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# FINAL REPORT

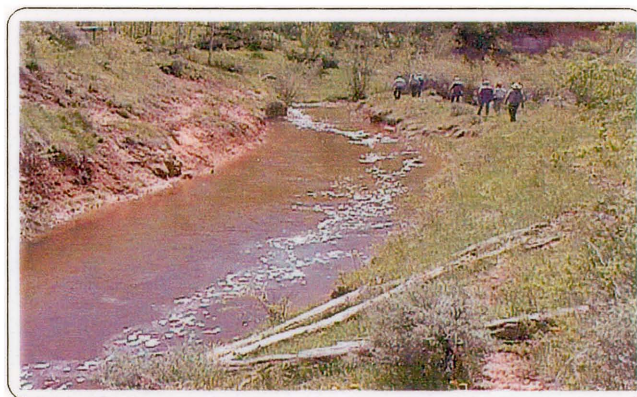
## Highline Watershed Improvement District Ditch Rehabilitation Project Level II

### PREPARED FOR:

Wyoming Water Development Commission  
122 W. 25<sup>th</sup> Street  
Herschler Building  
Cheyenne, WY 82002

### PREPARED BY:

Anderson Consulting Engineers, Inc.  
2900 South College Avenue, Suite 3B  
Fort Collins, CO 80525  
(ACE Project WYWDC14)



November 1, 1999



**ANDERSON CONSULTING ENGINEERS, INC**  
*Civil • Water Resources • Environmental*



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**FINAL REPORT**

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DITCH REHABILITATION PROJECT  
LEVEL II**

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**November 1, 1999**



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### SHEETS

Sheet 1:	Existing System Inventory
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# I. INTRODUCTION

## 1.1 General

On June 1, 1999, Anderson Consulting Engineers, Inc. (ACE) entered a contract with the Wyoming Water Development Commission (WWDC) to provide professional services to the Highline Ditch Watershed Improvement District (District) Ditch Project. ACE was retained to conduct an irrigation rehabilitation study for the District. Severe erosional problems within the three main irrigation delivery ditches threaten the integrity of the existing structures and the irrigation system. The purpose of this study was to identify and evaluate the feasibility of various rehabilitation alternatives for mitigating the major erosion problems associated with the three main irrigation ditches. This report documents the results of all tasks associated with this effort.

## 1.2 History of the Project

The Highline Watershed Improvement District is in Carbon County, east of Saratoga, Wyoming. The boundary of the District is presented in Figure 1.1. Although greater than 10,000 irrigated acres are found within the district boundary, this project specifically involves the rehabilitation of the upper portions of three ditches: the Highline Ditch, Elk Hollow Ditch and Wiant Ditch. Consequently, this project focuses on the rehabilitation of irrigation facilities located in Sections 1 and 2 of Township 16 North, Range 82 West (Sheet 1). Given the location of irrigation facilities identified for rehabilitation, not all of the irrigated acreage within the district will benefit by the improvements.

Historically, severe erosion of the existing canals associated with the Highline Ditch, Elk Hollow Ditch and Wiant Ditch have required continual maintenance. The Natural Resources Conservation Service (NRCS) has completed several studies related to the improvements necessary to mitigate the existing erosion problems. Recent NRCS studies documented costs exceeding \$120,000 to rehabilitate the existing facilities and mitigate the erosion problems. Faced with costs of this amount, the landowners irrigating under the three ditches decided to form a watershed improvement district to obtain funding for the improvements.

The water conveyed by the Highline Ditch, Elk Hollow Ditch and Wiant Ditch is primarily diverted from North Brush Creek. The Wiant Ditch can divert as much as 99.1 cfs based on 1 cfs/70 acres and almost 200 cfs if water is available to divert a double appropriation of water. In recent years, the Wiant Ditch has diverted as much as 124 cfs in 1997 and 131 cfs in 1998. Similarly, the



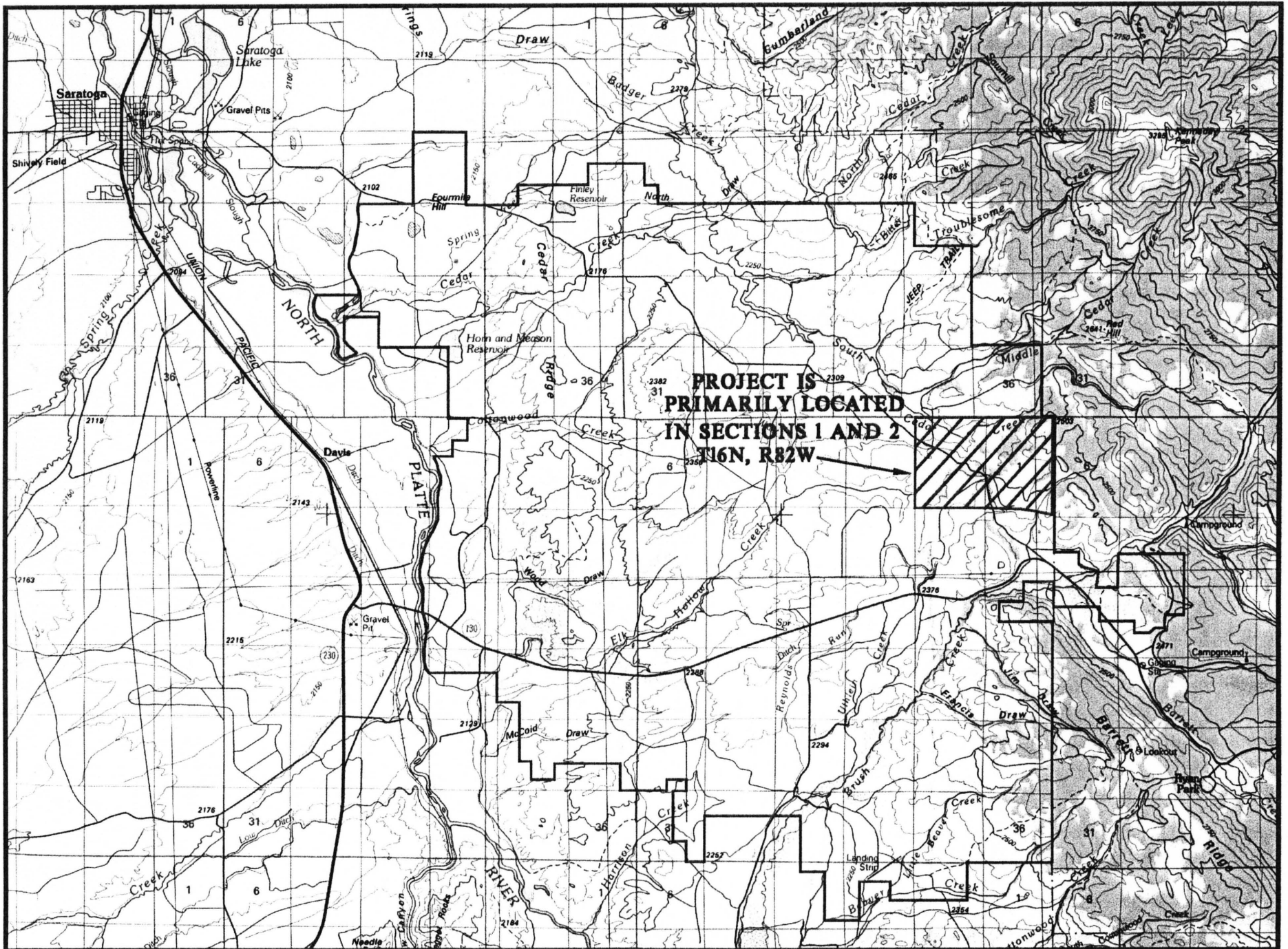


Figure 1.1 Project Vicinity Map

Highline Ditch can divert as much as 94 cfs based on 1 cfs/70 acres and approximately 188 cfs if water is available for diversion. The Elk Hollow Ditch can divert 10.4 cfs based on 1 cfs/70 acres and as much as 20.8 cfs if water is available to divert a double appropriation. The Wiant Ditch presently conveys water associated with the Elk Hollow Ditch.

Daily maintenance of the ditch facilities has historically been completed by a ditch rider. The ditch rider monitors the delivery of water through the system and removes trash and debris from headgates during the irrigation season. For major maintenance work, a contractor has been hired by the existing shareholders. A shareholders meeting is typically scheduled to identify the necessary repairs. The costs for both the ditch rider and the maintenance contractor are apportioned to the shareholders on the basis of water diversions (1 cfs/70 acres). The maintenance costs (for both the ditch rider and maintenance contractor) have varied from \$3,000 to \$10,000 per year depending on the magnitude and extent of the maintenance requirements.

### 1.3 Summary of Existing Problems

As stated previously, major erosion and canal stability problems continue to plague the Highline Ditch, Elk Hollow Ditch and Wiant Ditch. Sheet 1, attached to this report, displays these ditches and highlights the problem areas. The Highline Ditch is threatened by a massive headcut that is moving upstream and endangering existing facilities and adjacent irrigation ditches (Figure 1.2). This headcut is more than 25 feet high and is actively migrating upstream (Figure 1.3). Channel incision upstream of the headcut has produced near vertical streambanks greater than 20 feet.



Figure 1.2 Headcut on Highline No. 4 Ditch, During Irrigation Season.

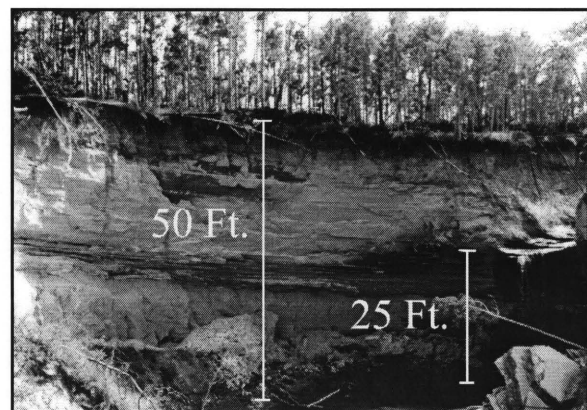


Figure 1.3 Headcut on Highline No. 4 Ditch, Approximately 25 Feet High.

The Wiant Ditch is also deeply incised and is experiencing actively migrating headcuts as shown in Figure 1.4. This type of canal erosion continues to threaten existing structures/flumes plus existing roadways next to the ditch. Recently, the county had to relocate County Road 504 because of encroachment of the Wiant Ditch. Three diversions from the Highline Ditch cross the Wiant Ditch via suspended pipelines. Efforts have been made to protect these pipelines from canal degradation by placing auto bodies along the banks (Figure 1.5).

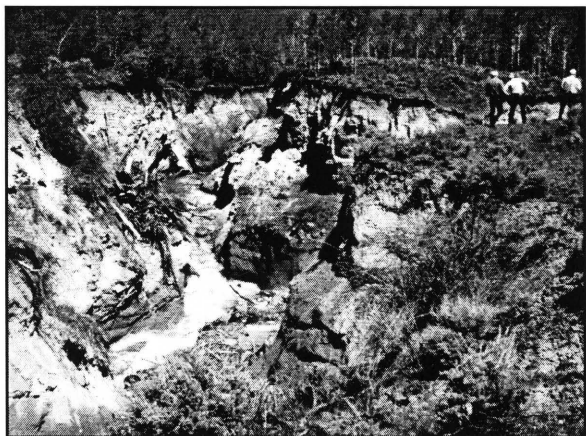


Figure 1.4 Degradation of Wiant Ditch in Vicinity of Elk Hollow Washout.



Figure 1.5 Degradation of Wiant Ditch at Ryan Foreman Pipeline Crossing.

The Elk Hollow Ditch is experiencing similar erosion problems with deeply incised channels and actively eroding channel banks. The continual bank erosion and migration of the Elk Hollow Ditch have almost captured the Wiant Ditch.

In summary, the continual erosion problems in area are severe. Rehabilitation of these problems is justified for numerous reasons:

- Existing flumes, diversion structures, crossover structures and other appurtenant structures associated with the District are threatened.
- Continued erosion could result in the capture and commingling of the irrigation water diverted by the three ditches.
- County Road 504, which has already been relocated due to erosion of the Wiant Ditch, will continue to be threatened.
- Surface water quality downstream of the problem area may continue to be degraded due to excessive sediment loading. This sedimentation could be detrimental to downstream fisheries.

- Failure of the irrigation system would adversely impact existing agriculture and ranching activities and livelihoods within the District.

#### **1.4 Project Purpose and Issues**

In view of the previous discussions, the purpose of this Level II project is to:

1. Identify, evaluate and design at the conceptual level, alternatives for mitigating the major erosion problems associated with the Highline Ditch, Wiant Ditch, and Elk Hollow Ditch; and
2. Develop cost estimates and a prioritized implementation plan for the proposed improvements that are sensitive to the ability-to-pay associated with the members of the District.

## II. DATA COLLECTION EFFORTS

### 2.1 Initial Data Collection

To more fully understand the history and management of the irrigation delivery system, an effort was made to collect available data on the ditches and the general area. During this process, ACE conducted a preliminary review of available literature, interviewed several sources of information and participated in an initial field reconnaissance of the project site. This work primarily consisted of the items listed below:

1. Reviewing the historic flow records for the Wiant Ditch and Highline Canal No. 4 as measured by gaging stations operated by the Wyoming State Engineers Office (WSEO).
2. Reviewing the water rights inventory for Water Division 1 and specifically identifying some of the water rights associated with the Highline Watershed Improvement District. Water rights and flow estimates through the washout areas were discussed with Mr. Jack Gibson of the WSEO.
3. Collecting and reviewing maps and aerial photographs pertinent to the Highline Watershed Improvement District.
4. Discussing the existing problems, available reports and data, operational aspects, and water rights issues of the Highline Watershed Improvement District with members of the District Board, Mr. Mark Shirley (NRCS), and Mr. Jack Gibson (WSEO).

### 2.2 Project Scoping Meeting

A project scoping meeting was conducted in the office of the Natural Resources Conservation Service on June 9, 1999. The individuals identified in the following table were present at the meeting.

Name	Representing
Mr. Bruce Brinkman	Wyoming Water Development Commission
Mr. Brad Anderson	Anderson Consulting Engineers, Inc.
Mr. Chris Pauley	Anderson Consulting Engineers, Inc.
Mr. Andy Long	Wyoming Department of Transportation
Mr. Paul McCarthy	PMPC Consulting Engineers
Mr. J. C. York	PMPC Consulting Engineers
Mr. Alden Condict	Highline Watershed Improvement District
Mr. John Lunt	Highline Watershed Improvement District
Mr. Wynn Condict	Highline Watershed Improvement District
Mr. Kurt Bucholz	Highline Watershed Improvement District
Mr. Mark Shirley	Natural Resources Conservation Service
Mr. Jack Gibson	Wyoming State Water Control Board

Specific problem areas, study goals and procedures were discussed along with the schedule for completing the project. Specific alternative improvements to the existing structures were also presented for discussion.

During the scoping meeting, the District members provided insight to the existing problems and alternative improvements. Comments generated by the District are summarized below.

- The Wiant Washout is of immediate concern, the headcut is threatening the Ryan Foreman Pipe Crossing and will soon affect the Twin Pipe and Gross Pipe crossings. The District would like to see the Wiant Washout portion of the ditch abandoned.
- The Highline Washout area is also a concern. While not immediately threatening the systems operation, in time a headcut may advance upstream and threaten Diversion Structure No. 2.
- The Macannany Washout has deposited large amounts of sediment in South Cedar Creek. This washout area should be bypassed, possibly routing flow east from Diversion Structure No. 3 to South Cedar Creek.

Possible solutions to the erosion problems were also discussed. The District suggested that the project team consider commingling of the Wiant Ditch and Highline Ditch irrigation deliveries if this alternative proves to be cost effective.

### **2.3 Field Investigation**

A detailed field investigation of the project site was conducted during several visits to the site spanning the period from May to September 1999. ACE personnel collected field data to promote the evaluation of potential alternatives to the existing problems in the system. The focus of the field investigation was to: (a) inventory and assess the condition of the existing structures, and (b) collect specific data to promote the analysis of channel hydraulics and the hydraulic capacity of existing structures and proposed improvements. Specific activities that were undertaken included:

1. assessment of the condition of the existing structures with respect to type of materials, associated maintenance costs and remaining design life;
2. assessment of the hydraulic efficiency and capacity of the structures and the potential for debris blockage;
3. assessment of the erosional stability of the three main irrigation ditches;
4. photographic documentation of the structures within the main canal and laterals; and
5. collection of field survey data necessary for the evaluation of potential alternatives and the conceptual design of the selected alternative.

Prior to, and in conjunction with the completion of the field work, additional data and information were collected and reviewed. This information included stream gaging performed by PMPC Consulting Engineers and Jack Gibson (SEO) on June 18, 1999 and soil sampling by Inberg-Miller Engineers. All field and inventory data, mapping and existing information was compiled, reviewed and evaluated during the initial work.

### III. INVENTORY OF EXISTING STRUCTURES

During the field investigations, an inventory of the existing structures within the study area was completed. This area extended a distance of approximately one-half mile upstream and downstream of the Wiant and Highline Washouts. The inventory included field measurements of the structures, photographic documentation, and estimates of the remaining design life of each structure. Field measurements were taken to promote the hydraulic evaluation of the existing facility and design criteria for any proposed improvements. Sheet 1 presents the location of the facilities identified and inventoried during the field investigation. Table A.1 in Appendix A provides an itemized summary of the structures inventoried during the field work.

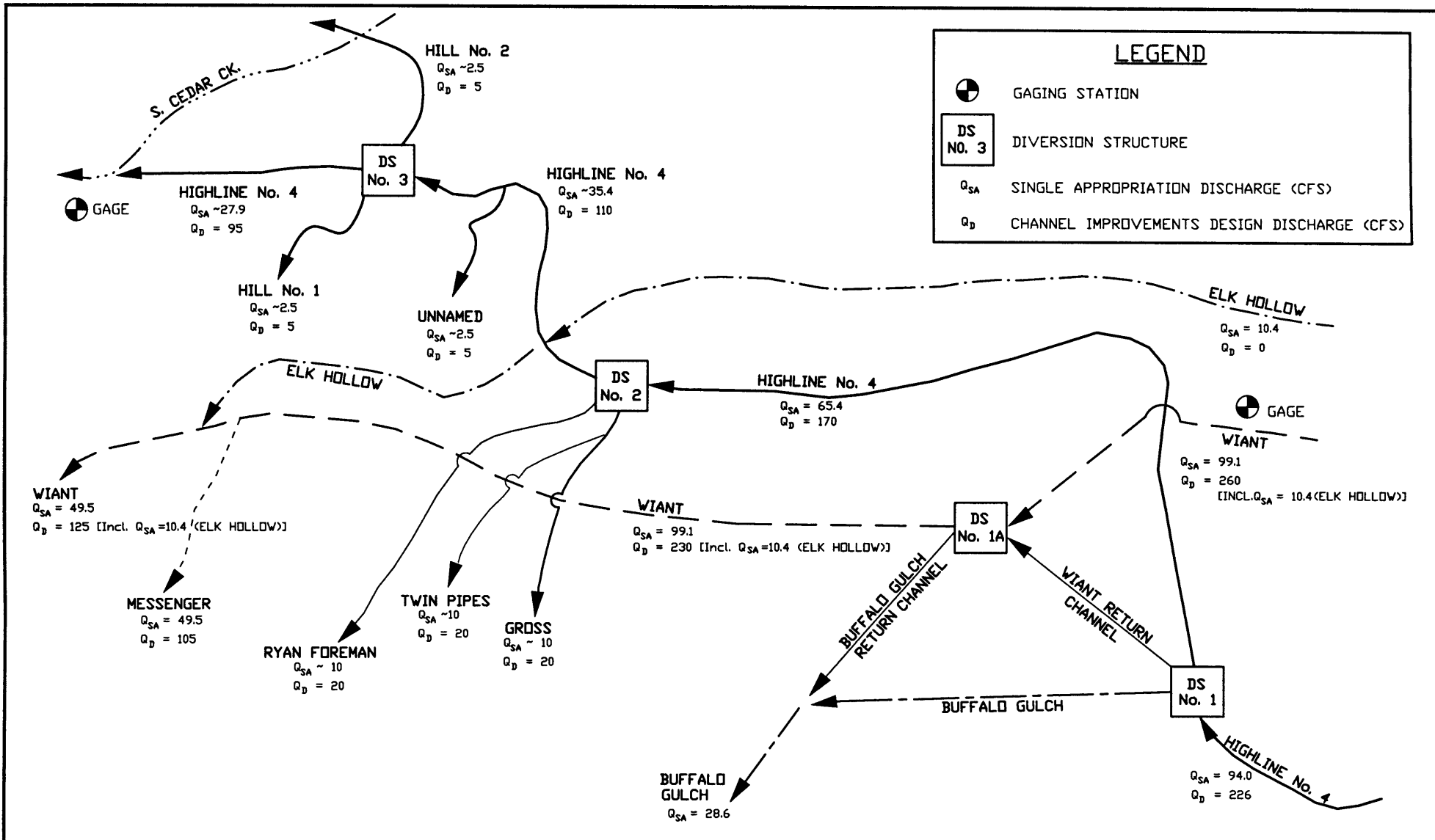
#### 3.1 Analysis of Water Rights

In order to hydraulically evaluate existing structures and to preliminarily design alternative solutions to the Wiant and Highline No. 4 Washouts, an evaluation was made to determine design discharges in various reaches of each ditch. The results of this evaluation are presented on Figure 3.1.

Based on information from the Wyoming State Engineers Office, the Elk Hollow, Wiant and Highline No. 4 Ditches have single appropriations consisting of 10.4, 99.1, and 94.0 cfs respectively. Of the Highline No. 4 appropriation, 28.6 cfs is diverted to water users located along Buffalo Gulch and an estimated 10 cfs is diverted to each of the Gross, Twin Pipes, and Ryan Foreman Ditches. For design purposes, it was assumed that the Elk Hollow Ditch would remain inoperable and its appropriation would be carried in the Wiant Ditch.

Design flows were computed for the Wiant and Highline No. 4 Ditches by assuming a double appropriation in each ditch and adding approximately 20 percent to account for storm inflows. For the Wiant Ditch at the gage, the design flow (including the Elk Hollow double appropriation) was determined to be 260 cfs. Approximately 30 cfs of the Wiant Ditch storm flows were assumed to be conveyed to Buffalo Gulch, leaving 230 cfs conveyed through the Wiant Washout reach. For the Highline No. 4 Ditch, the design flow approaching Diversion Structure No. 1 was determined to be 226 cfs. Approximately 16 cfs of the Highline No. 4 storm flows were assumed to be conveyed to Buffalo Gulch, leaving 210 cfs in the Highline No.4 ditch downstream of Diversion Structure No. 1. Assuming that the Gross, Twin Pipes, and Ryan Foreman Ditches divert their double appropriation, the Highline No. 4 design discharge downstream of Diversion Structure No.2 becomes





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**HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
 DITCH PROJECT LEVEL II**

**DISCHARGE SCHEMATIC**

Project No.	WYWDC14
Date:	10/04/99
Design:	JDS/CJP
Drawn:	MRC/TLT
Revisions:	10/22/99
ACAD FILE:	SCHM-FLOWS

**FIGURE  
 3.1**

150 cfs. A conservative estimate of 170 cfs was utilized for the evaluation and design of improvements to the Highline No. 4 ditch downstream of Diversion Structure No. 2. Downstream of Diversion Structure No. 3, a discharge of 95 cfs was used for design of the Macannany Washout improvements. Likewise, the design discharge for the Ryan Foreman Washout improvements was 20 cfs.

## 3.2 Highline No. 4 Ditch

### 3.2.1 Diversion Structures

#### Diversion Structure No. 1

The first diversion structure in the inventoried reach of the Highline Canal is Diversion Structure No. 1 at Station 3+00 (Figure 3.2). From this structure the District returns Buffalo Gulch appropriations carried in Highline No. 4 to the Buffalo Gulch Channel. Highline water may also be diverted to the Wiant Ditch as required by the District. The structure consists of a concrete headwall with six slide gates; one servicing the Wiant Return Canal, two spilling to Buffalo Gulch Channel, and three controlling flows down the main Highline No. 4 Ditch. The headwall and gates are in excellent condition. Minor erosion was noted at the lip of the downstream aprons to the Buffalo Gulch and Wiant Return Channel. Both aprons have rounded riprap protection; future inspections should be aware of the potential for increased erosion. A large amount of debris was noted in and around Diversion Structure No. 1. A debris collection system could simplify maintenance and insure that flow settings remain accurate while the structure is unattended. Sediment accumulation does not appear to be a problem at this structure. There are no flow measuring devices at the diversion structure.



Figure 3.2 Diversion Structure No. 1.

#### Diversion Structure No. 2

Diversion Structure No. 2 is located in the vicinity of Station 48+00 (Figure 3.3). From this structure the District diverts Highline flows into the Gross, Twin Pipes, and Ryan Foreman Ditches.

The structure consists of a headwall and four slide gates: one each for the Gross/Twin and Ryan Foreman inlets and two for the Highline No. 4 Ditch. The headwall and gates are in good condition, only minor cracking and spalling of the concrete were noted. Minimum debris and sediment accumulation was noted at Diversion Structure No. 2. There are no flow measuring devices at the diversion structure.

### Diversion Structure No. 3

Diversion Structure No. 3 is located in the vicinity of Station 76+00 (Figure 3.4). This structure can divert flow into the Hill No. 1 and No. 2 ditches. Water that is not diverted continues down the Highline No. 4 Ditch to its confluence with South Cedar Creek. The structure consists of concrete headwalls with a timber board check structure and two turnout gates. The main ditch apron consists of welded steel plate on top of remnant concrete from a previous apron. The headwalls and timber check structure are in fair condition. The apron areas of the main ditch and both turnouts are experiencing moderate to severe erosion. Debris blockages of the turnout gates and one to two feet of sediment accumulation were evident during the field inspection. There are no flow measuring devices at the diversion structure.

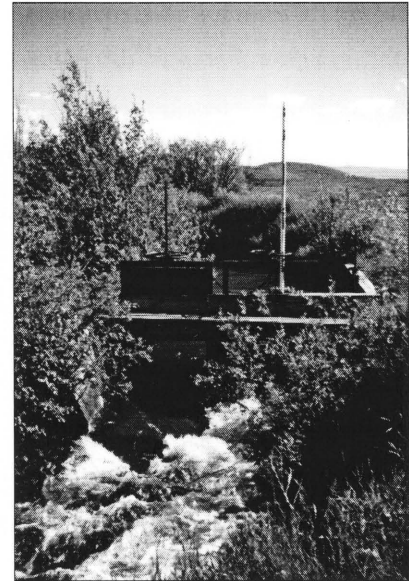


Figure 3.3 Diversion Structure No. 2.



Figure 3.4 Diversion Structure No. 3.

### **3.2.2 Highline No. 4 Main Ditch**

The criteria used to evaluate the main canal included the capability of the structure to convey the maximum potential diversion plus freeboard. The watershed has minimal reservoir storage and is a system fed primarily by snow melt. Therefore, maximum potential flows in the system are subject to diurnal fluctuations at the source plus local storm inflows. The maximum potential diversion was determined to be 20% greater than the maximum legal diversion at the headgate to reflect potential increases in the flows due to local storms. The maximum flow was reduced through the main ditch given an estimate of the diversions at the major diversions. A freeboard criterion of 1 foot was assumed for the evaluations. For the purposes of this evaluation, the Highline No. 4 canal was separated into four reaches below Diversion Structure No. 1:

- Reach 1. Diversion Structure No. 1 to Diversion Structure No. 2,
- Reach 2. Diversion Structure No. 2 to the Highline Washout,
- Reach 3. The Highline Washout to Diversion Structure No. 3, and
- Reach 4. Diversion Structure No. 3 to the South Cedar Creek Confluence.

