SOURCES OF SEDIMENTS IN STRAWBERRY CREEK ON U. C. BERKELEY CAMPUS

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ABSTRACT: Strawberry Creek consists of two distinct ecological systems; the watershed of the upper portion of the creek is disturbed oak-woodland habitat while the watershed of the lower portion of the creek is more urbanized. However, the sediment budget suggested that more sediment was lost from the vegetated upper canyon and accumulated in the urban lower creek than would be expected in this type of system. This project was designed to estimate the sediment accumulation and erosion of both the upper and lower stretches of Strawberry Creek over the course of the 1997 water year(Fall 1997-Spring 1998). Seventeen cross-sectional profiles(14 at lower/3 at upper) between Fall 1997 and Spring 1998 were surveyed. Estimates of soil deposition and erosion were calculated, and the results showed: (1) More soil accumulation occurred at the lower creek. (2) Soil erosion was greater at the upper than the lower creek. (3) There is a negative correlation between the erosion pattern and vegetation distribution in these parts of the Strawberry Creek. There are few trees along the banks of the upper portion creek while they are abundant along the lower Creek especially after the restoration project in 1987 which can explain this distribution of sediment. Methods to control distribution of soil loss and deposition strategies include: building more check dams, and planting more vegetation (native preferred) at the upper portion of the Strawberry Creek.

INTRODUCTION:

Urbanization of the watershed produces fundamental changes in watershed hydrology. Infiltration is reduced by the creation of extensive roof area and pavement, and runoff moves quickly from upland to stream through storm sewers. As the result, runoff from the watershed occurs more rapidly by reducing the hydrograph and increasing flood hazard.

Urbanization can also produce large changes in erosion and transport of sediment to and down the stream channel (Kondolf 1991). During the rainy season within natural areas - that is, an area relatively undisturbed by humans - the plant absorbs much of the excess water. Also, soil is protected by organic material which acts like sponge. What the soil cannot absorb runs off into the stream or creek, which may spill over its banks in the flood plain; by expanding over floodplain, the erosive energy of the peak flows is also reduced. On the other hand, in areas developed for human use, much of the plant cover is removed. Buildings and paved roads do not absorb water, so runoff is significantly greater and erosion and flooding are more likely to happen.

Located in an urban area, excessive erosion in Strawberry Creek has many consequences. Water quality is degraded as the result of erosion. The soil comes in contact with vast qualities of chemicals of various types and levels of toxicity. The transportation of these substances from erosion sites poses a potential danger to the health of ecosystem because chemical substances are dissolved very easily and erosion processes are widely dispersed non-point source of pollution over large areas which makes it difficult to clean up (Holy 1980). Some chemicals occur naturally, but erosion and sedimentation can concentrate them so that levels become toxic.

The consequences of increasing levels of sedimentation in Strawberry Creek water thus poses a serious problem to humans and aquatic species. Chemical substances can infiltrate surface and ground waters and limit the use of drinking water resources (Holy 1980). Moreover, accelerated erosion can also increase sediment load to the creek environment, degrading habitat by clogging creek substrate (Morley 1994). Lastly, increasing nitrogen and phosphorus levels cause the eutrophication of many ponds and lakes limiting their use for recreation and other purposes (Holy 1980).

In this paper, I examined the effect of urbanization on erosion and sediment transport in Strawberry Creek on the U.C. Berkeley campus and in its upper canyon. I estimated the sediment transfer in both areas to determine the sediment budget for the upper and lower portions of Strawberry Creek. Also, I evaluated whether or not there is a correlation between erosion and

vegetation distribution in Strawberry Creek (Chau 1998 pers. comm.).

DESCRIPTION OF STUDY SITE:

This research was conducted in Strawberry Creek at the University of California at Berkeley. The headwaters of Strawberry Creek (37 degree 52' 30" N; 122 degree 15' 30" W) are located in Strawberry and Blackberry Canyons above the University of California, Berkeley, campus (see map 1 and 2 attached). The catchment covers 470 ha and is drained by two branches - the North and South Forks - which converge on the central campus grounds to form the main stem of the creek (Charbonneau 1992). As it leaves the central campus, Strawberry Creek enters a culvert which flows beneath the city of Berkeley to central San Francisco Bay.

Development of Strawberry Creek watershed and subsequent creek erosion began in the late 1800s when land was cleared for grazing and the establishment of the University of California. By 1987 approximately 40% of the watershed was urbanized (Charbonneau, 1987). This urbanization caused erosion of banks and channels and degraded the aquatic and riparian habitat quality. The conversion of permeable surface area in the watershed to impermeable has continued, as can be seen from construction projects such as the U. C. Botanical Gardens parking lot expansion and Witter Field resurfacing.

Erosion control has been implemented in Strawberry Creek on U.C. Berkeley campus to prevent erosion and protect species, buildings and bridges. In 1980, trees were planted along creek banks to reduce further erosion (Morley 1994). In 1987, the U.C. Berkeley initiated a Strawberry Creek Restoration Program in which the Redwood Cribwall above Stephen's Hall and many check dams along North and South Forks were built to reduce erosion rates and capture sediment (Charbonneau 1990).

Cross-sectional profiles were constructed to monitor the erosion rate and sediment deposition at this lower portion of creek following restoration efforts. Many reposts have suggested the reduction of creek erosion due to these control measures (Morley 1994). A follow-up report was conducted by Tseng on Spring 1997. She found that erosion from the on-campus stream portion could not account for deposition in the same area. Another study evaluating the stream bed and material size (Shahid 1997) showed that there was no relationship between erosion and pebble size at this portion. Thus, I will evaluate whether more sediment deposition occurs than erosion at this portion of the creek? And if so, how much sediment is present and where does this extra sediment come from?

METHODS:

There are three possible methods for determining the sediment yield of a given watershed. These methods are (1) obtaining sediment load data directly, (2) estimating rates of erosion within the watershed, and (3) comparing the watershed with neighboring basins for which sediment yield data are available (Lustig 1965). This study focusses on the second method. I estimated the sediment yield of the Strawberry Creek watershed by estimating both surface loss from hillslopes and erosion from channels, then comparing these values the channel to deposition within channels in my study.

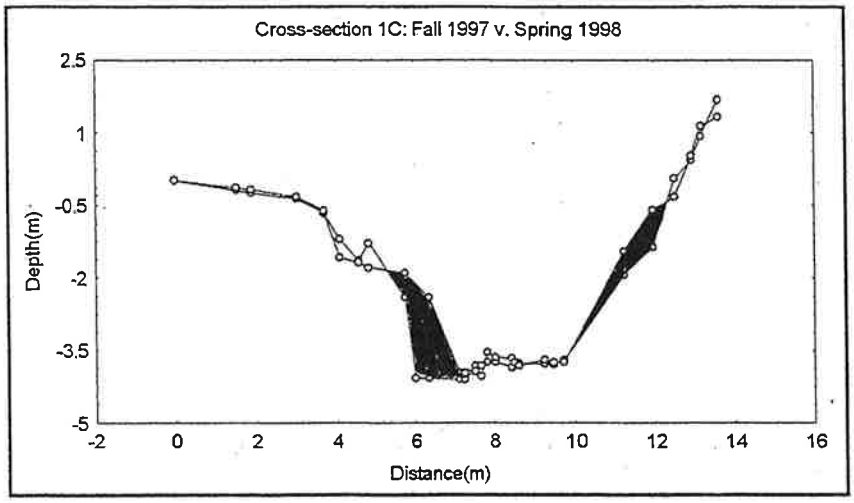
I analyzed changes in the cross-sectional profiles of both parts of the creek to determine the erosion and deposition rate in channel. Fourteen cross sections established in 1994 were resurveyed at the lower portion (Shahid 1997 and see map 1 attached). At upper portion of the creek, since there was no previous study I decided to conduct my study on three sites called 1C, 2C, and 3C (see map 2 attached). I used the cross sectional study method introduced in previous studies (Morley 1994) with minor modifications. In this study, I measured the depth of the creek instead of the elevation as most previous studies did. The left bank at each site was set arbitrarily to zero and changes from that level were measured in the nearest centimeter, referenced to the left bank datum. The top of right bank could be higher, lower or equal to the top left bank. There are two measurements at each pin mark, one at the bottom which is on the ground, and another at the top which is on the tree trunk. By comparing these two marks over the year, I can be sure that the level at my sites remained constant.

To estimate the surface loss from hillslopes erosion, I surveyed five different locations on the hillslopes in which I determined the mean of surface soil loss at the end of my study. I nailed 40 1-ft pins in the ground at each of five described areas. Pins were placed 0.5 to 1m intervals. The depth of these nails were recorded for later comparisons.

Since no data were available for the upper portion of the creek, I divided my study into two phases to include channel profiles and surface loss detection methods before the rainy season (Oct to Nov 1997) and again following the rainy season (March to April 1998) to detect changes.

After collecting data, I used the 'Statistica' software to draw the cross sectional profiles. I plotted the Fall 1997 and Spring 1998 data of each site on the same graph to quantify changes and estimate the sediment yield.

Figure 1: Cross-section of 1C comparing erosion and deposition from Fall 1997 to Spring 1998



Sediment yield at each site was estimated directly on the plot by subtracting the erosion area from the deposition area. The sediment yield at each portion then will be the sum of sediment yield at each site in that portion. Finally, I compared the sediment yield of both locations to draw my final conclusion about the source of sediments. The sediment yield is the sum of erosion in channels, and hillslopes surface minus the soil deposition in those areas. The sediment yield within the watershed was expressed in m^3 per year.

