Riparian Restoration

Bar Code Inside →

AQUATIC + WETLANDS CONSULTANTS

A PROPOSAL FOR

CONTROL OF NONPOINT SOURCE POLLUTION

IN

BOULDER CREEK WITH BEST MANAGEMENT PRACTICES

A Demonstration Project

AQUATIC AND WETLAND CONSULTANTS, INC.

AQUATIC + WETLAND CONSULTANTS

A PROPOSAL FOR CONTROL OF NONPOINT SOURCE POLLUTION IN BOULDER CREEK WITH BEST MANAGEMENT PRACTICES

A Demonstration Project

Prepared For:
City of Boulder
Department of Public Works/Utilities
1739 Broadway P.O. Box 791
Boulder, Colorado 80306
Phone 441-3200

Prepared By:
Aquatic and Wetland Consultants, Inc.
1911 11th Street, Suite 301
Boulder, Colorado 80302
Phone 442-5770

14 October 1988

AQUATIC + WETLAND [illegible]

TABLE OF CONTENTS

List of Figures

List of Tables

I. INTRODUCTION

Material contained herein has been excerpted in whole or refined from a previously prepared report titled "A Proposal for Elimination of Nonpoint Source Pollution from the Boulder Creek Watershed" dated 4 November 1987, and incorporates the concept of a "phased " demonstration project for nonpoint source pollution control in the Boulder Creek basin.

Specific best management practices (BMP's) have been selected that will not only control NPS pollution but facilitate aquatic and riparian zone habitat restoration and ecosystem function over time. It is intended that the demonstration reach will function as a "reference reach" against which all future, downstream NPS pollution control efforts (and those in other, similar watersheds) and BMP's can be compared.

II. BACKGROUND

This proposal is based on reported observations and documentation that:

1) the basin physical stream habitat degradation precludes attainment of the Class 1 and 2 Warm Water Aquatic Life use designations (Windell and Rink 1987a). A number of non-water quality factors directly related to nonpoint source pollution have been identified as limiting to aquatic life.

2) some past reported un-ionized ammonia excursions cannot be explained and appear strongly related to nonpoint source pollution inputs. Inputs from irrigation return flows are known to contribute significant amounts of sediment, fertilizers, nutrients, various xenobiotics (herbicides, pesticides, fungicides, etc.), and ammonia nitrogen. On a yearly basis, one can only speculate whether excursions are a result of nonpoint sources or the basin dischargers.

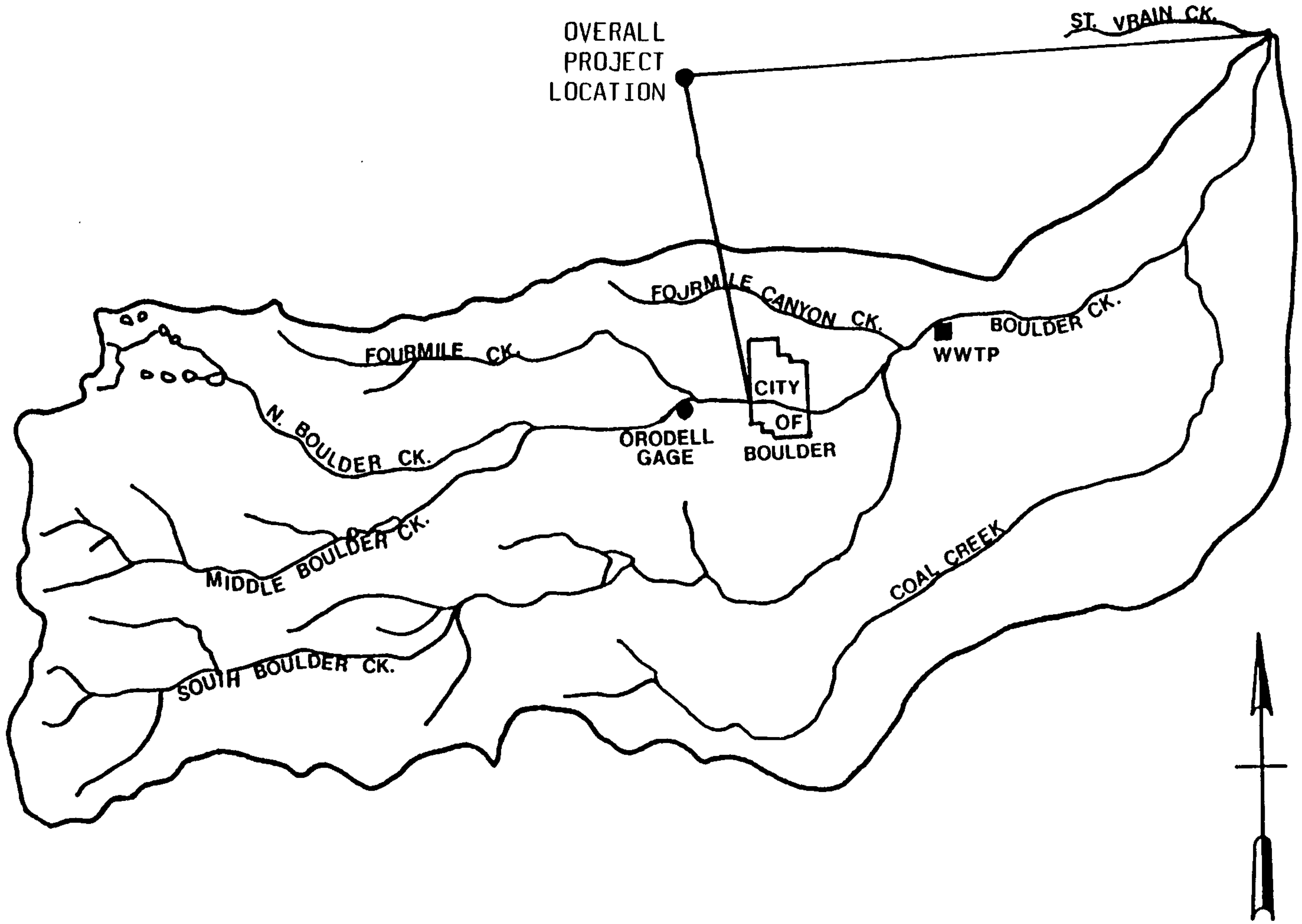
3) nonpoint sources of pollution were reported to contribute a significant amount of all pollutants entering the basin by the year 2000 (DRCOG 1977). For example, it was predicted that nonpoint sources will contribute 60% of the biological oxygen demand (BOD), 83% of the total dissolved solids (TDS), and 82% of the NO_3 to the Boulder Creek basin (Table 1). Nonpoint sources were also predicted to contribute 30% of the phosphates and 17% of the ammonia. Sediment continues to be produced from removal of natural vegetation, removal of riparian vegetation, disturbance of soil profiles, alteration of natural drainage patterns (surface or in-stream by channelization), and creation of impervious surfaces (DRCOG 1977). Recent visual observation

TABLE 1: Percent contributions of point and nonpoint source pollution to Boulder Creek by the year 2000 (DRCOG 1976).

POLLUTANT	PERCENT NONPOINT	PERCENT POINT SOURCE
BOD	60.0	40.0
TDS	83.0	17.0
Fecal Coliform	93.0	7.0
Fecal Strep	99.7	0.3
NH_3	17.0	83.0
NO_3	82.0	18.0
PO_4	30.0	70.0

TABLE 2: Categories of nonpoint source pollution identified in the basin and associated suspected pollutants.

SOURCE	SUSPECTED POLLUTANTS
A. Return Flow Inputs Irrigation Gravel Mining Reservoirs Developments	Nutrients and Sediment
B. Streambank Erosion Destruction of Riparian Zone Overgrazing	Sediment
C. Channel Erosion Downcutting from Channelization	Sediment
D. Overland Flow Agricultural Overuse Semi-Arid Nature Lack of Filtering Riparian Zone	Sediment and Nutrients



General project location extending from the mouth of Boulder Canyon downstream to its confluence with St. Vrain Creek, a distance of 23.6 miles.