Reach 1 consists of an earthen canal from Station 3+00 to 48+00. The maximum potential flow in this reach is 210 cfs. In this reach, the canal can be characterized as a trapezoidal section with a 18-foot bottom width, an average depth of 6 feet, and 1:1 (H:V) sideslopes. Given an average slope of 0.00075 ft/ft, the capacity of the canal varied from approximately 350 to greater than 450 cfs. The reach appears to have adequate capacity everywhere except between Stations 5+00 to 20+00. The canal appears to be very stable in this reach with only minor bank erosion evident.

Reach 2 consists of an earthen canal from Station 48+00 to 59+50. The maximum potential flow in this reach is 170 cfs. In this reach, the channel is trapezoidal with a 10- to 15-foot bottom width, near vertical sideslopes, and average depths varying from 8 to 25 feet. The major feature of this reach is the Highline Washout between Stations 58+00 and 59+50. In this area the canal invert drops 25 feet over a headcut into a washout area measuring more than 50 feet deep and approximately 100 to 150 feet across. Upstream of the headcut, the average canal slope in this reach is approximately .0185 ft/ft. Since this is a highly incised reach, canal capacity is not a problem. Ongoing erosion in this reach may threaten Diversion Structure No. 2 at some time in the future.

Reach 3 extends from Station 59+50 to 76+00. It consists of an earthen canal beginning downstream of the Highline Washout. The maximum potential flow in this reach is 110 cfs. The channel is trapezoidal with a 12 foot bottom width, 1:1 (H:V) sideslopes, and an average depth of approximately 6 feet. With an average slope of .015 ft/ft, the capacity of the reach is greater than 350 cfs. Due to the large sediment load generated in the headcut reach upstream, this reach of canal has experienced increasing maintenance requirements associated with sediment removal.

Reach 4 consists of a highly incised canal between Stations 76+00 and 107+00 and is referred to as the Macannany Washout. The channel varies in shape from trapezoidal to 'V' shaped, with bottoms widths ranging between 5 and 15 feet, near vertical sideslopes, and an average depth of approximately 20 feet. The channel bottom is characterized by numerous headcuts that are threatening Diversion Structure No. 3. Due to the incised nature of the canal, conveyance capacity is adequate to convey design discharge of approximately 195 cfs.

### **3.2.3 Flow Measuring Structures**

A flow measuring structure is not located in the specific reaches of the Highline Canal which were inventoried. However, two gages exist nearby that provide insight into flows being conveyed through the inventoried canal reach.

A measurement structure is in place at the headgate of the Highline No. 4 Ditch from North Brush Creek. The gage site consists of a Stevens A-35 recorder on a natural channel section. Historic records for this gage were provided by the Wyoming Board of Control for the years 1982 through 1998. Copies of these historic gage records are provided in the project notebook. This gage site was not inventoried during this project.

A gaging station is also located on South Cedar Creek approximately 2,400 feet downstream of its confluence with the Highline No. 4 Ditch. The gaging station consists of a 4-foot Parshall flume, stilling well, and recorder. The flume and recorder housing were in fair condition. They were slightly rusted but still in good working condition. The gaging site is heavily vegetated with shrubs. Clearing of some of the vegetation may be warranted to prevent blockages of the flume. Historic gage data was not obtained for this site as the gage is heavily influenced by sources of flow not attributable to the Highline Canal. Besides Highline Canal tailend flows, the gage receives flows from natural South Cedar Creek runoff and return flows from the Wiant Ditch upstream of County Road 504.

### **3.3 Wiant Ditch**

#### **3.3.1 Diversion Structures**

Diversion Structure No. 1A is found on the Wiant Ditch at Station 6+50 (Figure 3.5). The structure is used by the District to control the flow in the Wiant Ditch. Any flow not diverted to the Wiant Ditch at this structure is diverted into Buffalo Gulch. The structure consists of two wooden slide gates and a pedestrian bridge over the Buffalo Gulch Return Channel. The Wiant Return Channel from Diversion Structure No. 1 on the Highline Canal enters the Wiant Ditch immediately upstream of Diversion Structure No. 1A. When the wooden slide gates are closed, they are covered in plastic to provide a seal against leakage. The gates are in fair condition and the bridge is in good condition. This structure could be replaced with a concrete headwall and a steel-gated structure to provide better control of flows at this diversion point. Debris and sediment did not appear to be a major problem at this diversion as they probably pass on through to Buffalo Gulch.

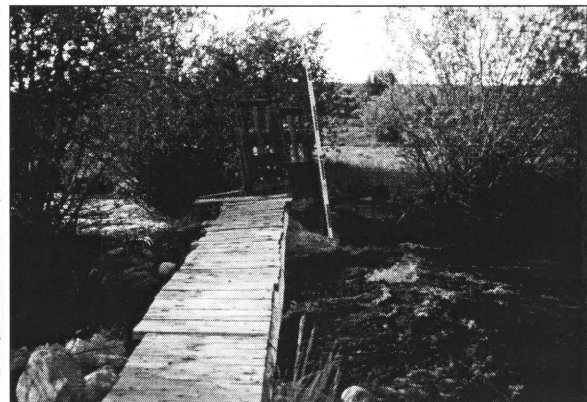


Figure 3.5 Wiant Ditch: Diversion Structure 1A.

### 3.3.2 Wiant Ditch Main Canal

The Wiant Ditch was separated into four reaches below the flume gage:

- Reach 1. Flume Gage to downstream of Diversion Structure No. 1A,
- Reach 2. Diversion Structure No. 1A to the Gross Ditch Crossing,
- Reach 3. The Gross Ditch Crossing to downstream of the Wiant Washout, and
- Reach 4. Downstream of the Wiant Washout to County Road 504.

Reach 1 consists of an earthen canal from Station 0+00 to 10+00. The maximum design flow in this reach is 260 cfs which includes the double irrigation appropriation for both the Wiant and Elk Hollow Ditches. In this reach, the canal can be characterized as a trapezoidal channel with a 12-foot bottom width, an average depth of 2 feet, and sideslopes of approximately 5:1 (H:V). The canal resembles a small natural creek bed which likely follows the general alignment of the natural Buffalo Gulch channel. Given an average slope of .0135 ft/ft, the capacity of the canal is approximately 350 cfs. The channel appears to be very stable in this reach. At Station 0+81 the channel crosses over the Highline No. 4 Ditch in a steel flume (Figures 3.6 and 3.7). The flume is in good condition.

Reach 2 consists of an earthen canal between Stations 10+00 and 40+00. The maximum design flow in this reach is 230 cfs. In this reach, the canal can be characterized by a trapezoidal section with a 12-foot bottom width, average depth of 6 feet, and 1:1 (H:V) sideslopes.

The average slope of this reach is approximately 0.00072 ft/ft. Given this slope, the reach appears to have adequate conveyance capacity.

Reach 3 consists of an earthen canal from Station 40+00 to 58+00. The maximum design flow in this reach is 230 cfs. In this reach, the canal can be characterized by a trapezoidal to 'V' shape as it incises through the Wiant Washout area. This reach of channel has a bottom width of 5 to 15-feet, an average depth of 25 feet, and near vertical sideslopes. Numerous headcuts are present in the channel bottom and banks are actively eroding during the irrigation season



Figure 3.6 Wiant Ditch Flume.

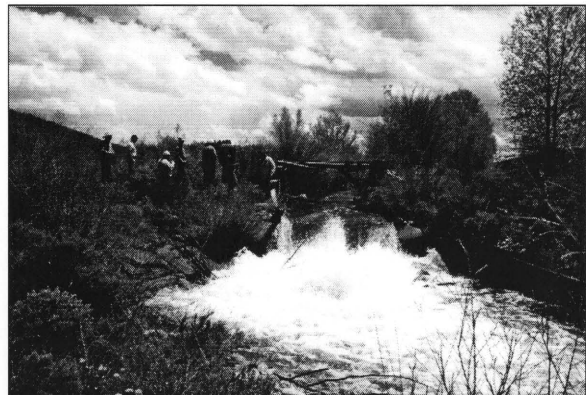


Figure 3.7 Wiant Ditch at Flume Over Highline No. 4 Ditch.

(Figure 3.8). The average slope of this reach is approximately 0.055 ft/ft. Channel capacity in this reach is adequate, but the channel is highly unstable. This reach of the channel is threatening the Gross, Twin Pipes, and Ryan Foreman Pipe Crossings over the Wiant Ditch.



Figure 3.8 Wiant Ditch Washout (Reach 3).

Reach number 4 consists of an earthen canal from Station 58+00 to 97+00. The maximum design flow in this reach is 230 cfs. In this reach, the canal can be characterized by a trapezoidal section with a 12-foot bottom width, average depth of 5 feet, and 1:1 (H:V) sideslopes. Given an average slope of .0034 ft/ft, the capacity appears adequate.

### 3.3.3 Flow Measuring Structures

A gaging station is present on the Wiant Ditch immediately upstream of the flume at Station 0+30. The gage site consists of a uniform/stable channel section, a stilling well, and recorder. The site appeared in excellent working condition. Flow records from 1994 to 1998 were reviewed for this gage. Copies of the flow records are presented in the project notebook.

### 3.4 Other Structures

Several other structures were inventoried during the field investigation that were not directly associated with the Highline or Wiant ditches. These structures consisted of the three pipe crossings over the Wiant Ditch: the Gross, Twin Pipes, and Ryan Foreman Ditch Crossings.

The Gross Pipe Crossing consists of a 36-inch diameter steel pipe approximately 73 feet long (Figure 3.9). The pipe spans the Wiant Ditch approximately 8 feet above the invert. The pipe and the inlet and outlet structures are in good condition.



Figure 3.9 Gross Ditch Pipe Crossing Over Wiant Ditch.

The Twin Pipes Crossing (Figure 3.10) consists of two steel pipes measuring 24 inches and 36 inches in diameter. The Twin Pipes are approximately 41 feet long. The pipes and the inlet and outlet structures are in good condition. Bank instability from the Wiant Washout is currently threatening the integrity of the Twin Pipes Crossing.

The Ryan Foreman Crossing consists of a 24-inch steel pipe (Figure 3.11). The pipe spans the Wiant Ditch approximately 20 feet above the invert. The pipe and the inlet and outlet structures are in good condition. Bank instability from the Wiant Washout is currently threatening the integrity of the Ryan Foreman Pipe Crossing. Bank protection (auto bodies) has been placed along the banks of the Wiant Ditch as a temporary bank protection measure.

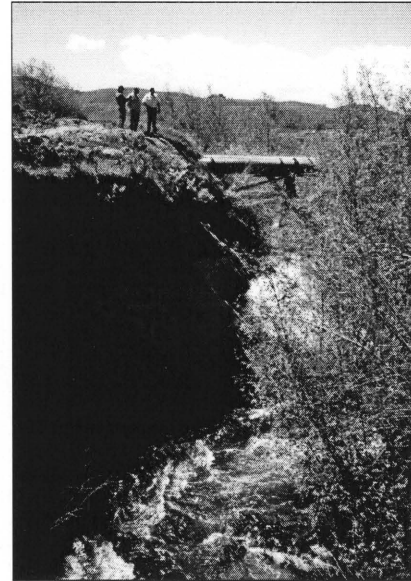


Figure 3.10 Twin Pipes Crossing Over Wiant Ditch.



Figure 3.11 Ryan Foreman Pipe Crossing Over Wiant Ditch.

### 3.5 Geotechnical Investigation

A geotechnical investigation was conducted by Inberg-Miller Engineers. It included a site reconnaissance at each of the identified erosion problem areas and collection of near-surface soil samples to test for appropriate index and engineering properties. A copy of this report is included as Appendix C.

Briefly, the geotechnical investigation found the soils in the study area to consist of silty fine sands derived from weathered sandstone. Underlying materials in the study area consist of silty fine sandstones with layers of tuffaceous sandstones. Where more competent sandstone layers are encountered, the increased resistance to erosion has resulted in vertical headcuts. The most notable headcut being that found on the Highline No. 4 Ditch.



## IV. REHABILITATION ALTERNATIVES

### 4.1 General

In this chapter, several conceptual rehabilitation alternatives are reviewed for each of the problem areas identified in Chapter 3. Specifically, these problem areas consist of the Highline No. 4 Ditch Washout, the Macannany Washout, the Wiant Ditch Washout and the Ryan Foreman Washout. Given the severity of erosion occurring at these locations, these sites were designated as the principal problems within the study area and conceptual alternatives to mitigate these problem areas were developed. In addition, the incorporation of flow measurement structures to optimize management of the irrigation system was evaluated

The rehabilitation alternatives discussed in this chapter were developed using two primary water management strategies: (1) the irrigation diversions of the Highline No. 4 and Wiant Ditches remain separated and (2) the irrigated diversions are commingled. The purpose of the “Commingled Diversions” scenario was to determine if combining the diversions would be cost effective in comparison with the “Separate Diversions” scenario. In the following sections, several alternatives are reviewed for each of the individual components necessary to rehabilitate the system under either scenario. Evaluations of the Macannany and Ryan Foreman Washouts are not affected by the two water management scenarios.

### 4.2 Separate Discharge Scenario

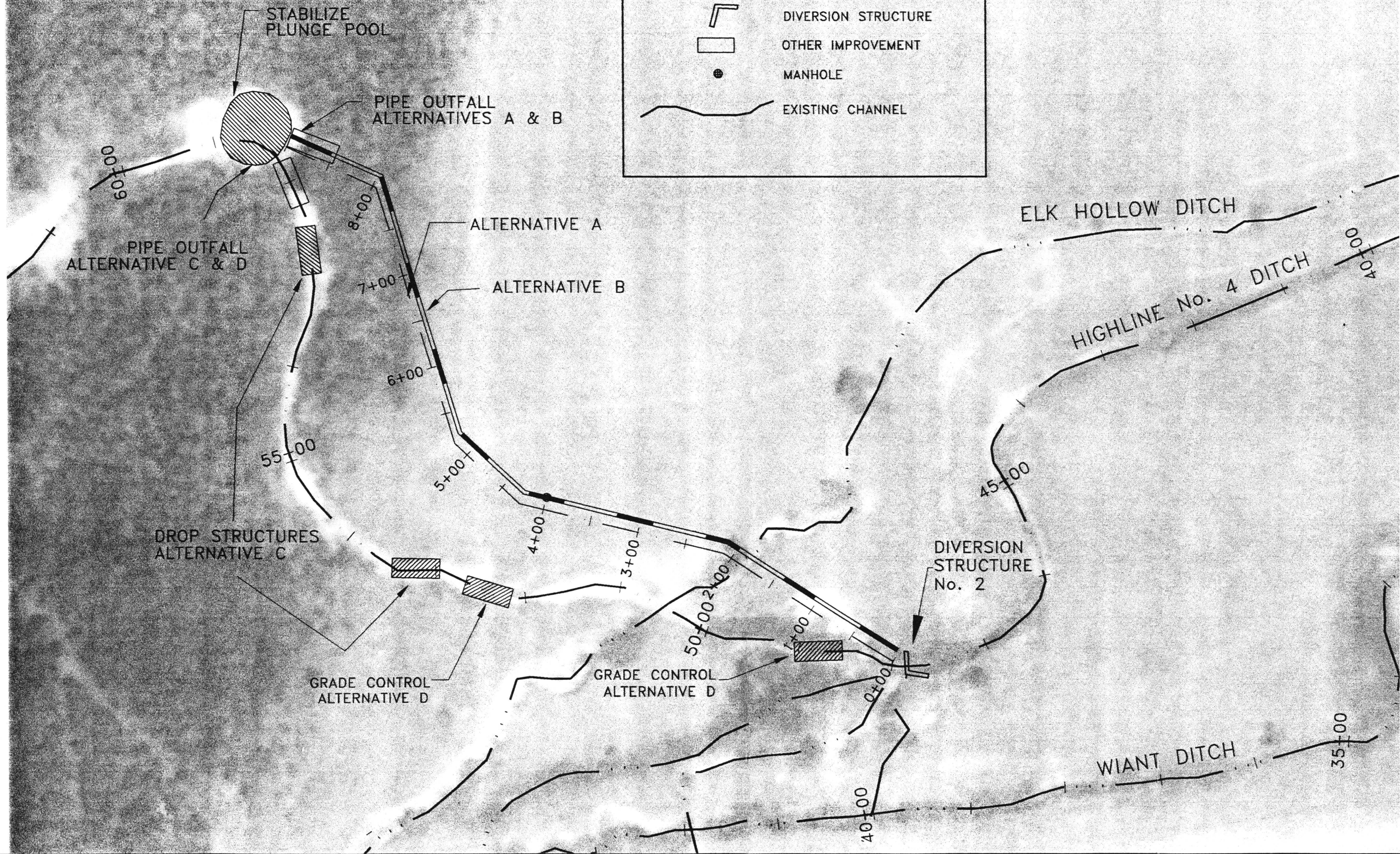
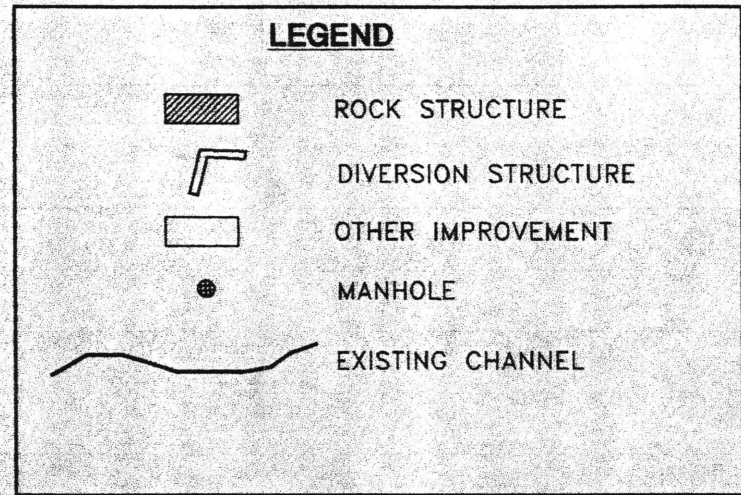
Under this design scenario, the diversions of the Wiant Ditch and the Highline Ditch are kept in their separated condition. System components evaluated under this scenario included the individual rehabilitation of the Highline and Wiant Ditches. Several alternatives were evaluated for the rehabilitation of each ditch.

#### 4.2.1 Rehabilitation of the Highline No. 4 Ditch

Four design alternatives were evaluated for the rehabilitation of the Highline No. 4 Ditch. The general alignment and configuration of each is presented on Figure 4.1.



SCALE  
1" = 100'



**HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
DITCH PROJECT LEVEL II  
CONCEPTUAL DESIGNS:  
HIGHLINE WASHOUT REHABILITATION ALTERNATIVES**

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Project No.	WYWD14
Date:	9/27/99
Design:	JDS/CJP
Drawn:	MRC
Revisions:	10/22/99
ACADFILE:	PROPIMPVEMT.DWG

**FIGURE  
4.1**

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### Highline Ditch Alternative A: Open Channel

Under this alternative, an open channel is required between Station 48+20 (Diversion Structure No. 2) and Station 57+88 (Highline Washout). The new channel is 12 feet wide with 2.5:1 (H:V) sideslopes. The existing Highline Ditch will then be abandoned. At the washout area, a 48-inch pipe outfall structure will be constructed allowing a controlled freefall to a plunge pool stabilized with 24-inch ( $D_{50}$ ) rock riprap. With this alignment, the channel would daylight at the washout area on the south wall of the site. By incorporating such a feature, capable of accommodating a vertical drop of more than 45 feet, the new channel can be constructed at a minimum slope to reduce earthwork quantities. The existing diversion structure does not need alteration or improvement under this alternative. This alternative also includes placement of a geomembrane liner in the plunge pool to prevent water contact with the erodible material.

### Highline Ditch Alternative B: Pipeline Drop Structure

This alternative is similar to the Highline Ditch Alternative A, but the open channel is replaced by a 60-inch RCP pipeline. The existing Highline Ditch from Station 48+20 to 57+88 will be abandoned. Diversion Structure No. 2 will not require alteration or improvement because the pipe inlet could be constructed downstream of the diversion. As with Alternative A, a 48-inch steel pipe outfall structure will be necessary at the site of the Highline Washout. The plunge pool will be required as indicated for Alternative A.

### Highline Ditch Alternative C: Stabilization of Existing Channel

Reconstruction of a geomorphically stable channel through the degraded reach of the Highline Ditch was evaluated. Under this alternative, a 48-inch steel pipe outfall structure and stabilized plunge pool identical to that described under Alternatives A and B will be required at the existing location of the washout. However, under this alternative, it is located within the existing ditch. This structure would serve to anchor the downstream end of the project reach while providing approximately 25 feet of vertical drop to a stabilized plunge pool below. To rehabilitate the steep reach between the pipe outfall and Diversion Structure No. 2, two riprap drop structures will be placed in the channel on foundations of compacted fill. The drop structures will be approximately 12 feet wide and 5 and 9 feet in height, respectively. The crests of the structures are situated such that a stable channel slope exists following backfill of the channel with in situ bank material. A source of suitable fill for the foundations may need to be identified.

### Highline Ditch Alternative D: Stabilization of Existing Channel

Stabilization of the existing Highline Ditch channel may also be accomplished with: (a) construction of a 48-inch steel pipe outfall to arrest migration of the existing headcut, and, (b) placement of grade control structures at two locations. The grade control structures consist of trenches filled with rock riprap that span the channel bottom and sideslopes. The purpose of the grade control structures is to limit the potential degradation of the canal. Based upon survey data and a geomorphic assessment of the reach, there could still be approximately 14 feet of degradation at Diversion Structure No. 2 even with construction of the pipe outfall near the washout. Placement of two grade control structures, each consisting of rock riprap buried to a depth of 10 feet below the existing canal invert should provide adequate protection. A stabilized plunge pool is also necessary for this alternative.

#### **4.2.2 Rehabilitation of the Wiant Canal**

Four design alternatives were developed and evaluated for the rehabilitation of the Wiant Ditch. These alternatives are presented on Figure 4.2.

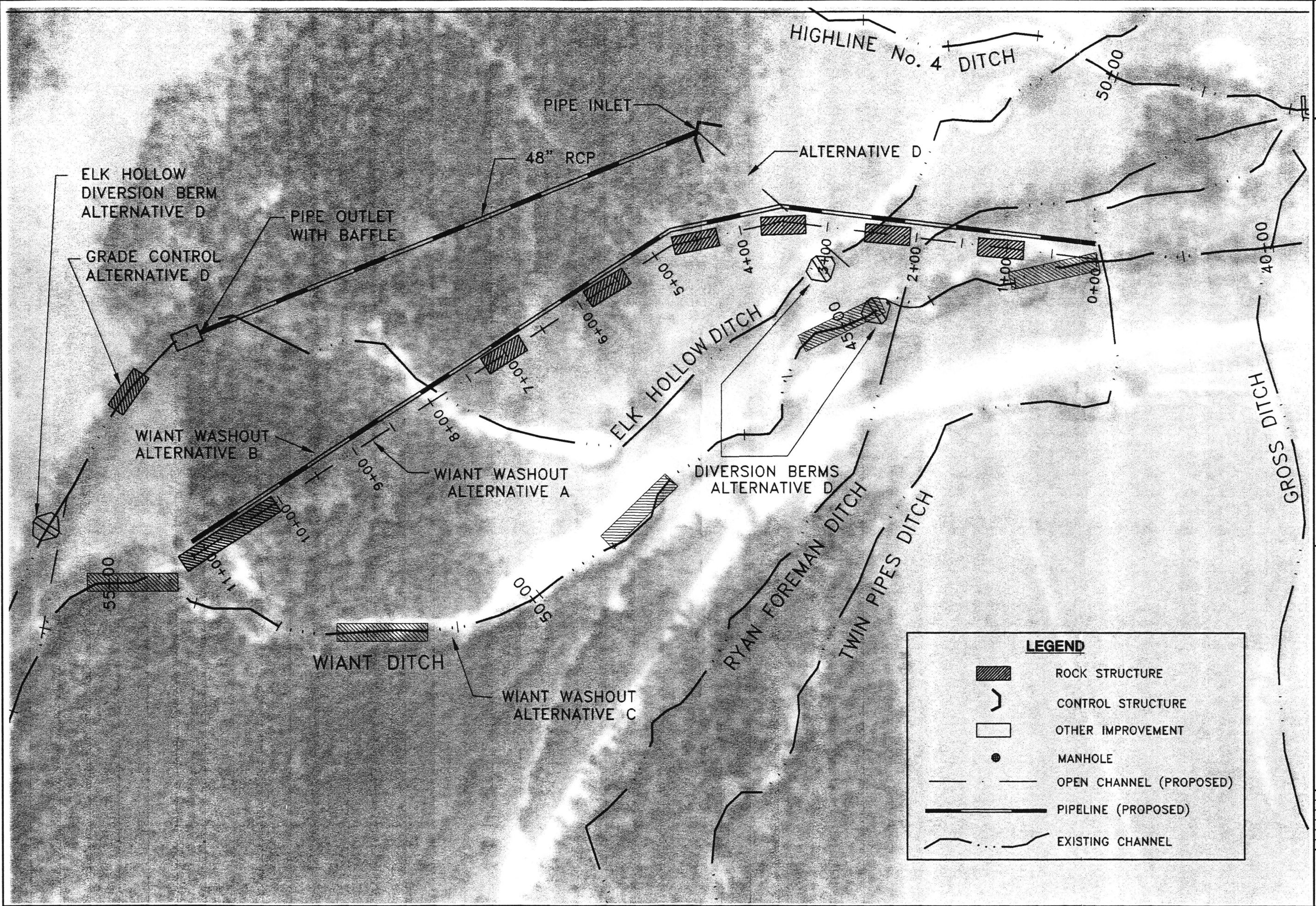
##### Wiant Ditch Alternative A: New Open Channel

This alternative would involve the construction of a new channel along an alignment east of the existing Wiant Ditch. The new channel begins on the Wiant Ditch near the Twin Pipes Crossing and extends downstream to the stable reach below the existing washout area. Because of the excessive drop in the ditch in the reach, an open channel will require significant stabilization. Approximately 7 to 8 rock riprap drop structures, each approximately 10 to 12 feet high, are required to convey the design discharge through the project reach in an erosionally stable manner.

##### Wiant Ditch Alternative B: Pipe Drop Structure

This alternative follows a similar alignment as described in Alternative A, however, a pipe drop structure is utilized in place of an open channel. The structure consists of a pipe inlet with trash rack, approximately 1,100 linear feet of 48-inch RCP, and a baffled outlet for dissipation of energy. The pipe line presented under this alternative diverts irrigation diversions conveyed in the Wiant Ditch in the vicinity of the Twin Pipes Crossing and returns these diversions to the Wiant Ditch downstream of the washout area where the ditch appears to be stable.








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SCALE  
1" = 100'

HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
DITCH PROJECT LEVEL II  
CONCEPTUAL DESIGNS:  
WIANT WASHOUT REHABILITATION ALTERNATIVES

**LEGEND**

-  ROCK STRUCTURE
-  CONTROL STRUCTURE
-  OTHER IMPROVEMENT
-  MANHOLE
-  OPEN CHANNEL (PROPOSED)
-  PIPELINE (PROPOSED)
-  EXISTING CHANNEL

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Project No.	WYWDC14
Date:	9/27/99
Design:	JDS/CJP
Drawn:	MRC
Revisions:	10/22/99
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**FIGURE**  
4.2

### Wiant Ditch Alternative C: Stabilization of Existing Channel

Stabilization of the existing Wiant Ditch was evaluated under this alternative. Within the ditch, approximately 5 rock riprap drop structures, each approximately 20 feet high, will be built. The drop structures will be constructed on compacted fill foundations that would serve to raise the drop structure inverts to the elevations necessary to form a stable channel between structures. Local bank material will be used for backfill material behind the drop structures to support the raised channel. A source of suitable fill for the foundations may need to be determined for this alternative.