RESULTS:

At the upper creek, a comparison of Fall 1997 and Spring 1998 cross sectional profiles shows severe erosional patterns at three sites (100%) 1C, 2C, and 3C (fig.1,2,and 3 attached). Bank erosion is observed in most cases, while downcutting happens at (33%) of sites(fig.3 attached). There is a little deposition ($0.479m^2/yr$) compared to erosion rate ($1.45m^2/yr$) at this area. Thus, a net of $0.97m^2/yr$ sediment will be transferred to the lower creek.

At the lower creek, more deposition ($0.22m^2/yr$) was observed compared to erosion ($0.178m^2/yr$) (see table 2). There was little to no correlation between erosion or deposition and longitudinal location. The highest erosion rate ($1m^2$) was at Cross section 2.1 at the end of the creek, while the lowest erosion rate was at section 7.1 next to that area. The highest deposition rate was at site 7.1 ($1.13m^2$), and the lowest rate at site 2.1 ($0m^2$); site 17.1 ($0m^2$); and site17.2 ($0m^2$).

Bank erosion was rare at most of sites of the lower creek, except at sites 31 and 4 (Fig.

5 and 15). At site 4.0, most bank erosion happened on the left bank (0.216m²). At site 31, the greatest erosion occurred on the right bank (0.390m²). Little erosion occurred at the stream bed (see figs.4, 9, and 13 attached). The stream bank at the lower portion of Strawberry Creek generally appeared to be more stable than at the upper portion. Overall, the erosion rate exceeded the deposition rate at the upper Creek, while the opposite was true at the lower Creek. Thus, the extra 0.97 m²/yr will be transferred to the lower.

Finally, the average of surface soil loss is 0.21cm/year. Some sites at the bottom of slope experienced deposition up to 3.5cm/yr. The highest soil loss at the top of the slope was 1.7 cm, and the lowest was 0.2 cm over the course of one rainy season.

Figure 18: mean of erosion v. deposition (m^2) at upper creek

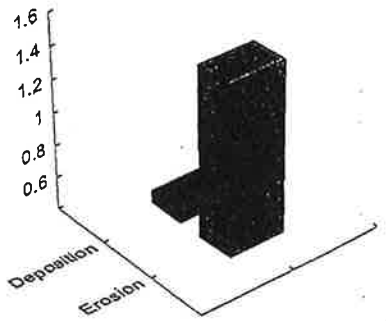


Figure 19: mean of erosion v. Deposition (m^2) at lower creek.

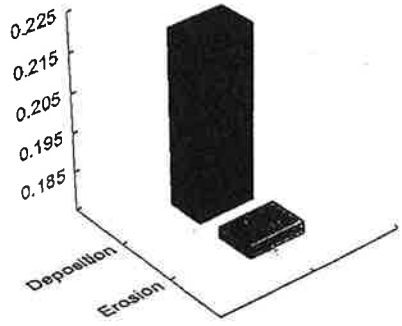


Table 1: Estimation of erosion and deposition rate at the upper canyon creek

Cross-section	Erosion(m^2)	Deposition(m^2)	Sediment yield(m^2)
1C	2.84	0.64	2.200
2C	0.267	0.147	0.100
3C	1.250	0.650	0.600
Mean	1.450	0.479	0.970

Table 2: Estimation of erosion and deposition from the lower creek

Cross-section	Erosion(m^2)	Deposition(m^2)	Sediment yield(m^2)
2.1	1.000	0.000	1.000
4.0	0.216	0.096	0.120
7.1	0.000	1.130	-1.130
15.0	0.041	0.007	0.034
16.1	0.011	0.099	-0.088
17.1	0.096	0.000	0.096
17.2	0.038	0.000	0.038
22.0	0.069	0.920	-0.850
25.0	0.196	0.198	-0.002
26.0	0.391	0.044	0.348
28.0	0.040	0.462	-0.420
31.0	0.390	0.000	0.390
32.0	0.014	0.120	-0.106
36.0	0.000	0.002	-0.002
Mean	0.178	0.220	-0.042

Table 3: Net soil transfers to the Bay

	Erosion(m^3/yr)	Deposition(m^3/yr)	Sediment yield in channel(m^3/yr)	Sediment yield on hillslopes(m^3/yr)
Upper Creek	3552.50	1173.55	+ 2378.95	+ 5922.00
Lower Creek	369.90	451.00	-86.00	

DISCUSSION:

There is more erosion than deposition at the upper creek which can therefore be considered a source of sediment to the lower creek. At the upper creek, the streambanks have little or no vegetation; thus bank erosion is a major concern here . In addition, the bankslopes are also very steep, and it is more likely for the soil to slide down from the top to the bottom of the slope. There are little or no tree roots or herbaceous/brushy vegetation on the stream bank to assist in bank stabilization. There is not much deposition at the upper Creek, because there is nothing to hold back the sediment such as woody debris or check dams. Thus, most of the soil will be washed away and end up at the lower Creek and eventually the Bay.

At the lower Creek, we see less bank erosion because the bankslope is not steep and there is more vegetation on the stream bank. After the restoration in 1989, most of the banks were improved with increased vegetative cover and artificial crib walls. However, while there are still few problems with the down cutting of streambed at sites 2.1, 17.1, and 26, the overall result shows that deposition exceeded erosion. This can be explained by the use of check dams at this portion of the creek. The check dams slow down the water velocity, and thus hold more sediment at most sites. In addition, vegetation can also play a major role in holding sediment and stabilize the banks. Its rough surface slows the water velocity, and its roots restrain soil particles which is a major factor in stabilizing the stream bank. For instance, redwood trees, Algerian ivy, and many other native plant species were planted along the streambank at the lower creek while at the upper part herbaceous covers are less likely to be found along the streambank.

My overall data suggest that the source of the extra sediments in lower Creek is from the upper creek. As stated above, the sediment could come from (a)the lower creek, (b)the upper creek, and (c)construction sites. Here we can eliminate the lower Creek, because its erosion rate is far less than it deposition rate. Also, I can also eliminate the construction sites as a source of

is far less than it deposition rate. Also, I can also eliminate the construction sites as a source of the sediment, because I have examined the sites and saw that all of the construction sites were in compliance with the regulations to minimize sediment runoff. The soil of these sites are surrounded by plastic or other materials to protect the soil from washing away.

There is a correlation between vegetation distribution on the streambank and the rate of erosion. As we see the difference between the upper and the lower creek, greater vegetation on the stream bank results in decreased erosion. There are few trees along the banks of the upper portion creek while they are abundant along the lower Creek especially after the restoration project in 1987.

CONCLUSION:

These data support the conclusion that sediment comes mostly from the upper part of the creek. The upper portion has more erosion than deposition, due to a lack of vegetation, check dams, and woody debris to stabilize the channel. On the other hand, at the lower Creek less erosion and more deposition demonstrates the effectiveness of the restoration project which initiated in 1987.

Because upper and lower creek are parts of the same creek, we should treat them as in a single system. More or less sediment on the creek can each harm organisms which rely on the system. Thus, we need to have a system restoration as a whole, not just on individual segments so that the habitat can support aquatic organisms.

My recommendation is to restore immediately the upper Creek in the Canyon where the system is extremely degraded. I recommend planting more vegetation to protect the stream bank, and at the same time build more check dams and/or do not remove any woody debris that enters streams to slow down the water velocity and the downcutting on the streambed. Native plant species should be used to reduce the cost of maintenance, and to avoid the competition to the native plants. Root growth is one factor by which to select plant species. They should have deep penetrating roots to hold the soil, and be able to survive in dry condition by getting ground water from deep within the soil.

ACKNOWLEDGEMENTS

This study would not have been possible without the help of several people. I want to take this opportunity to express my sincere gratitude to all of those special people who played a supportive role. First, I must thank my professor, Dr. Tom Dudley, who provided me with encouragement to take the project, and continued to be a source of thought-provoking critique throughout the year that I worked on the project. A special thanks to my Graduate Student Instructor, Caryl Waggett, who helped refine from the first to the last draft. Her time and energy have been priceless. I must also thank to my friend, Max Chau, who helped collecting data throughout many Saturdays, and Sundays. For his time and sincerity I am very grateful.

References:

Amimoto, P.Y. 1978. Erosion and sediment control handbook. Department of Conservation, California. 197pp.

Charbonneau, B., S. Kaza and V. Resh. 1990. Strawberry Creek: A walking tour of campus natural history. University of California, Berkeley. 15pp.

----.1992. Strawberry Creek on the University of California, Berkeley Campus: A case history of urban stream restoration. Aquatic conservation: Marine and Freshwater Ecosystem Vol 2: 293-307.

Gray, D.H., A.T. Leiser. 1982. Biotechnical slope protection and erosion control. Van Nostrand Rienhold Company Inc., New York, NY. 271pp.

Gu, Y. 1997. The effect of urbanization on sediment deposition in Strawberry Creek. Pp13. Unpublished report for U.C. Berkeley Environmental Sciences Senior Seminar, Berkeley, CA.

Holy, M. 1980. Erosion and environment. Pergamon Press Inc, New York.225pp.

Kondolf, G.M., and E.A. Keller. 1991. Management of urbanizing watersheds. California watersheds at the urban interface, proceeding of the third Bienial wahtershed conference, University of California Water Resources Center, report No. 75.

Leopold, L.B. 1960. Water: a primer. W.H. Freeman and Company, San Francisco. 172pp.

Lustig, L.K. 1965. Sediment yield of the Castaic watershed, Western Los Angeles County California – A quantitative geomorphic approach. United States Government Printing Office, Washington. 23pp.

Maranzana, S., K. Hans and J. Allman. 1996. 1996 Strawberry Creek cross-section follow-up report. Unpublished report for Office of Environmental, Health and Safety, University of California, Berkeley.4pp.