LOWER BOULDER CREEK	AQUATIC AND WETLAND CONSULTANTS, INC.	FIGURE 1 OF 2 DATE 10/12/88

indicated a significant sediment load attributed to nonpoint source irrigation ditch return flows (Windell and Rink 1987a). Nonpoint source contributions to Coal Creek and to St. Vrain Creek are similar. Thus, while the 1977 DRCOG report showed significant contributions of nonpoint sources to total pollution load on an annual basis, actual day-to-day, week-to-week, and month-to-month contributions depend on factors such as precipitation, discharge, and timing of irrigation and fertilization. Major sources of NPS include:

a. return flows from irrigation canals, storage reservoirs and storm sewers;
b. degraded, slumped, and wasted streambanks resulting from overgrazing, channelization and gravel mining operations;
c. channel erosion caused by downcutting, a result of historic channelization; and
d. sheet flow and runoff from the land in the absence of the buffer and filtering function of the riparian zone vegetation.

These sources and suspected pollutants are summarized in Table 2.

III. GENERAL LOCATION OF PROPOSED PROJECT

The overall location of the proposed project includes that portion of the Boulder Creek watershed between the mouth of Boulder Canyon downstream to the Boulder Creek - St. Vrain Creek confluence, a distance of 23.6 miles (Figure 1). The creek has been divided into five major reaches for analytical purposes as follows (see Table 3 for a summary of Reach location).

<u>Reach 1.</u> Reach 1 begins at the mouth of Boulder Canyon where the Creek enters the City of Boulder limits. It flows through the urbanized center of the City for 4.8 miles until it bisects 55th Street. The entire reach is bordered on both streambanks by a well vegetated linear park system containing a 10 foot wide pedestrian and bicycling trail. Although approximately 90 percent of this reach was formerly channelized, 2.5 miles has received instream habitat restoration.

<u>Reach 2.</u> Reach 2 extends from 55th Street downstream to the 75th Street WWTP for a distance of 3.3 miles. The creek flows through light industrial areas, gravel mining sites, and briefly through agricultural lands.

<u>Reach 3.</u> Reach 3 extends from the 75th Street WWTP 3.2 miles downstream to a point upstream of 95th Street where channelization begins. Although least impacted by NPS pollution, it is characterized by natural meandering and a rubble, gravel, sand substrate. Long term grazing has resulted in riparian zone and streambank degradation.

Table 3: Summary of Boulder Creek Reach locations, lengths, segmentation, and station identification.

REACH NO.	LOCATION	TOTAL LENGTH	SEGMENTS AND LOCATIONS	SEGMENT LENGTH	STATION NO.
Reach 1	Mouth of Boulder Canyon to 55th Street	4.8 miles	none identified yet	---	-----
Reach 2	55th Street to WWTP effluent outfall	3.3 miles	Segment A	3.3 miles	-----
Reach 3	WWTP effluent outfall to a point upstream of 95th Street	3.2 miles	Segment A: WWTP to 75th Street	0.3 miles (1710 ft)	1000 + 00 to 1017 + 10
			Segment B: 75th St. to Weiser's property	0.3 miles (1450 ft)	1017 + 10 to 1031 + 60
			Segment C: Weiser's property	0.9 miles (5010 ft)	1031 + 60 to 1081 + 70
			Segment D: Ertl's property	1.4 miles (7330 ft)	1081 + 70 to 1155 + 00
			Segment E: Hartnegel's property	0.2 miles (1320 ft)	1155 + 00 to 1168 + 20
Reach 4	Upstream of 95th St. to Coal Creek	5.3 miles	none identified yet	---	-----
Reach 5	Coal Creek to St. Vrain Creek	7.0 miles	none identified yet	---	-----

Reach 4. Reach 4 extends a distance of 5.3 miles between 95th Street and the confluence with Coal Creek. It is characterized as highly disturbed by a varety of impacts including channelization, gravel mining, grazing, etc.

Reach 5. Reach 5 extends from the Boulder Creek-Coal Creek confluence to the St. Vrain Creek confluence a distance of 7.0 miles. Most of this reach lies within Weld County, has been channelized, gravel mined, overgrazed and lacks a functional riparian zone.

IV. SPECIFIC LOCATION OF PROPOSED PROJECT

The proposed project lies wholly within Reach 3 beginning at the 75th Street WWTP and extending downstream to a point upstream of 95th Street where severe channelization begins (Figure 2). Reach 3 has been divided into five subreaches or "Segments" described below (ownership is summarized in Table 4). Appendix I contains a photocopy of a 1"=400' scale aerial photograph which illustrates Reach 3 in its entirety.

Segment A. Segment 1 extends from the WWTP outfall east 0.3 miles to 75th Street. This Segment is owned and managed by the City of Boulder Public Works Department.

Segment B. Segment B extends from 75th Street 0.3 miles downstream. This Segment is owned by the Ertl family and managed as a conservation easement by the City of Boulder Open Space/Real Estate Department.

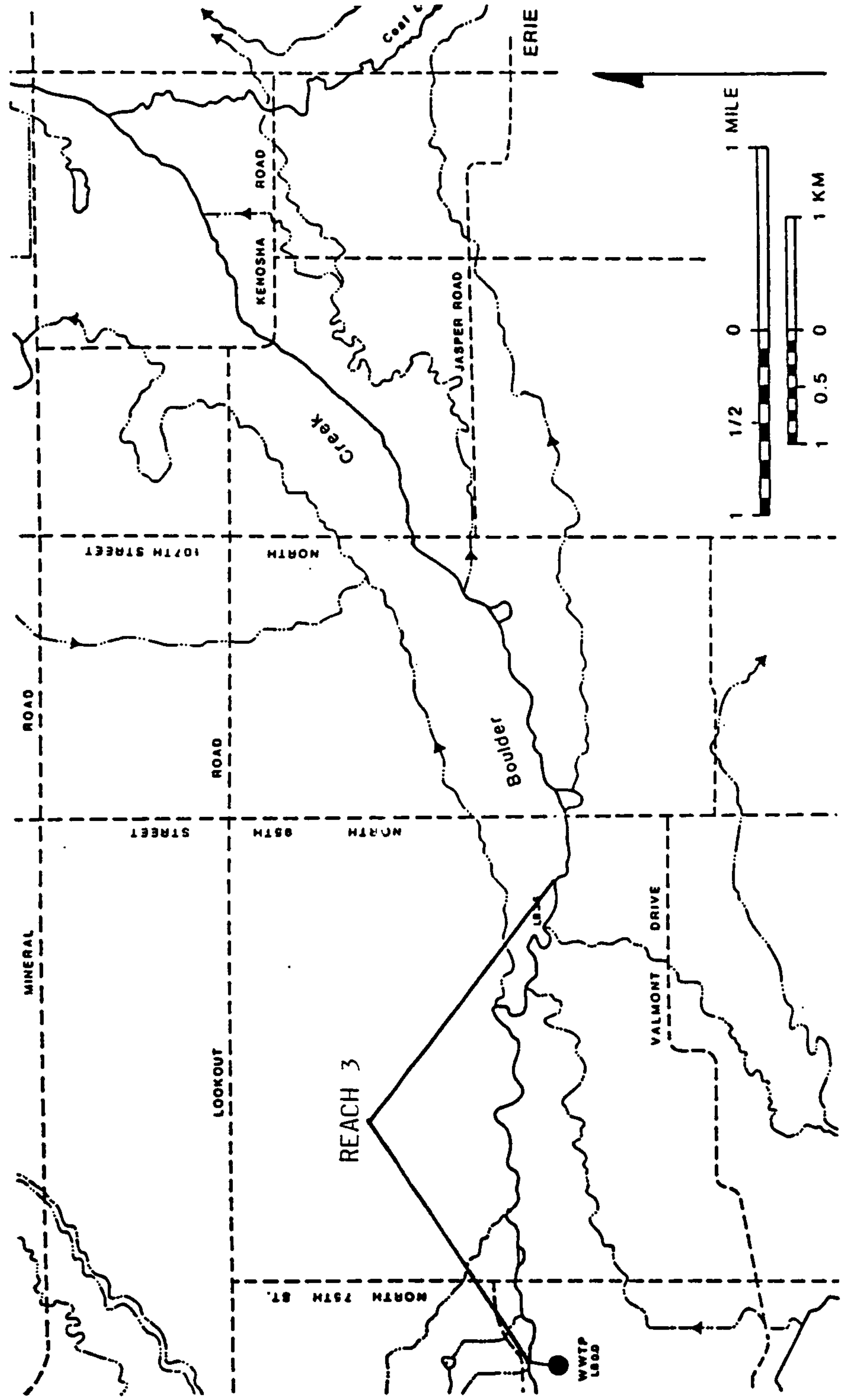
Segment C. Segment C extends from the downstream property line of the Open Space parcel 0.9 miles. This Segment is privately owned and maintained by the owner as a "natural preserve". This segment is not included in this proposal.