### Wiant Ditch Alternative D: Combination Pipeline/Open Channel

This alternative follows a similar alignment and strategy as that which has been recently evaluated by the NRCS. This alternative involves abandoning the existing Wiant Ditch through the degraded reach by diverting flows to a pipe drop structure placed to the east. Diversion berms will be constructed within the Wiant and Elk Hollow Ditches to divert flows to an open channel and ultimately the pipe inlet. The pipe conveys the design flows to a baffled outlet for energy dissipation before discharging to the Elk Hollow Ditch. After flowing down the Elk Hollow for approximately 250 feet, the diversions are diverted back into the Wiant Ditch through construction of a diversion berm and a return channel. Upstream of the Wiant Ditch diversion berm, a rock riprap drop structure is required to stabilize the upstream portion of the ditch. The height of the drop structure is estimated to be 12 feet high.

## **4.3 Commingled Diversion Scenario**

Under this scenario, the Wiant Ditch is bypassed by combining the Wiant and Highline Ditch diversions and conveying these diversions beyond the problem area via the Highline No. 4 Ditch once it is rehabilitated. The diversions are divided downstream of the Highline Washout area and returned to the Wiant Ditch via a conveyance structure. Under this rehabilitation scenario, three items are required: (1) diversion structure to combine flows; (2) rehabilitation of the Highline No. 4 Ditch; and (3) construction of a channel or pipeline to return the appropriate diversions to the Wiant Ditch.

#### **4.3.1 Wiant to Highline Diversion Channel**

Selection of any alternative involving commingling of Wiant Ditch and Highline Ditch waters requires a conveyance structure near the Wiant crossover flume. This alternative is presented on Figure 4.3. A structure is required to divert Wiant Ditch flows to the Highline Ditch while still allowing a portion of these flows to bypass the diversion and continue downstream to the Wiant Ditch or Buffalo Gulch. From this structure, a new ditch will be necessary from the structure to the Highline Ditch. Construction of this alternative requires removal of the existing stream gage and replacement upstream to a site to be determined. The design discharge for this alternative is 230 cfs. A Cipolletti weir for flow measurement would be built between the new diversion structure and the Highline Ditch.

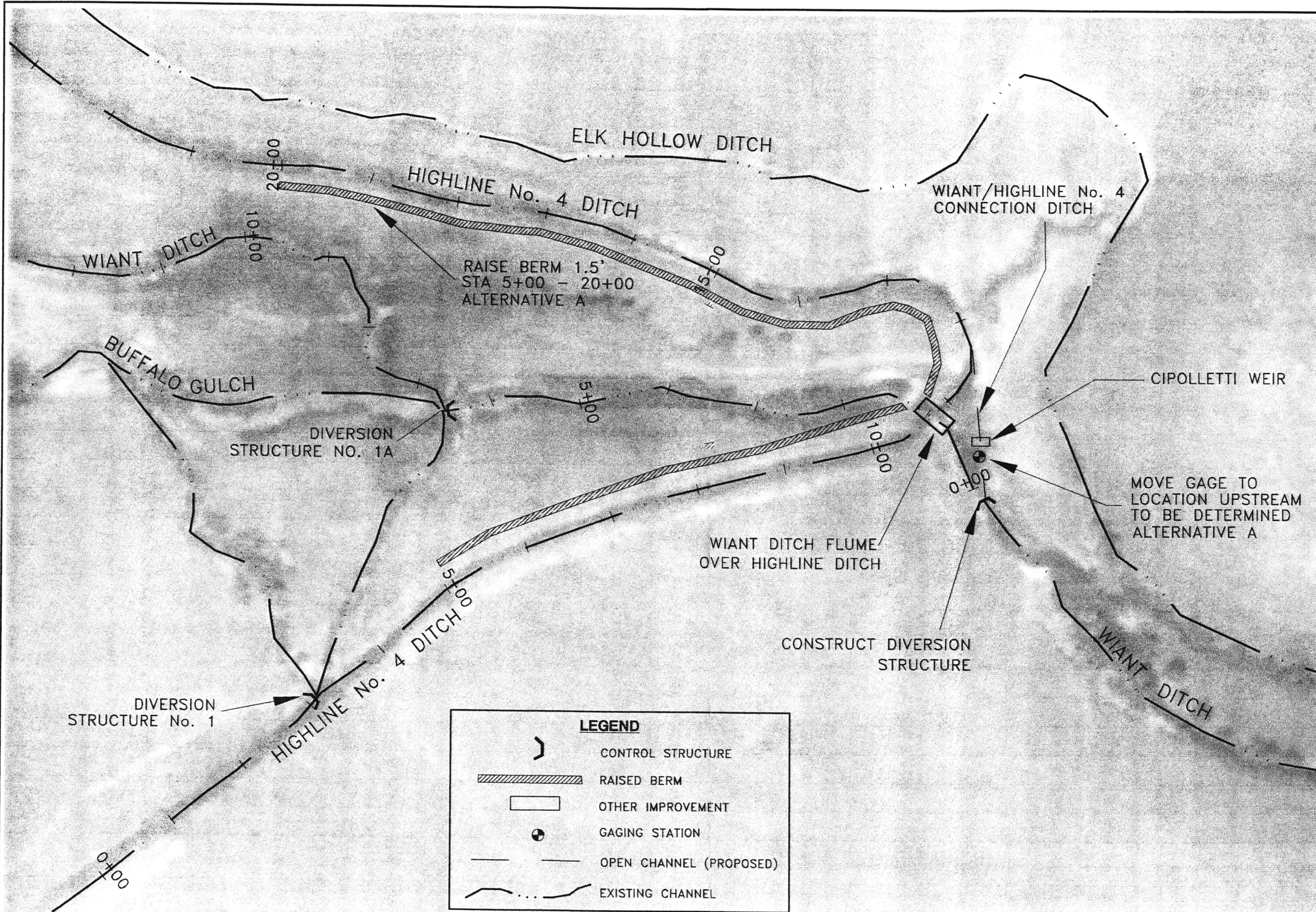
#### **4.3.2 Highline Ditch Improvement**

The capacity of the Highline Ditch was evaluated to determine if it could safely convey the additional discharge associated with any commingling alternative. This evaluation showed that from Station 20+00 to Diversion Structure No. 2, the ditch has adequate capacity. However, from Station 5+00 to approximate Station 20+00, the eastern berm should be raised approximately 1.5 feet to provide sufficient freeboard (see Figure 4.3).

#### **4.3.3 Highline No. 4 Main Canal Rehabilitation**

Four conceptual alternatives were evaluated to improve the Highline No. 4 Ditch to enable it to convey the combined diversions of both the Wiant and Highline Ditches through or around the degraded area. These alternatives are essentially identical to those alternatives described above in Section 4.2.1 and presented in Figure 4.1 (i.e., rehabilitation of the Highline No. 4 Ditch under the “Separate Diversions” scenario). For this scenario, however, the four conceptual alternatives are designed to convey the increased discharge. The primary differences between these alternatives and those discussed previously, is the increase in the size of the conveyance structures. In addition, Diversion Structure No. 2 requires improvement to accommodate the increased discharges associated with this scenario.

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 SCALE  
 1" = 100'

**HIGHLINE WATERSHED IMPROVEMENT DISTRICT**  
**DITCH PROJECT LEVEL II**  
**CONCEPTUAL DESIGNS:**  
**WIANT/HIGHLINE No. 4 DITCH**

**Anderson Consulting Engineers, Inc**  
 Civil • Water Resources • Environmental  
 2900 S. College Avenue, Suite 3B, Fort Collins, CO 80525  
 Phone (970) 226-0120 / Fax (970) 226-0121



Project No. WYWDC14  
 Date: 9/27/99  
 Design: JDS/CJP  
 Drawn: MRC  
 Revisions: 10/22/99  
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**FIGURE**  
**4.3**



### Highline Ditch Alternative A: Open Channel

Under this alternative, Diversion Structure No. 2 is improved to facilitate the management of increased discharges. A new channel is required between Station 48+20 (Diversion Structure No. 2) and Station 57+88 (Highline Washout). The new channel is 20 feet wide with 2.5:1 (H:V) sideslopes. The existing Highline Ditch will be abandoned. At the washout a 72-inch pipe outfall structure is necessary to allow a controlled fall to a plunge pool stabilized with 24-inch ( $D_{50}$ ) rock riprap. With this alignment, the channel daylights at the washout area on the south wall of the site. By incorporating such a feature, which accommodates a vertical drop of more than 45 feet, the new channel can be constructed at a minimum slope to reduce earthwork quantities. The existing diversion structure does not need alteration or improvement under this alternative.

### Highline Ditch Alternative B: Pipeline Drop Structure

This alternative is similar to the Highline Ditch Alternative A, but the open channel is replaced by a 72-inch RCP pipeline. The existing Highline Ditch from Station 48+20 to 57+88 would be abandoned. Diversion Structure No. 2 will need to be modified to facilitate conveyance of the increased discharges. In addition, the pipe would likely tie into the existing Highline Ditch at this location. As with Alternative A, a 72-inch pipe outfall structure and plunge pool is required at the site of the Highline Washout.

### Highline Ditch Alternative C: Stabilization of Existing Channel

Reconstruction of a geomorphically stable channel through the degraded reach of the Highline Ditch was evaluated (Stations 48+20 to 57+88). Under this alternative, a 72-inch pipe outfall structure and plunge pool identical to that described under Alternatives A and B is required at the existing location of the washout. However, under this alternative, it is located within the existing ditch. This structure would serve to anchor the downstream end of the project reach while providing approximately 25 feet of vertical drop to a stabilized plunge pool below. To rehabilitate the steep reach between the pipe outfall and Diversion Structure No. 2, two in-channel rock riprap drop structures are required. The drop structures are approximately 20 feet wide, and 5 and 9 feet in height, respectively. The crests of the structures are situated such that a stable channel slope exists following backfill of the channel with local bank material. A source of suitable fill for the foundations may need to be identified.

### Highline Ditch Alternative D: Stabilization of Existing Channel

Stabilization of the existing Highline Ditch channel may also be accomplished with: (a) construction of a 72-inch pipe outfall to arrest migration of the existing headcut; (b) placement of rock riprap to stabilize the plunge pool; and (c) placement of grade control structures at two locations. The grade control structures consist of rock riprap trenches spanning the channel bottom and sideslopes. The purpose of the grade control structures is to limit the potential degradation of the canal. Based upon survey data and geomorphic assessment of the reach, there could still be approximately 14 feet of channel degradation at Diversion Structure No. 2 even with construction of the pipe outfall near the washout. Placement of two grade control structures, each consisting of rock buried to a depth of 10 feet below the existing channel invert should provide adequate protection.

#### **4.3.4 Wiant Return Conveyance Structure**

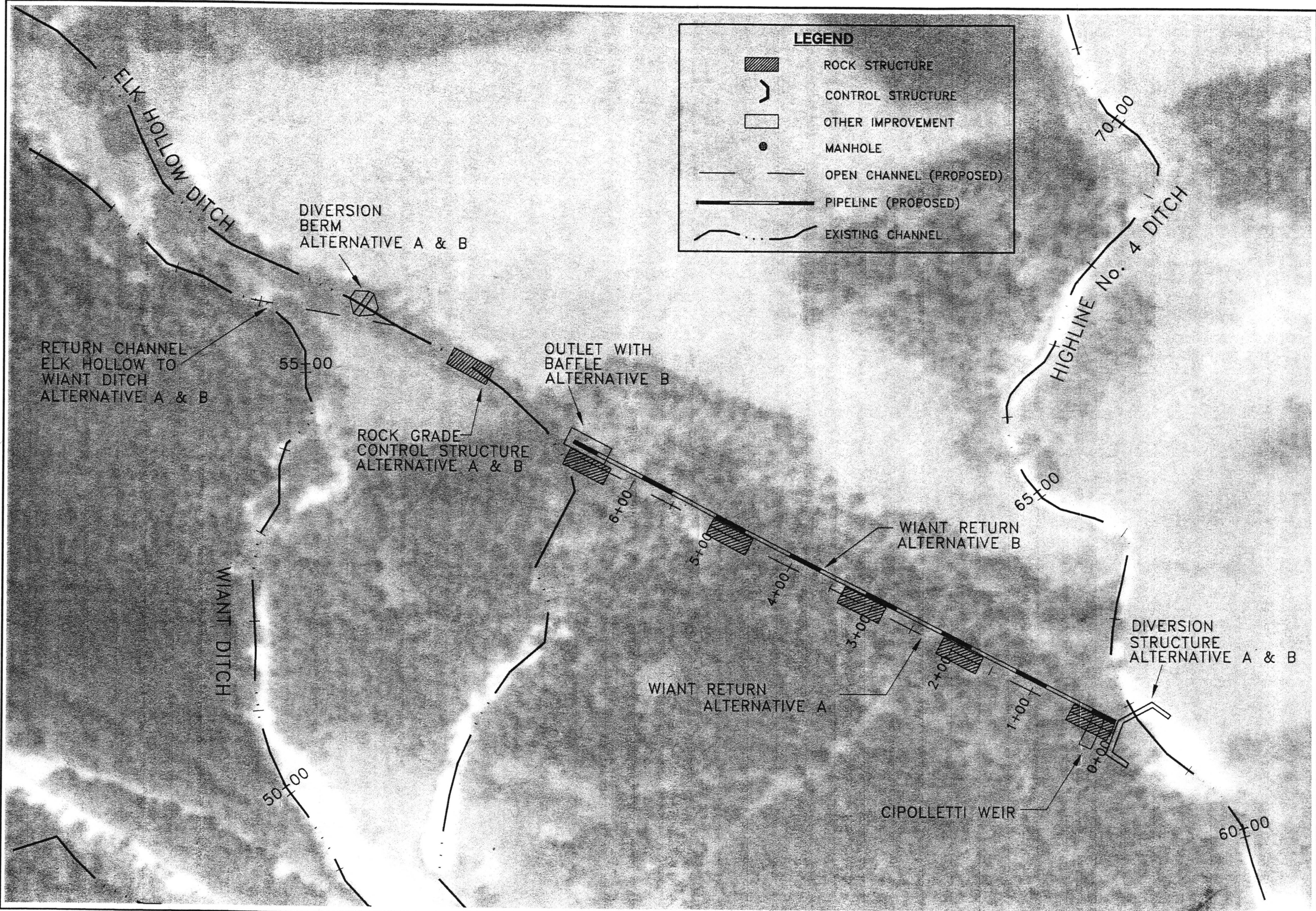
Two alternatives were evaluated to convey the Wiant Ditch portion of the commingled diversions back into the Wiant Ditch downstream of the degraded reaches (see Figure 4.4). The alignment of this alternative takes advantage of an existing swale between the Highline No. 4 Ditch and the Elk Hollow Ditch.

##### Alternative A: Wiant Return Ditch

This alternative requires construction of a new diversion structure on the Highline No. 4 Ditch downstream of the washout near Station 62+00. The new structure would allow the diversion of the Wiant portion of the commingled flows back into the Wiant Ditch. At the new diversion structure, a Cipolletti Weir would be built to measure flows diverted to the Wiant Ditch. From the new diversion, an open channel, 12 feet wide with 2.5:1 sideslopes, would convey the water to the Elk Hollow Ditch downstream of its degraded reach. The channel requires approximately 5 rock riprap drop structures ranging in height from 8 to 12 feet. Once in the Elk Hollow Ditch, the flows follow the Elk Hollow Ditch for approximately 250 feet. A berm is required in the Elk Hollow Ditch to divert the flow into the Wiant Ditch via an open channel.

##### Alternative B: Wiant Return Pipeline

This alternative is identical to Alternative A above, however, the open channel segment of the alternative is replaced with a 48-inch RCP pipeline. The new diversion structure and modifications to the Elk Hollow Ditch are identical.



SCALE  
1" = 100'

HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
DITCH PROJECT LEVEL II  
CONCEPTUAL DESIGNS:  
WIAINT No. 2 RETURN ALTERNATIVES

Anderson Consulting Engineers, Inc.  
Civil • Water Resources • Environmental  
2900 S. College Avenue, Suite 3B, Fort Collins, CO 80525  
Phone (970) 226-0120 / Fax (970) 226-0121



Project No. WYWD14  
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Design: JDS/CJP  
Drawn: MRC  
Revisions: 10/22/99  
ACADFILE: PROPIMPVMENT.DWG

FIGURE  
4.4

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## **4.4 Other Rehabilitation Measures**

### **4.4.1 Macannany Washout Rehabilitation**

This alternative requires construction of a series of pipe drop structures to convey the Highline No. 4 design flows through the degraded reach between Diversion Structure No. 3 and South Cedar Creek (Figure 4.5). Three pipe drop structures would be required to accommodate the vertical drop of approximately 150 feet which exists within this reach. The combined length of the pipe drop structures is estimated to be 1,200 linear feet. Between the pipe drop structures, the existing canal would be used. Each pipe drop structure would terminate with a baffled outlet for energy dissipation. A rock riprap grade control structure would be required at each pipe outlet to ensure protection against possible canal incision.

Along with reconstruction of the Highline No. 4 ditch, a portion of the Hill No. 2 ditch would require rehabilitation. Continued erosion of the Hill No. 2 ditch would likely undermine Diversion Structure No. 3 as well as any improvements made to the Highline No. 4 ditch. Therefore, a 12-inch PVC pipe would be constructed from Diversion Structure No. 3 as shown on Figure 4.5. Downstream of the new pipe, the Hill No. 2 is deeply incised but it was assumed continued erosion would not threaten the integrity of the proposed improvements. In the future, rehabilitation of this ditch should be considered.

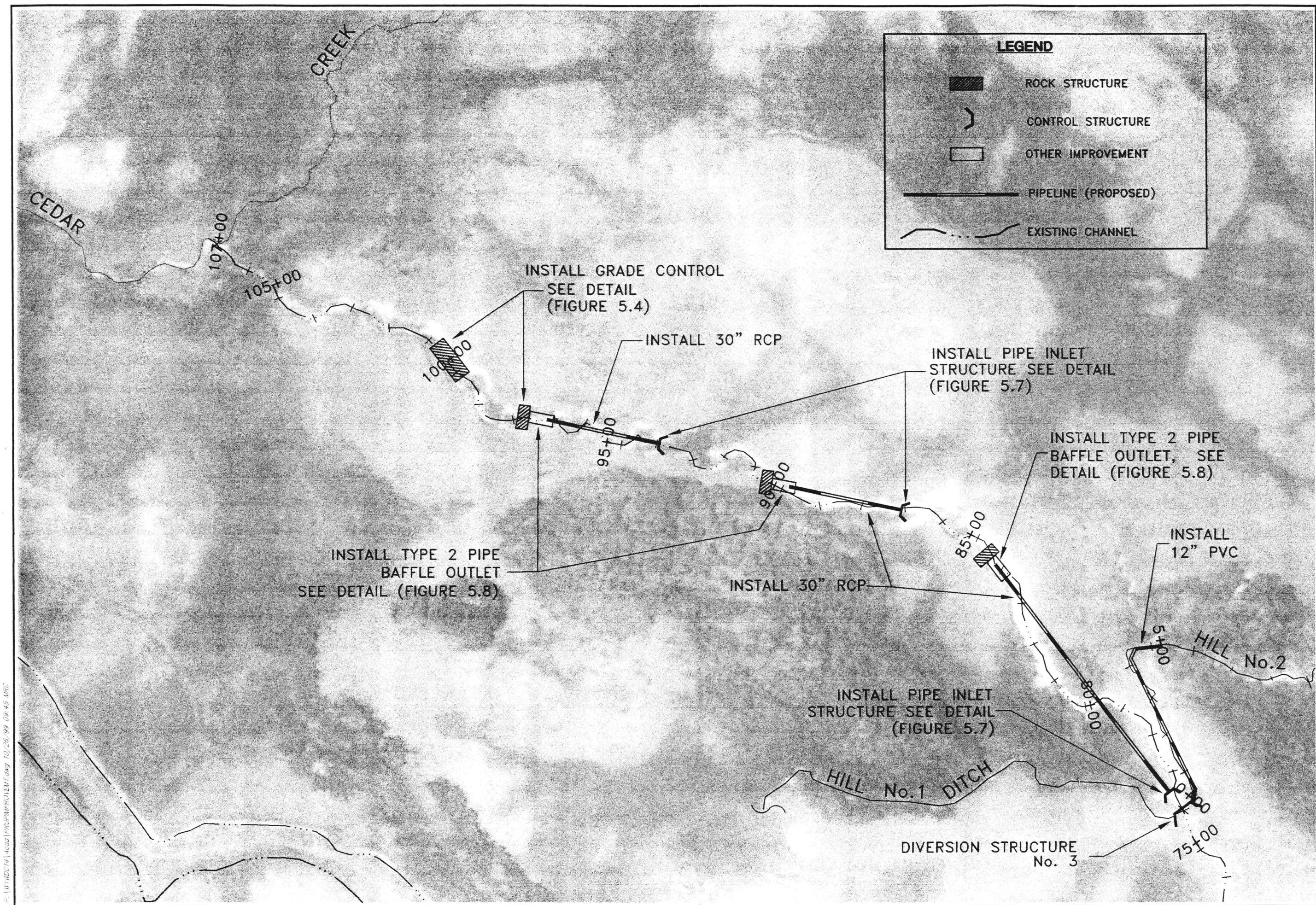
Other alternatives considered at this location included diversion of Highline No. 4 flows into the Hill No. 2 for conveyance to South Cedar Creek. This alternative would require significant enlargement of the Hill No. 2 Ditch, construction a pipe drop structure from Diversion Structure No. 3 to the Hill No. 2 ditch, and significant improvements to the affected reach of South Cedar Creek. In addition, potential wetland issues related to Cedar Creek would make implementation of this alternative not only cost prohibitive, but difficult to permit.

### **4.4.2 Ryan Foreman Rehabilitation**






This alternative involves the bypass of the degraded portion of the Ryan Foreman Ditch with approximately 700 linear feet of 12-inch PVC (Figure 4.6). The pipeline would begin at an earthen plug in the Ryan Foreman Ditch and extend along the western side of the existing washout.

### **4.4.3 Measurement Structures**

Currently, there are no measurement structures at Diversion Structure Nos. 1, 2, or 3. This alternative involves incorporation of Cipolletti weirs on the main ditches at these locations. In



**LEGEND**

-  ROCK STRUCTURE
-  CONTROL STRUCTURE
-  OTHER IMPROVEMENT
-  PIPELINE (PROPOSED)
-  EXISTING CHANNEL

SCALE  
1" = 200'

HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
DITCH PROJECT LEVEL II  
CONCEPTUAL DESIGNS:  
MACANNANY WASHOUT REHABILITATION

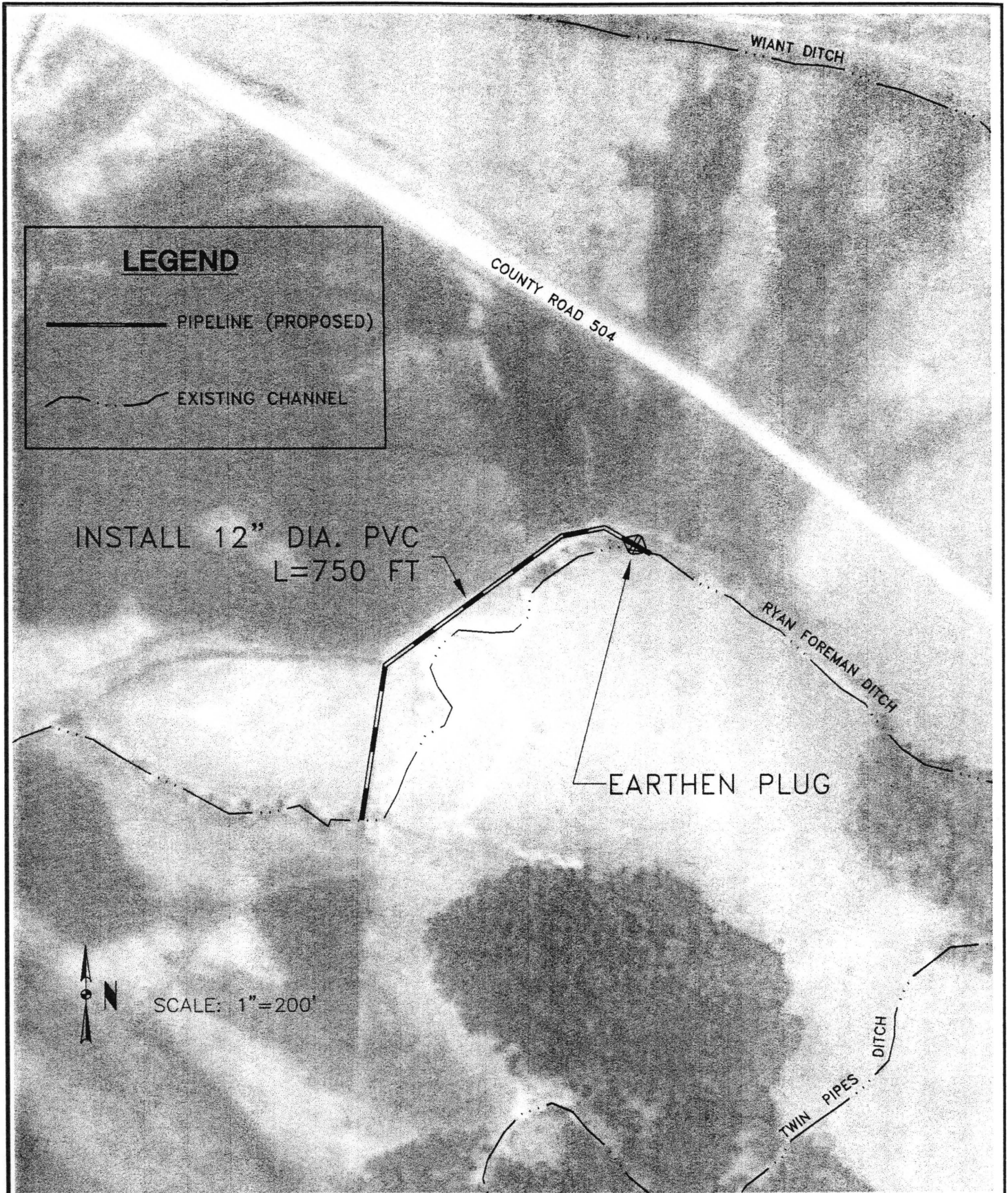
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ACAD FILE:	PROPIMPVMENT.DWG

**FIGURE 4.5**

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**LEGEND**

———— PIPELINE (PROPOSED)

- - - - - EXISTING CHANNEL

INSTALL 12" DIA. PVC  
L=750 FT

EARTHEN PLUG



SCALE: 1"=200'



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**HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
 DITCH PROJECT LEVEL II**

**CONCEPTUAL DESIGNS:  
 RYAN FOREMAN WASHOUT REHABILITATION**

Project No.	WYDC14
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Revisions:	
ACADFILE:	PROPIMPROVEMT.DWG

**FIGURE 4.6**

addition, Parshall flumes would be placed on the smaller ditches: Gross, Ryan Foreman, Twin Pipes Ditches, Hill No. 1, Hill No. 2, and the unnamed ditch immediately upstream of Diversion Structure No. 3.

**4.5 Conceptual Cost Estimates**

To promote the evaluation of the conceptual alternatives presented in this chapter, cost estimates were prepared. These estimates included 10% for final design, 10% for engineering during construction and 15% contingency. Tables 4.1 and 4.2 summarize the results of the cost estimates associated with the “Separated Diversions” and “Commingled Diversions” scenarios, respectively. Table 4.3 summarizes the results of the cost estimates associated with the other rehabilitation measures evaluated. Itemized estimates for each alternative are provided in Appendix B.