Mendonca, A. 1997. Do artificial creek banks affect the stream channel morphology of Strawberry creek? Pp8. Unpublished report for U.C. Berkeley Environmental Sciences Senior Seminar, Berkeley, CA.

Morley, S. 1994. Strawberry Creek cross section report. Unpublished report for office of Environmental, Health and Safety, University of California, Berkeley. 9pp.

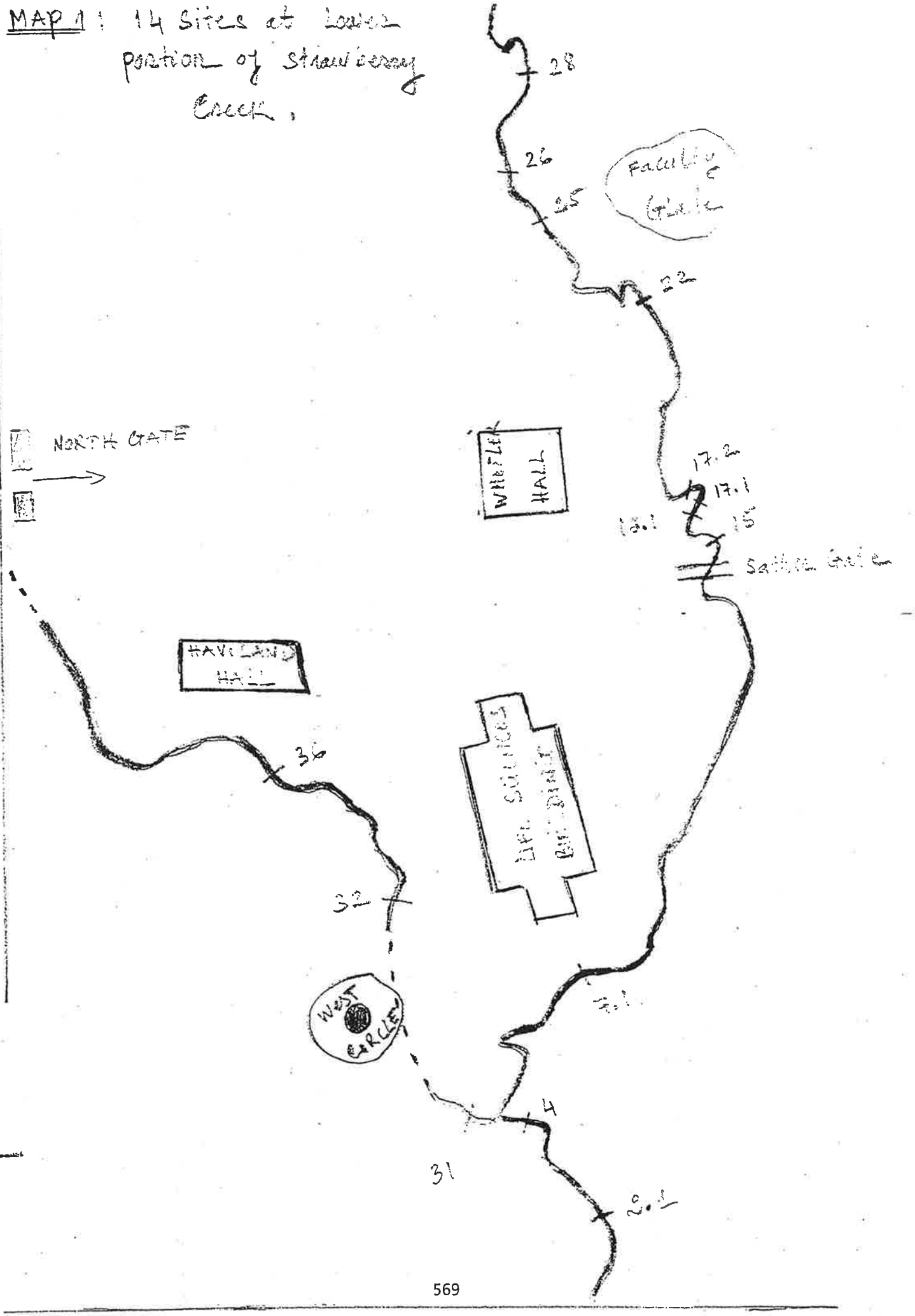
Scott, K.M., and R.P. Williams. 1974. Erosion and sediment yields in mountain watersheds of the transverse ranges. Ventura and Los Angeles Counties, California – Analysis of rates and processes. U.S. Geological survey, California. 66pp.

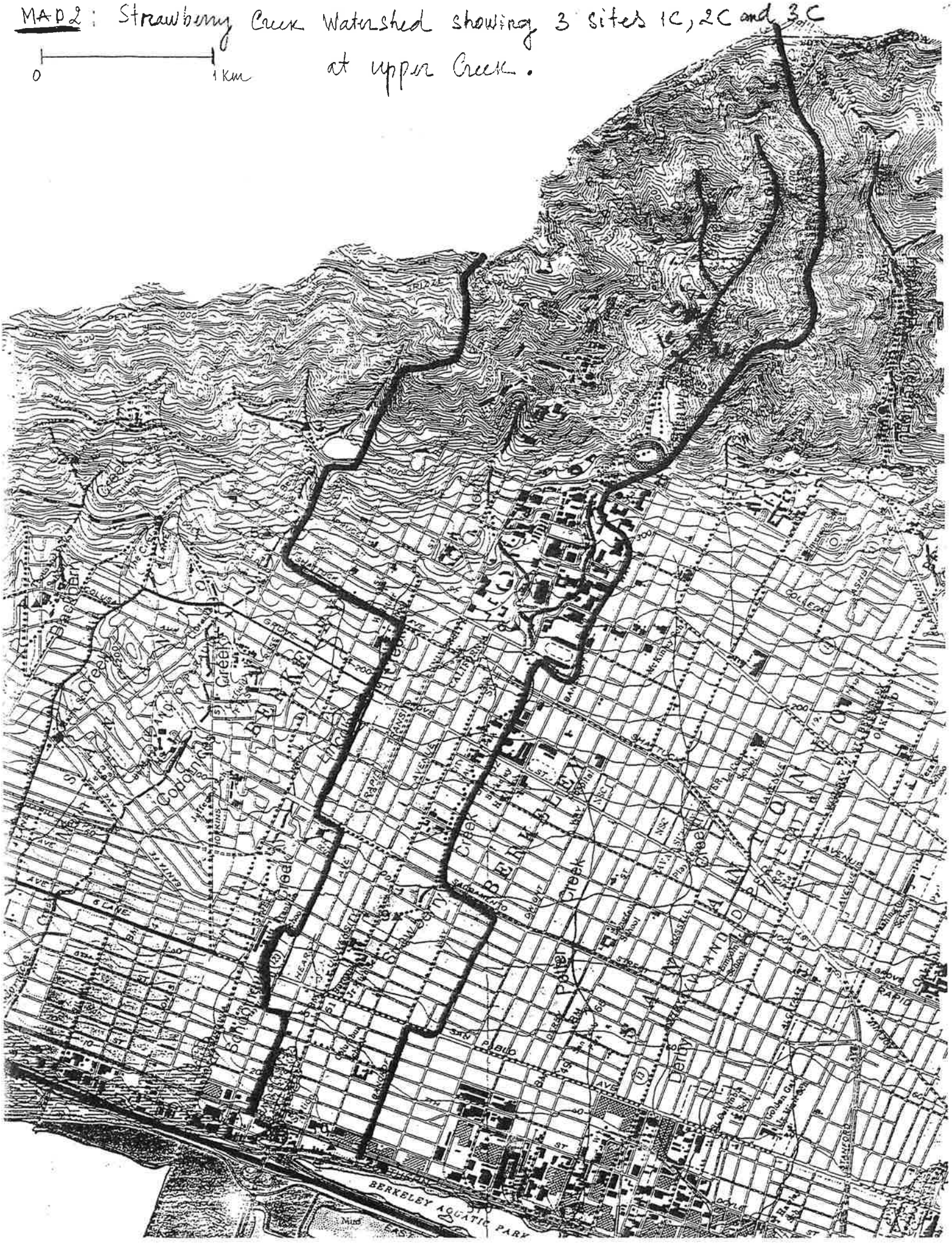
Shahid, H. 1997. 1997 Strawberry Creek surface bed material size study. Pp7. Unpublished report for U.C. Berkeley Environmental Sciences Senior Seminar, berkeley, CA.

Sreenivasan, M. 1997. Erosion control of bioengineering stream restoration techniques; Case studies: Strawberry Creek and Blackberry Creek. Pp12. Unpublished report for U.C. Berkeley Environmental Sciences Senior Seminar, Berkeley, CA.

