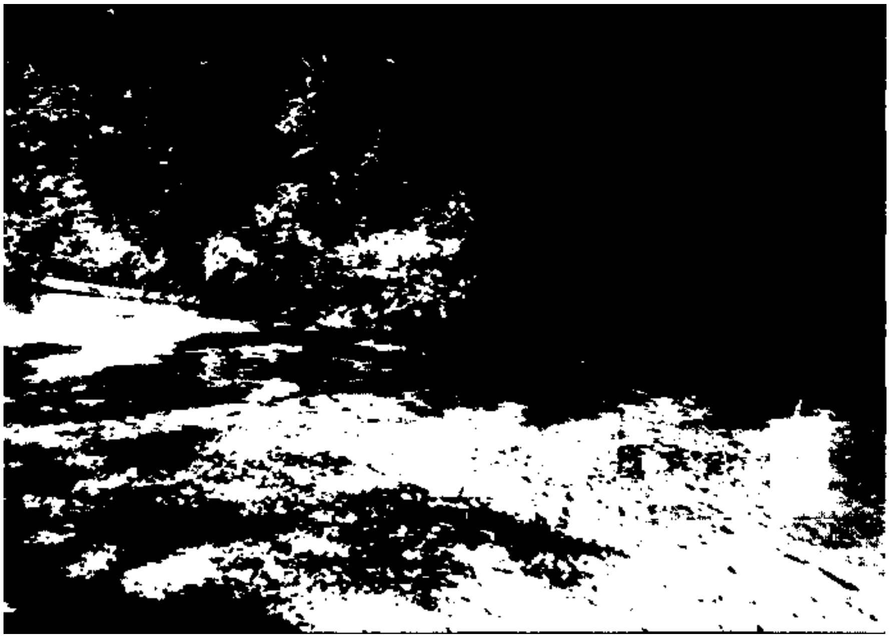



Figure 12. Mean column water VELOCITIES at Site 7 on Lagunitas Creek before (1986) and after (1989) treatment with boulder cluster.

SITE 7 CONTROL - Figure 13.



This control site was similar to Site 7 in 1986, except for a large uprooted alder lying along the right bank at the toe of the riffle. None of the habitat in Site 7C met the habitat criteria for yearling or older steelhead in 1986 or in 1989 (Figures 14 and 15). Nine percent of the reach met the criteria for juvenile coho habitat in 1986. By the summer of 1989, scour adjacent to the root-mass increased the depth there and the amount of coho habitat had doubled. Even so, the total habitat area was only 60 sqft.