Table 4.1 Summary of Construction Costs: Separate Diversion Scenario.

Project	Cost of Project Components
<b>Highline No. 4 Ditch Rehabilitation</b>	
Alternative A: Open Channel	\$67,000.00
Alternative B: Buried Pipeline	\$173,150.00
Alternative C: Stabilization of Existing Channel	\$104,267.00
Alternative D: Stabilization of Existing Channel	\$65,400.00
<b>Wiant Ditch Rehabilitation</b>	
Alternative A: Open Channel	\$425,560.00
Alternative B: Buried Pipeline	\$232,566.00
Alternative C: Stabilization of Existing Channel	\$436,419.00
Alternative D: Pipe / Open Channel	\$179,365.00
<b>Separate Diversion Scenario: Least Cost Alternatives</b>	
Highline No. 4 Ditch Rehabilitation Alternative D: Stabilization of Existing Channel	\$65,400.00
Wiant Ditch Rehabilitation Alternative D: Pipe / Open Channel	\$179,365.00
<b>Combined Least Cost</b>	<b>\$244,765.00</b>

Table 4.2 Summary of Construction Costs: Commingled Diversion Scenario.

Project	Cost of Project Components
<b>Highline No. 4 Ditch Rehabilitation</b>	
Alternative A: Open Channel	\$92,800
Alternative B: Buried Pipeline	\$217,023
Alternative C: Stabilization of Existing Channel	\$136,125
Alternative D: Stabilization of Existing Channel	\$81,200
<b>Wiant Return Conveyance Structure</b>	
Alternative A: Wiant Return Ditch	\$254,309
Alternative B: Wiant Return Pipeline	\$161,030
<b>Wiant to Highline Diversion Channel</b>	\$46,760
<b>Commingled Diversion Scenario: Least Cost Alternatives</b>	
Wiant to Highline Diversion Channel	\$46,760
Wiant Return Conveyance Structure, Alternative B	\$161,030
Highline No. 4 Ditch Rehabilitation, Commingled Alternative D	\$81,200
<b>Combined Least Cost</b>	<b>\$288,990</b>

Table 4.3 Summary of Construction Costs: Other Rehabilitation Measures.

Project	Cost of Project Components
Macannany Washout Rehabilitation	\$174,000
Ryan Foreman Washout	\$10,500
Measurement Structures	\$84,200
<b>Combined Cost</b>	<b>\$268,700</b>



## V. CONCEPTUAL DESIGN

Following review of the conceptual rehabilitation alternatives presented in Chapter 4 and their relative costs, the “Separate Diversion” scenario was determined to be the most cost effective rehabilitation strategy. The cost associated with the suite of alternatives comprising this scenario was exceeded by those of the “Commingled Diversion” scenario. It is our understanding that the District is interested in pursuing a “Commingled Diversion” scenario if significant cost savings are incurred. Given the lower costs associated with maintaining separated diversion, the following improvements were selected for further investigation:

- Rehabilitation of the Highline No. 4 Ditch as described under Alternative D: Stabilization of the Existing Ditch; and
- Rehabilitation of the Wiant Ditch as described under Alternative D: Combined Pipeline and Open Channel.

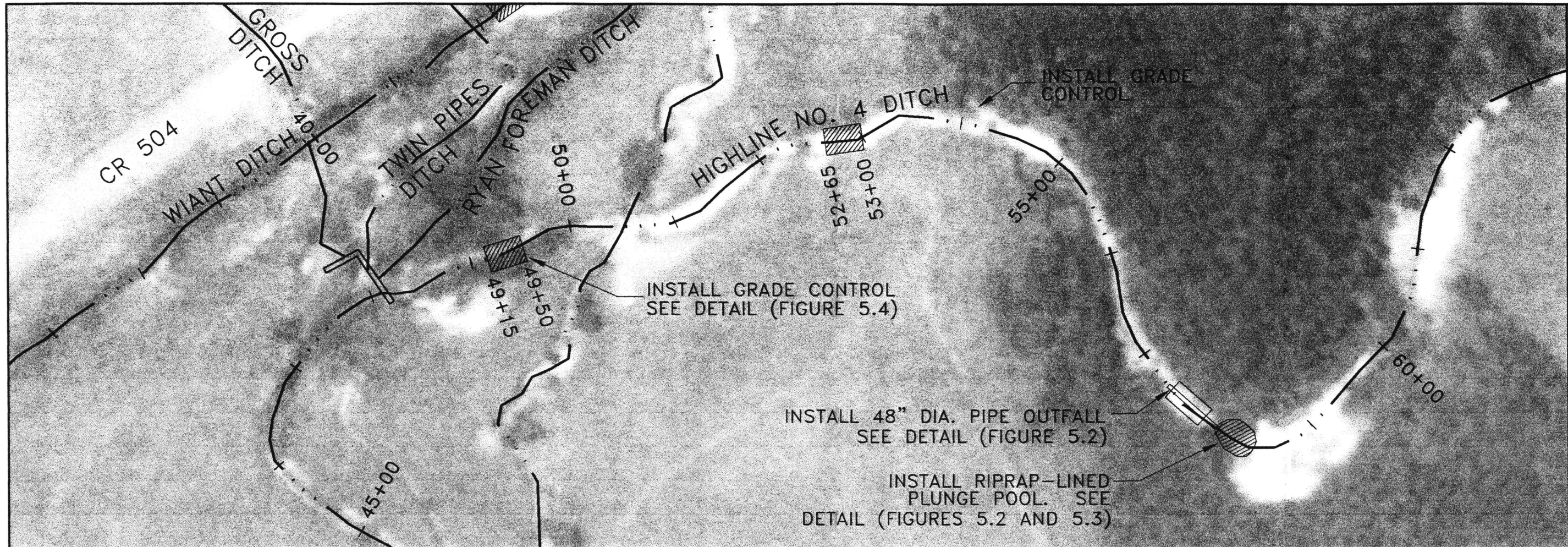
Following comments received from the District, other improvements recommended for conceptual design are:

- Rehabilitation of the Macannany Washout;
- Rehabilitation of the Ryan Foreman Washout; and
- Installation of Measurement Structures.

The recommended improvements are delineated on Figures 5.1 through 5.11. These figures illustrate the location of these improvements and provide a design details of each recommended improvement. The following paragraphs more fully describe the improvements and present additional details pertinent to the conceptual design.

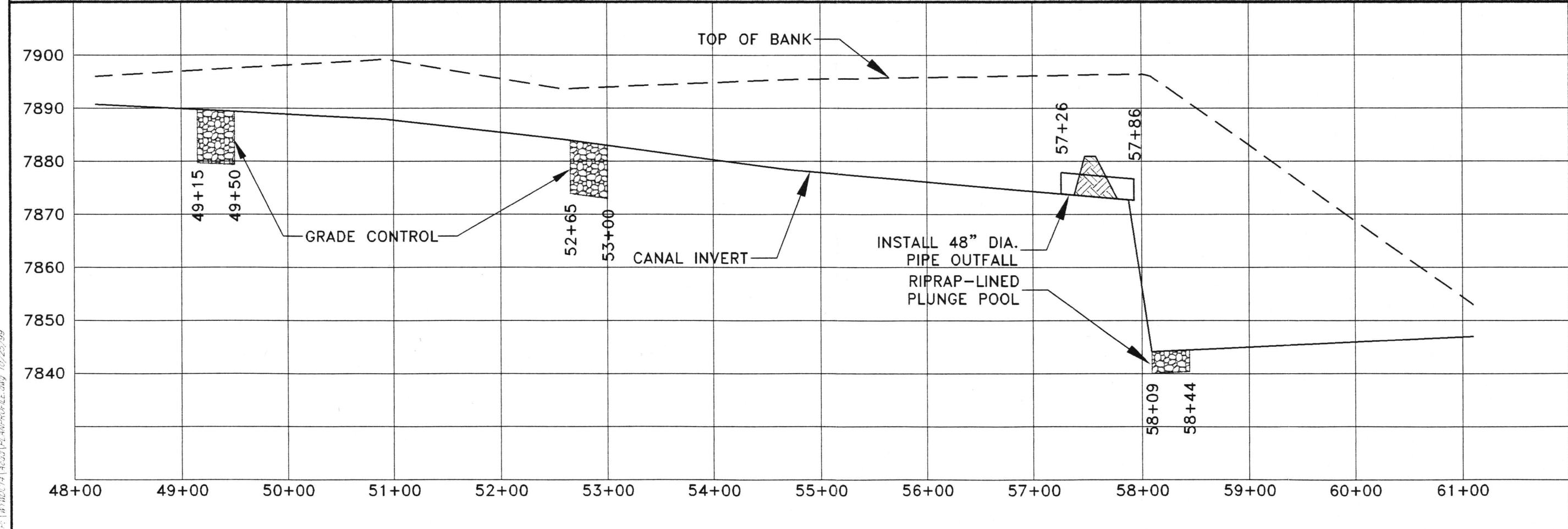
### 5.1 Highline No. 4 Ditch Rehabilitation

The recommended alternative for rehabilitation of the Highline No. 4 Ditch consists of stabilization of the existing ditch as described below:



SCALE  
1" = 100'

HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
DITCH PROJECT LEVEL II  
CONCEPTUAL DESIGN PLAN AND PROFILE:  
HIGHLINE WASHOUT REHABILITATION ALT. D



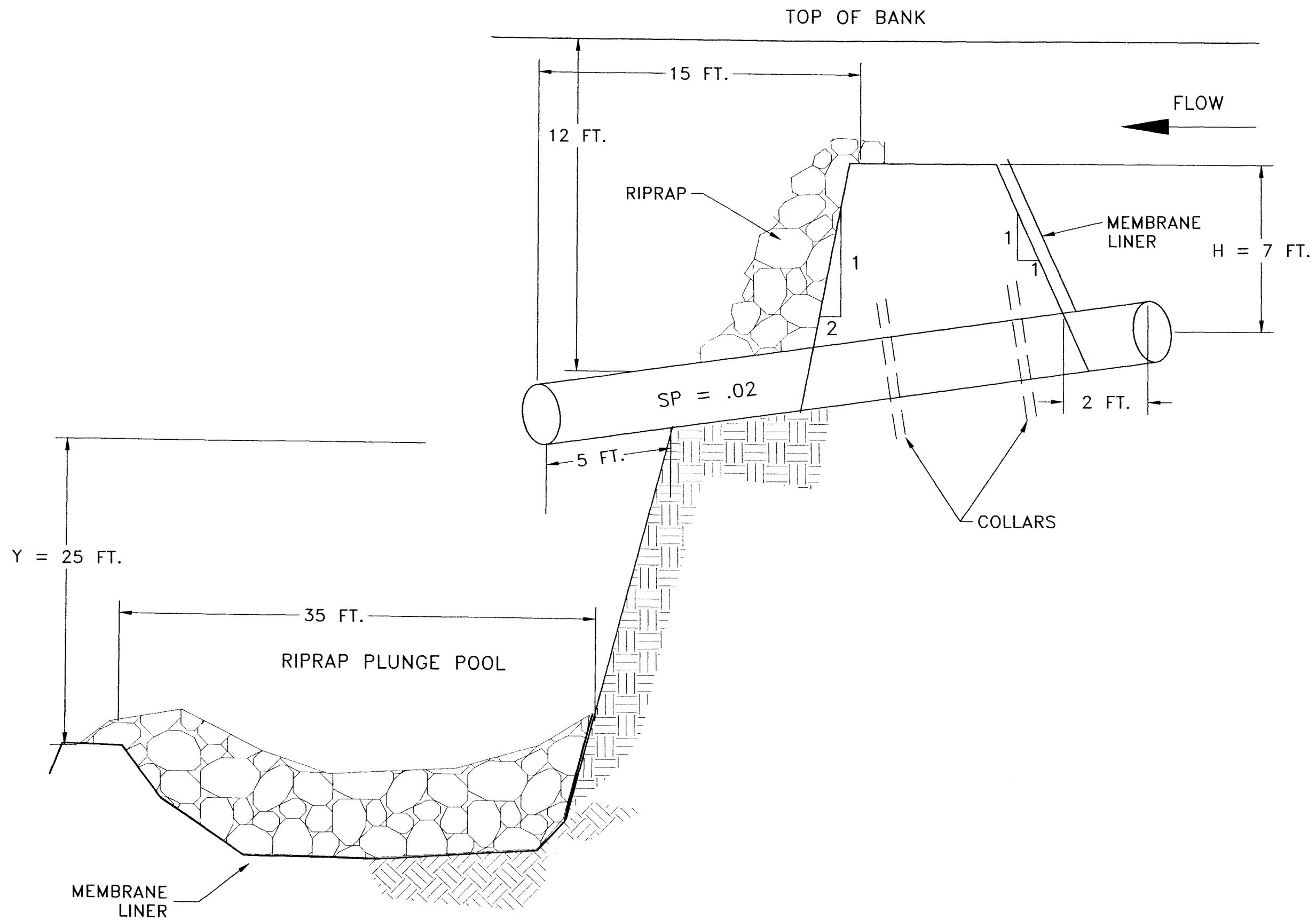
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Design:	JDS/CJP
Drawn:	CLD
Revisions:	10/99 CLD
ACADFILE:	PLANPROFILE.DWG

**FIGURE 5.1**

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HIGHLINE No. 4 DITCH PIPE OUTFALL  
STRUCTURE PROFILE VIEW

NOT TO SCALE

NO SCALE

HIGHLINE No. 4 DITCH REHABILITATION

PIPE OUTFALL DETAILS

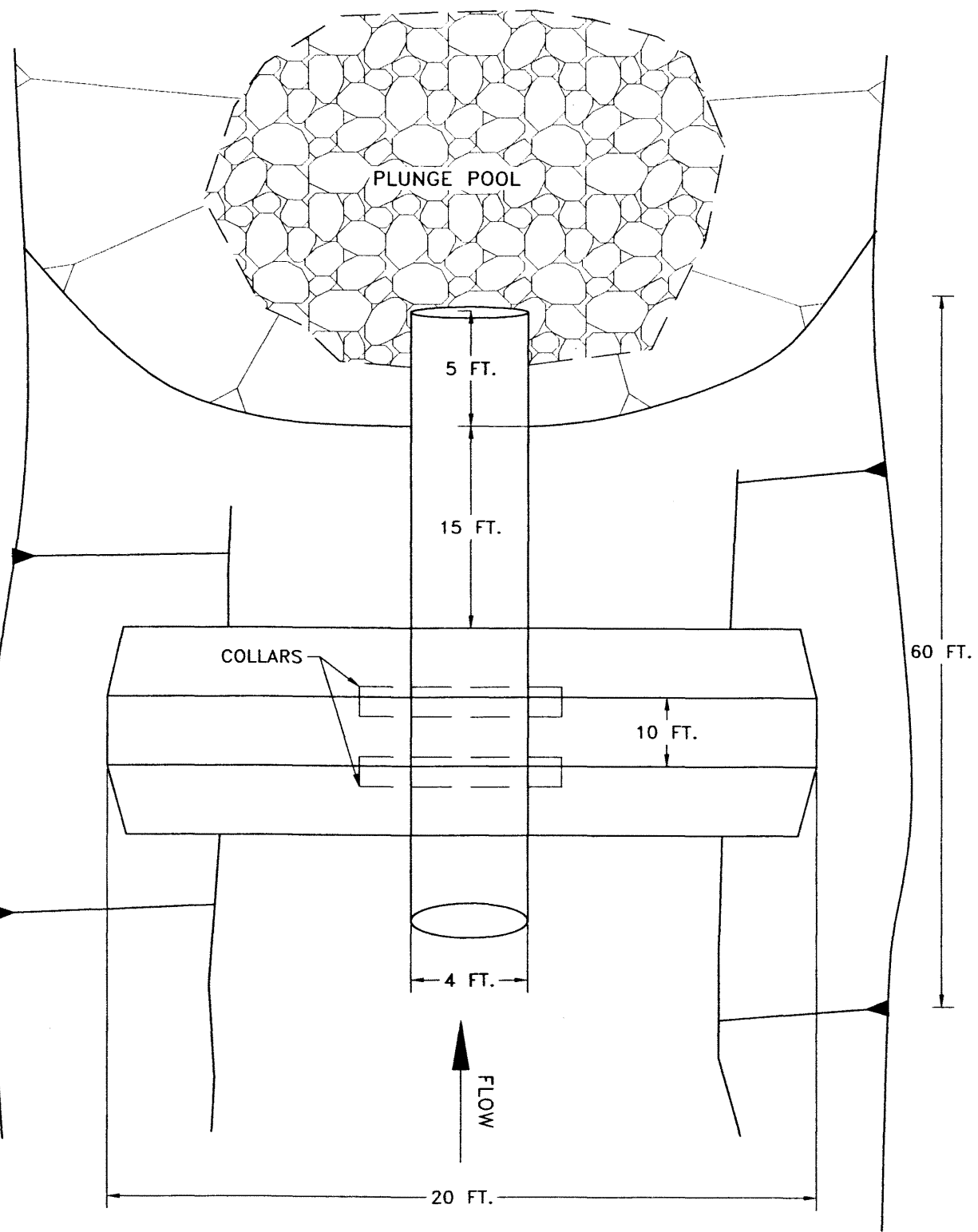
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Project No.	WYDC14
Date:	10-01-99
Design:	JDS/CJP
Drawn:	JF/MRC
Revisions:	
ACAD FILE:	WYDC14-FIG.DWG

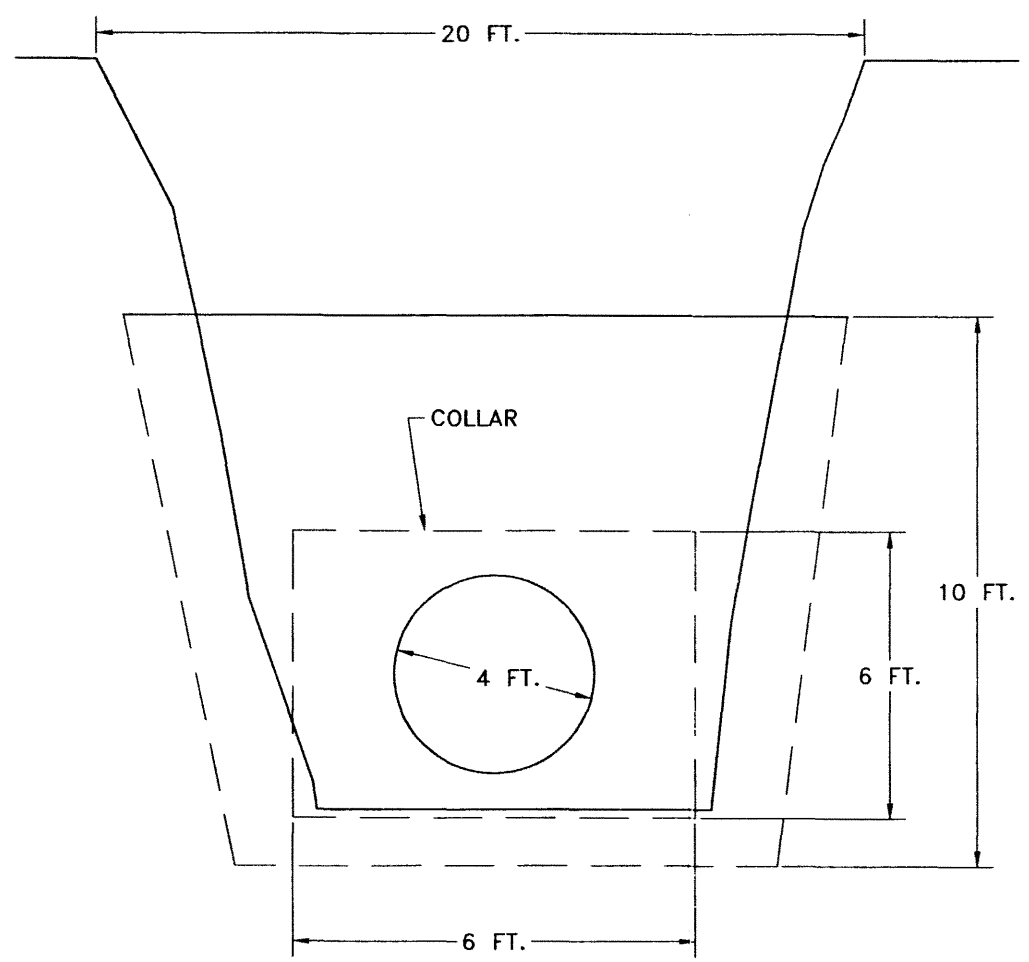
FIGURE  
5.2

P:\WYDC14\1400\WYDC14-FIGURE 10/02/99 9.25 MRC



**HIGHLINE No. 4 DITCH PIPE OUTFALL  
STRUCTURE PLAN VIEW**

NOT TO SCALE



**HIGHLINE No. 4 DITCH PIPE OUTFALL STRUCTURE  
CROSS SECTION VIEW**

NOT TO SCALE

NO SCALE

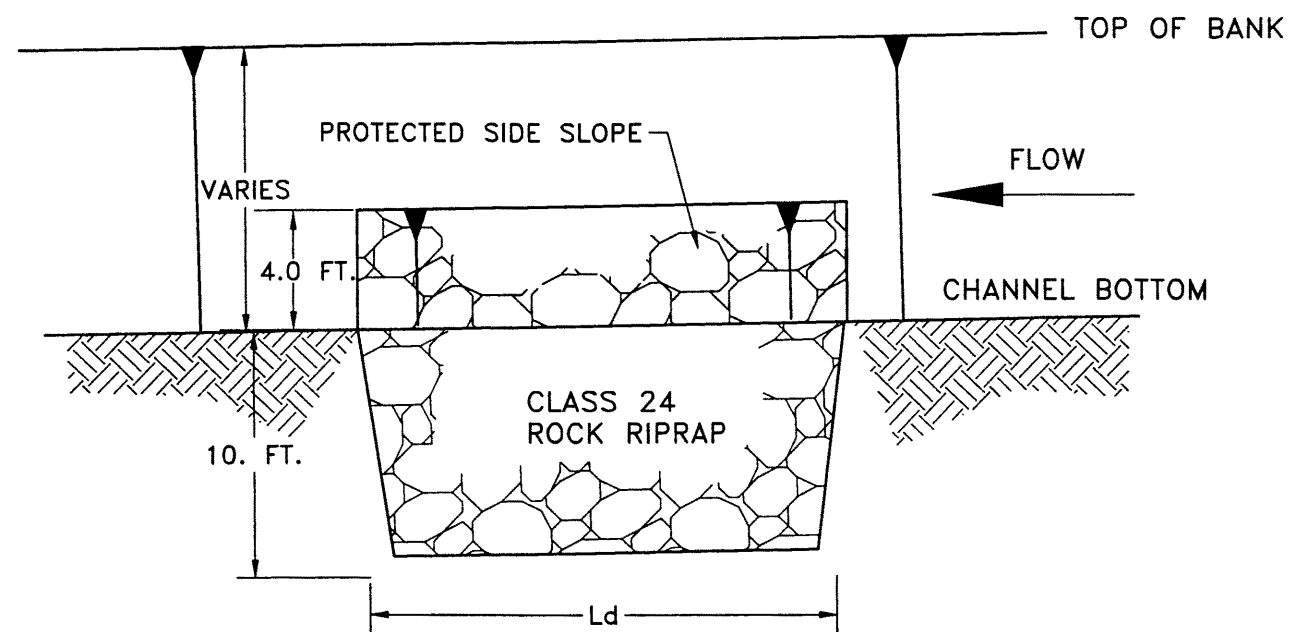
**HIGHLINE No. 4 DITCH REHABILITATION  
PIPE OUTFALL DETAILS**

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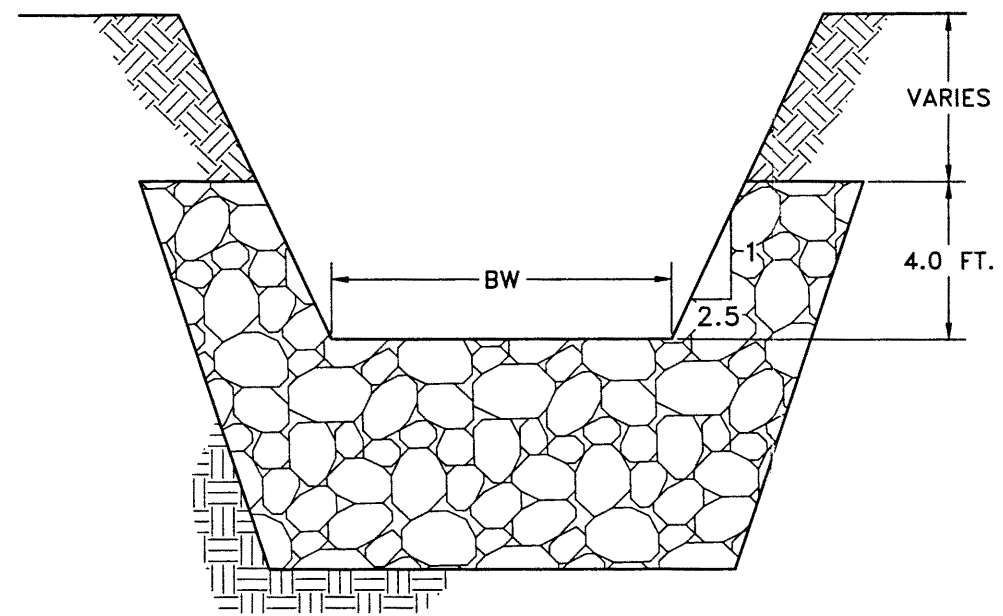


Project No.	WYDC14
Date:	10-01-99
Design:	JDS/CJP
Drawn:	JF/MRC
Revisions:	
ACADFILE:	WYDC14-FG.DWG