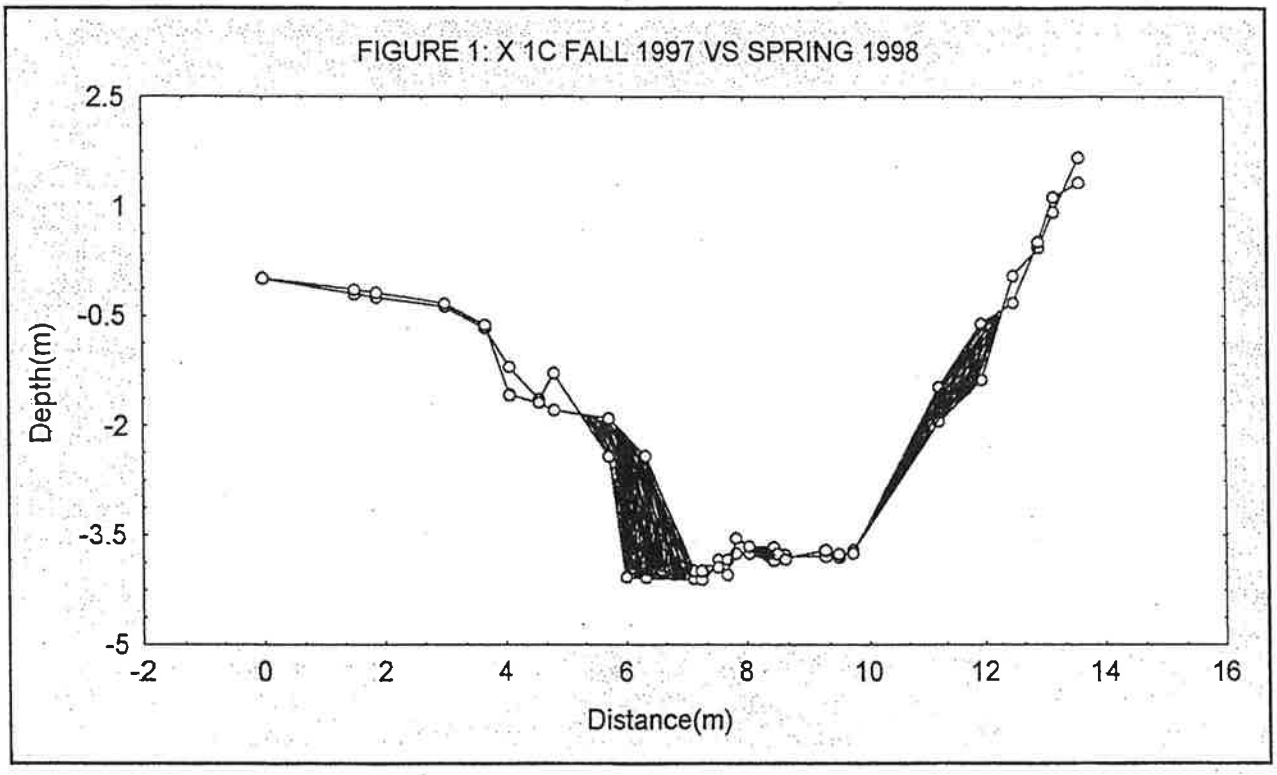
Tseng, L. 1997. 1997 Strawberry Creek cross-section report. Pp1-7. Unpublished report for U.C. Berkeley Environmental Sciences Senior Seminar, Berkeley, CA.

MAP 1 : 14 Sites at lower portion of Strawberry Creek.

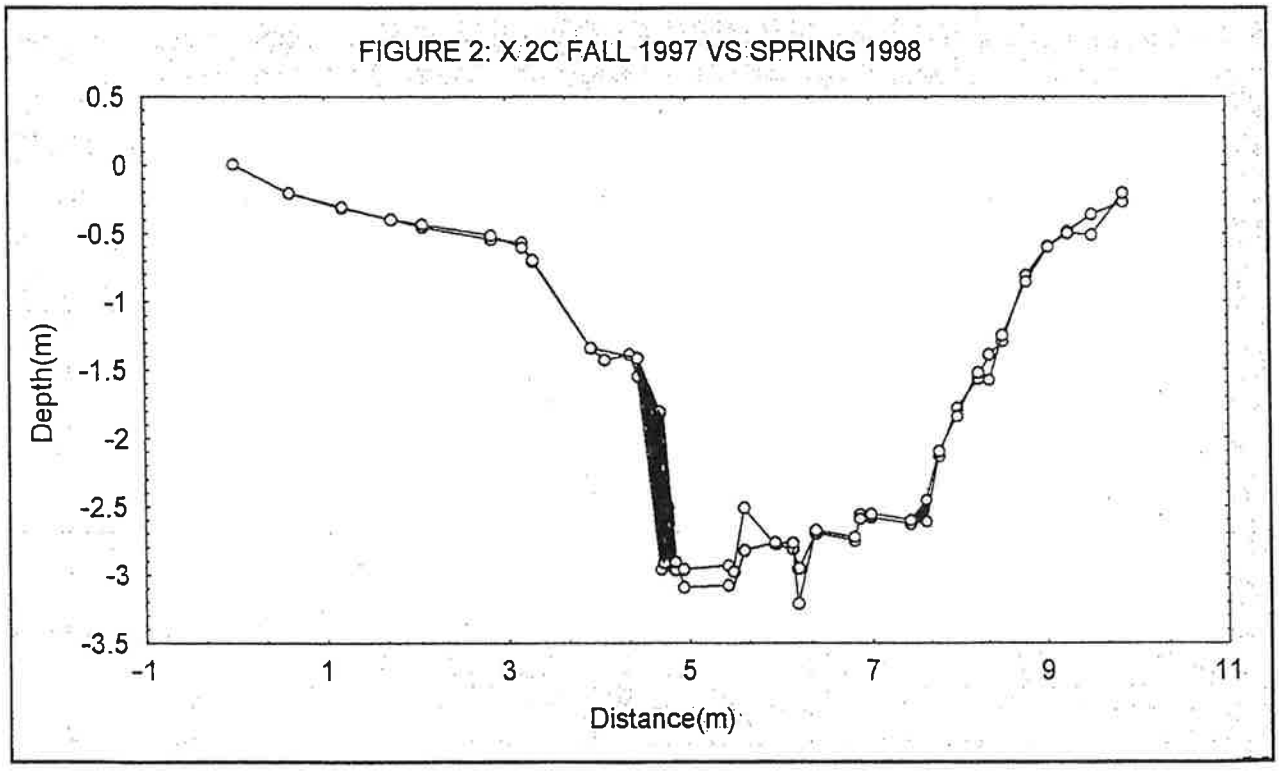



MAP 2: Strawberry Creek Watershed showing 3 sites 1C, 2C and 3C at upper Creek.
0
1 Km
BERKELEY AQUATIC PARK

Attach map : Cross_section transects showing location of erosion & deposition ○.



● Erosion
○ Deposition



● Erosion
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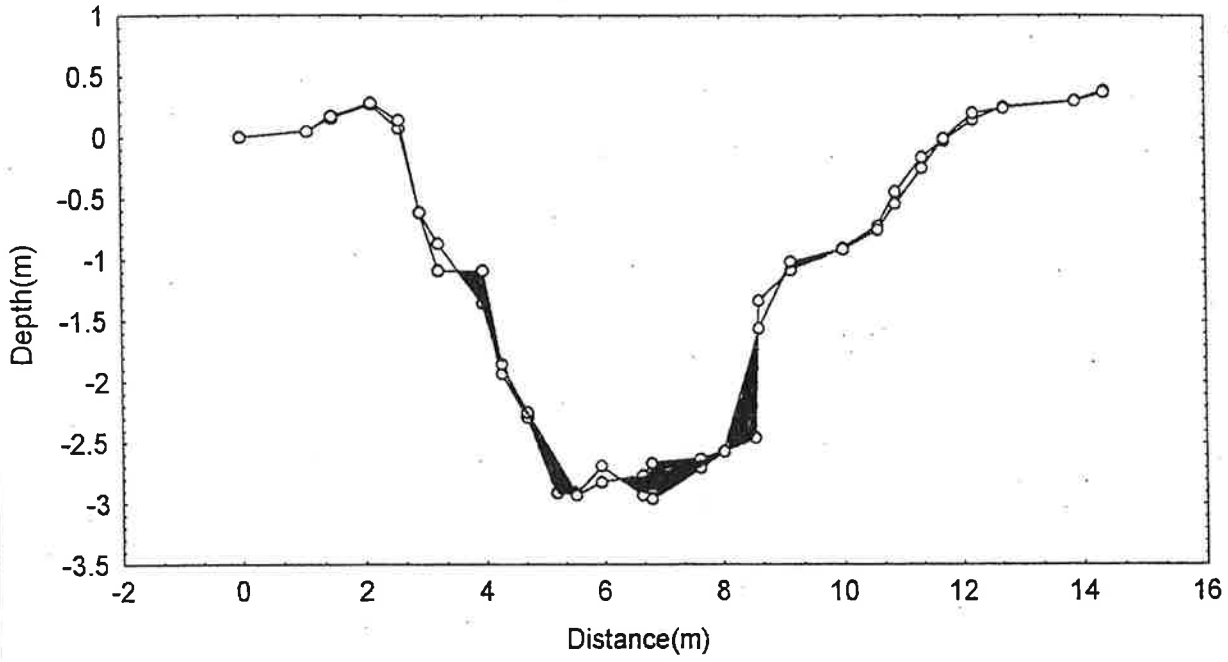
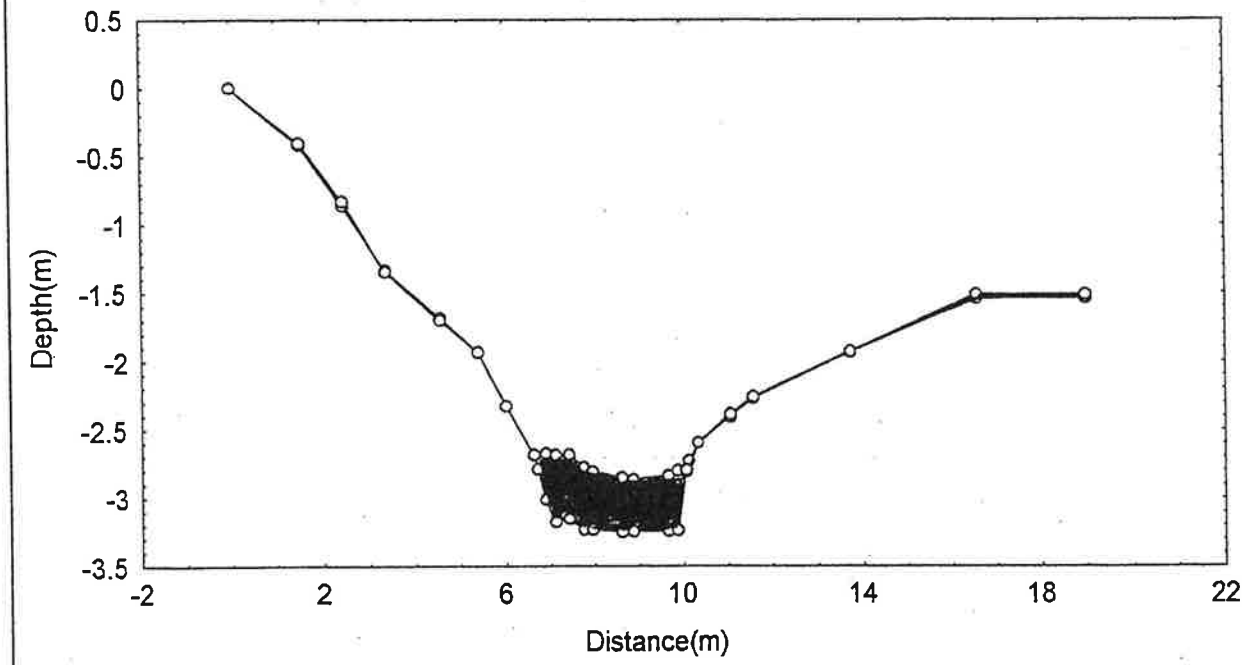
FIGURE 3: X 3C FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