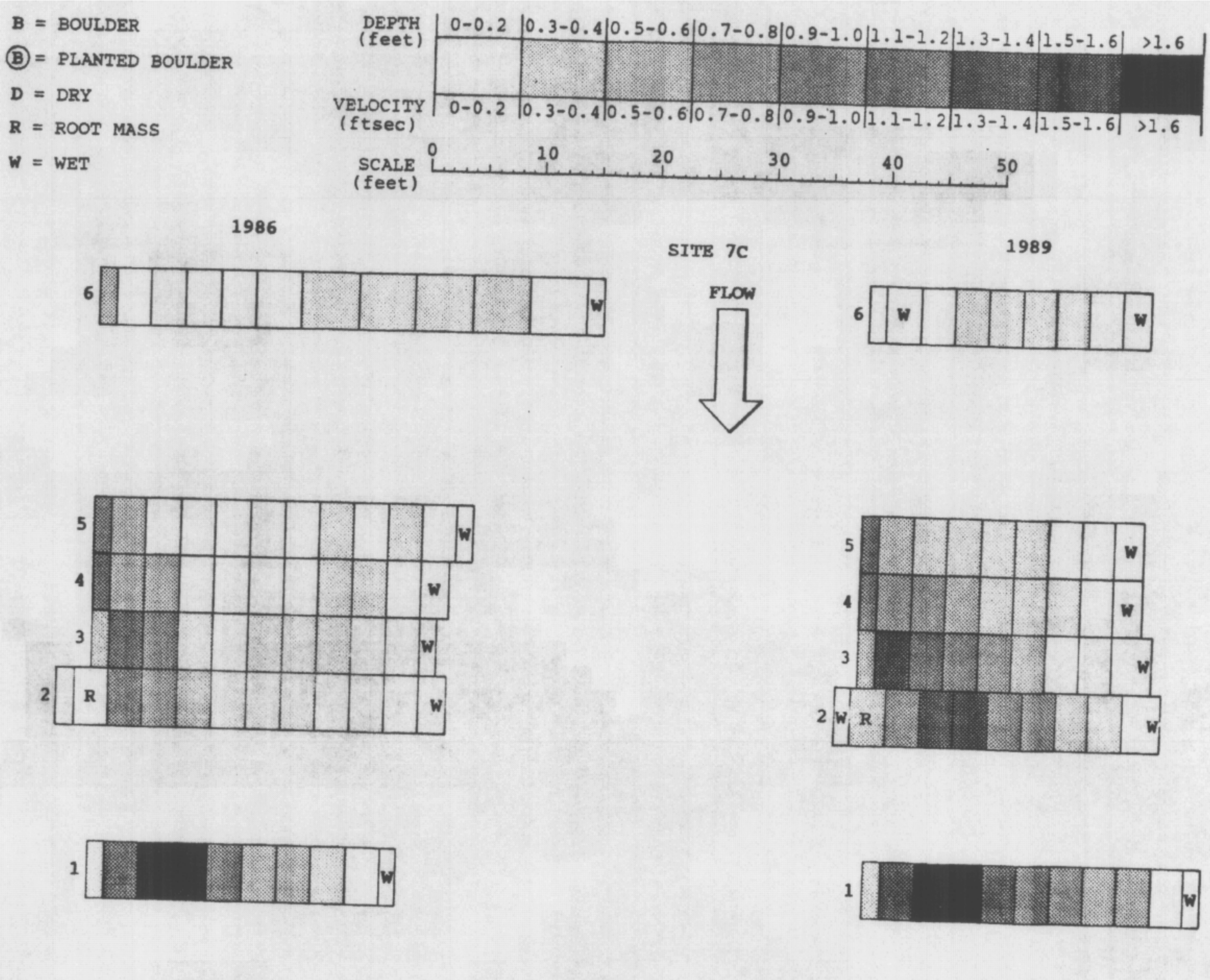



Figure 14. DEPTHS at Site 7C (control for Site 7) on Lagunitas Creek, July 1986 and 1989.