**FIGURE  
5.3**



TYPICAL GRADE CONTROL STRUCTURE - PROFILE VIEW  
NOT TO SCALE



TYPICAL GRADE CONTROL STRUCTURE - CROSS SECTION VIEW  
NOT TO SCALE

NO SCALE

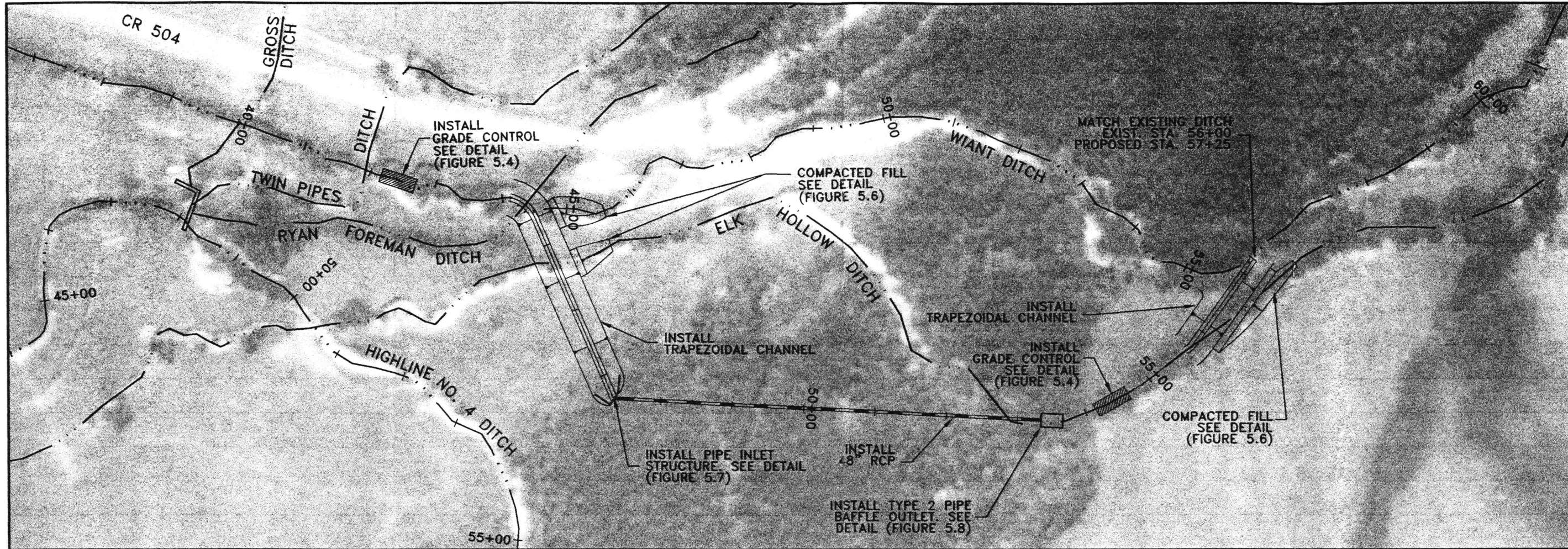
HIGHLINE No. 4 DITCH REHABILITATION  
GRADE CONTROL STRUCTURE DETAILS

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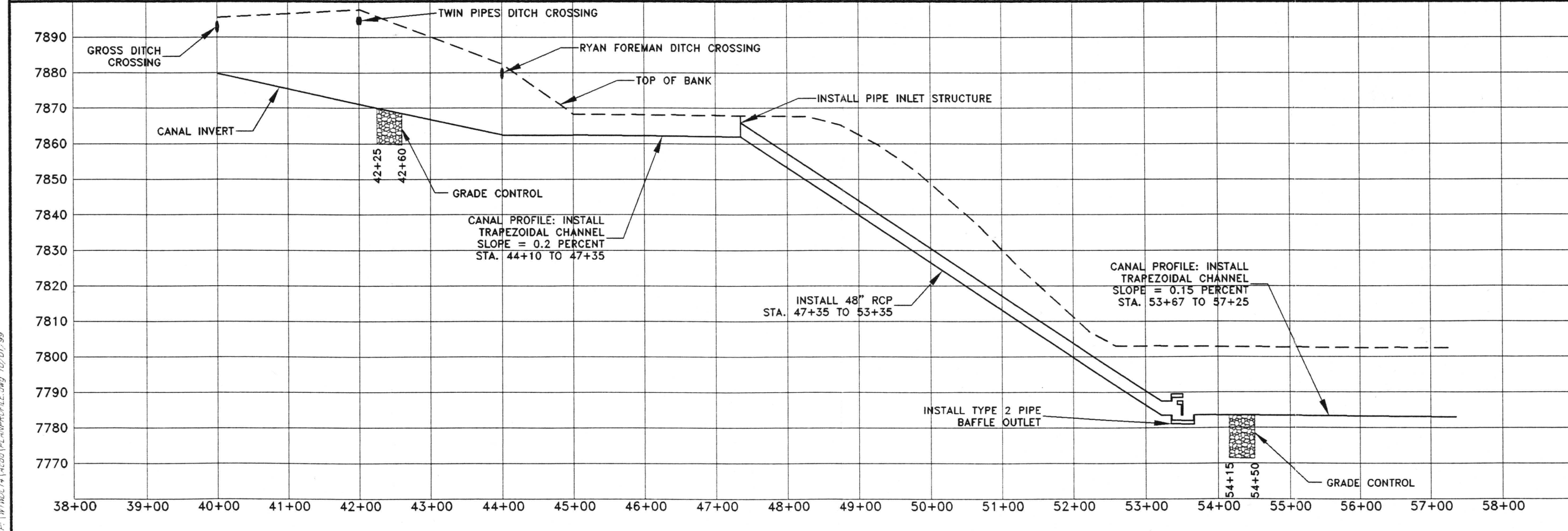
Project No.	WYWDC14
Date:	10-01-99
Design:	JDS/CJP
Drawn:	JF/MRC
Revisions:	
ACADFILE:	WYWDC14-FIG.DWG

FIGURE  
5.4



SCALE  
1" = 150'

HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
DITCH PROJECT LEVEL II  
CONCEPTUAL DESIGN PLAN AND PROFILE:  
WIANT WASHOUT REHABILITATION ALT. D



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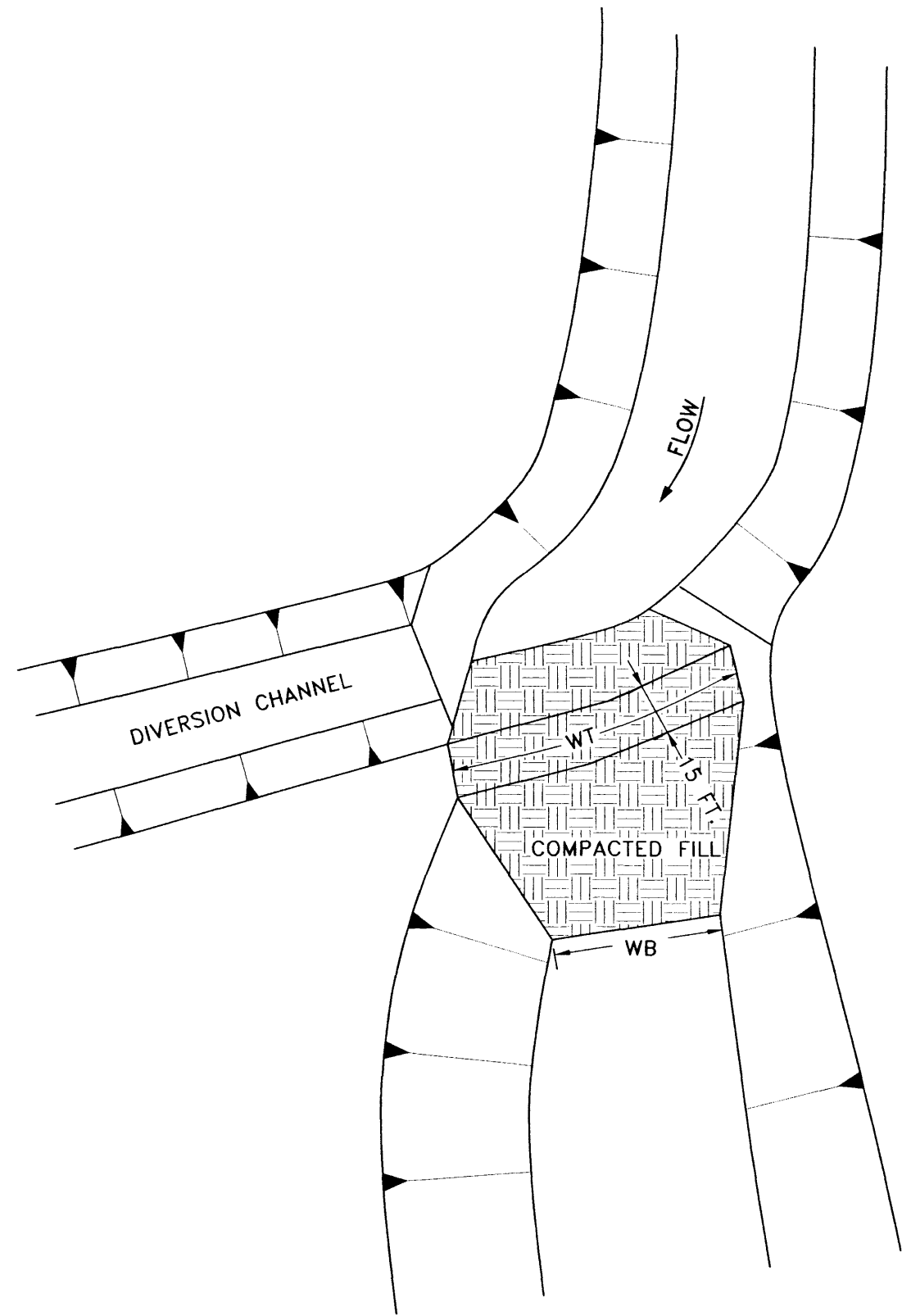


Project No.	WYDC14
Date:	9/27/99
Design:	JDS/CJP
Drawn:	CLD
Revisions:	10/99 CLD
ACAD FILE:	PLANPROFILE.DWG

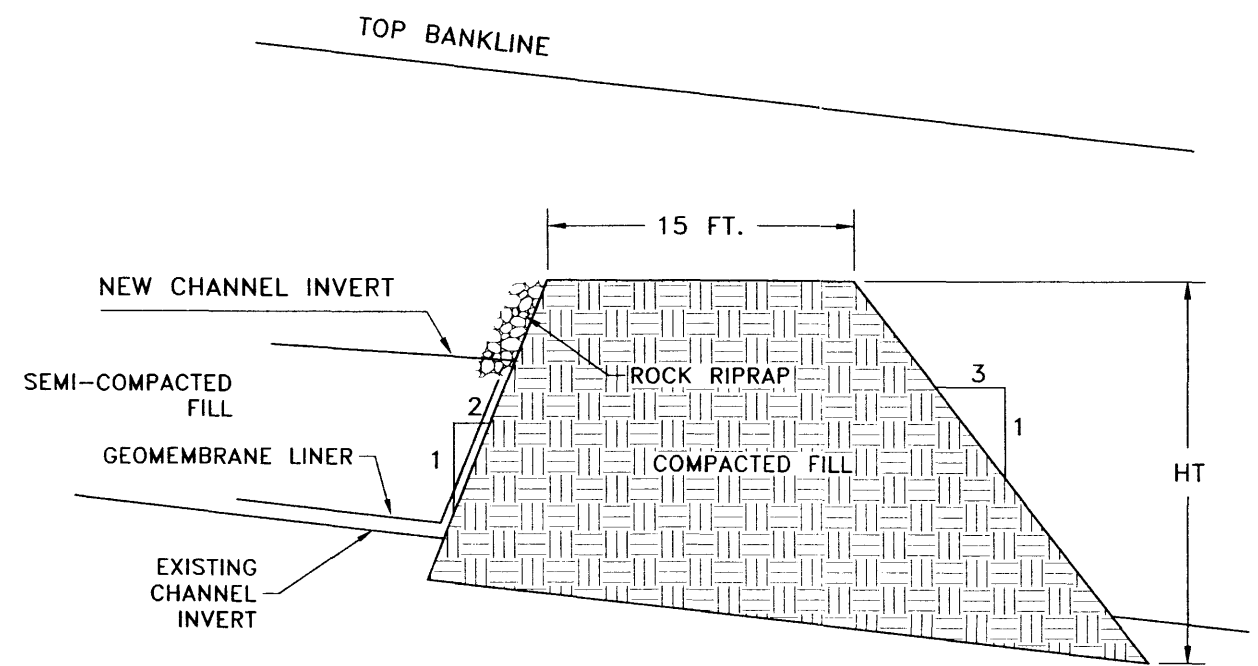
**FIGURE 5.5**

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TYPICAL DIVERSION BERM - PLAN VIEW  
NOT TO SCALE



TYPICAL DIVERSION BERM - PROFILE VIEW  
NOT TO SCALE

NO SCALE

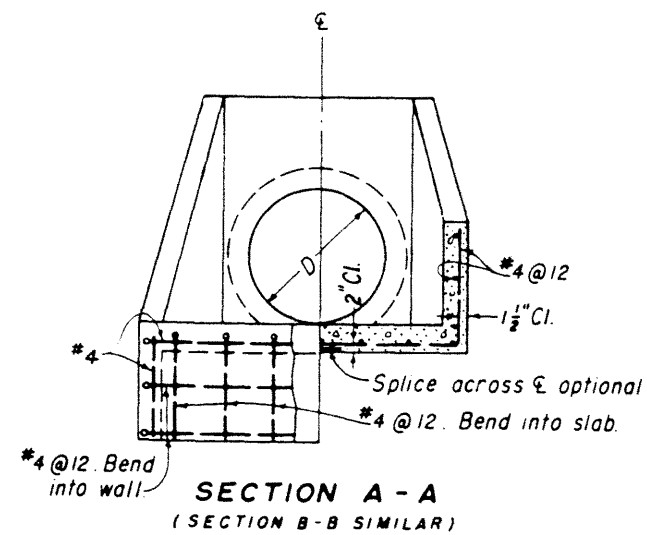
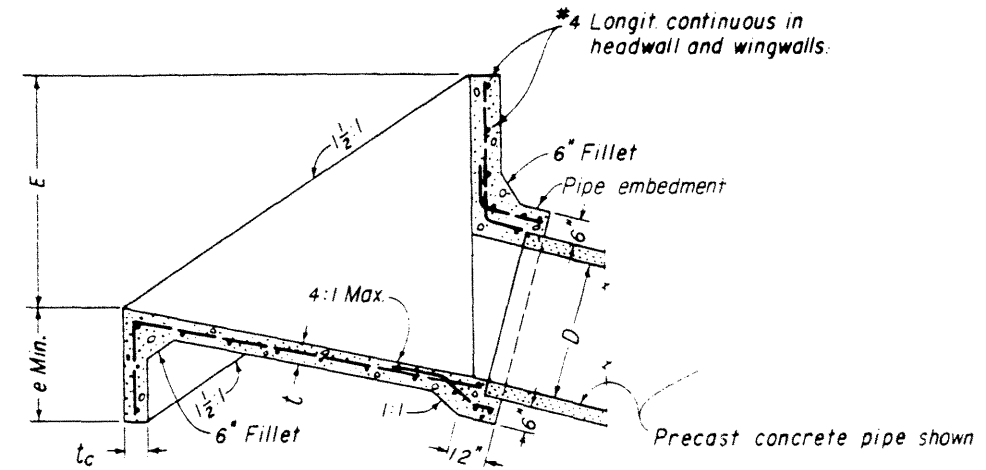
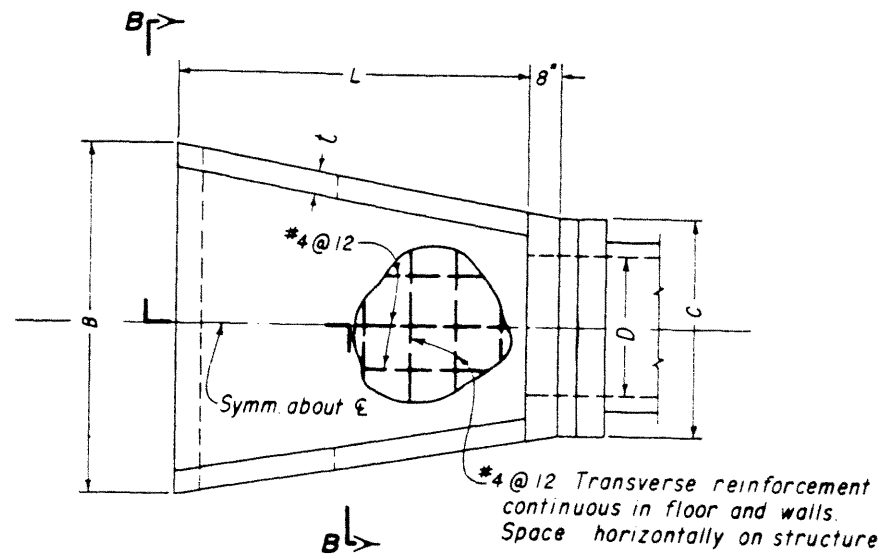
WIANT DITCH REHABILITATION  
EARTHEN BERM DETAILS

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Date:	10-01-99
Design:	JDS/CJP
Drawn:	JF/MRC
Revisions:	
ACADFILE:	WYDC14-FE.DWG

FIGURE 5.6



NO SCALE

WANT DITCH REHABILITATION  
PIPE INLET DETAIL

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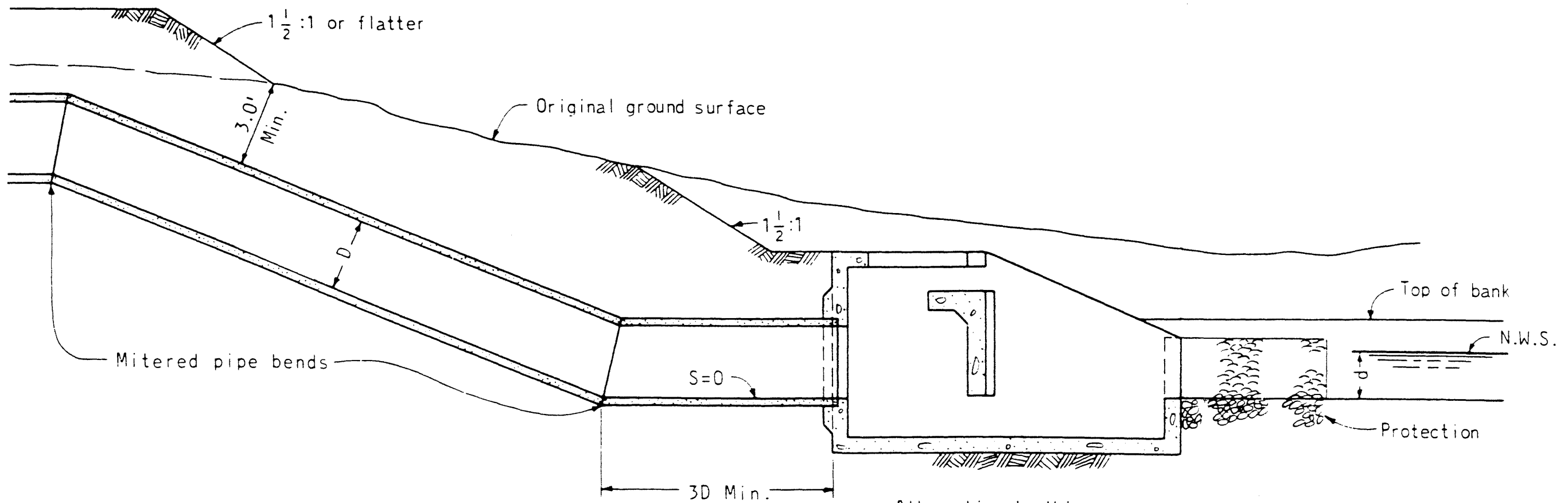


Project No.	COFC04
Date:	1/7/99
Design:	BFS/AMH/BAA
Drawn:	BFS
Revisions:	
ACAD FILE:	FO04-RCE-EX-SCH.DWG

FIGURE  
6.7



P:\W\WDC14\Acad\W\WDC14-FIGURE.DWG 10/04/99 8:35 AM RC



Alternative to this baffled outlet is a stilling pool.

NO SCALE

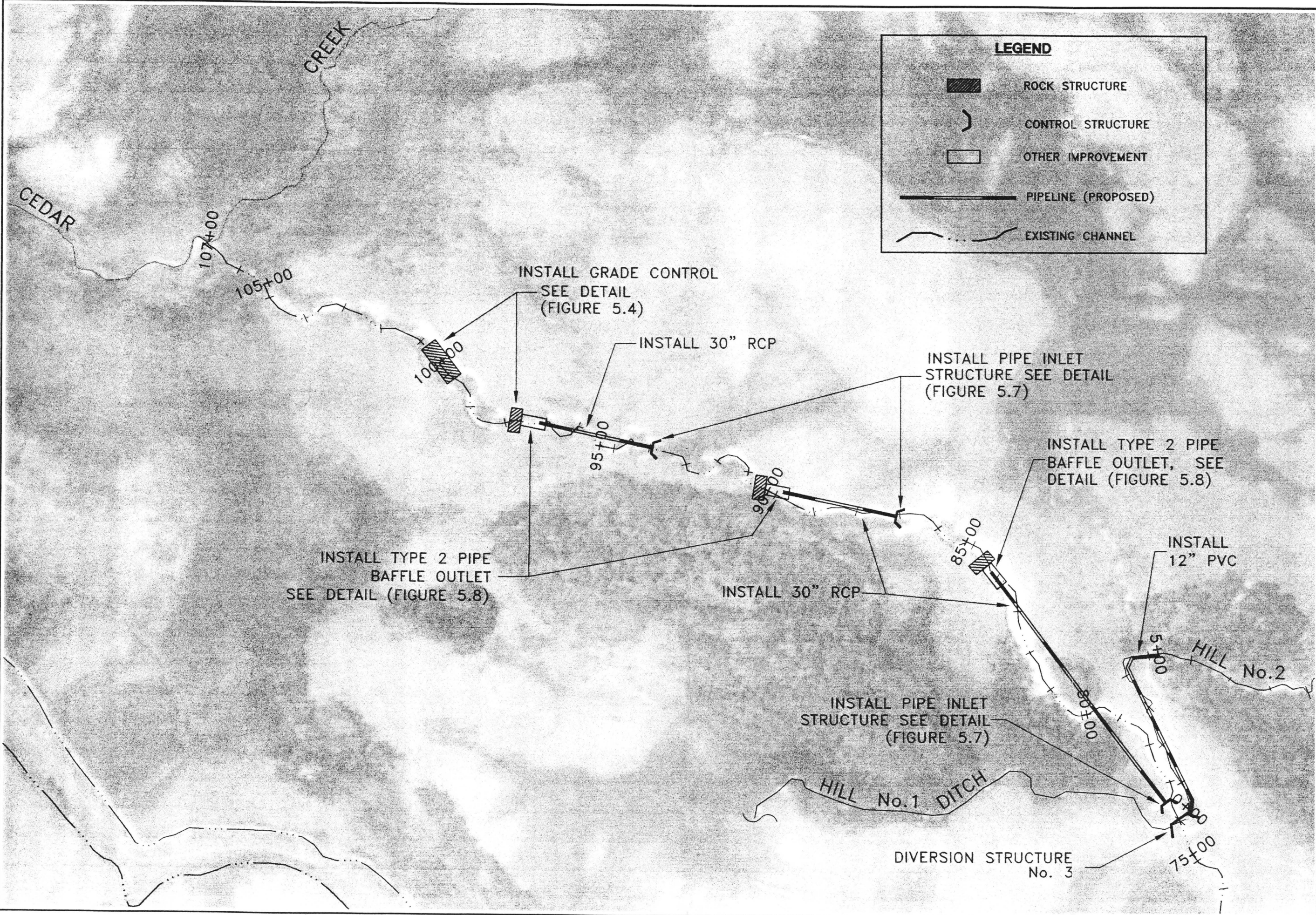
WANT DITCH REHABILITATION

**TYPE 2 DITCH PIPE DROP DETAIL**






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**FIGURE 5.8**



**LEGEND**

-  ROCK STRUCTURE
-  CONTROL STRUCTURE
-  OTHER IMPROVEMENT
-  PIPELINE (PROPOSED)
-  EXISTING CHANNEL

  
 SCALE  
 1" = 200'

HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
 DITCH PROJECT LEVEL II  
 CONCEPTUAL DESIGN PLAN:  
 MACANNANY WASHOUT REHABILITATION

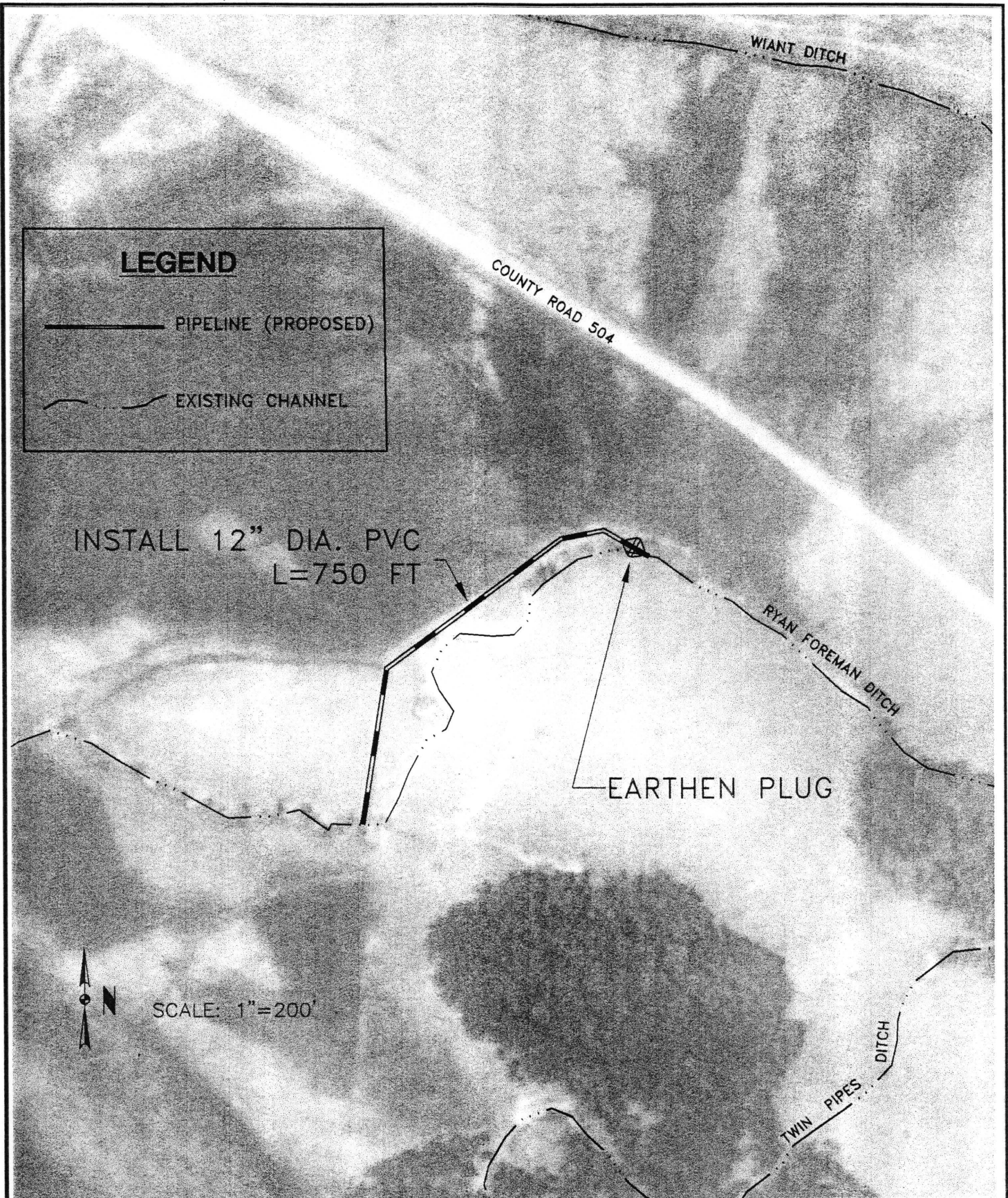
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ACAD FILE:	PROPIMP001.DWG

**FIGURE 5.9**

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**HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
 DITCH PROJECT LEVEL II  
 CONCEPTUAL DESIGN PLAN:  
 RYAN FOREMAN WASHOUT REHABILITATION**

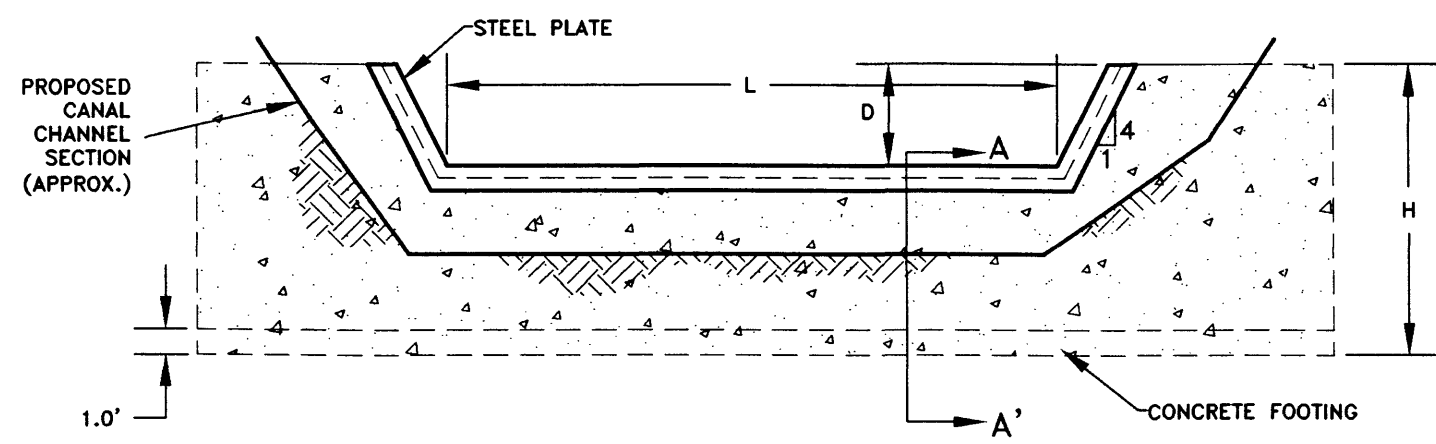
Project No.	WYDC14
Date:	10/22/99
Design:	JDS/CJP
Drawn:	MRC
Revisions:	
ACADFILE:	PROIMPROVEMT.DWG

**FIGURE 5.10**

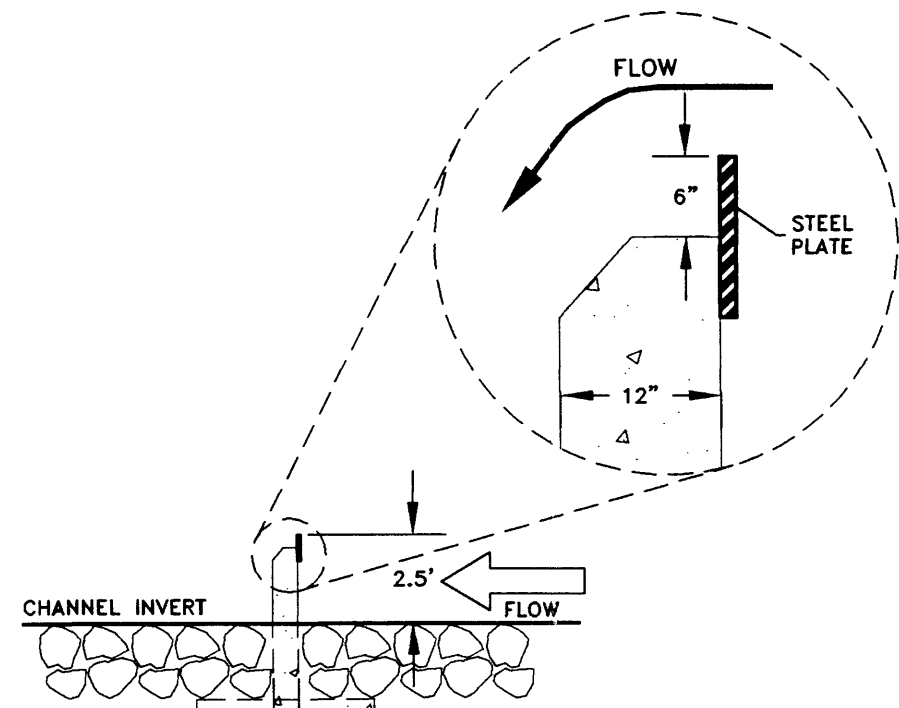


NTS

HIGHLINE WATERSHED IMPROVEMENT DISTRICT  
DITCH PROJECT LEVEL II  
CONCEPTUAL DESIGN PLANS:  
CIPOLLETTI WEIR DETAILS



**WEIR SECTION**  
(LOOKING DOWNSTREAM)  
N.T.S.



**SECTION A-A'**  
N.T.S.

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Revisions:	
ACAD FILE:	CIPWEIR.DWG

**FIGURE**  
**5.11**

1. The existing washout at Station 57+88 is stabilized by building a pipe outfall structure, and;
2. The incised channel between the headcut and Diversion Structure No. 2 is stabilized by placement of two grade control structures at appropriate locations in the reach.