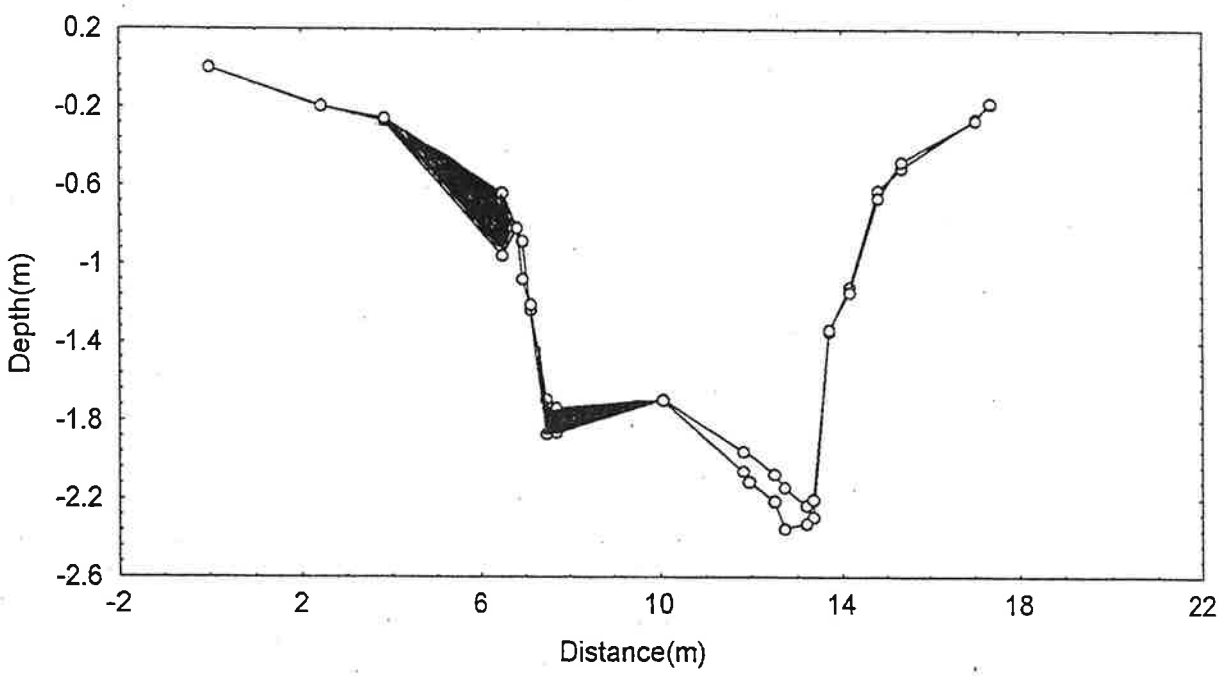
FIGURE 4: X 2.1 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

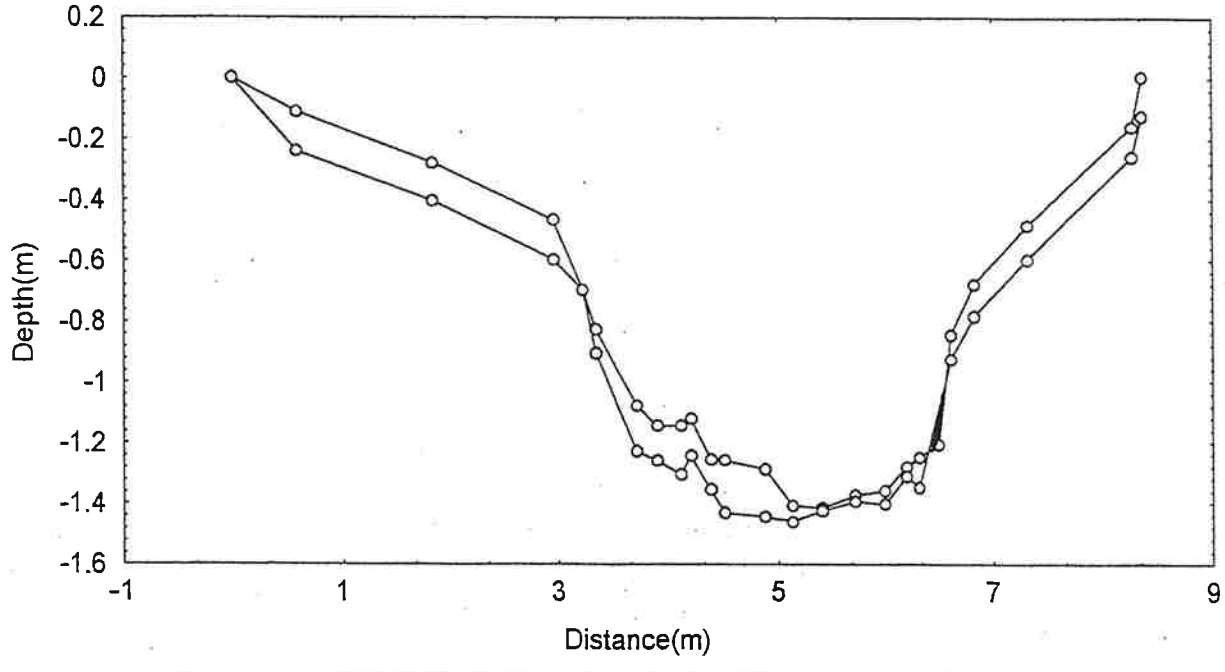
FIGURE 5: X 4.O FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

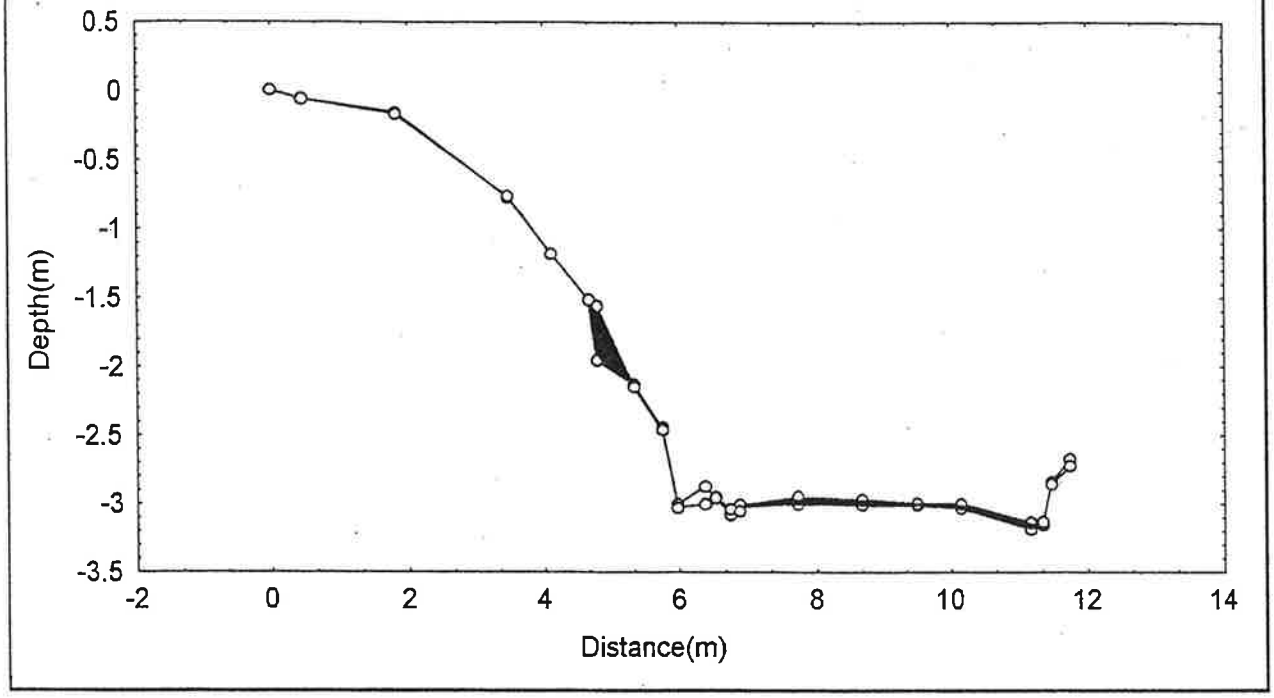
FIGURE 6: X 7.1 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