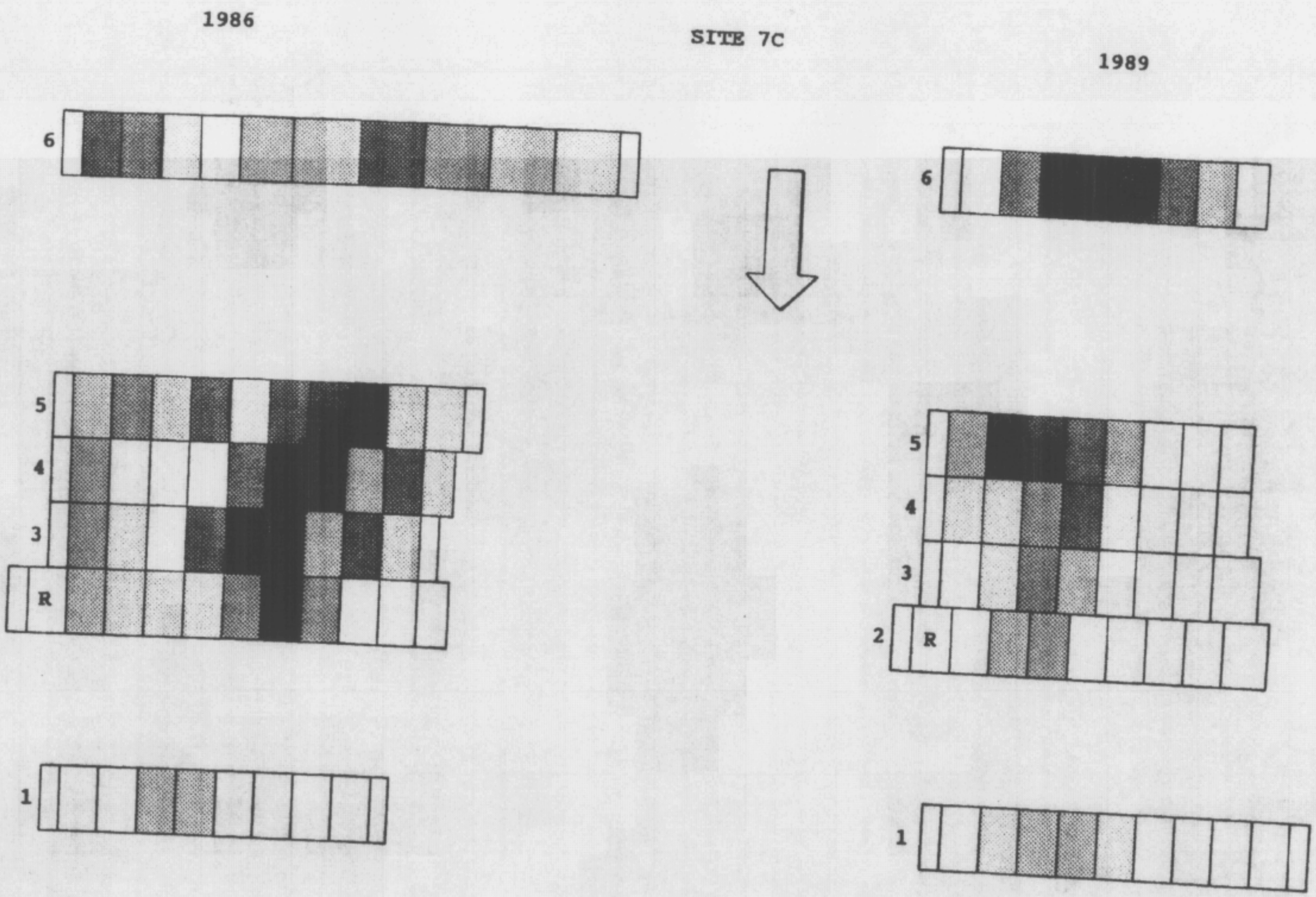



Figure 15. Mean column water VELOCITIES at Site 7C (control for Site 7) on Lagunitas Creek, July 1986 and 1989.

SITE 8 - Figure 16.

Site 8 was a shallow riffle with a sand and gravel bottom that provided no habitat for yearling steelhead or young-of-the-year coho in 1986. Five boulders were placed in the center of the channel in the V-shaped configuration with the apex pointing downstream (Figures 17 and 18). In 1989 the depths near the boulders had increased from an average of 0.3 ft to depths ranging from 0.6 to 1.0 ft. A gravel bar immediately upstream of the boulder cluster had expanded. Even with these changes in 1989, there was no significant amount of habitat in Site 8 for either yearling steelhead or young-of-the-year coho.