Figure 5.1 presents the plan and profile views of this alternative. In the following paragraphs, the individual features of this alternatives are discussed.

### **5.1.1 Diversion Structure No. 2**

Under this alternative, Diversion Structure No. 2 requires no modifications or improvements. The flows conveyed through the structure would not change because there is no commingling of diversions. As discussed in Chapter 3, the structure is in good condition and improvements are not recommended at this time.

### **5.1.2 Pipe Outfall Structure**

The washout that exists at Station 57+88 is approximately 25 feet high and the irrigation ditch is incised approximately 18 feet below the existing banks at that location. A pipe outfall structure is recommended which would facilitate the vertical drop required to convey the water to the stable ditch downstream. Figures 5.2 and 5.3 provide conceptual design details for the installation of the outfall. Before construction, site preparation would include removal of any cantilevered or overhanging foundation material. The structure will be constructed within the existing channel upstream of the washout. The outfall structure incorporates an anchored steel pipeline, 48-inches in diameter, which projects approximately 5 feet beyond the lip of the ditch bed. The pool below the outfall will be stabilized by placing approximately 180 cubic yards of rock riprap ( $D_{50} = 24$  inches) over an impermeable liner. Where necessary, appropriate bedding material should be placed over the liner to prevent puncturing during placement of the rock riprap.

### **5.1.3 Grade Control Structures**

With construction of the pipe outfall structure, an elevation difference of approximately 18 feet exists between the invert of Diversion Structure No. 2 and that of the pipe outfall. At this slope, conveyance of the design discharge is considered to be erosive and channel degradation is expected to continue. However, with the headcut stabilized, the maximum potential degradation is estimated

to be approximately 14 feet. Mitigation of this potential degradation can be accommodated by placing grade control structures at key locations within the unprotected reach.

Figure 5.4 presents the details associated with the proposed grade control structures. These structures consist of rock riprap placed to a depth of approximately 10 feet below the elevation of the channel invert. If the channel does incise to this depth, the rock forms a protective “hard point” in the channel and arrests incision at that location. Based upon the existing profile of the Highline No. 4 Ditch and access considerations, grade control structures are recommended at Stations 49+30 and 54+15.

## **5.2 Wiant Ditch Rehabilitation**

The recommended alternative for rehabilitation of the Wiant Ditch is Wiant Ditch Alternative D: Combination Pipeline and Open Channel. Figure 5.5 presents the plan and profile views of this conceptual design alternative. The design objective of this alternative is to relocate Wiant Ditch diversions from the existing section of canal that is highly erosive and erosionally unstable. The improvements include construction of: (a) diversion berms on the Wiant and Elk Hollow Ditches and a channel from the Wiant Ditch; (b) a pipe drop structure to the Elk Hollow Ditch; and (c) a diversion channel from the Elk Hollow Ditch to the Wiant Ditch.

### **5.2.1 Diversion Berm and Channel**

A berm constructed of compacted fill material will be constructed across the Wiant Ditch at Station 45+00. Likewise, a diversion berm will be constructed on the Elk Hollow Ditch. Typical details of the berm are presented on Figures 5.6. The purpose of the berm is two fold: (1) to raise the invert of the Wiant Ditch to promote a reduction in channel slope, thereby reducing degradation potential; and (2) provide a point of diversion for Wiant Ditch irrigation flows. A liner is placed on the upstream face of the berm to reduce the potential of failure due to seepage. The upstream and downstream faces of the berm are be 2:1 (H:V) and 3 :1 (H:V), respectively. A grade control structure will be placed in the reach between the Wiant Ditch diversion berm and Diversion Structure No. 2 to add further protect of upstream structures from potential channel incision.

From the berm on the Wiant Ditch, an earthen channel is established at a slope of approximately 0.0015 ft/ft, crossing the Elk Hollow Ditch at an earthen berm, and continuing to a pipe inlet structure. The diversion channel incorporates a trapezoidal cross section with a bottom width of 12 feet and sideslopes of 2.5:1 (H:V). Given the available information, the channel is estimated to be approximately 325 feet long. The alignment shown on Figure 5.5 is approximate;

the actual alignment should be determined after detailed topographic data are collected during final design efforts.

### **5.2.2 Pipe Drop Structure**

The proposed improvements included construction of a pipe drop structure from Station 47+35 to Station 53+35 of the new alignment. The alignment of the pipeline generally follows that of the alternative previously evaluated by the NRCS. At Station 47+35 a pipe inlet with trash rack will be built to form a transition between the open channel and the pipeline (Figure 5.7). Approximately 600 feet of 48-inch RCP is required. At Station 53+35, a pipe outlet with energy dissipation baffle will be constructed (Figure 5.8). The pipe outlet would discharge to a stable portion of the Elk Hollow Ditch.

### **5.2.3 Elk Hollow to Wiant Diversion Channel**

Approximately 450 feet of the Elk Hollow Ditch are required to convey Wiant Ditch irrigation flows. The Elk Hollow Ditch has incised in this reach but appears to have reached a stable condition. A grade control structure is incorporated to provide protection of any potential incision which may occur, thereby protecting the pipe outlet structure. Conveyance capacity is not limited in this reach.

A berm constructed of compacted fill material is required across the Elk Hollow Ditch. Typical details of the berm are presented on Figures 5.6. A liner is placed on the upstream face of the berm to reduce the potential of failure due to seepage. The upstream and downstream faces of the berm would be 2:1 (H:V) and 3:1 (H:V), respectively.

An earthen channel will be excavated from the berm to the Wiant Ditch. The channel incorporates a trapezoidal cross section with a bottom width of 12 feet and sideslopes of 2.5:1 (H:V). The alignment shown on Figure 5.5 is approximate. The final alignment will be determined during the final design process.

## **5.3 Other Rehabilitation Measures**

### **5.3.1 Macannany Washout Rehabilitation**

The recommended alternative for rehabilitation of the Highline No. 4 Ditch through the Macannany Washout consists of stabilizing the ditch as described in Section 4.4.1. Improvements

associated with this alternatives are presented on Figure 5.9. Specifically the design features described below are included in the rehabilitation of the Macannany Washout.

1. The existing washout beginning at Diversion Structure No. 3 (Station 76+00) is stabilized by building a series of pipe drop structures (as indicated in Figure 5.8) within the existing canal.
2. The downstream end of the reach is stabilized by constructing a grade control structure (see Figure 5.4) to prevent additional canal incision.
3. The upper 500 feet of the Hill No. 2 ditch will be stabilized by construction of a 12-inch PVC pipeline beginning at Diversion Structure No. 3 and extending as shown on Figure 5.9.

### **5.3.2 Ryan Foreman Washout Rehabilitation**

The recommended alternative for rehabilitation of the Ryan Foreman Ditch consists of stabilizing the ditch as described in Chapter 4.4.2. Improvements associated with this alternative are presented on Figure 5.9. Specifically, this alternative involves the bypass of the unstable portion of the Ryan Foreman Ditch with approximately 700 lineal feet of 12-inch PVC. The pipeline would begin at an earthen plug in the Ryan Foreman Ditch and would be extended along the western side of the existing washout.

### **5.3.3 Measuring Structures**

The recommendation for installation of measurement structures consists of the placement of Cipolletti weirs and Parshall flumes in the vicinity of the existing diversion structures in order to maximize the operation and management of the irrigation delivery system. Table 5.1 summarizes the recommended structures. A total of seven Cipolletti weirs ranging in size from 7 feet to 18 feet would be installed. In addition, 6 Parshall flumes would be installed (three 9-inch and three 18-inch).

The Cipolletti weirs would consist of a reinforced concrete headwall with a steel plate crest (see Figure 5.11). The Parshall flumes would be pre-fabricated, reinforced fiberglass structures set in concrete. Staff gages will be placed in the vicinity of each structure to facilitate flow measurement.



Table 5.1 Summary of Recommended Flow Measurement Structures.

Location	Design Discharge (cfs)	Structure Type	Size
Diversion Structure No. 1: Highline No. 4	226	Cipolletti Weir	L=17 ft.
Diversion Structure No. 1: Wiant Return	260	Cipolletti Weir	L=15 ft.
Diversion Structure No. 1: Buffalo Gulch	400	Cipolletti Weir	L=18 ft.
Diversion Structure No. 1A: Buffalo Gulch	300	Cipolletti Weir	L=17 ft.
Diversion Structure No. 1A: Wiant Ditch	230	Cipolletti Weir	L=13 ft.
Diversion Structure No. 2: Highline No. 4	110	Cipolletti Weir	L=8 ft.
Diversion Structure No. 3: Highline No. 4	95	Cipolletti Weir	L=7 ft.
Gross Ditch	20	Parshall Flume	Width = 18 in.
Twin Pipes Ditch	20	Parshall Flume	Width = 18 in.
Ryan Foreman Ditch	20	Parshall Flume	Width = 18 in.
Unnamed Upstream of Diversion Structure No. 3	5	Parshall Flume	Width = 9 in.
Hill No. 1	5	Parshall Flume	Width = 9 in.
Hill No. 2	5	Parshall Flume	Width = 9 in.

## VI. COST ESTIMATES

Based on the conceptual design details provided in Chapter V, detailed cost estimates for construction of the improvements to the irrigation ditch system of the Highline Watershed Improvement District were prepared. The construction cost components associated with the recommended improvements were identified and construction costs assigned to each component.

A final cost estimate and repayment plan, presented in Table 6.1, was generated for the project improvements. As indicated in Table 6.1, the final cost estimate and repayment plan includes 10% for engineering services during construction and 15% for construction contingencies. The WWDC funding for the project was assumed to be in the form of a 50% grant and 50% loan. The terms of the loan were assumed to be 6.0% for a period of 20 years.

Information related to the detailed cost estimate for the improvements to the Highline No. 4 Ditch, the Wiant Ditch, and other recommended improvements, including unit cost data, is presented in Appendix B. The cost estimates reflected in Table 6.1 are based on placement of RCP for the pipe drop structure in the Wiant Ditch improvements. It is acknowledged that alternative pipe materials (such as High Density Polyethylene) exist which may be less costly to install. The magnitude of the momentum forces in the pipeline along with the proposed life expectancy of the improvements (greater than 40 years) resulted in the selection of RCP for the pipe drop structure.

It should be noted that the final cost estimate and repayment plan assumes rehabilitation of Highline No. 4 Ditch, the Wiant Ditch, the Macannany Washout, and the Ryan Foreman Ditch. The District may choose to prioritize the implementation of these improvements based on increased assessments or ability-to-pay considerations. If this is the case, it is recommended that the Wiant Ditch improvements receive the highest priority.

Table 6.1 Final Cost Estimate and Repayment Plan.

Item Description	Highline Rehabilitation	Wiant Rehabilitation	Macannany Rehabilitation	Ryan Foreman Rehabilitation	Measurement Structures	Total
Cost of Project Components	\$65,400	\$179,365	\$174,000	\$10,500	\$84,200	\$513,465
Engineering (10%)	\$6,540	\$17,937	\$17,400	\$1,050	\$8,420	\$51,347
Subtotal	\$71,940	\$197,302	\$191,400	\$11,550	\$92,620	\$564,812
Contingency (15%)	\$10,791	\$29,595	\$28,710	\$1,733	\$13,893	\$84,722
Total Construction Cost	\$82,731	\$226,897	\$220,110	\$13,283	\$106,513	\$649,533
Final Plans / Specifications	\$8,273	\$22,690	\$22,011	\$1,328	\$10,651	\$64,953
Permitting and Mitigation	\$1,500	\$1,500	\$1,500	\$500	\$250	\$5,250
Legal Fees	\$1,000	\$1,000	\$1,000	\$500	\$250	\$3,750
Access and Rights-of-way	\$500	\$500	\$500	\$500	\$250	\$2,250
Total Project Cost	\$94,004	\$252,586	\$245,121	\$16,111	\$117,914	\$725,737
50% Loan	\$47,002	\$126,293	\$122,561	\$8,055	\$58,957	\$362,868
Repayment Factor (20 years @ 6.0%)	0.08718	0.08718	0.08718	0.08718	0.08718	0.08718
Annual Payment	\$4,098	\$11,011	\$10,685	\$702	\$5,140	\$31,637

## VII. ECONOMIC ANALYSIS

Economic factors and the ability-to-pay of the water users often become the overriding factors which determine project feasibility and implementation. Consequently, an economic analysis was completed to assess the ability of the users for the District to pay for the cost associated with the proposed improvements. This chapter presents the results of the economic analysis.

### 7.1 Impact on the Current Annual Assessment

This District is in its infancy with respect to an annual assessment levied to its water users. The need to implement this project resulted in the formation of the District; consequently, historic data related to the annual assessment is not available.

The legal entity sponsoring this project is an improvement district. It is our understanding that only those water users which benefit from the improvements will incur an increase in assessment. Consequently, a map of irrigated acreage which derive water downstream of the proposed improvements is necessary to determine the per-acre increase in assessment. Presently, neither the District or the State Engineers' Office has compiled the information necessary to accurately determine the location and number of irrigated acres which will benefit from the proposed improvements. This information must be compiled and utilized to ultimately determine the assessment. In the meantime, the analysis for this project estimated the number of irrigated acres which benefit by applying the 1 cfs/70 acres criteria to the irrigation diversions above the proposed improvements. For the Highline No. 4 Ditch, the magnitude of the irrigation diversions (single appropriation) was determined to be 65.4 cfs which resulted in a benefit to 4,578 acres. The Wiant Ditch irrigation diversions were determined to be 99.1 cfs which provided a supply to 6,937 acres. The total irrigated acreage which benefits by the proposed improvements becomes 11,515 acres. For the Macannany Washout, the magnitude of irrigation diversions was determined to be 35.4 cfs which resulted in a benefit to 2,478 acres. Similarly, a total of 700 acres were determined to benefit from the 10 cfs conveyed in the Ryan Foreman Ditch.

Table 7.1 summarizes the results of the economic analysis. As indicated in Chapter VI, the annual payment to retire the debt associated with construction of all the proposed improvements is \$31,637. This payment consists of \$4,098 for the improvements to the Highline No. 4 Ditch, \$11,011 for the improvements to the Wiant Ditch, \$10,685 for rehabilitation of the Macannany Washout, \$702 for improvements to the Ryan Foreman Ditch, and \$5,140 for installation of measurement structures. If the District decides to construct all of the proposed improvements and the costs associated with the improvements are assessed equally to all acreage, the annual assessment will need to be increased by \$2.75. Assuming the improvements are assessed based only

on the number of acres which directly benefit from a given improvement, the annual assessment varies as tabulated in Table 7.1. It should also be noted that irrigators downstream of the Macannany Washout will also benefit by the Highline No. 4 Ditch rehabilitation. Consequently, the assessment for these water users may be as high as \$5.21 per acre.

Table 7.1 Summary of Annual Assessment for Remediation Alternatives

Alternative	Annual Payment	Acres Benefitted	Annual Per Acre Assessment
Highline Rehabilitation	\$4,098	4,578	\$0.90
Wiant Rehabilitation	\$11,011	6,937	\$1.59
Macannany Rehabilitation	\$10,685	2,478	\$4.31
Ryan Foreman Rehabilitation	\$702	700	\$1.00
Measurement Structures	\$5,140	11,515	\$0.45
All Projects	\$31,637	11,515	\$2.75

## 7.2 Alternative Funding Sources

During completion of the project, discussions with the representatives of the District indicated that the ability-to-pay among the majority of the water users was limited. The limited ability-to-pay of the water users was one of the incentives for formation of the District and the pursuit of funding through the Wyoming Water Development Program. Given this consideration, alternative sources of funding become vital if the District wishes to implement all of the proposed improvements.

One potential source of funding may be the state or county highway departments. The close proximity of the roadway to the Wiant Ditch may create a hazard to vehicular traffic should the ongoing canal erosion migrate closer to the roadway. Stabilizing this erosion and canal instability provides benefit to the users of the roadway. Consequently, additional discussions with the highway departments are warranted.

An additional alternative to reduce the costs associated with construction of the proposed improvements may also exist. The WWDC could approve the utilization of the grant portion of the appropriation for the materials associated with the improvements. This funding alternative has been successfully implemented for the Horse Creek Conservation District in Hawk Springs as well as the Goshen Irrigation District in Torrington. To be approved for this funding alternative, the WWDC may require that the District demonstrates it has the capability to install the improvements. Furthermore, the District would be responsible for all engineering, legal, and permitting costs as well as the acquisition of access/right-of-way. The engineering must be performed by a professional

engineer registered in the State of Wyoming. It is recommended that the District consider this alternative to reduce the costs associated with the improvements and initiate discussions with the WWDC to determine the requirements.

## VIII. PERMITTING

For this project to proceed to construction, the District will be required to obtain certain permits, rights-of-way and easements. State and federal agencies were contacted regarding potential permitting requirements associated with construction of the project. The following information was generated during an investigation into these requirements.

### 1. U.S. Army Corps of Engineers

The Corps of Engineers (COE) should be contacted with a letter describing the project during the initial stages of the final design of the improvements. This letter will determine the Section 404 Permit requirements for the project. Based on previous conversations and experience, the COE will respond with a letter indicating the permitting requirements that are necessary prior to construction of the project. Given the scope of the improvements as presented in this report, Section 404 permitting may be required but may not involve the submittal of an individual permit.

### 2. Wyoming Game and Fish Department.

If a Section 404 permit is required, formal approval with the Wyoming Game & Fish Department (WGFD) will be necessary for this project to proceed to construction. Comments will be provided by the WGFD during the permit review process for the Section 404 permit.

### 3. Wyoming DEQ, Water Quality Division

A Section 401 authorization will likely be required if a Section 404 permit is necessary. If a Section 404 permit is not required by the COE, the State does not require Section 401 authorization.

### 4. State Historic Preservation Office

Formal approval from the State Historic Preservation Office must be obtained if the Section 404 Permit is required.

### 5. Wyoming State Engineer's Office

Plans and specifications detailing the construction of the improvements to either the diversion facilities or gaging stations will be required by the State Engineer's Office.

### 6. Land Ownership and Property Owners

Where applicable, permission should be negotiated for easement/right-of-access for all construction activities associated with the project.

## IX. CONCLUSIONS AND RECOMMENDATIONS

Based on the information presented in the previous chapters, the following conclusions and recommendations are provided.

1. The Highline Watershed Improvement District (District) is presently experiencing erosion and stability problems associated with three existing supply ditches (Wiant Ditch, Elk Hollow Ditch and Highline No. 4 Ditch). These problems threaten existing structures as well as the long-term conveyance of irrigation deliveries to the water users within the District. Previous studies completed by the NRCS have documented improvements that ultimately resulted in the formation of the District and the submittal of an application to the WWDC for funding this Level II Rehabilitation Project.
2. A detailed field investigation was conducted to identify and document the nature and magnitude of the existing stability problems. This work was followed by the development and evaluation of alternative improvements to mitigate these problems. The alternative evaluation resulted in the preparation of conceptual designs and cost estimates for the items listed below.

Highline No. 4 Ditch Improvements: Construction of a pipe outfall structure, rock riprap plunge pool and two grade control structures. The total project cost associated with the construction of these items is estimated to be \$94,004. Assuming a 50% grant and 50% loan (20 years @ 6.0%), the annual payment necessary to reduce the loan is estimated to be \$4,098.

Wiant Ditch Improvements: Construction of two diversion berms, two diversion channels and a pipe drop structure. The total project cost associated with the construction of these items is estimated to be \$252,586. Assuming a 50% grant and 50% loan (20 years @ 6.0%), the annual payment necessary to reduce the loan is estimated to be \$11,011.

Macannany Washout Rehabilitation: Construction of three pipe drop structures with rock grade control structures, and a separate grade control structure. In addition, 500 feet of the Hill No. 2 would be improved with the placement of a 12-inch PVC pipeline. The total project cost associated with the construction of these items is estimated to be \$245,121. Assuming a 50% grant and 50% loan (20 years @ 6.0%), the annual payment necessary to reduce the loan is estimated to be \$10,685.

Ryan Foreman Ditch Rehabilitation: Construction of 700 lineal feet of 12-inch PVC pipeline. The total project cost associated with the construction of this item is estimated to be \$16,111. Assuming a 50% grant and 50% loan (20 years @ 6.0%), the annual payment necessary to reduce the loan is estimated to be \$702.

Measurement Structures: Installation of 7 Cipolletti weirs and 6 Parshall flumes to facilitate accurate flow measurement at the diversion structures and optimize



operation and management of irrigation water deliveries. The total project cost associated with the construction of these items is estimated to be \$117,914. Assuming a 50% grant and 50% loan (20 years @ 6.0%), the annual payment necessary to reduce the loan is estimated to be \$5,140. Costs of this alternative is assumed to be shared by all water users in the District.

3. The improvements benefit approximately 11,515 acres within the District based on an evaluation of the water rights appropriations conveyed within each ditch and a criteria of 1 cfs/70 acres. To meet debt retirement, the District will need to assess the water users \$2.75 per acre if all improvements are constructed and the assessment is equally allocated to all water users which benefit from the improvements.

Assuming the improvements to the Highline No. 4 Ditch and Wiant Ditch are assessed on an individual basis, the annual assessment becomes \$0.90 per acre for the users associated with the Highline No. 4 Ditch and \$1.59 per acre for the users associated with the Wiant Ditch. If the Macannany Washout is included, assessment to those the Highline No. 4 Ditch water users increases by an additional \$4.31 per acre. Those irrigators benefitting from rehabilitation of the Ryan Foreman Ditch will incur an assessment of \$1.00 per acre. The assessment for installation of the measurement structures is estimated to be \$0.45 per acre.

4. Alternative funding sources may provide monies to offset the potential loan obligations associated with construction of the improvements. Given the proximity of the Wiant Ditch to the county road, an additional source of funding through the state or county highway departments should be investigated.

The WWDC could also approve the utilization of the grant portion of the appropriation for the materials associated with the improvements. The District would be responsible for the engineering and installation of the improvements. To be approved for this funding alternative, the WWDC may require that the District demonstrate that it has the capability to install the improvements. Furthermore, the District would be responsible for all engineering, legal and permitting costs as well as acquisition of access/right-of-way. It is recommended that the District investigate this alternative to reduce the costs associated with construction of the improvements.

Numerous benefits may be gained by the District and the State of Wyoming with the implementation of this project. In addition to significant improvements to the overall operation and management of the irrigation delivery system, the following factors should also be considered.

- Severe and continuing erosion of private and State lands may be significantly reduced or eliminated.
- Surface water quality downstream of the problem area may be improved by removal of sediment sources associated with existing canal erosion. Likewise, potential adverse impacts to downstream fisheries resulting from canal erosion would be minimized.

- Utilization of existing flumes, diversion structures, crossover structures and other appurtenant structures associated with the District would no longer be threatened by canal erosion and incision.
- County Road 504, which has already been relocated due to erosion of the Wiant Ditch, would no longer be threatened.
- Failure of the irrigation system would adversely impact existing agriculture and ranching activities and livelihoods within the District.

Given the information presented above, it is recommended that the District identify and prioritize the improvements that require immediate implementation. Considering the magnitude of the existing stability hazards, the improvements to the Wiant Ditch should receive the highest priority. Following this work, an application for funding of the proposed improvements should be prepared and submitted to the WWDC. Depending on the ability-to-pay of the individual water users as well as the availability of alternative funding sources/strategies, several of the project improvements, especially those on the Wiant Ditch, should be seriously considered for Level III design and construction.