Segment D. Segment D extends from the downstream private property line 1.4 miles and is also owned by the Ertl family. The upstream portion of the property is managed as a conservation easement by the City of Boulder Open Space/Real Estate Department while the downstream portion is managed by the Ertls.

Segment E. Segment E is a small portion of the Boulder Creek corridor owned by the Hartnegels. It comprises the downstream-most 0.2 miles of stream within the unchannelized Reach 3.

V. PROPOSED WORK PLAN

Existing conditions of Reach 3 have been previously documented and are contained in the report titled "A proposal for Elimination of Nonpoint Source Pollution from the Boulder Creek Watershed" (Windell and Rink 1987b) and Windell and Rink 1987a.



Specific project location of Reach 3.

LOWER BOULDER CREEK	**AQUATIC AND WETLAND CONSULTANTS, INC.**	**FIGURE** 2 **OF** 2 **DATE** 10/12/88

TABLE 4: Boulder Creek Reach 3 ownership.

SEGMENTS	LENGTH (miles)	STATION NO.	OWNERSHIP
Segment A	0.3	1000+00 to 1017+10	City of Boulder Public Works
Segment B	0.3	1017+10 to 1031+60	Ertl w/ Conservation Easement to City of Boulder Open Space
Segment C	0.9	1031+60 to 1081+70	Weiser
Segment D	1.4	1087+70 to 1155+00	Ertl w/ Conservation Easement to City of Boulder Open Space
Segment E	0.2	1155+00 to 1168+20	Hartnegel

Refer to Appendix I for a 1" = 400' scale aerial photograph which illustrates the demonstration project reach and associated Station numbers. Appendix II contains a complete description and illustrations of how each BMP will be implemented. Slides illustrating existing conditions at point locations are contained in Appendix III. Reference to slides throughout the text will be indicated by "S-slide number".

A. Segment A. Station 1000+00 to 1017+10 (Length = 1710 feet)

1) Revegetation. This segment requires an approximate 50% revegetation effort along both streambanks for a total length of 3420 lineal feet. A 100% effort is not required since some riparian vegetation currently exists (see S1). Individual trees and shrubs will be planted at centers ranging from 5 to 15 feet beginning at the water edge and extending 25 feet away from the active channel. Total area to be planted is 2.0 acres (25' X 3420'). This treatment is based on no existing or expected (future) grazing pressure. Specifications for planting are in accordance with Section A of Appendix II.

2) No other BMP's are required in this reach. An existing reaeration structure and USGS gaging station is located just upstream of the 75th Street bridge.

B. Segment B. Station 1017+10 to 1031+60 (Length = 1450 feet)

1) Fencing. Existing fencing on the south streambank precludes the need for fencing. However, the cattle water access ramp currently located on the concave bank of a degrading meander will be relocated at the nearest downstream point bar. No fencing is required on the north streambank. Specifications for relocating the cattle access ramp are in accordance with Section A of Appendix II.

2) Revegetation. This segment requires an approximate 50% revegetation effort along the north streambank and 100% effort on the south streambank for a total length of 2900 lineal feet (see S2). Individual trees and shrubs will be planted in open areas at centers ranging from 5 to 15 feet beginning at the water edge and extending 25 feet away from the active channel. Total area to be planted is 1.7 acres (0.8 acre on each side). Specifications for planting are in accordance with Section B of Appendix II.

3) Streambank Stabilization. The streambank at station 1027+20 will be stabilized with tree revetment. The eroded cutbank is 60 feet in length and 4 feet high for a total of 240 square feet (see S3). Specifications for construction are in accordance with Section C of Appendix II.

4) Wetland Detention Pond. A one quarter acre detention pond and an associated one quarter acre wetland will be constructed at

station 1031+60 on the north streambank. This area will intercept storm sewer drainage from the Heatherwood subdivision (see S4). Specifications for construction are in accordance with Section D of Appendix II.

5) Thalweg Channel. A thalweg channel will be constructed along 1450 feet of the active channel with special attention given to concentrating the yearly 8.5 months of low flow. Maximum thalweg establishment will occur along the concave streambanks of the meanders and least thalweg construction will occur within the riffle areas between concave banks. Specifications for construction are in accordance with Section E of Appendix II.

C. Segment C. Station 1031+60 to 1081+70 (5,010 feet)

No plans exist for the utilization of BMP's to control NPS pollution at the landowners request.

D. Segment D. Station 1081+70 to 1155+00 (7330 feet)

1) Fencing. Existing fencing extends from 1081+70 to 1111+00, a length of 2,930 feet and no additional fencing will be required. Fencing will be constructed along both streambanks from Station 1111+00 to 1155+00, a length of 4,400 feet (see S5). Two cattle watering access ramps will be constructed on the north and two on the south streambanks for a total of four. These will be located at each of four point bars at the following stations.

a. Station No. 1120+00 South Bank

b. Station No. 1127+00 North Bank

c. Station No. 1135+00 South Bank

d. Station No. 1140+00 North Bank

2) Revegetation. This segment requires 100% effort on both streambanks extending between Stations 1081+70 to 1155+00; a lineal distance of 7,330 feet (see S6). Therefore, an area 25 feet in width and 14,660 feet in length (both streambanks) for a total of 16.8 acres will receive vegetative treatment. Specifications for types of species and methods of planting are in accordance with Section B of Appendix II.

3) Streambank Stabilization. A total of 17 eroded and degrading streambank locations exist within Segment D. The first 4 will be stabilized with tree revetment. Specification for construction of the tree revetment are in accordance with Section C of Appendix II. The location, length, height and total square feet requiring treatment of the first four and the remaining 13 are as follows (see S7, S8, S9, and S10, respectively).

No.	Station	Cut Bank Length X Height	Square Feet
1.	1096+20	125 X 2	250
2.	1102+00	175 X 6	1050
3.	1106+10	75 X 3	150
4.	1107+50	140 X 3	420
5.	1108+60	75 X 3	150
6.	1111+60	150 X 2	300
7.	1115+00	80 X 25	2000
8.	1120+00	150 X 2	300
9.	1127+00	500 X 3	1500
10.	1130+00	50 X 3	150
11.	1131+50	200 X 2	400
12.	1136+00	400 X 3	1200
13.	1140+00	190 X 3	570
14.	1142+50	200 X 2	400
15.	1144+50	120 X 3	360
16.	1146+30	120 X 2	240
17.	1150+00	260 X 3	780

4) Reaeration Structure. A reaeration structure will be located at Station 1095+00. Specifications for the structure are provided in Section C of Appendix II. One existing 3.5 foot drop structure is located at the confluence of Boulder Creek and Liggett Ditch, Station 1116+20.