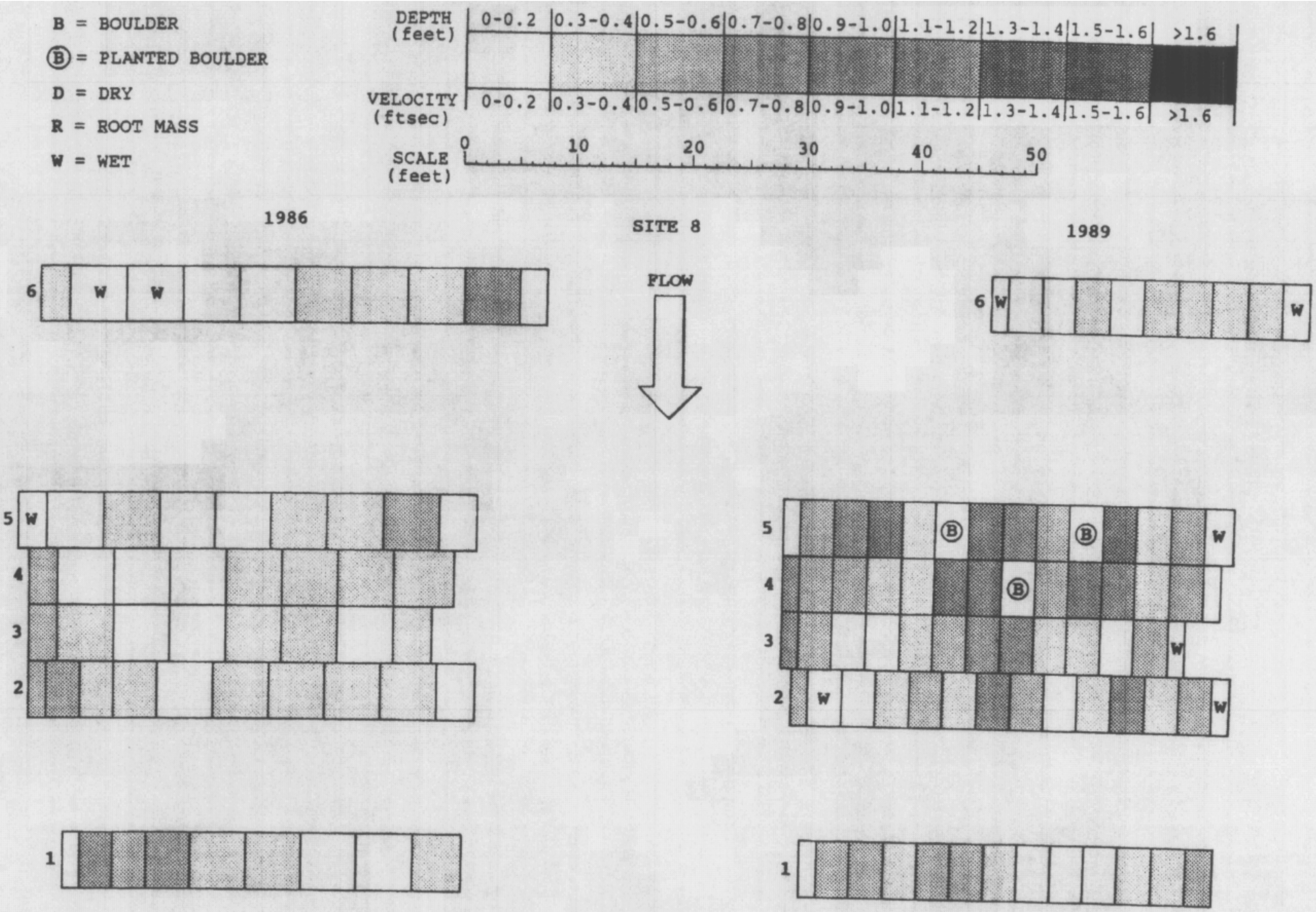



Figure 17. DEPTHS at Site 8 on Lagunitas Creek before (1986) and after (1989) treatment with boulder cluster.