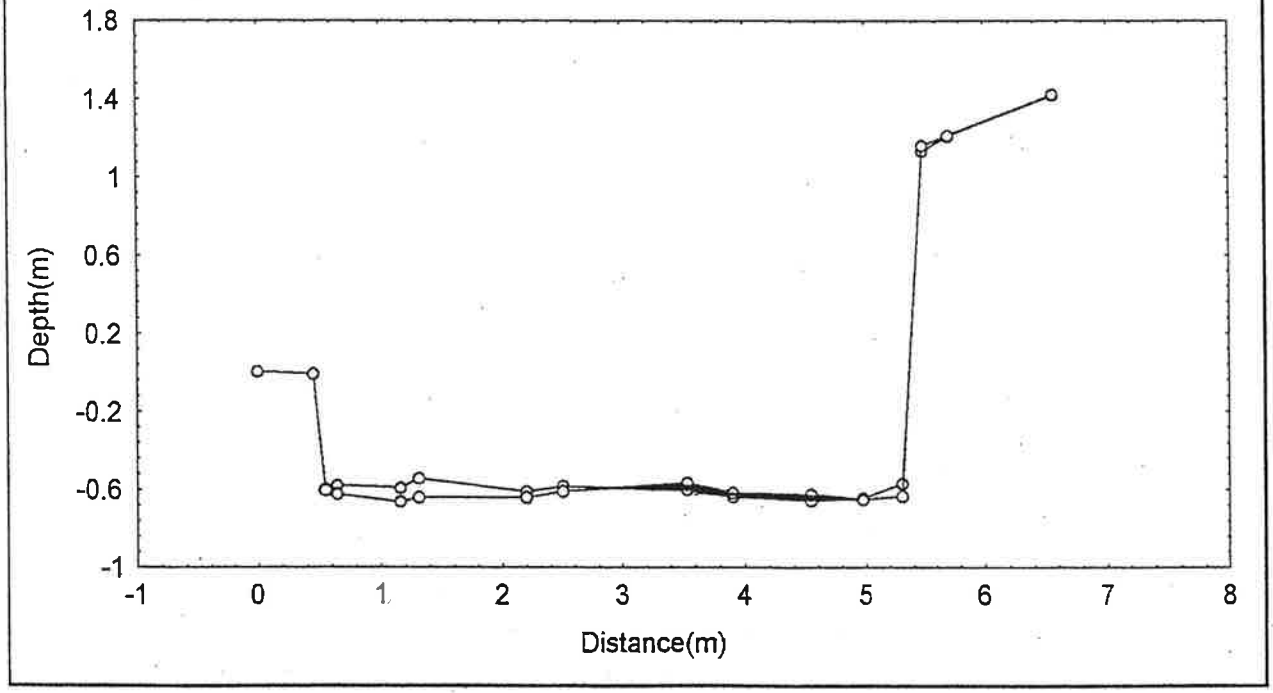
FIGURE 7: X 15.0 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

FIGURE 8: X 16.1 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

FIGURE 9: X 17.1 FALL 1997 VS SPRING 1998

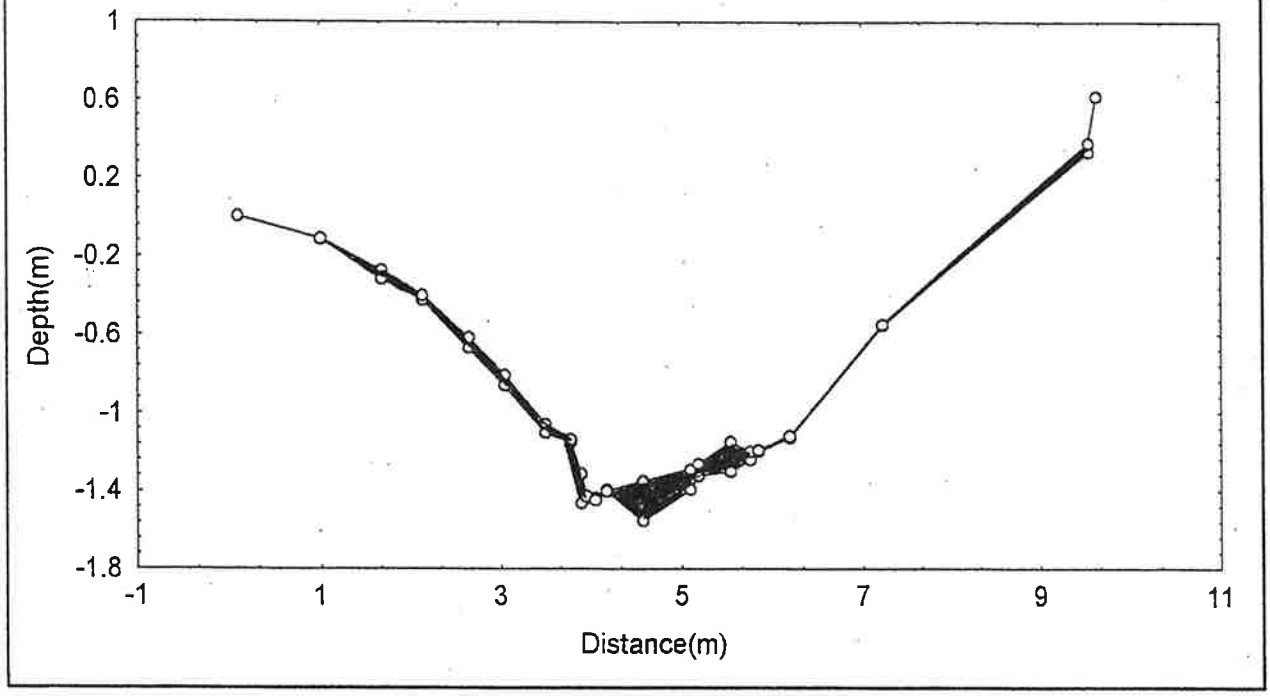


FIGURE 10: X 17.2 FALL 1997 VS SPRING 1998

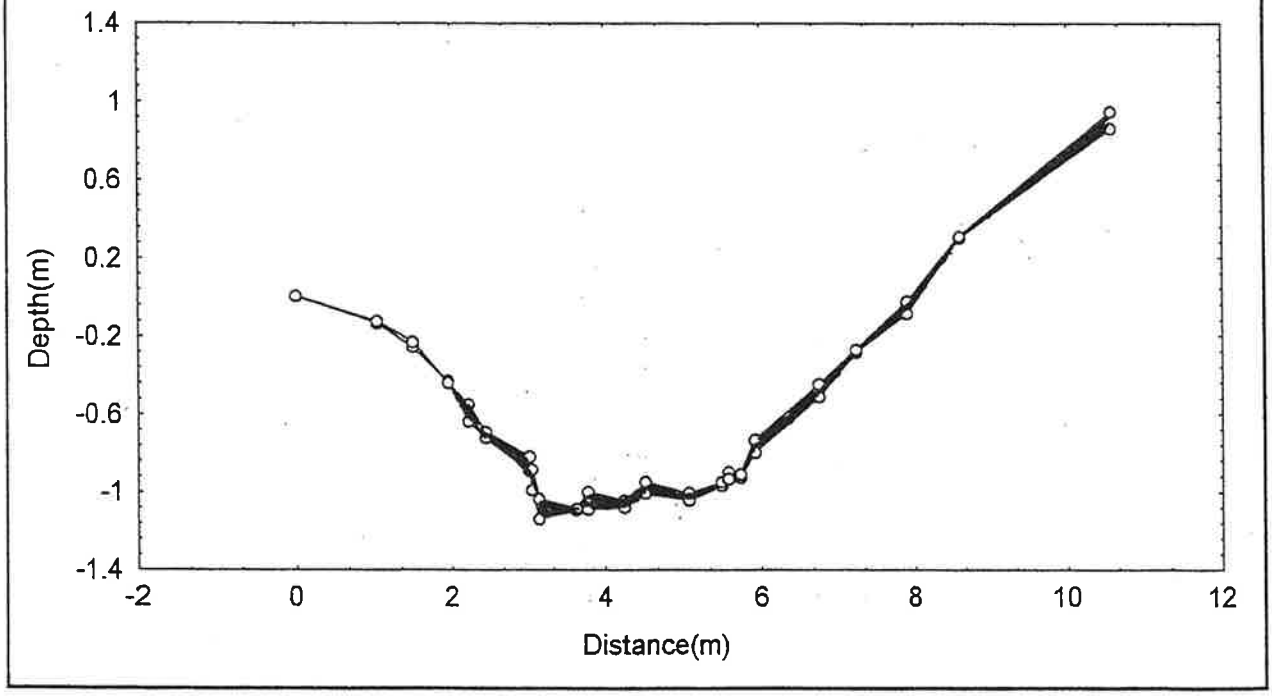
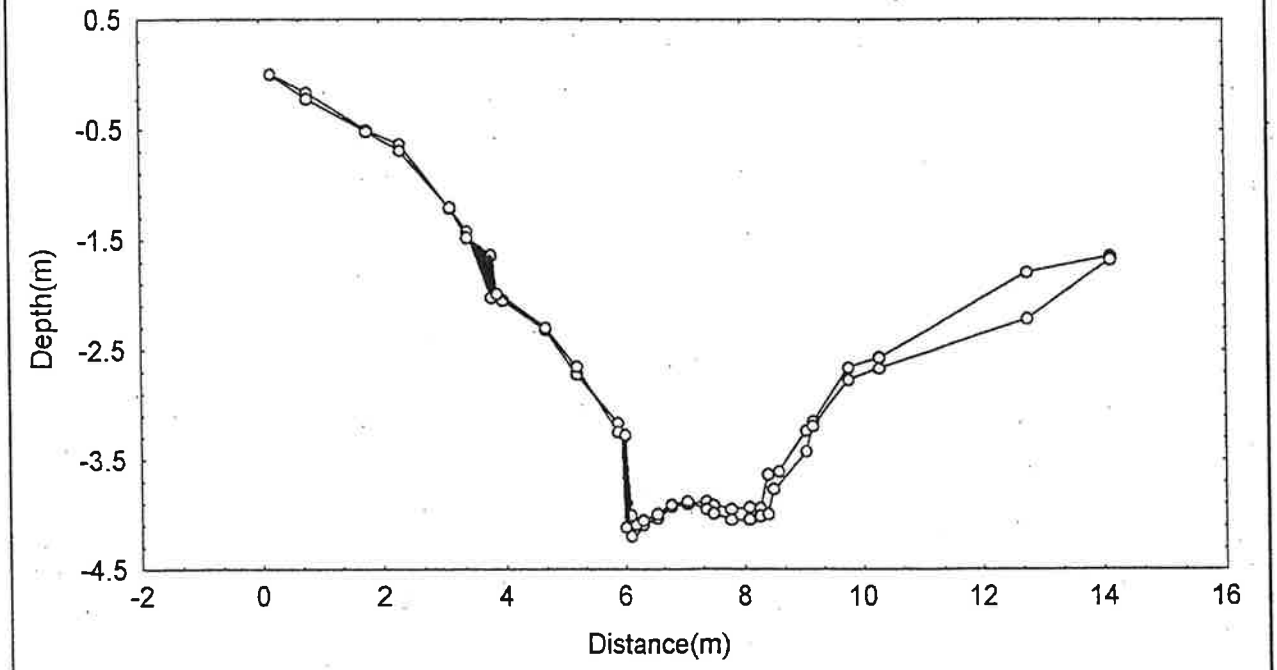