5) Wetland Detention Pond. Although 4 NPS inputs have been identified in Segment D, each requires further investigation including locating the: 1) source, 2) type of NPS pollutant(s), and 3) level of pollutant(s). Preliminary investigation identified the input locations as follows.

a. Station 1098+70 - possible irrigation return flow

b. Station 1127+00 - unknown origin (see S11)

c. Station 1039+60 - unknown origin

d. Station 1148+30 - unknown origin (see S12)

It may be possible to route these sources of NPS through abandoned gravel mining pits and wetland prior to entering Boulder Creek.

6) Thalweg Channel. No thalweg channel will be constructed in Segment D during the pilot or demostration project.

7) Future BMP Implementation. Future BMP implementation should include the: 1) stabilization of the 13 other eroded and degraded streambanks, 2) creation of additional thalweg channel, 3) increased width of riparian vegetation zone, 4) wetland detention ponds, 5) reaeration, etc. However, the implementation of the heretofore recommended BMP's will facilitate evaluation and data gathering that will be compared to future BMP implementation.

E. Segment E. Station 1155+00 to 1168+20

This Segment, although located within Reach 3, is at the downstream most portion of the demonstration reach. Upstream implementation of BMP's is of highest priority and additional work will need to be completed on Segment D before proceeding to Segment E.

VI. COST ESTIMATE

Table 5 summarizes specific costs associated with implementation of each BMP for each Segment. Three total costs have been identified and are different based on total width of the riparian zone revegetation effort. The lowest cost of approximately $99,000 is based on revegetating 25 feet adjacent to both streambanks. The upper price of approximately $200,000 is based on revegetating a 75 foot width. A mid-range cost is offered for revegetation of 50 feet.

TABLE 5: Cost estimate summary of the demonstration project.

BEST MANAGEMENT PRACTICE	ESTIMATED COST $	ALTERNATIVE* COSTS $	
Fencing			
Segment B (relocation of water access)	500		
Segment D (Fencing 2 streambanks)	14,520		
(4 watering access ramps)	6,000		
Revegetation			
Segments A,B, & D			
75' wide			175,520
50' wide		117,260	
25' wide	58,270		
Reaeration Rock Structure			
Segment D	4,000		
Wetland Detention Pond			
Segment B	5,000		
Thalweg Channel Creation			
Segment B	2,000		
Streambank Stabilization (tree revetment)			
Segment B	1,085		
Segment D (4 locations of 17)	8,115		
TOTAL COST	$99,490	$158,480	$208,625

*Three alternative riparian zone revegetation widths are identified; 25', 50' and 75' adjacent to each streambank. Costs vary significantly between widths, thus the wide range between the three total costs.

VII. LITERATURE CITED

Adamus, P.R. and L.T. Stockwell. 1983. A method for wetland functional assessment. Vol. I. Critical review and evaluation concepts. FHWA-IP-82-83.

Bock, J.H. 1972. An ecological survey of the vegetation of Boulder Creek. Thorne Ecological Institute, Boulder, Co. 24 pp.

DRCOG, 1977. Denver Regional Council of Government's Clean Water Program. Technical Report, October 1977.

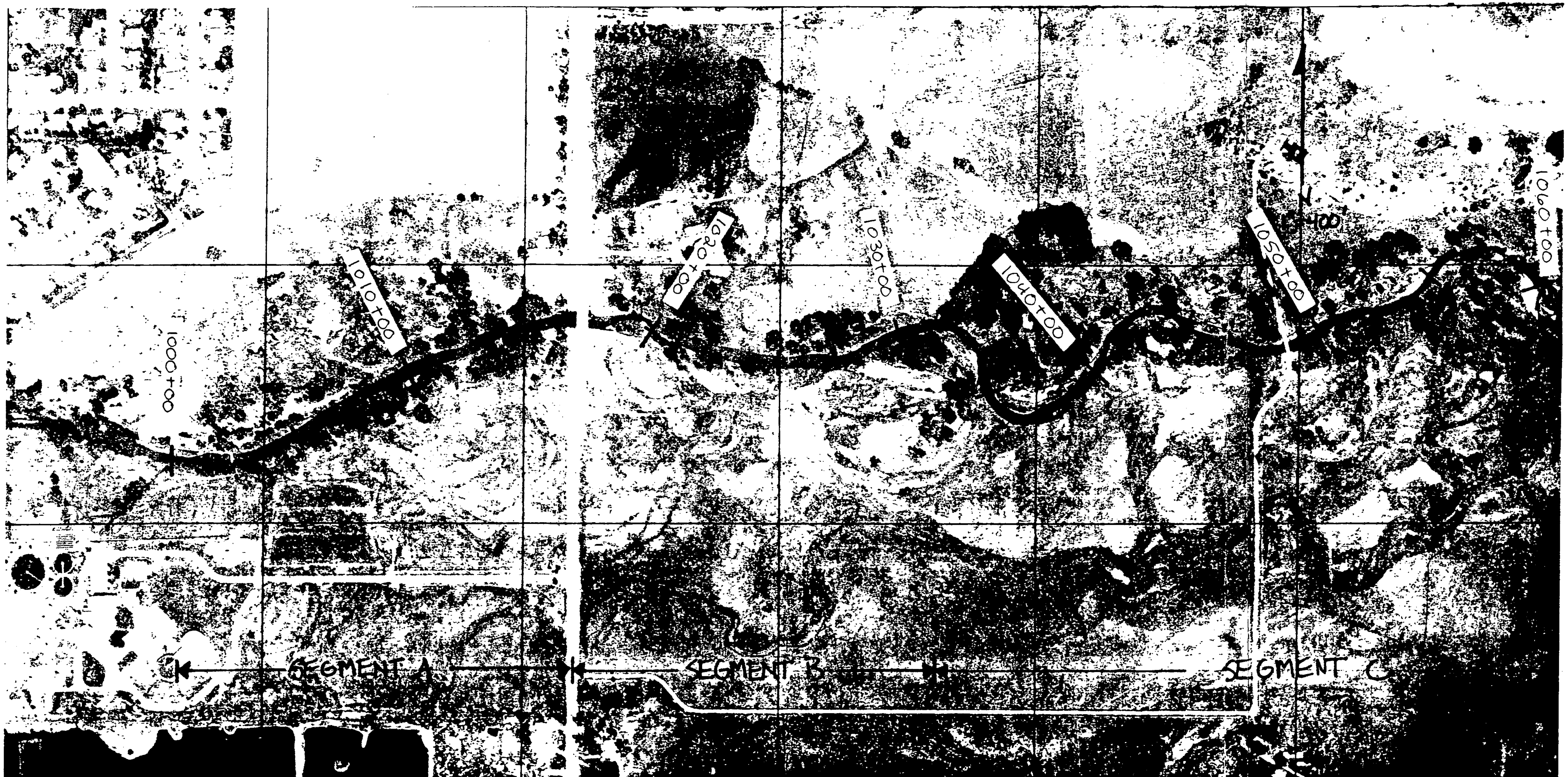
Wineager, H.H. 1977. Camp Creek fencing; plant, wildlife, soil, and water responses. Rangeman's Journal 4(1):10-12).

Windell, J.T. and L.P. Rink. 1987a. A use attainability analysis of lower Boulder Creek Segments 9 and 10 (Final). Aquatic and Wetland Consultants, Inc., Boulder, Co. 68 pp. plus appendices.

Windell, J.T. and L.P. Rink. 1987b. A proposal for the elimination of nonpoint source pollution from the Boulder Creek watershed (Draft).