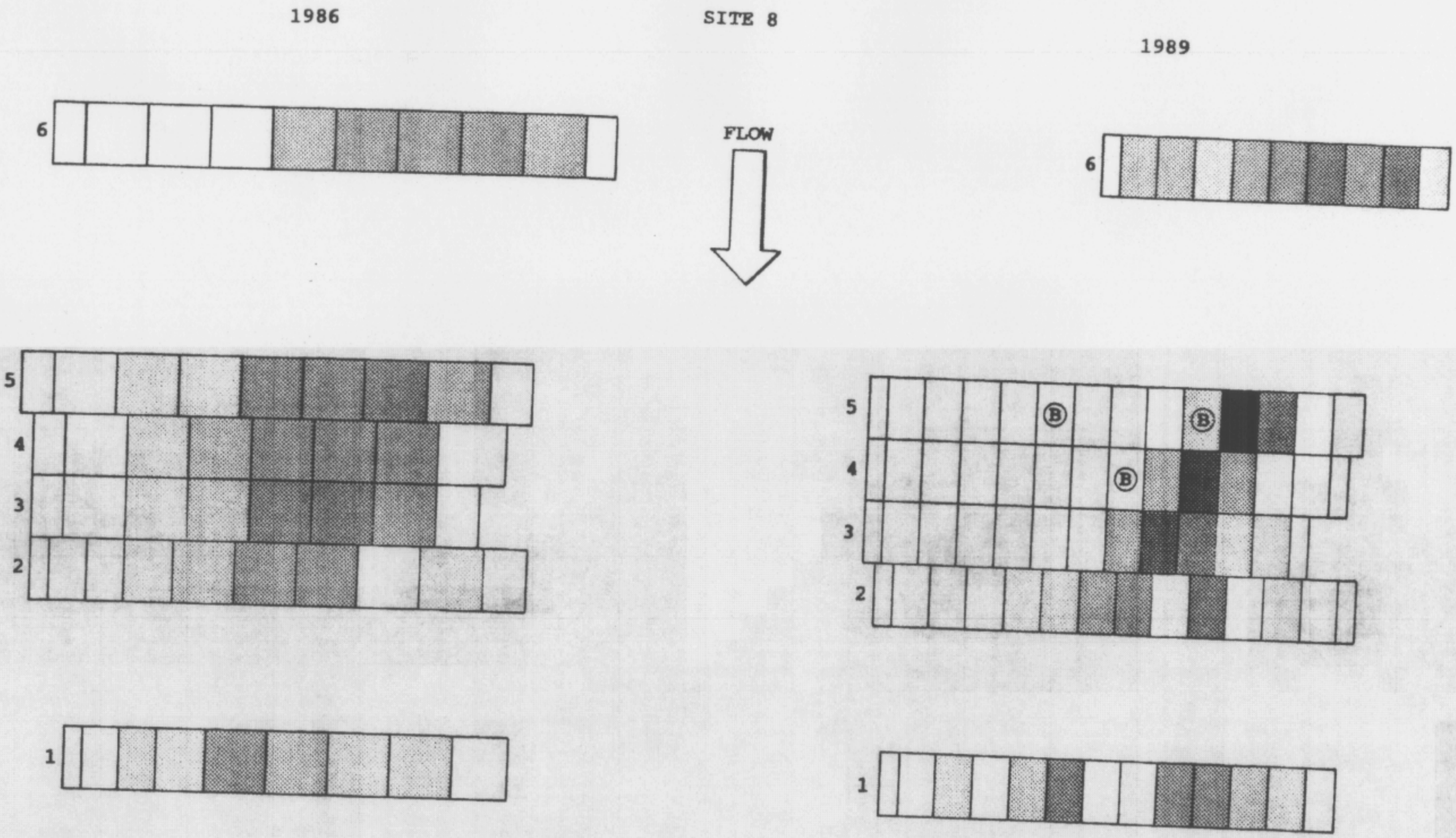



Figure 18. Mean column water VELOCITIES at Site 8 on Lagunitas Creek before (1986) and after (1989) treatment with boulder cluster.

SITE 10 - Figure 19.

In 1986, this long, shallow glide was selected for treatment because of its poor habitat and a slight bend in the creek that resulted in the concentration of flow near the left bank where the influence of scour was evident (Figures 20 and 21). The placement of a boulder cluster at this bend was intended to increase scour and depth. Immediately downstream of the boulders, depth increased from an average of 0.4 ft in 1986 to 0.4-1.2 ft in 1989. Velocities, however, decreased. This is the only site treated with boulder clusters that achieved any measurable increase in steelhead habitat. The increase, however, was very small—only 15 sqft. None of this reach qualified as coho habitat either in 1986 or 1989. Where depths were sufficient, velocities were too high.