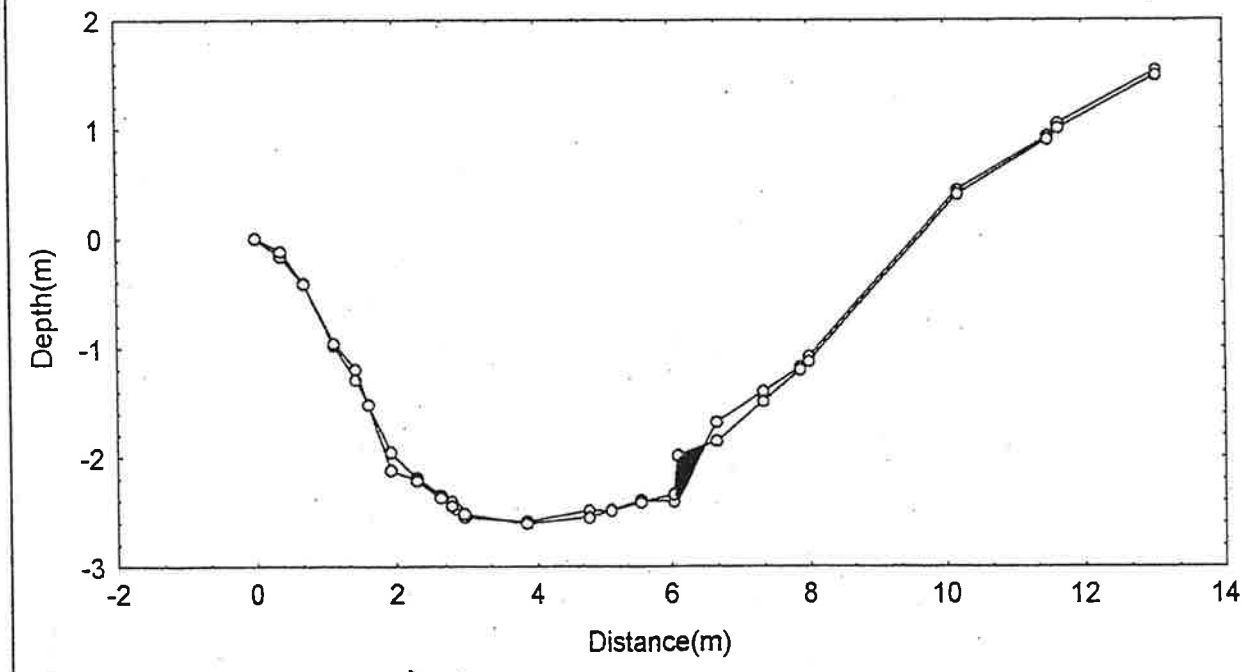
FIGURE 11: X 22.0 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

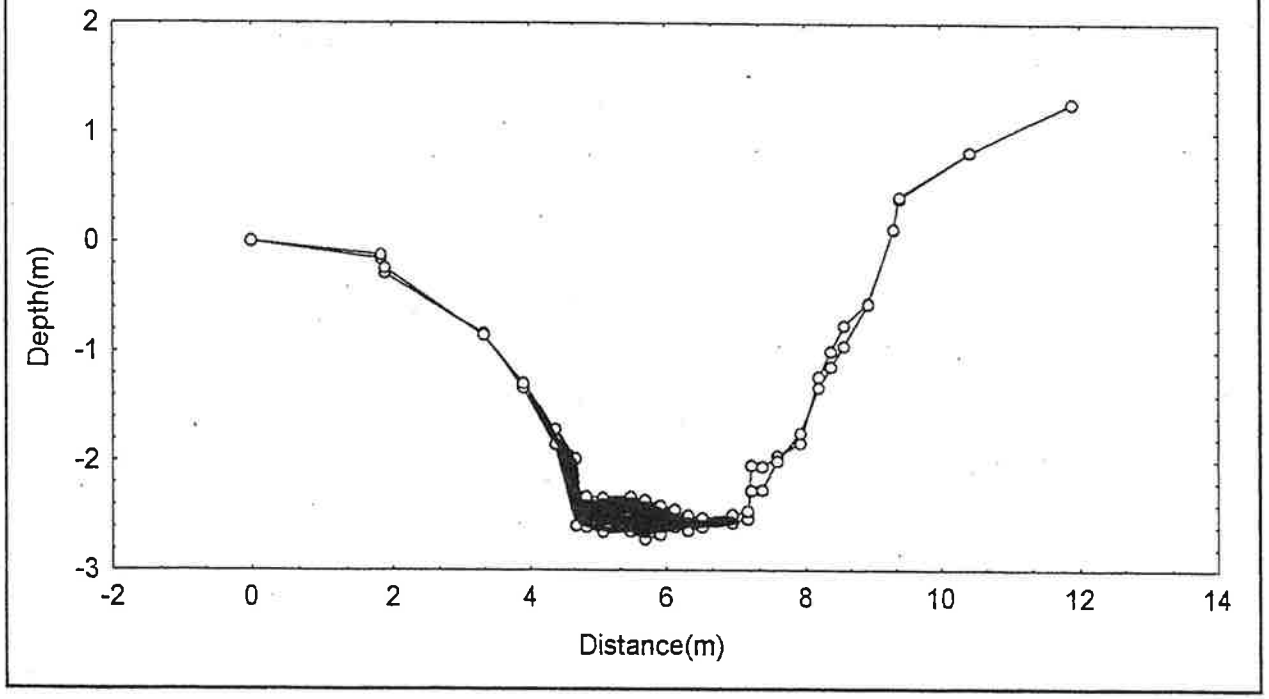
FIGURE 12: X 25.0 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

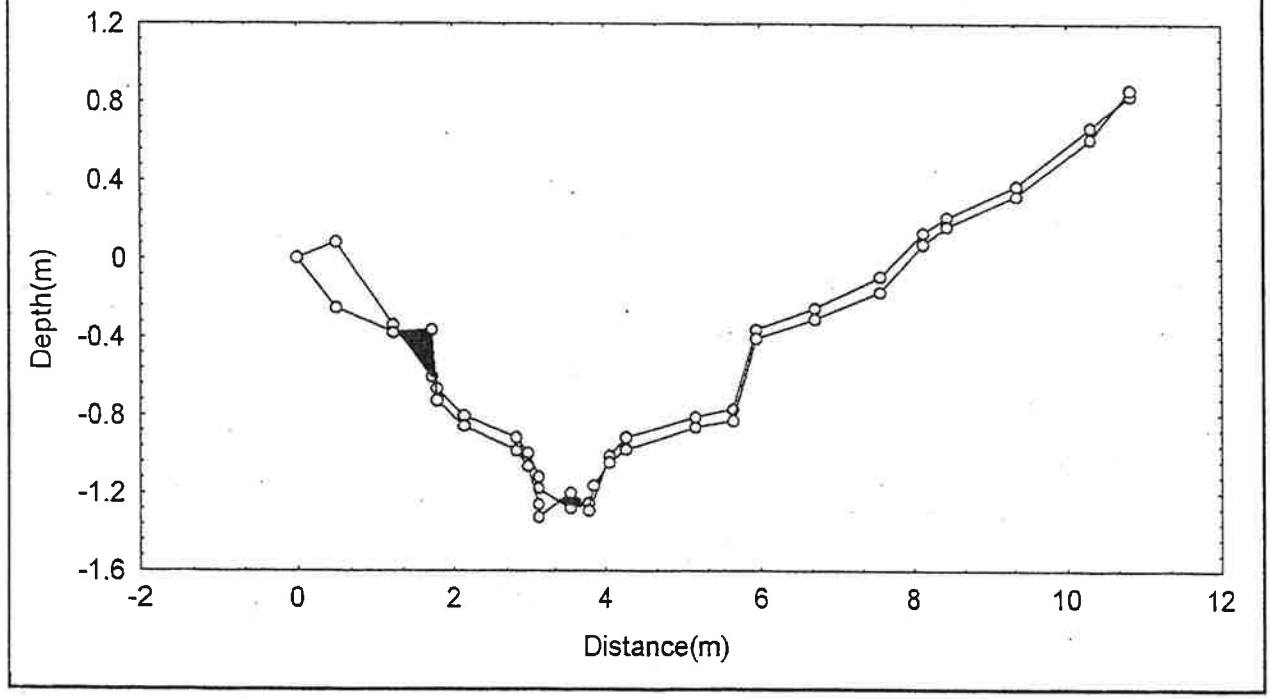
FIGURE 13: X 26.0 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