APPENDIX I

Boulder Creek Demonstration Reach
Aerial Photography 1"=400'
1984



1000+00
1010+00
1020+00
1030+00
1040+00
1050+00
1060+00
400
SEGMENT A
SEGMENT B
SEGMENT C


1070+00
1080+00
1090+00
1100+00
1110+00
1120+00
1130+00
1140+00
1150+00
N
1"=400'

APPENDIX II

Description of Best Management Practices

DESCRIPTION OF BEST MANAGEMENT PRACTICES

The following Best Management Practices (BMP's) for riparian and aquatic habitat restoration are recommended specifically for implementation on Boulder Creek Segments A, B and D. The BMPs should have the capability of providing cost-effective water quality improvement singley and in combination with the 75th Street WWTP. Each BMP is described as follows.

A. Fencing

In order to maintain an effective, fully functional riparian corridor, a minimum 125 foot setback from the highwater mark of each streambank will be protected. Protection can be achieved by way of proper management (i.e., a conservation easement) and must involve the exclusion of cattle.

To effectively exclude cattle in locations where cattle are currently present, or may be present in the future, the 125 foot wide riparian corridor will be fenced in keeping with other City of Boulder open space/green belt property. Specifically, the fencing should be passable to deer and other wildlife but not livestock. It shall 1) require low maintenance, 2) consist of smooth, six-strand, high tensile strength (2000 psi), 42 inch high wire, 3) be installed with 30 feet between posts, and 4) have a 30 year guarantee (Figure 1).

Livestock access to the creek for watering will be accomodated (Figure 1) and upstream rock diversion structures will be constructed to protect fencing from debris buildup. Watering access points will be provided at a rate of approximately two per mile per streambank. Access points will be placed at the point bar on the inside of a meander to minimize erosion.

Numerous studies have documented the correlation between livestock exclosure and riparian zone recovery. Additionally, streambank stability increases, wildlife utilization increases and sediment input decreases (Wineager 1977).

B. Riparian Zone Revegetation

Native riparian trees and shrubs will be planted adjacent to both streambanks in an attempt to revegetate and restore the riparian zone that historically flanked Boulder Creek. Vegetation will be planted from the channel edge out 25 feet, 50 feet or 75 feet depending on available monies. A width of 75 feet is the preferred alternative.

Individuals will be planted at 5 foot centers at the channel's edge, at 10 foot centers at a 10 foot setback from the streambank, and at 15 foot centers at a 25 foot setback from the streambank. Fifteen foot centers will be continued thereafter to the edge of the specified revegetation zone (Figure 2). It is anticipated that vegetation will become established naturally within two to five years within the remaining riparian corridor width (i.e., within the fenced zone). As vegetation becomes established and water tables rise, additional vegetation will grow and tend to migrate to the drier upland.

The best and cheapest source of vegetation is from the Colorado State Forest Service, Ft. Collins, Colorado. Materials of choice include native narrowleaf cottonwood (Populus augustifolia), plains cottonwood (Populus sargentii), sandbar willow (Salix exiqua and Salix interior), cracked willow (Salix fragilis), and alder (Alnus tenuifolia) (Bock 1972). Standard size is one foot tall, but trees will likely be 4 to 5 feet tall.

C. Streambank Stabilization

Revet means to provide or protect a bank of earth or wall. Tree revetments have been commonly used to protect degrading and slumping streambanks in several states. Preferably, tree revetments should be constructed with live, heavy limbed, scrub pine trees (preferably Ponderosa pine) that are over lapped with the ends cabled together (Figure 3) with minimum 3/8" diameter cable. Every second or third tree should be cabled to a log-deadman buried four feet deep and 10 feet from the bank. Consideration can be given to the use of metal posts or rebar driven four to six feet deep. The butt of the first tree should be pointed, and be protected by a 10 cubic yard rock deflector, but this is probably not necessary in all cases.

Streambanks in need of stabilization were measured and a square footage calculated. Trees used as revetment will cover with either trunks, limbs or foliage the entire square footage requiring stabilization.

Advantages of tree revetment include the production of excellent fish habitat, a change in the thalweg, a slowing of the water flow against the eroded bank, and a strong tendency for silt and sediment to settle out on the bank side of the revetment. Vegetation tends to grow very quickly and luxuriantly in the rich deposit and the roots add to streambank stability.

D. Wetland Detention Systems

Irrigation return flow ditches and storm sewer drainage will be diverted into existing gravel ponds, irrigation holding water ponds, or constructed detention ponds that subsequently overflow into either an existing or constructed wetland (Figure 4). The intent is to improve water quality by sediment retention and nutrient removal prior to its return to the creek.

Detention ponds will be sized according to their expected storm flows and associated velocities. They will be constructed to detain up to the 2-year, 6-hour storm for a period sufficient to settle 95% of the suspended sediment load. Ponds will be nonstructural (i.e., earthen dams, rock spillways) but will be monitored and dredged as necessary.

An associated wetland will be constructed downstream of the pond outlet and will contain locally available species (i.e., transplanted from nearby ditches and ponds). Transplants will be supplemented with Scirpus acutus and Scirpus lacustrus (Bulrushes) which are species known to be effective at filtering storm runoff. Wetlands will not be 100 percent functional following construction but will require a 2 to 3 year grow our period.

Wetland vegetation will be planted around the shallow edge of the detention ponds as grade allows.

Wetlands associated with retention and sedimentation ponds have many diverse functions. These functions include ground water recharge, ground water discharge, flood storage and desynchronization, shoreline anchoring and dissipation of erosive forces, sediment trapping, nutrient retention and removal, food chain support, and habitat for wildlife (Adamus 1983). Of these functions, sediment trapping and nutrient retention and removal are perhaps the most important for improving water quality.

E. Thalweg Restoration

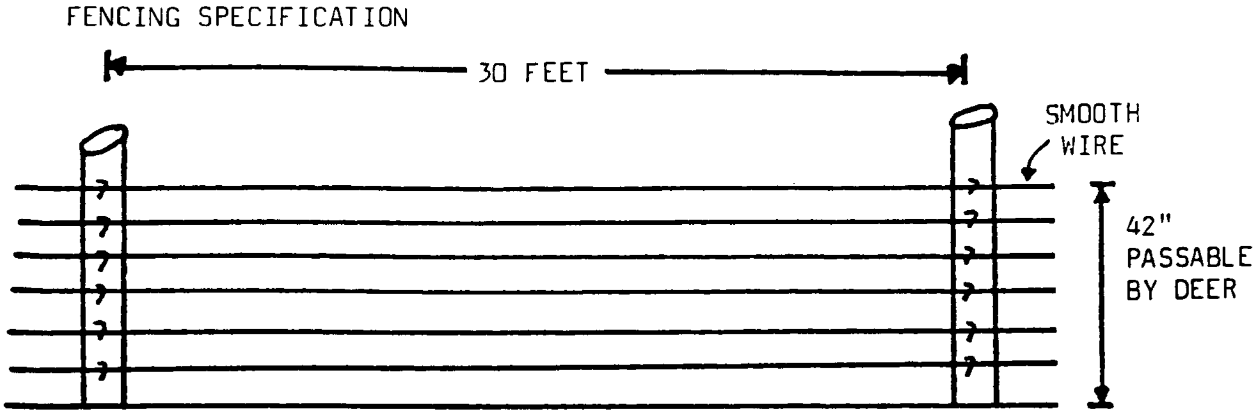
A thalweg channel (or low flow channel) will be reestablished by excavating within the existing trapezoidal channel. The goal is to reduce the water width area except during the spring runoff or major storms. This will be accomplished by constructing a channel that is narrower, deeper, and longer than the existing channel and one that contains meanders, pools and riffles.