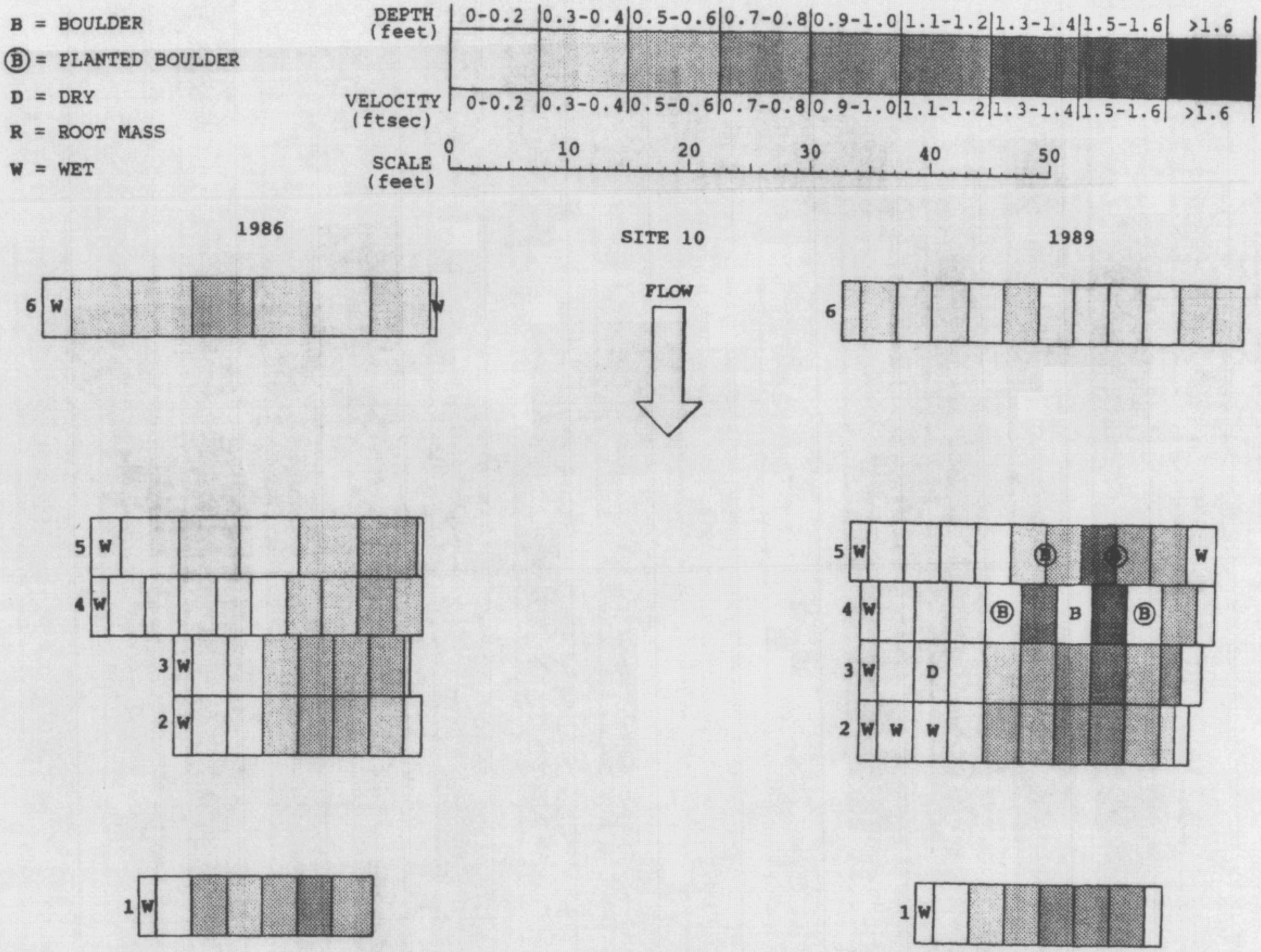



Figure 20. DEPTHS at Site 10 on Lagunitas Creek before (1986)
and after (1989) treatment with boulder cluster.