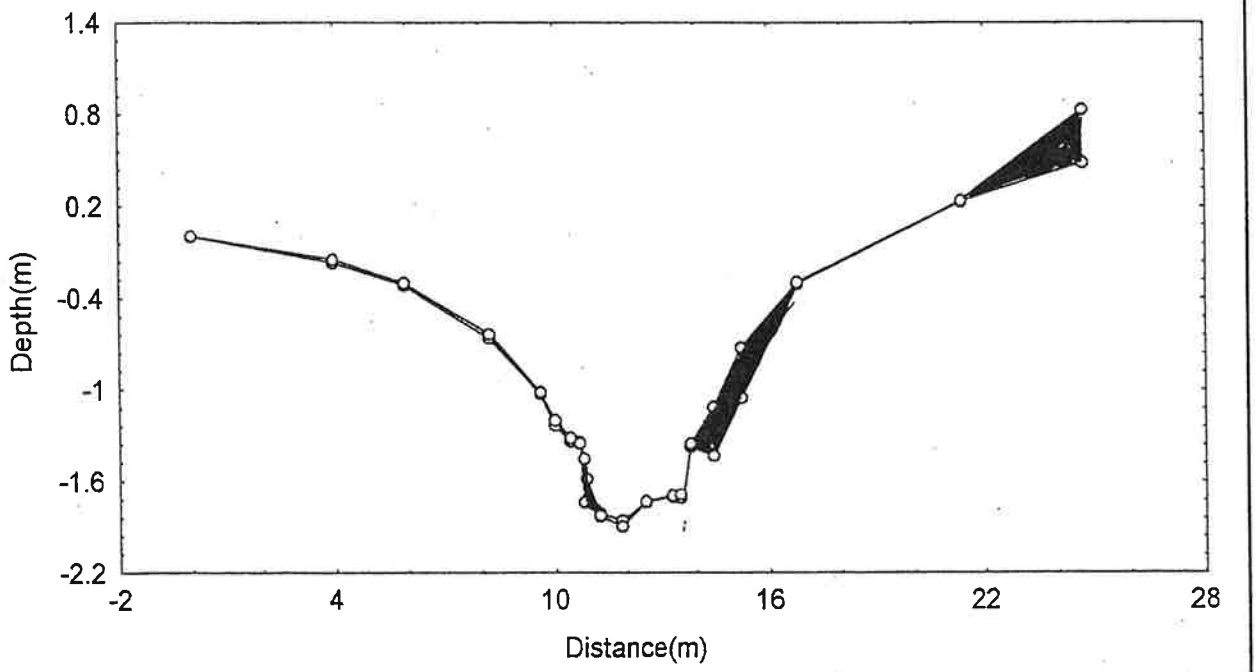
FIGURE 14: X 28.0 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

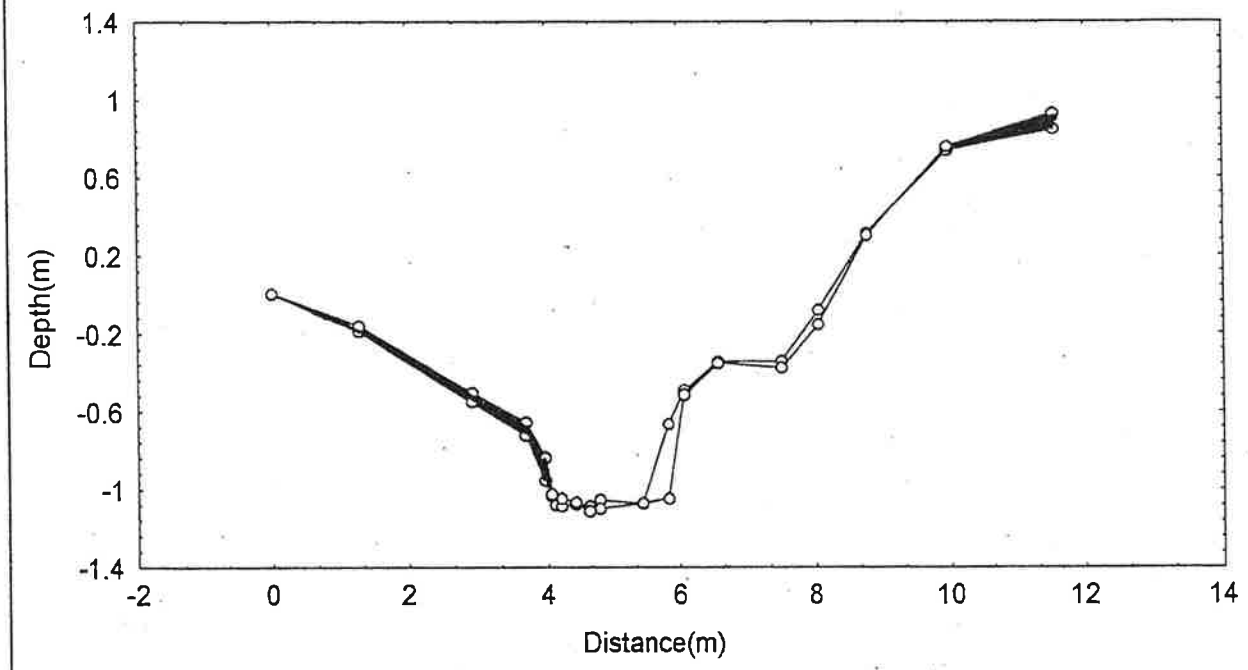
FIGURE 15: X 31.0 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

FIGURE 16: X 32.0 FALL 1997 VS SPRING 1998



● Erosion

○ Deposition

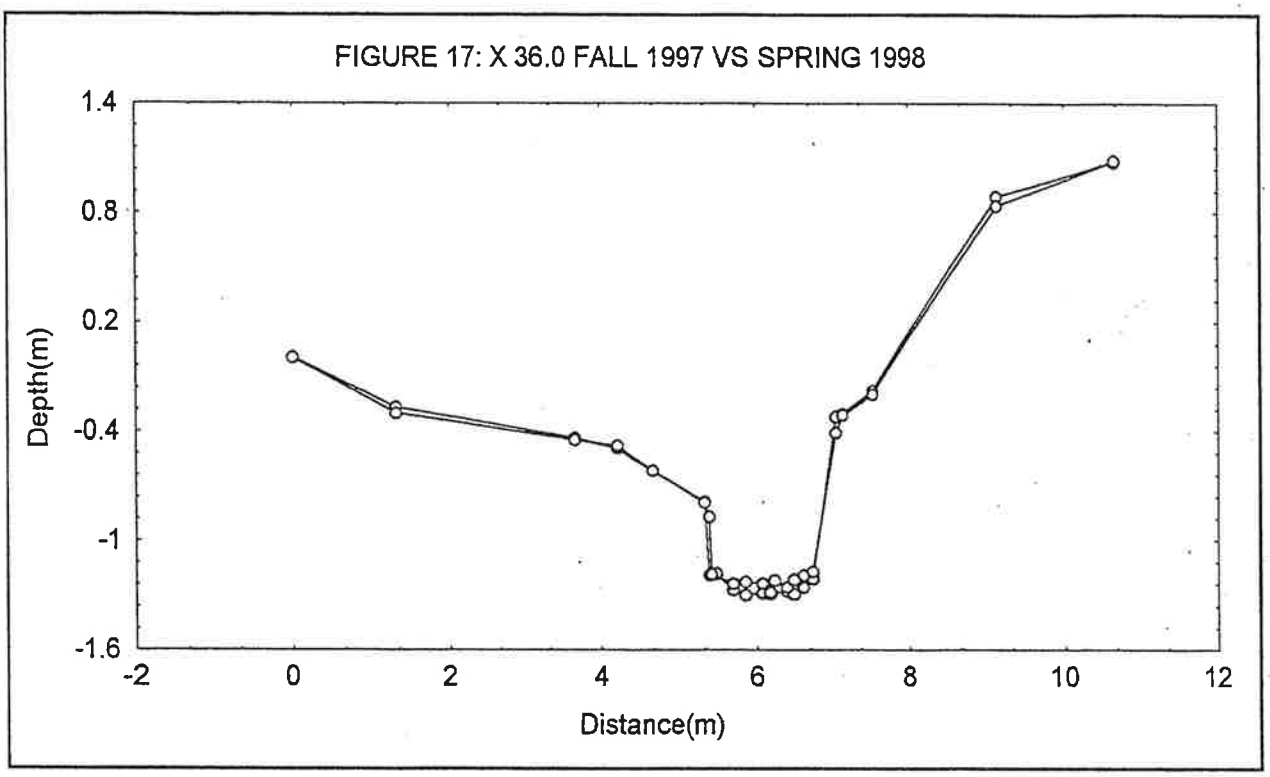


FIGURE 17: X 36.0 FALL 1997 VS SPRING 1998
1.4
0.8
0.2
-0.4
-1
-1.6
Depth(m)
-2
0
2
4
6
8
10
12
Distance(m)
Erosion
Deposition