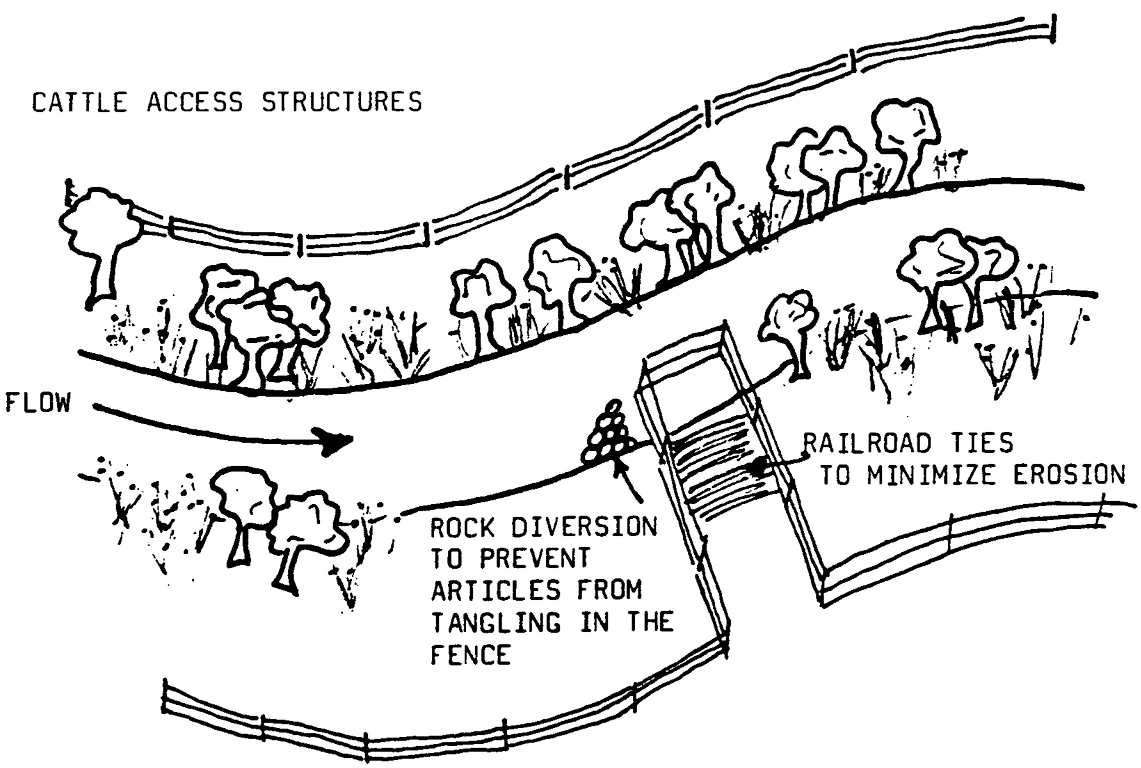
The channel bottom will be rearranged to create a 15 to 20 foot wide low flow channel designed to concentrate flows during the 8.5 month low flow period each year (Figure 5). A backhoe will be used to scrape a channel that follows the natural path of the historic thalweg from concave bank, to the riffle cross-over, to the next concave bank. The thalweg will be deepest at the outside of meanders (2 to 4 feet) and less discernable at the riffle cross-over). Available rock and organic matter (i.e., root wads) will be selectively placed as deflectors to train the flow into the appropriate pattern. Excess material will be redistributed within the active channel or removed off-site. Under no circumstances will this material be placed within existing wetlands or on the streambank.

The remaining and active channel will be maintained and will function during the runoff, storms and the nightly releases by the PSC hydropower plant.

F. Reaeration Structures

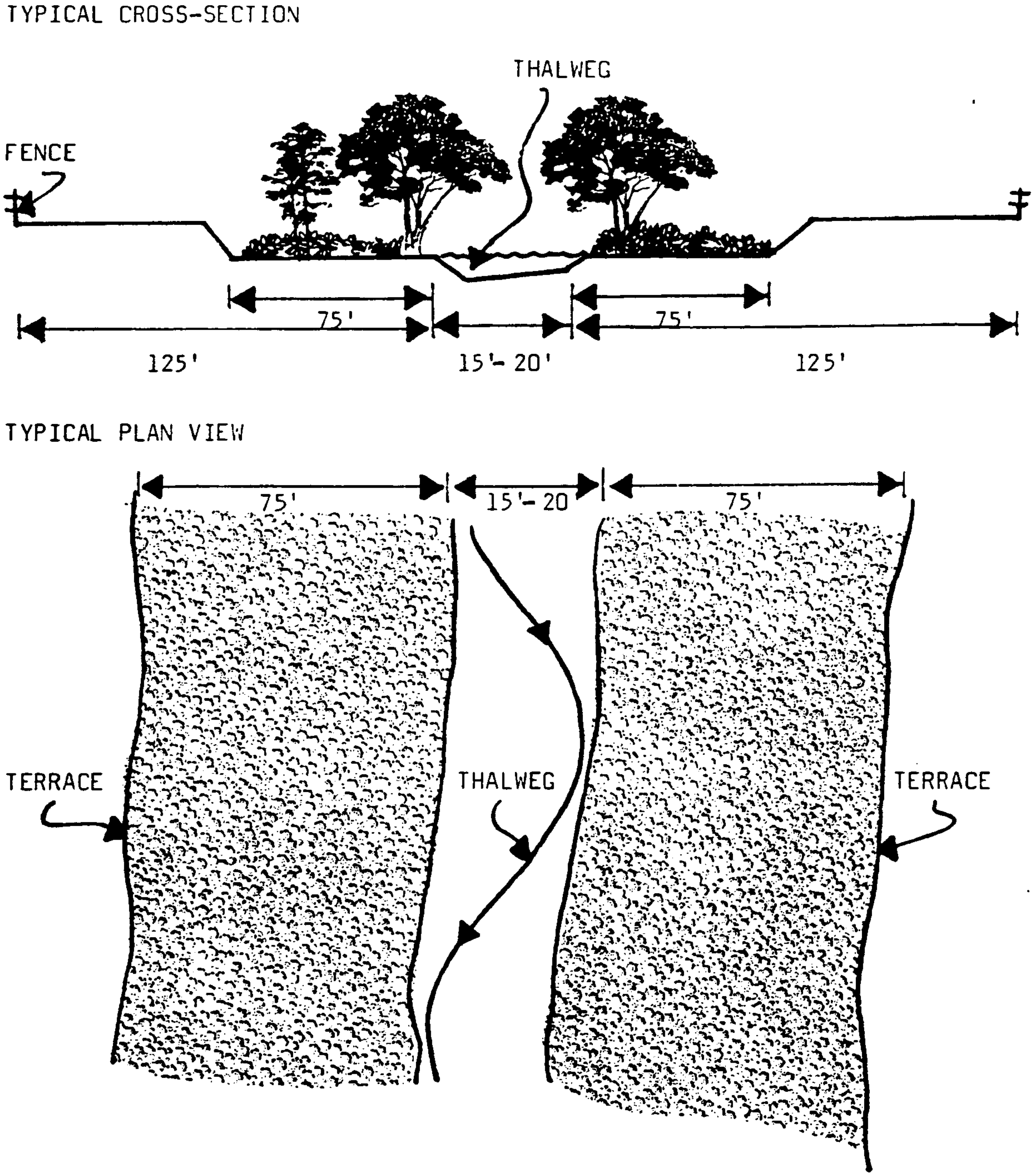
Two rock reaeration structures will be constructed per mile to increase carbon dioxide and oxygen concentrations during periods of high temperature and pH. Each rock structure will be approximately 15 to 20 feet in width 50 to 75 feet long and 2 to 4 feet high at its upstream location (Figure 6). Rock diameter will range between two and four feet. The purpose of increasing the carbon dioxide concentration is to maintain a lower pH. Since conversion of total ammonia to the un-ionized form is highly dependent on pH, and pH is highly dependent on the uptake of carbon dioxide by photosynthesizing plant life, pH can be stabilized by replacing carbon dioxide consumed in photosynthesis during the spring and fall excursion periods.