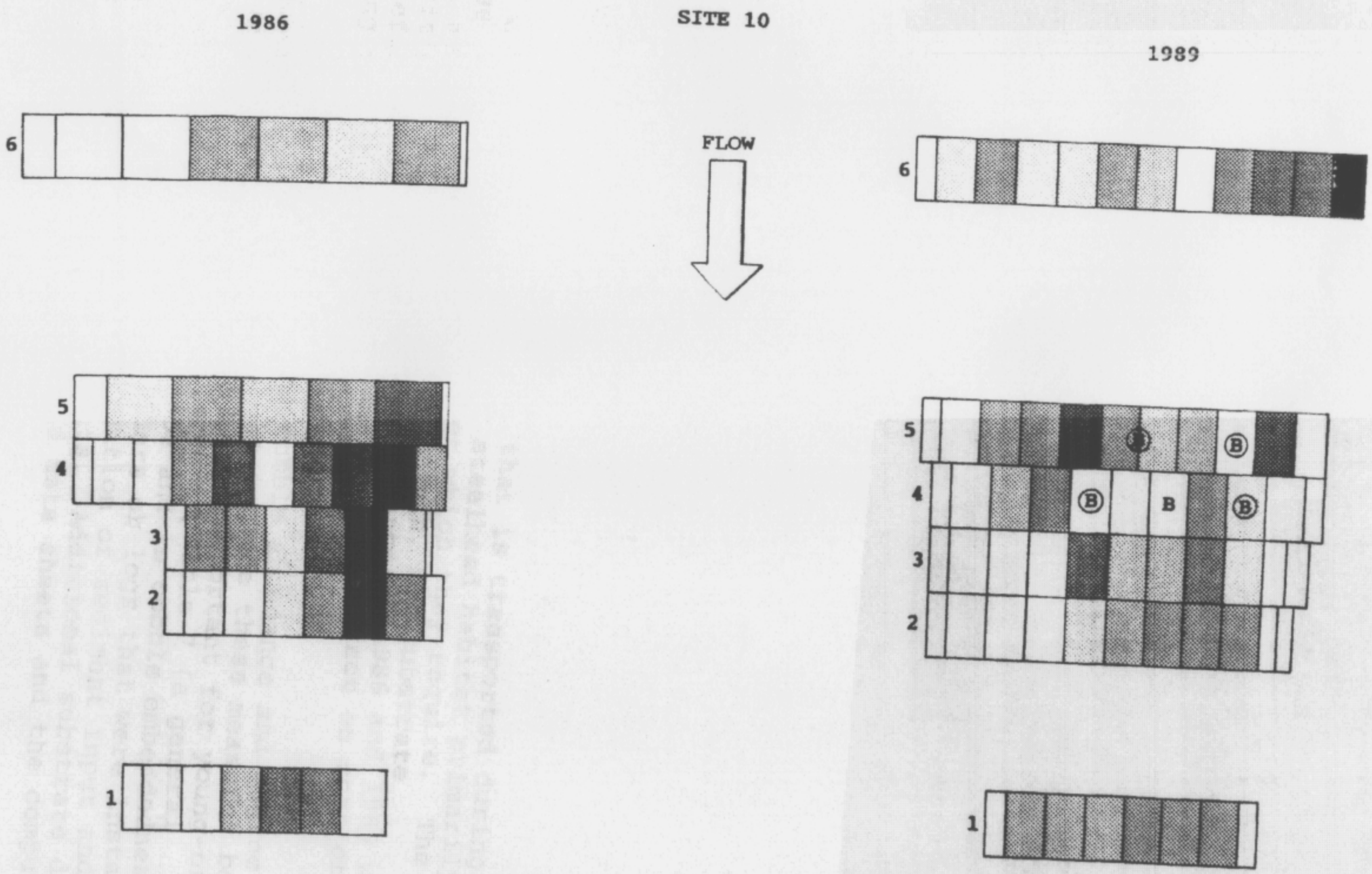



Figure 21. Mean column water VELOCITIES at Site 10 on Lagunitas Creek before (1986) and after (1989) treatment with boulder cluster.

Page 35
The Conclusions page
is missing from this
KRIS edition
of this document.
We are sorry for the inconvenience, and are working
to rectify the problem.

## REFERENCES


Bratovich, Paul M. and Don W. Kelley. 1988. Investigations of salmon and steelhead in Lagunitas Creek, Marin County, California. Volume I. Migration, Spawning, Embryo Incubation and Emergence, Juvenile Rearing, Emigration. Prepared for the Marin Municipal Water District, Corte Madera, California. March 1988.

Bustard, D. R. and D. W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal Fisheries Resources Board Canada 32:667-680.

Dettman, D. H. and D. W. Kelley. 1986. Assessment *of* the Carmel River steelhead resource. Volume I. Biological investigations. Prepared for the Monterey Peninsula Water Management District, Monterey, California. September 1986 113 pp.

Hartman, G. F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal Fisheries Research Board Canada 22:1035-1081.

Mason, J. C. 1966. Behavioral ecology of juvenile coho salmon (O. kisutch) in stream aquaria with particular reference to competition and aggressive behavior. Ph D. thesis, Oregon State University. 195 typed pp.

Mason, J. C. and D. W. Chapman. 1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. Journal Fisheries Research Board Canada 22:173-190.

Mundie, T. H. 1969. Ecological implications of the diet of juvenile coho in streams. Pp. 135-152 IN T. G. Northcote (Editor). Symposium on Salmon and Trout in Streams. Held at University of British Columbia, February 22-24, 1968. The University of British Columbia, Vancouver, Canada.

Nickelson, Thomas E., Willard M. Beidler, and Mitchell J. Willis. 1979. Streamflow requirements of salmonids. Final Report Fish Research Project AFS-62. Oregon Department of Fish and Wildlife, 506 S. W. Mill St., Portland, Oregon 30 pp.

Pearlstone, P. S. M. 1976. Management implications of summer habitat characteristics of juvenile steelhead trout (Salmo gairdneri) in the Big Qualicum River. Fisheries Management Report No 67. November 1976.

Ruggles, C. P. 1966. Depth and velocity as a factor in stream rearing and production of juvenile coho salmon. Canadian Fish Culturist 38:35-53.

Ward, B. R. and P. A. Slaney. 1979. Evaluation of in-stream enhancement structures for the production of juvenile steelhead trout and coho salmon in the Keogh River. Progress 1977 and 1978. Fisheries Technical Circular No. 45. Ministry of Environment, British Columbia, Canada.