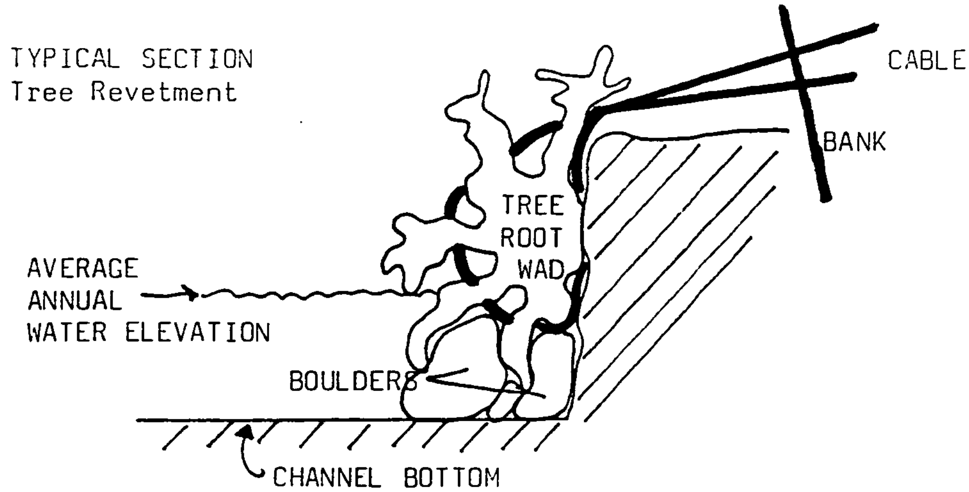
Riparian corridor fencing specifications.

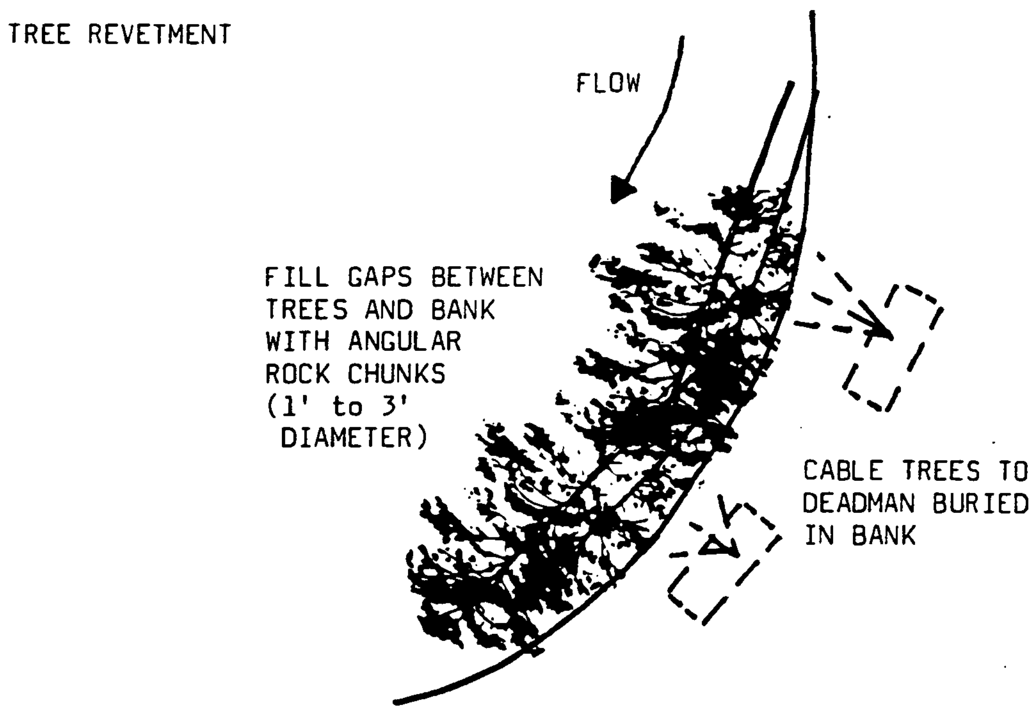
LOWER BOULDER CREEK	**AQUATIC AND WETLAND CONSULTANTS, INC.**	**FIGURE** 1 **OF** 6 **DATE** 10/12/88



Riparian corridor revegetation, illustrating a 75 foot wide zone.

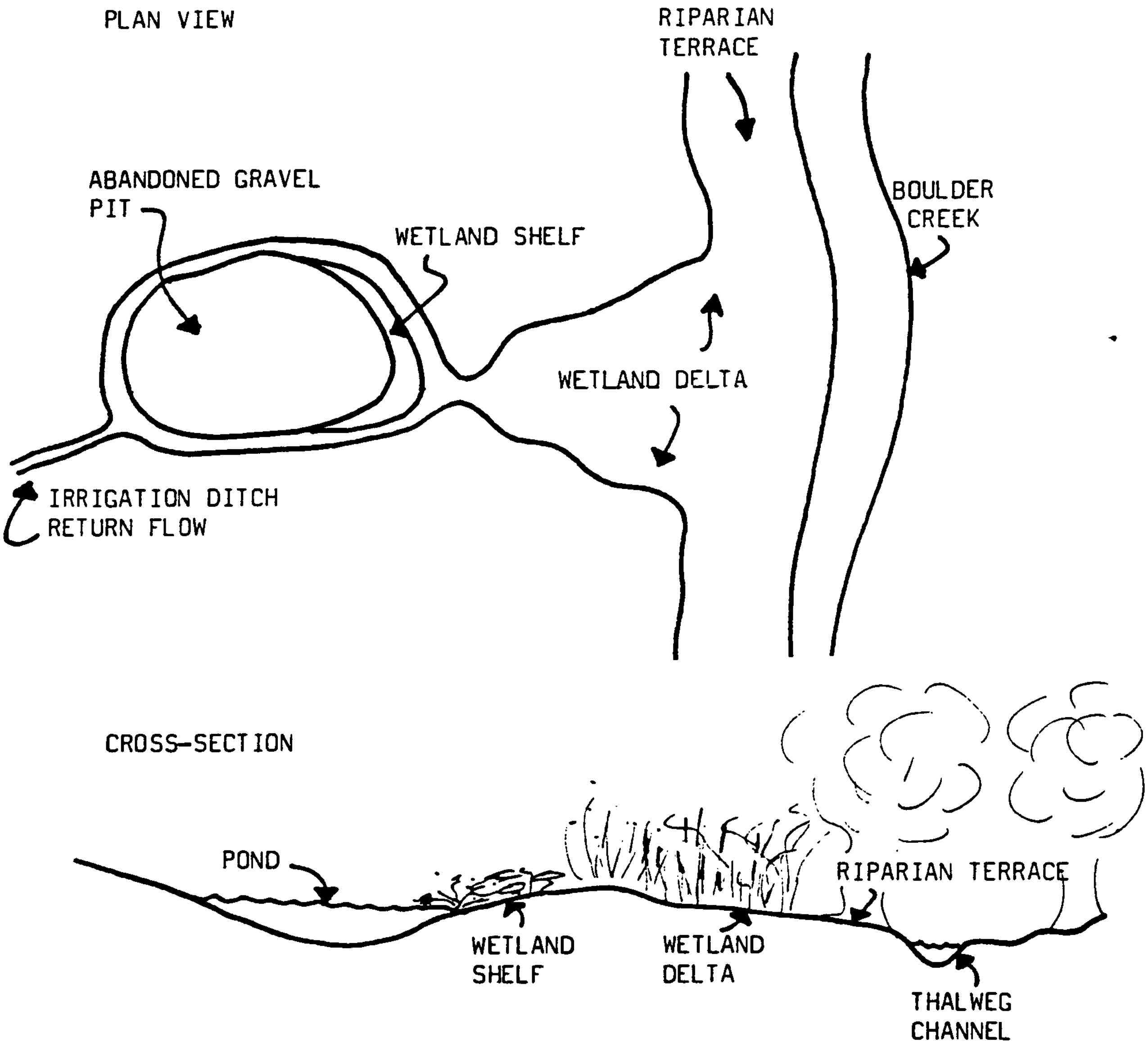
LOWER BOULDER CREEK	**AQUATIC AND WETLAND CONSULTANTS, INC.**	**FIGURE** 2 **OF** 6 **DATE** 10/12/88





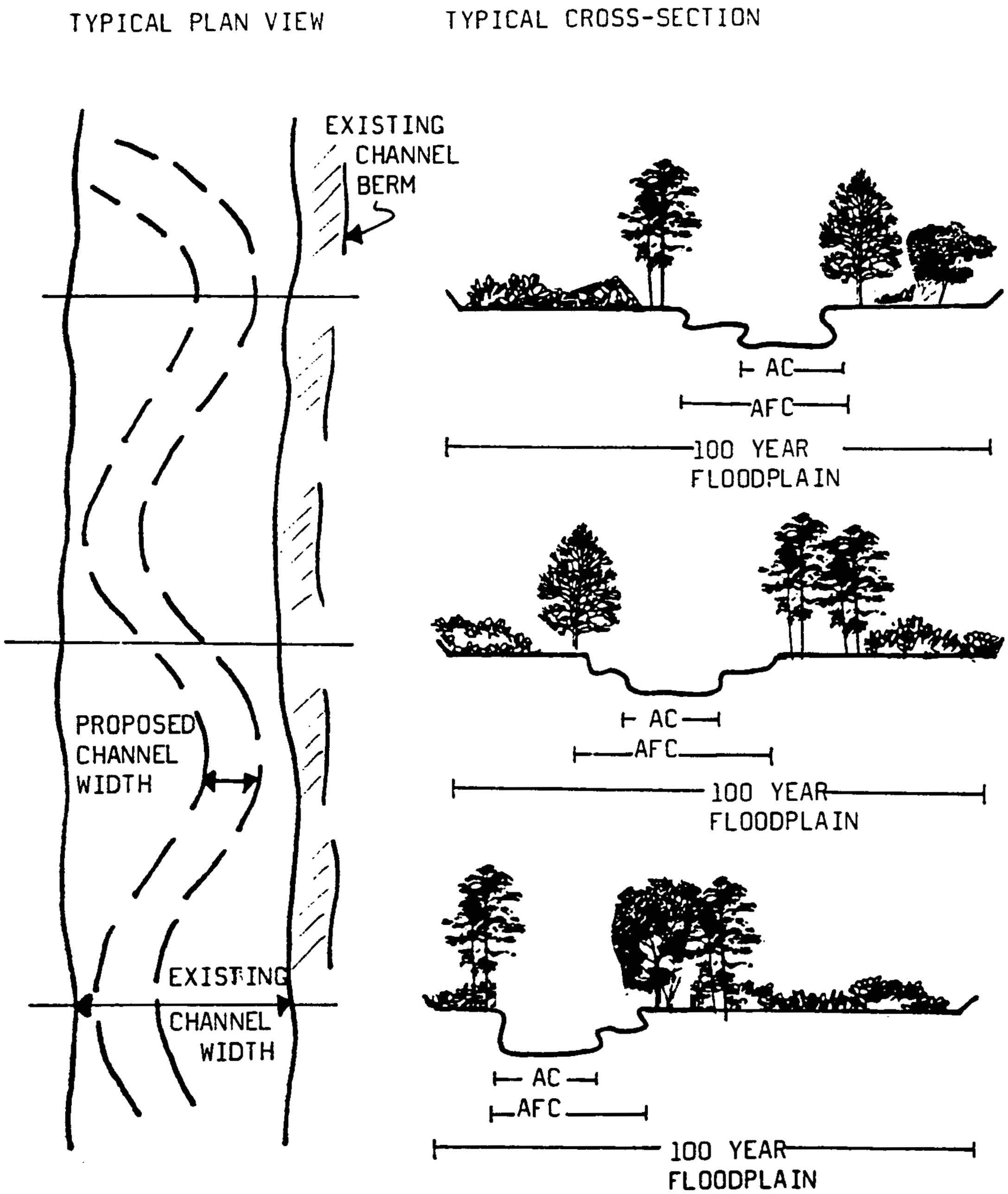
Tree revetment for repair of eroding banks.

LOWER BOULDER CREEK	**AQUATIC AND WETLAND CONSULTANTS, INC.**	**FIGURE** 3 **OF** 6 **DATE** 10/12/88



Typical plan and cross-section views of utilizing abandoned gravel pits and existing wetlands as sediment detention and filtration systems for irrigation return flows (not to scale).

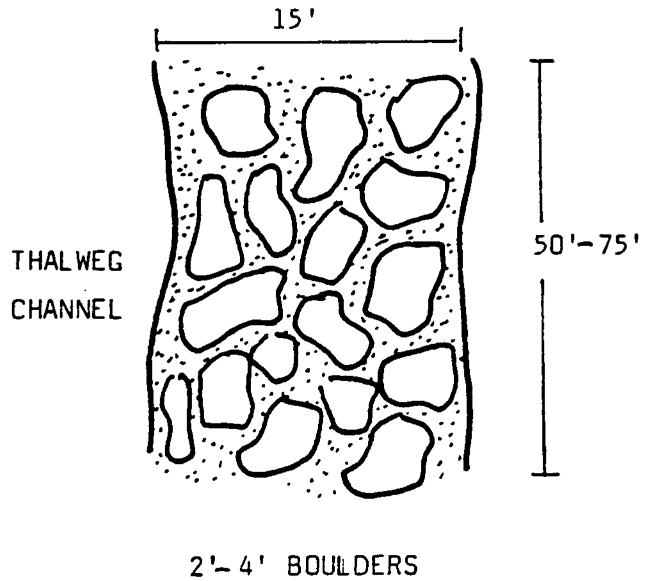
LOWER BOULDER CREEK	AQUATIC AND WETLAND CONSULTANTS, INC.	FIGURE 4 OF 6 DATE 10/12/88



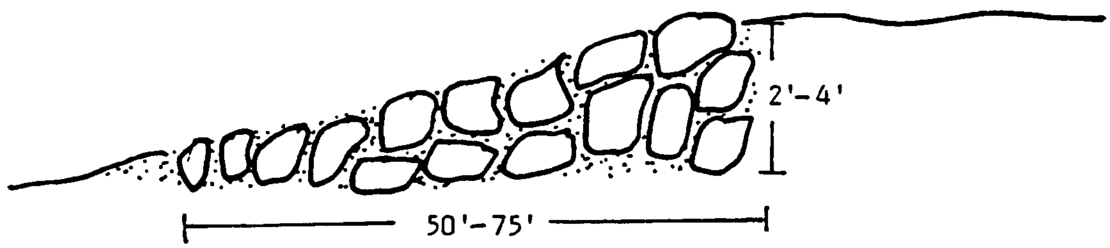
Restoration of a thalweg channel to concentrate water during low flow periods (AC = Active Channel, AFC = Active Flood Channel).

LOWER BOULDER CREEK	AQUATIC AND WETLAND CONSULTANTS, INC.	FIGURE 5 OF 6 DATE 10/12/88

PLAN VIEW



CROSS-SECTION VIEW



Typical plan and cross sectional views of reaeration structures (not to scale).

LOWER BOULDER CREEK	**AQUATIC AND WETLAND CONSULTANTS, INC.**	**FIGURE** 6 **OF** 6 **DATE** 10/12/88

APPENDIX III

Slides Illustrating Specific Reference Points

(NOT INCLUDED)