***APPENDIX A***  
***SYSTEM INVENTORY***

Table A-1. Summary of Structure Inventory for the Highline Watershed Improvement District

Station	Description	Condition/Comments	Remaining Design Life
3+00	Highline No. 4 Ditch Diversion Structure #1	The overall condition of the diversion headgate is excellent. The concrete headwall and gate wheels are in good condition. Debris appears to be a problem at this structure, would recommend trash rack or collection system improvement. At this structure water may be diverted down Buffalo Gulch and/or sent down the Wiant Ditch.	Greater than 10 years
49+00	Highline No. 4 Ditch Diversion Structure #2	The overall condition of the structure is good. Some minor erosion of the downstream aprons. The gate structures appear in good condition. At this structure water is diverted to the Gross Ditch and Twin Pipes Ditch through one headgate and to the Ryan Foreman Ditch through another headgate.	Greater than 10 years
76+00	Highline No. 4 Ditch Diversion Structure #3	The overall condition of the structure is poor. Debris and sediment accumulation are problems at this structure. In addition, the Macannanney Washout has eroded the downstream apron which is temporarily being protected by loose riprap and concrete debris. The Hill #2 Ditch is actively incising and too may threaten this structure.	Less than 5 years
1+00	Wiant Ditch Flume over Highline #4	The structure is a steel flume founded on concrete mortared rocks. The steel and concrete are in good condition. Timbers above the steel bed are in poor condition. There is minor erosion around the downstream steel chute/apron. The overall condition of the structure is good.	5 - 10 years
6+50	Wiant Ditch Diversion Structure #1A	This timber diversion structure consists of two wooden slide gates on the Wiant Ditch and a pedestrian bridge over the Buffalo Gulch return channel. Immediately upstream of this structure the Wiant Return Channel from Diversion Structure #1 confluences with the Wiant Ditch. The gates are in fair condition and the pedestrian bridge is in good condition. To obtain better control over water going down the Wiant a permanent concrete structure may be constructed.	Less than 5 years
N/A	Ryan Foreman Ditch Pipe Crossing The Wiant	This 24-inch steel pipe carries Ryan Foreman Ditch water over the Wiant. The pipe and inlet headwall are in good condition. The left and right bank support of the pipe is being undermined by bank erosion from the Wiant Washout. Several car bodies are being used as bank protection.	Less than 5 years

Table A-1. Summary of Structure Inventory for the Highline Watershed Improvement District

Station	Description	Condition/Comments	Remaining Design Life
N/A	Twin Pipes Ditch Pipe Crossing The Wiant	This crossing consists of twin 24-inch steel pipes carrying Twin Pipes Ditch water over the Wiant Ditch. The pipe and inlet headwall are in good condition. The left and right bank support of the pipe is being undermined by bank erosion from the Wiant Washout.	Less than 5 years
N/A	Gross Ditch Pipe Crossing The Wiant	This 36-inch steel pipe carries Gross Ditch water over the Wiant Ditch. The pipe is in good condition.	5 - 10 years

***APPENDIX B***

***IMPROVEMENTS COST ESTIMATES***

# Highline Ditch Washout Bypass / Reconstruction

## Alternative A: Construction of new open channel

### *Alternative A1: Highline Flow Only*

Description	Unit	Quantity	Unit Cost	Cost
Excavation, unclassified	cu yd	14000	\$2.00	\$28,000.00
Pipe Outfall Structure (48 in.)	ea	1	\$39,000.00	\$39,000.00
<b>Total</b>				<b>\$67,000.00</b>

### *Alternative A2: commingled Discharges (Wiant and Highline)*

Excavation, unclassified	cu yd	19000	\$2.00	\$38,000.00
Pipe Outfall Structure (60 in.)	ea	1	\$43,500.00	\$43,500.00
Diversion Structure #2	ea	1	\$11,300.00	\$11,300.00
<b>Total</b>				<b>\$92,800.00</b>

# Highline Ditch Washout Bypass / Reconstruction

## Alternative B: Construction of Buried Pipeline

### *Alternative B1: Pipeline w/ Highline Flows Only*

Excavation, unclassified	cu yd	5041	\$2.00	\$10,082.00
Earthfill, semi-compacted	cu yd	4412	\$1.50	\$6,618.00
60" RCP	lin ft.	865	\$130.00	\$112,450.00
Manhole 12'	ea	1	\$5,000.00	\$5,000.00
Pipe Outfall Structure (48 in.)	ea	1	\$39,000.00	\$39,000.00
<b>Total</b>				<b>\$173,150.00</b>

### *Alternative B2: Pipeline w/ Commingled Flows (Wiant and Highline)*

Excavation, unclassified	cu yd	5809	\$2.00	\$11,618.00
Earthfill, semi-compacted	cu yd	4903	\$1.50	\$7,354.50
72" RCP	lin ft.	925	\$150.00	\$138,750.00
Manhole 13'	ea	1	\$4,500.00	\$4,500.00
Pipe Outfall Structure (60 in.)	ea	1	\$43,500.00	\$43,500.00
Diversion Structure #2	ea	1	\$11,300.00	\$11,300.00
<b>Total</b>				<b>\$217,022.50</b>



# Highline Ditch Washout Bypass / Reconstruction

## Alternative C: Channel Stabilization W/ Drop Structures

### *Alternative C1: Stabilize Channel to Convey Highline Flows Only*

Excavation, unclassified	cu yd	4018	\$2.00	\$8,036.00
Earthfill, compacted	cu yd	1786	\$7.00	\$12,502.00
18" Rock riprap	cu yd	620	\$60.00	\$37,200.00
Gravel Bedding	cu yd	126	\$25.00	\$3,150.00
Flexible Membrane Liner	sq ft	911	\$3.00	\$2,733.00
Geotextile filter fabric	sq yd	823	\$2.00	\$1,646.00
Pipe Outfall Structure (48 in.)	ea	1	\$39,000.00	\$39,000.00
<b>Total</b>				<b>\$104,267.00</b>

### *Alternative C2: Commingled Discharges (Wiant and Highline)*

Description	Unit	Quantity	Unit Cost	Cost
Excavation, unclassified	cu yd	4018	\$2.00	\$8,036.00
Earthfill, compacted	cu yd	1786	\$7.00	\$12,502.00
24" Rock riprap	cu yd	879	\$60.00	\$52,740.00
Gravel Bedding	cu yd	140	\$25.00	\$3,500.00
Flexible Membrane Liner	sq ft	911	\$3.00	\$2,733.00
Geotextile filter fabric	sq yd	907	\$2.00	\$1,814.00
Pipe Outfall Structure (60 in.)	ea	1	\$43,500.00	\$43,500.00
Diversion Structure #2	ea	1	\$11,300.00	\$11,300.00
<b>Total</b>				<b>\$136,125.00</b>

# Highline Ditch Washout Bypass / Reconstruction

## Alternative D: Stabilization w/ Grade Control Structures

### *Alternative D1: Highline Flow Only*

Description	Unit	Quantity	Unit Cost	Cost
24" Rock riprap	cu yd	440	\$60.00	\$26,400.00
Pipe Outfall Structure (48 in.)	ea	1	\$39,000.00	\$39,000.00
<b>Total</b>				<b>\$65,400.00</b>

### *Alternative D2: Commingled Discharges (Wiant and Highline)*

Description	Unit	Quantity	Unit Cost	Cost
24" Rock riprap	cu yd	440	\$60.00	\$26,400.00
Pipe Outfall Structure (60 in.)	ea	1	\$43,500.00	\$43,500.00
Diversion Structure #2	ea	1	\$11,300.00	\$11,300.00
<b>Total</b>				<b>\$81,200.00</b>

# Wiant Ditch Washout Bypass / Reconstruction

## Alternative A: Construction of new open channel

Description	Unit	Quantity	Unit Cost	Cost
Excavation, unclassified	cu yd	12630	\$2.00	\$25,260.00
24" Rock riprap	cu yd	5180	\$60.00	\$310,800.00
Pipe Outfall Structure (60 in.)	ea	1	\$43,500.00	\$43,500.00
Elk Hollow Crossing	ea	1	\$46,000.00	\$46,000.00
<b>Total</b>				<b>\$425,560.00</b>

## Alternative B: Construction of Buried Pipeline

Description	Unit	Quantity	Unit Cost	Cost
Excavation, unclassified	cu yd	4533	\$2.00	\$9,066.00
48" RCP	lin ft.	1100	\$110.00	\$121,000.00
Manhole 12'	ea	2	\$5,000.00	\$10,000.00
Pipe Inlet Structure / Headwall	ea	1	\$3,000.00	\$3,000.00
Pipe Outfall Structure (60 in.)	ea	1	\$43,500.00	\$43,500.00
Elk Hollow Crossing	ea	1	\$46,000.00	\$46,000.00
<b>Total</b>				<b>\$232,566.00</b>

# Wiant Ditch Washout Bypass / Reconstruction

## Alternative C: Channel Stabilization

Description	Unit	Quantity	Unit Cost	Cost
Earthfill, compacted	cu yd	15942	\$7.00	\$111,594.00
Earthfill, semi-compacted	cu yd	7638	\$1.50	\$11,457.00
24" Rock riprap	cu yd	5050	\$60.00	\$303,000.00
Flexible Membrane Liner	sq ft	3456	\$3.00	\$10,368.00
			<b>Total</b>	<b>\$436,419.00</b>

## Alternative D: Combination Pipe and Open Channel

Description	Unit	Quantity	Unit Cost	Cost
Excavation, unclassified	cu yd	2269	\$2.00	\$4,538.00
Earthfill, compacted	cu yd	2561	\$7.00	\$17,927.00
48" RCP	lin ft.	600	\$110.00	\$66,000.00
24" Rock riprap	cu yd	890	\$60.00	\$53,400.00
18" Rock riprap	cu yd	75	\$60.00	\$4,500.00
Manhole 12'	ea	1	\$5,000.00	\$5,000.00
Pipe Inlet Structure / Headwall	ea	1	\$3,000.00	\$3,000.00
Pipe Outlet Structure w/ energy dissipation	ea	1	\$25,000.00	\$25,000.00
			<b>Total</b>	<b>\$179,365.00</b>

# Wiant Return Channel

## Alternative A: Open Flow to Elk Hollow w/ Diversion to Wiant

Description	Unit	Quantity	Unit Cost	Cost
Earthfill, compacted	cu yd	3263	\$7.00	\$22,841.00
Earthfill, semi-compacted	cu yd	2445	\$1.50	\$3,667.50
24" Rock riprap	cu yd	3105	\$60.00	\$186,300.00
Cipolletti Weir (greater than 10 feet)	ea	1	\$10,000.00	\$10,000.00
Diversion Structure 2A	ea	1	\$31,500.00	\$31,500.00
			<b>Total</b>	<b>\$254,308.50</b>

## Alternative B: Pipe Flow to Elk Hollow w/ Diversion to Wiant

Description	Unit	Quantity	Unit Cost	Cost
Earthfill, compacted	cu yd	290	\$7.00	\$2,030.00
48" RCP	lin ft.	650	\$110.00	\$71,500.00
24" Rock riprap	cu yd	350	\$60.00	\$21,000.00
Pipe Outlet Structure w/ energy dissipation	ea	1	\$25,000.00	\$25,000.00
Cipolletti Weir (greater than 10 feet)	ea	1	\$10,000.00	\$10,000.00
Diversion Structure 2A	ea	1	\$31,500.00	\$31,500.00
			<b>Total</b>	<b>\$161,030.00</b>

# Wiant to Highline Diversion Channel

## Alternative A: Construction of New Open Channel

Description	Unit	Quantity	Unit Cost	Cost
Excavation, unclassified	cu yd	458	\$2.00	\$916.00
Earthfill, semi-compacted	cu yd	896	\$1.50	\$1,344.00
Diversion Structure #1B	ea	1	\$31,500.00	\$31,500.00
Cipolletti Weir (greater than 10 feet)	ea	1	\$10,000.00	\$10,000.00
Move Gage	ea	1	\$3,000.00	\$3,000.00
			<b>Total</b>	<b>\$46,760.00</b>

## Other Rehabilitation Measures

### Macananny Washout Rehabilitation

Description	Unit	Quantity	Unit Cost	Cost
30" RCP	lin ft.	1200	\$60.00	\$72,000.00
30" Pipe Outlet Structure w/ energy dissipation	ea	3	\$15,000.00	\$45,000.00
Pipe Inlet Structure / Headwall	ea	3	\$3,000.00	\$9,000.00
18" Rock riprap	cu yd	675	\$60.00	\$40,500.00
12" PVC	lin ft.	500	\$15.00	\$7,500.00
<b>Total</b>				<b>\$174,000.00</b>

### Ryan Foreman Washout

Description	Unit	Quantity	Unit Cost	Cost
30" RCP	lin ft.		\$60.00	\$0.00
30" Pipe Outlet Structure w/ energy dissipation	ea		\$15,000.00	\$0.00
Pipe Inlet Structure / Headwall	ea		\$3,000.00	\$0.00
12" PVC	lin ft.	700	\$15.00	\$10,500.00
30" RCP	lin ft.		\$60.00	\$0.00
<b>Total</b>				<b>\$10,500.00</b>

### Measurement Structures

Description	Unit	Quantity	Unit Cost	Cost
Cipolletti Weir (less than 10 feet)	ea	2	\$6,000.00	\$12,000.00
Cipolletti Weir (greater than 10 feet)	ea	5	\$10,000.00	\$50,000.00
9" Parshall flume	ea	3	\$3,000.00	\$9,000.00
18" Parshall flume	ea	3	\$4,400.00	\$13,200.00
<b>Total</b>				<b>\$84,200.00</b>

***APPENDIX C***

***GEOTECHNICAL ENGINEERING OBSERVATIONS***



OCT 11 1999

# INBERG-MILLER ENGINEERS

1120 EAST "C" STREET

CASPER, WYOMING 82601-2195

307-577-0806

October 7, 1999

8746-CX

Brad Anderson  
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Fort Collins, CO 80525

RE: GEOTECHNICAL ENGINEERING OBSERVATIONS  
HIGHLINE DITCH WATERSHED IMPROVEMENT DISTRICT PROJECT  
CARBON COUNTY, WYOMING

Dear Brad:

This letter summarizes our observations and testing for the above-referenced project. These services were performed in accordance with our proposal and services agreement dated August 16, 1999.

## PROJECT DESCRIPTION

It is our understanding that the proposed project will consist of identifying, evaluating and developing mitigation alternatives for the erosion problems in existing ditches of the above-referenced improvement district. We understand that the erosion problems include a massive headcut on the Highline Ditch, deep incisions and a headcut on the Wiant Ditch, and channel erosion on the Elk Hollow Ditch that threatens the adjacent Wiant Ditch. In addition, we understand that two smaller ditches, McKinerney and Ryan Forman, will also be evaluated. All of the problem areas of the ditches are located in Sections 1 and 2 of Township 16 North, Range 82 West, 6<sup>th</sup> Principal Meridian. Possible alternatives to mitigate the problems include the installation of pipe drops or drop structures, placement of cutoff walls and rock grade control structures, installation of large diameter pipes at washout locations, utilization of riprap to control bank erosion and possibly commingling flows in the trenches to avoid erosion problem areas.

## **SCOPE OF SERVICES**

Our scope of services includes performing a site reconnaissance at each of the identified erosion problem areas to observe the existing conditions. We propose to collect near-surface soil samples to test for appropriate index and engineering properties. Appropriate analyses will be performed to provide conclusions and recommendations regarding alternative improvements.

## **REGIONAL OBSERVATIONS**

The area of the ditches is located within the rolling foothills on the western flank of the Medicine Bow Mountains, approximately 13 miles east of Saratoga, Wyoming. The near surface geology is mapped as Upper Miocene rocks consisting of white to greenish gray, tuffaceous sandstone, siltstone and claystone of the North Park Formation.

## **SITE OBSERVATIONS**

We visited the project site on August 20, 1999 with J.C. York of PMPC. Ditches observed included the Highline, Wiant, Elk Hollow, McKinerney, and Ryan Forman Ditches. All of the problem areas appear to be the result of excessive erosion of the soil materials through which the ditches flow, however, the severity of the problem in each ditch varies. At the time of visit, water was flowing in only the Hihline and Ryan Foreman Ditches. Soil samples were collected at each location and returned to our laboratory for visual classification. Selected soil samples were tested for moisture-density, gradation, density and specific gravity. Test results are included with this letter.

### **Highline Ditch**

The Highline Ditch is experiencing a massive headcut which has apparently developed from the water flowing from a relatively stable soil to a more erodible soil. The headcut consists of an approximately 20 foot drop into an approximately 50 foot wide pool. From the appearance of stream side vegetation, it appears that the erosion at this location has occurred over a significant period of time.

The soils exposed in the erosional cut consist of approximately 7 feet of brown, silty fine sand overlying a pale brown, silty fine sandstone. The sandstone appears to be approximately 4 feet thick and is underlain by an approximately 6 inch thick layer of white, tuffaceous sandstone. Below the sandstone is similar silty sand, however, it appears to be less cemented. A sample of the underlying sandstone was tested for gradation, and resulted in a minus #200 fraction of 15 percent with most of the sample in the fine sand range. A sample of the white sandstone was allowed to soak in water in our laboratory for several days. After soaking, the sandstone was easily crushed with hand pressure.

**SITE OBSERVATIONS**, Continued

**Wiant Ditch**

The Wiant Ditch is experiencing severe downward cutting and lateral migration of the ditch. The erosion has resulted in a canyon approximately 20 feet deep, with near vertical sidewalls. We understand that past movement of the ditch resulted in the adjacent road having to be relocated. Portions of the ditch appear relatively stable, especially where the bottom of the ditch consists of sandstone. However, wherever erosion has started, a considerable amount of downward cutting has occurred. The Wiant and adjacent Elk Hollow Ditches are threatening to flow together at one location. The Wiant Ditch contains considerable debris, both man-placed such as automobile bodies, and natural, such as branches and brush.

The soils observed in the sidewalls of the ditch are similar to the Highline Ditch, consisting of layers of light brown to yellowish brown, silty fine sand to fine sandy silt. The sand appears to be highly weathered sandstone in most locations, but more competent layers of sandstone were also noted. These more competent layers appear to have resisted the water flow to some extent, resulting in a significant vertical drop. While not as pronounced as in the Highline Ditch, there appear to be at least two, approximately 3 inch thick layers of white, tuffaceous sandstone approximately 6 feet from the top of the ditch. Samples of the silty fine sand and sandy silt indicate that it exhibits minus #200 fractions ranging from approximately 36 to 82 percent. A sample was tested for moisture-density relationships and resulted in a maximum dry density of 95.0 pcf at an optimum moisture content of 20.5 percent, and a specific gravity of 2.63. The specific gravity of a sample of the white sandstone was 2.41. An undisturbed sample of the sandy silt was collected, and exhibited a dry density of 78.2 pcf at a natural moisture content of 14.8 percent. None of the samples were found to exhibit measurable plasticity.

**Elk Hollow Ditch**

The Elk Hollow Ditch is located adjacent to the Wiant Ditch, and appears similar with deep erosional cuts. The soils observed in the sidewalls of the ditch also appear to be similar, consisting primarily of silty fine sands. The sand possesses varying degrees of cementation, which likely indicates varying degrees of weathering of the parent sandstone. Because of the similarities to the Wiant Ditch, no soil samples were collected or tested for the Elk Hollow Ditch.

### *McKinerney Ditch*

The McKinerney Ditch is a smaller ditch located east of the Highline Ditch. The main erosion problems appear to be downward cutting of the ditch, resulting in relatively steep canyons. The problem appears similar to the other ditches described above. The soils exposed in the sidewalls of the ditch also appear similar. A gradation test performed on a sample of the sidewall soils indicated a minus #200 fraction of approximately 44 percent, with most of the material grading as a fine sand.

### *Ryan Foreman Ditch*

The Ryan Foreman Ditch is located west of the other ditches. The ditch appears to partially follow a previous drainage, but has resulted in significant erosion, mostly from meandering of the ditch. While the soils appear similar to the other locations, less cemented soils were observed in the sidewalls. A sample of the sidewall soil was tested for gradation, indicating a minus #200 fraction of 41 percent.

## CONCLUSIONS AND RECOMMENDATIONS

Based on our observations and the results of the tests performed on selected samples of the ditch soils, it is our opinion that the severe erosion experienced by the ditches is a result of excessive water flow over loose and highly erodible soils. Our observations indicate that much of the ditches appear stable, and are likely areas that the water velocity is lower and/or the underlying soils are more competent. The area soils can be characterized as predominantly a loosely cemented sandstone. The soundness of the sandstone varies considerably over a short distance, ranging from very poor to fairly sound. It appears that the variability in the soundness of the sandstone is a result of differences in original deposition and weathering.

Based on these conclusions, it appears that any method to stabilize the erosion should include lowering flow velocities and/or stabilizing the soils with engineered improvements. We understand that some consideration is being given to consolidating flow from the various ditches into one or two ditches, which would reduce the amount of ditch stabilization required. For the areas that will still require stabilization, we consider the following as possible alternatives.

### *Headcuts*

These are areas that have experienced significant incision into the ditch channel, resulting in a significant vertical drop. These areas include a portion of Highline Ditch and Wiant Ditch, which have experienced vertical drops on the order of 20 and 10 feet, respectively. These areas require structures that would allow the flow to drop in elevation, while dissipating the energy of the drop. Alternatives include concrete or rock drop structures.

**CONCLUSIONS AND RECOMMENDATIONS, Continued**

One alternative would include placing large riprap at the base of the drops, in order to dissipate the energy and reduce the undermining of the sandstone ledges. While it appears that the sandstone ledges that have developed at the headcuts are sound, it is possible that the sandstone does deteriorate with continued contact to water. Therefore, construction of a concrete structure at the top of the headcuts may be necessary.

Because of the loose, highly erodible nature of the area soils, we believe that a concrete structure may be difficult to construct and maintain. While the sandstone bottom of the ditches at the headcuts appear relatively sound, the soils beneath the sandstone as revealed in the cuts are very loose. Construction of structures in the ditch channel would require careful consideration of the soils beneath the sandstone. In addition, some method of energy dissipation at the bottom of the drops will still be necessary, such as large riprap or armor.

**Bank Erosion**

The areas of severe bank erosion, which is threatening to combine the Wiant and Elk Hollow Ditches, appear to be directly related to downward incision of the ditches. Therefore, we believe that significant energy dissipation techniques are required to slow the erosion. A series of rock or concrete drop structures would likely be necessary to provide lower flow velocities.

**CLOSURE**

We appreciate the opportunity to submit this proposal. If you have any questions regarding this proposal, please contact us.

Sincerely,

INBERG-MILLER ENGINEERS



Steven F. Moldt, P.E.  
Executive Vice President

SFM:gmd:prp\8746cx.rpt

Enclosures: Summary of Soil Tests  
Particle Size Analyses  
Moisture-Density Analysis

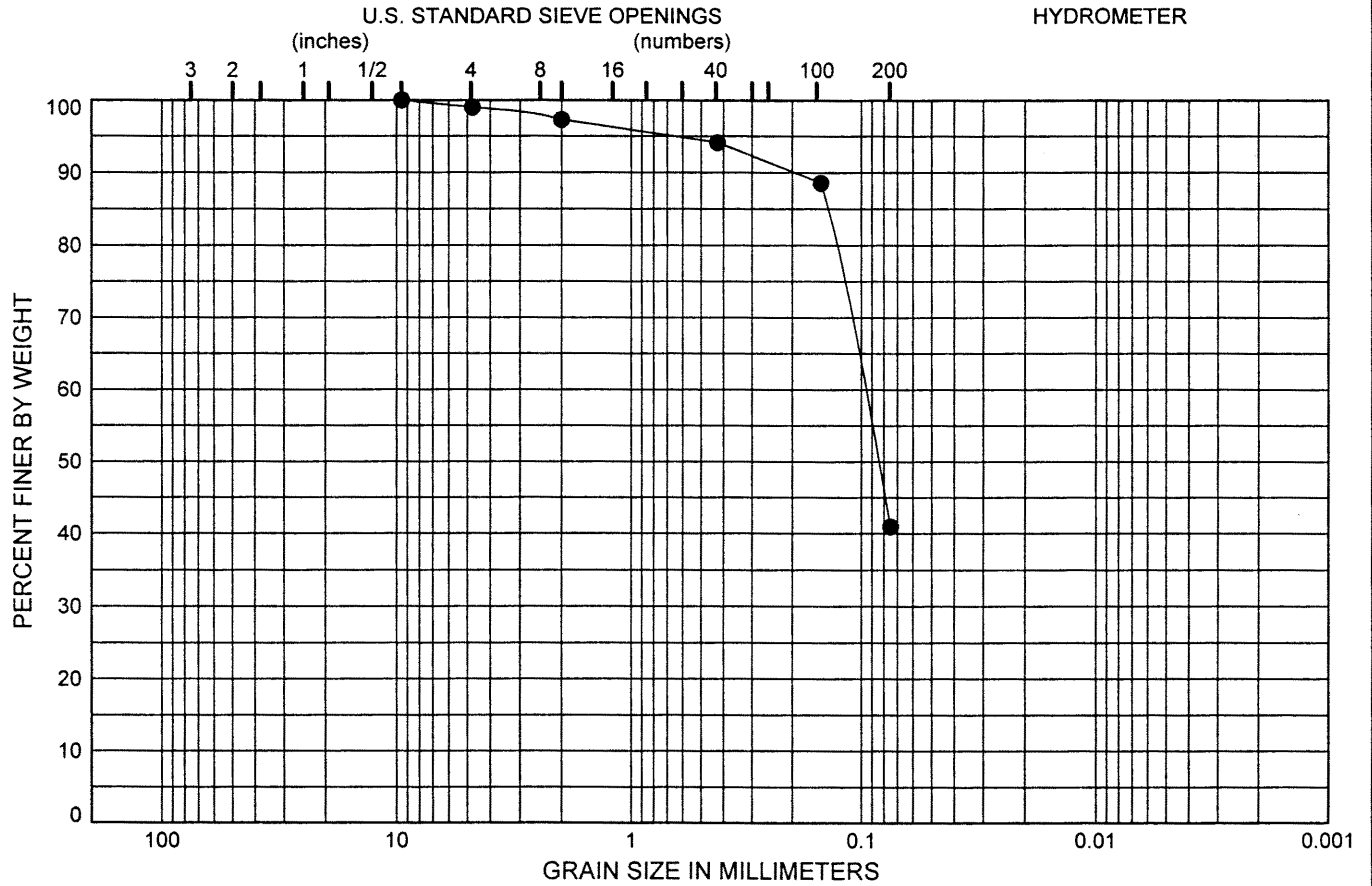
**Summary of Soil Tests**  
**Highline Ditch Watershed Irrigation Improvement District Level II Project**

8746-CX

Sample Number	Location	Soil Description	Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (%)	Specific Gravity	Other Tests Performed
S-1	Ryan Foreman	Pale Brown, Silty Fine Sand	4.5				Sieve
S-2	Wiant	White, Fine Sandy Silt (Sandstone)					
S-3	Wiant	Yellowish Brown, Silty Fine Sand	21		Non-Plastic		Sieve and Hydrometer
S-4	Wiant	White, Fine Sandy Silt (Sandstone)	4.1			2.41	Sieve and Hydrometer
S-5	Highline	Light Gray Silty Fine Sand	2.6				Sieve and Hydrometer
S-6	Highline	Pale Brown, Silty Fine Sand (Sandstone)					
S-7	McKinerney	Light Brown, Silty Fine Sand	12.9		Non-Plastic		Sieve and Hydrometer
S-8	Wiant	Light Brown, Silty Fine Sand	11.3			2.63	Sieve and Hydrometer, Moisture-Density
T-1	Wiant	Light Yellowish Brown, Fine Sandy Silt	14.8	78.22			Sieve

# PARTICLE SIZE ANALYSIS

PROJECT: Highline Ditch TEST DATE: 9/10/99  
 JOB NO.: 8746-CX TESTED BY: JMR  
 CLIENT: Anderson Consulting TEST METHOD: ASTM D422



COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	SILT	CLAY
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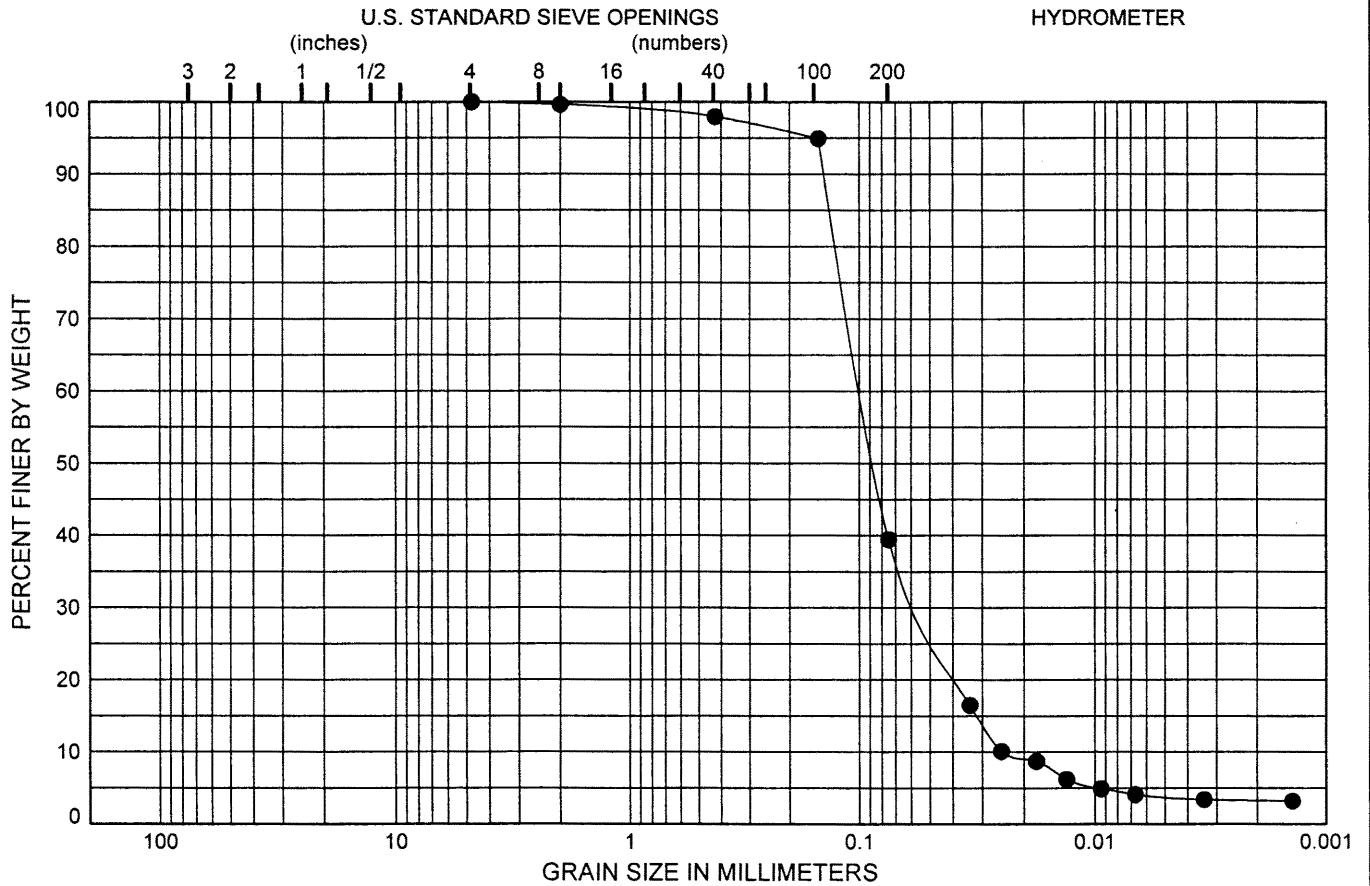
SOIL DESCRIPTION: Pale Brown, Silty Fine Sand SAMPLE NO.: S-1  
 SOURCE: Ryan Foreman Ditch DEPTH: 0  
 SAMPLED BY: SFM

LIQUID LIMIT: \_\_\_\_\_ PERCENT GRAVEL: 1.0  
 PLASTIC LIMIT: \_\_\_\_\_ PERCENT SAND: 58.0  
 PLASTICITY INDEX: \_\_\_\_\_ PERCENT SILT & CLAY: 41.0

SIZE ANALYSIS-1 8746-CX.GPJ INB\_MLLR.GDT 10/7/99

# PARTICLE SIZE ANALYSIS

PROJECT: Highline Ditch TEST DATE: 9/10/99  
 JOB NO.: 8746-CX TESTED BY: JMR  
 CLIENT: Anderson Consulting TEST METHOD: ASTM D422



COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	SILT	CLAY
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SOIL DESCRIPTION: Yellowish Brown, Silty Fine Sand SAMPLE NO.: S-3  
 SOURCE: Wiant Ditch DEPTH: 0  
 SAMPLED BY: SFM

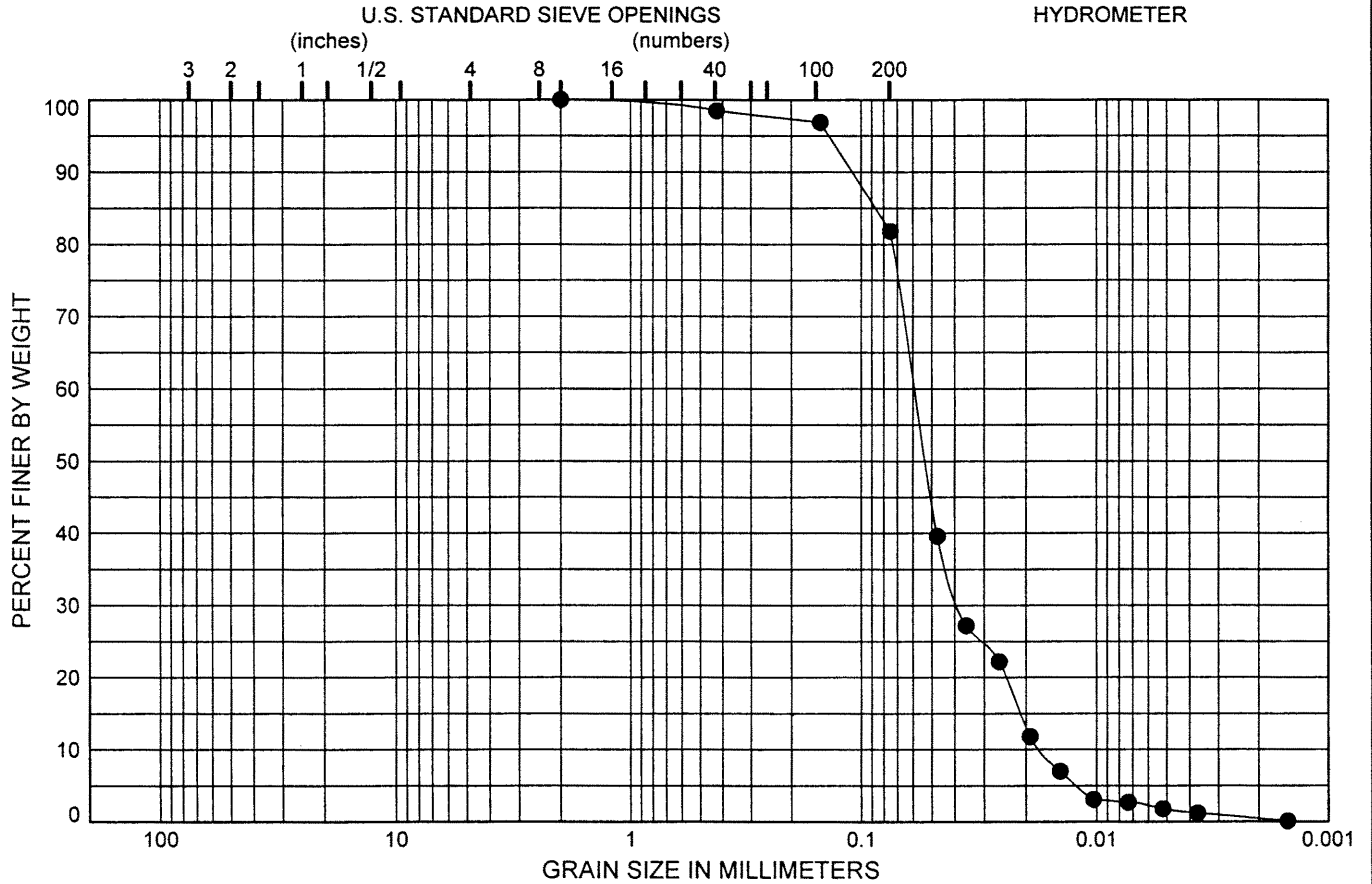
LIQUID LIMIT: \_\_\_\_\_ PERCENT GRAVEL: 0.0  
 PLASTIC LIMIT: \_\_\_\_\_ PERCENT SAND: 60.5  
 PLASTICITY INDEX: \_\_\_\_\_ PERCENT SILT & CLAY: 39.5

SIZE ANALYSIS-1 8746-CX.GPJ INB.MLLR.GDT 10/7/99



# PARTICLE SIZE ANALYSIS

PROJECT: Highline Ditch TEST DATE: 9/10/99  
 JOB NO.: 8746-CX TESTED BY: JMR  
 CLIENT: Anderson Consulting TEST METHOD: ASTM D422



COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	SILT	CLAY
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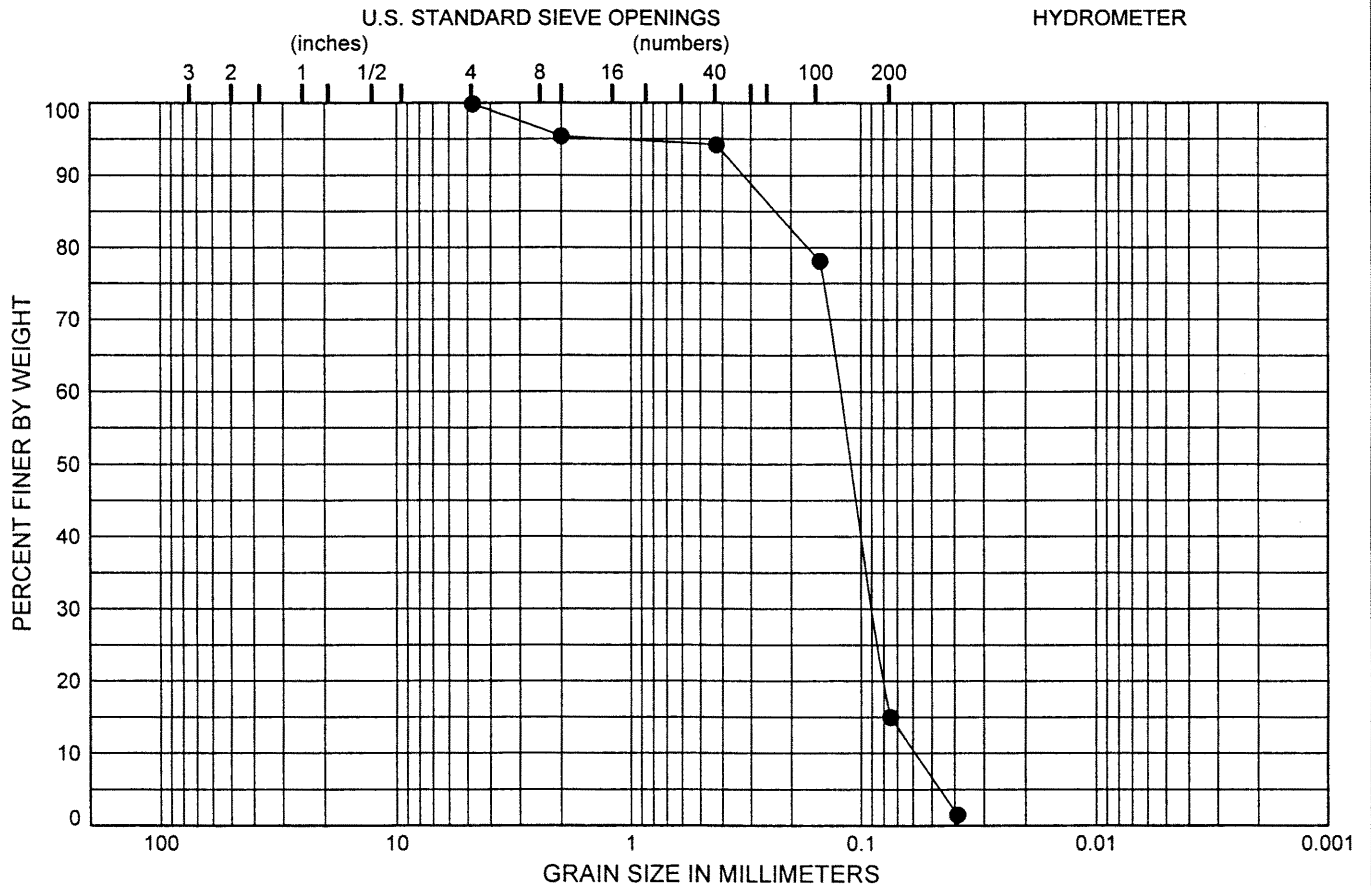
SOIL DESCRIPTION: White, Fine Sandy Silt SAMPLE NO.: S-4  
(Sandstone) SAMPLED BY: SFM  
 SOURCE: Wiant Ditch DEPTH: 0

LIQUID LIMIT: \_\_\_\_\_ PERCENT GRAVEL: 0.0  
 PLASTIC LIMIT: \_\_\_\_\_ PERCENT SAND: 18.2  
 PLASTICITY INDEX: \_\_\_\_\_ PERCENT SILT & CLAY: 81.8

SIZE ANALYSIS-1 8746-CX.GPJ INB\_MLLR.GDT 10/7/99

# PARTICLE SIZE ANALYSIS

PROJECT: Highline Ditch TEST DATE: 9/10/99  
 JOB NO.: 8746-CX TESTED BY: JMR  
 CLIENT: Anderson Consulting TEST METHOD: ASTM D422



COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	SILT	CLAY
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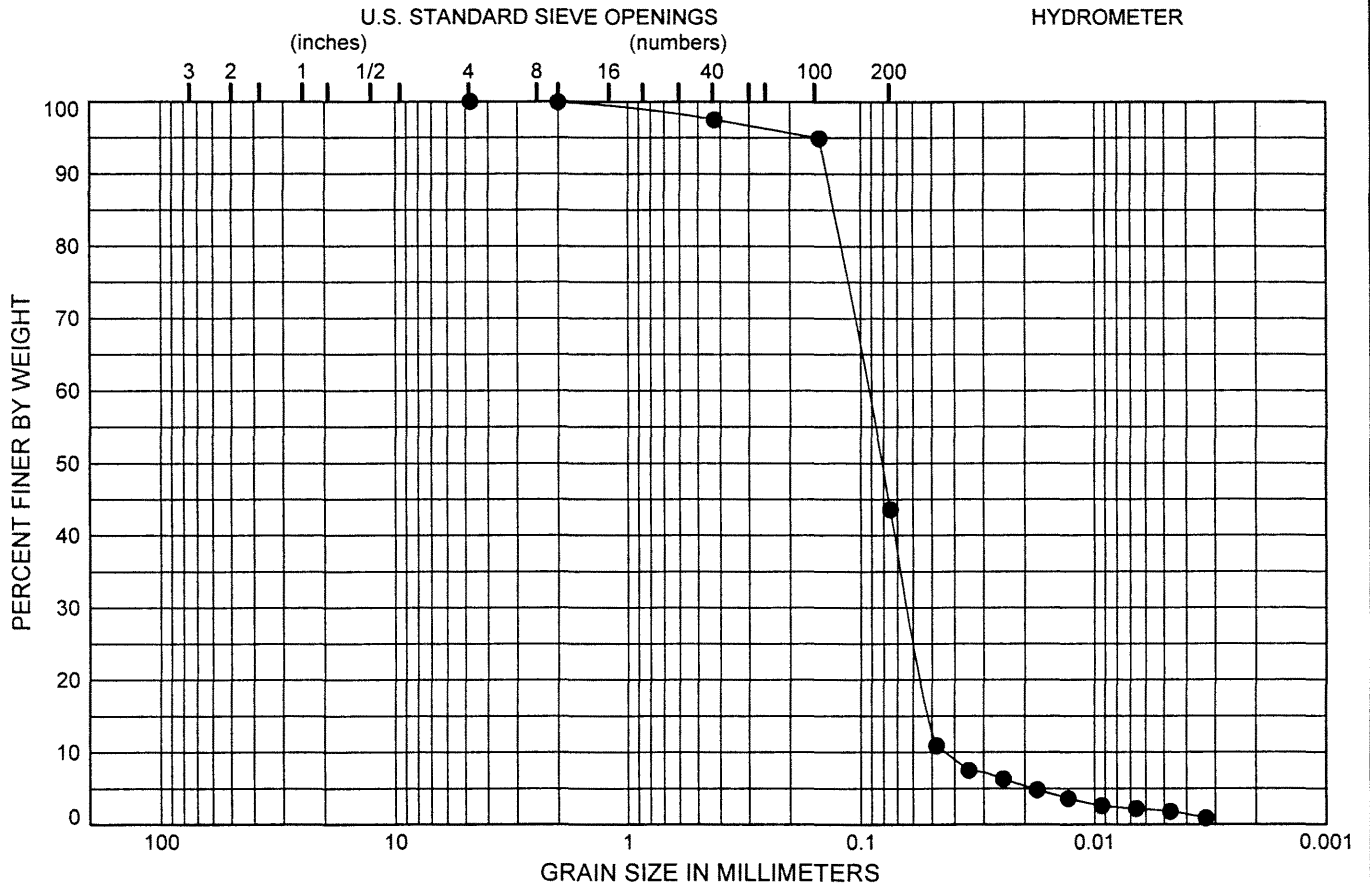
SOIL DESCRIPTION: Light Gray, Silty Fine Sand SAMPLE NO.: S-5  
 SOURCE: Highline Ditch DEPTH: 0  
 SAMPLER BY: SFM

LIQUID LIMIT: \_\_\_\_\_ PERCENT GRAVEL: 0.0  
 PLASTIC LIMIT: \_\_\_\_\_ PERCENT SAND: 84.8  
 PLASTICITY INDEX: \_\_\_\_\_ PERCENT SILT & CLAY: 15.0

SIZE ANALYSIS-1 8746-CX.GPJ INB\_MLLR.GDT 10/7/99

# PARTICLE SIZE ANALYSIS

PROJECT: Highline Ditch TEST DATE: 9/13/99  
 JOB NO.: 8746-CX TESTED BY: JMR  
 CLIENT: Anderson Consulting TEST METHOD: ASTM D422



COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	SILT	CLAY
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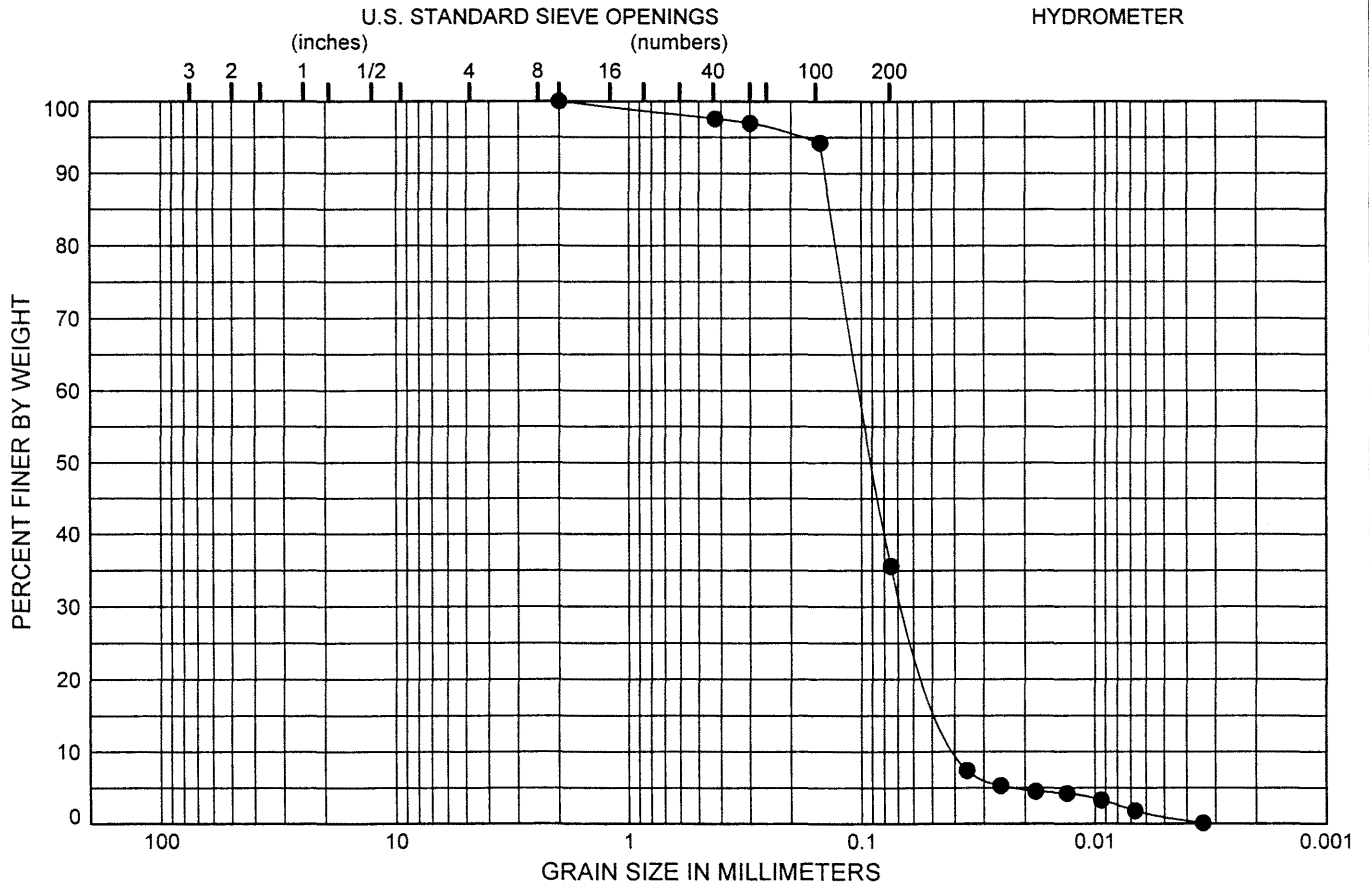
SOIL DESCRIPTION: Light Brown, Silty Fine Sand SAMPLE NO.: S-7  
 SOURCE: McKinerney Ditch DEPTH: 0  
 SAMPLER BY: SFM

LIQUID LIMIT: \_\_\_\_\_ PERCENT GRAVEL: 0.0  
 PLASTIC LIMIT: \_\_\_\_\_ PERCENT SAND: 56.4  
 PLASTICITY INDEX: \_\_\_\_\_ PERCENT SILT & CLAY: 43.6

SIZE ANALYSIS-1 8746-CX-GPJ INB MILLR GDT 10/7/99

# PARTICLE SIZE ANALYSIS

PROJECT: Highline Ditch TEST DATE: 9/8/99  
 JOB NO.: 8746-CX TESTED BY: JMR  
 CLIENT: Anderson Consulting TEST METHOD: ASTM D422



COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	SILT	CLAY
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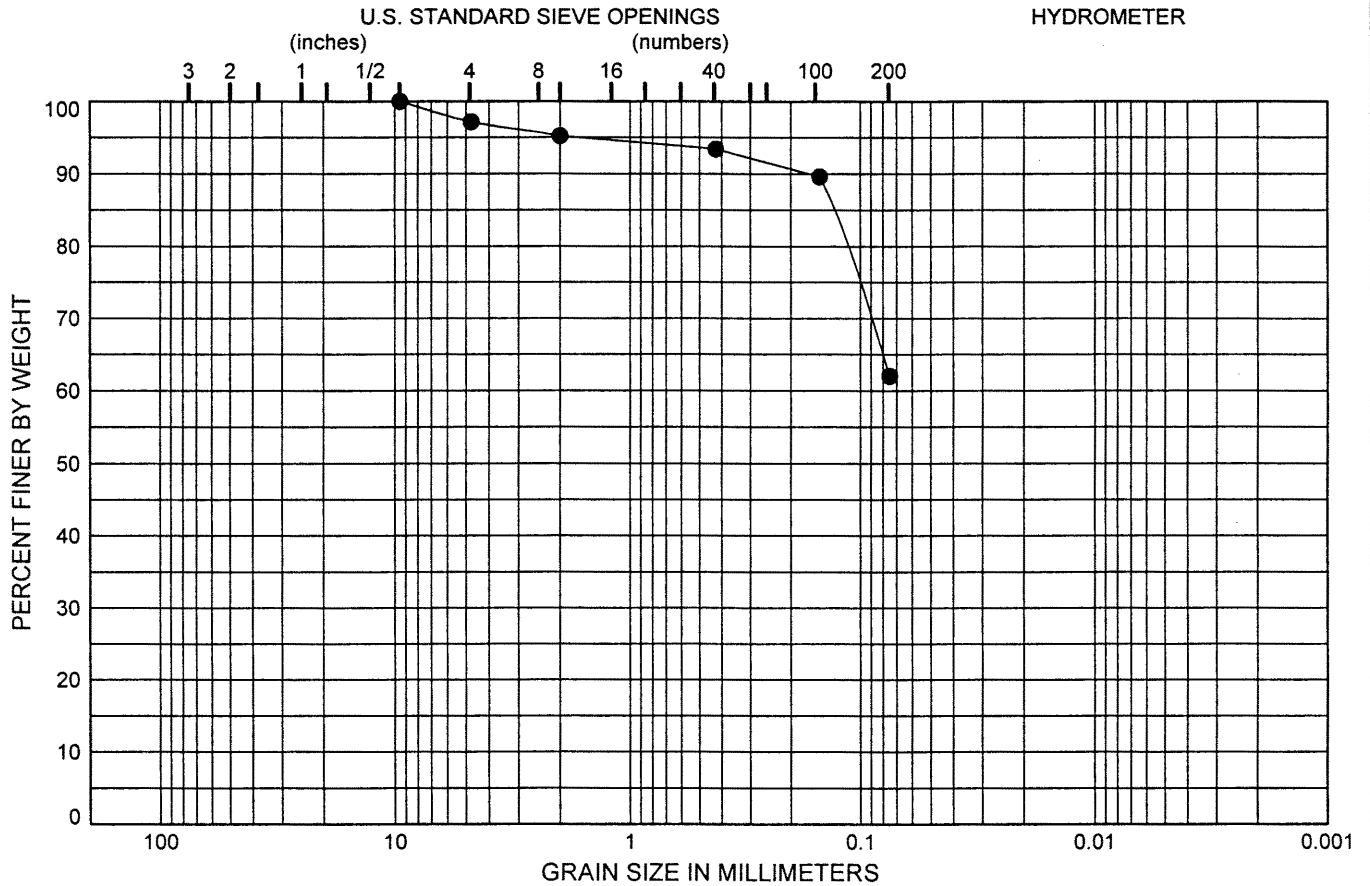
SOIL DESCRIPTION: Light Brown, Silty Fine Sand SAMPLE NO.: S-8  
 SOURCE: Wiant Ditch DEPTH: 0  
 SAMPLED BY: SFM

LIQUID LIMIT: \_\_\_\_\_ PERCENT GRAVEL: 0.0  
 PLASTIC LIMIT: \_\_\_\_\_ PERCENT SAND: 64.4  
 PLASTICITY INDEX: \_\_\_\_\_ PERCENT SILT & CLAY: 35.6

SIZE ANALYSIS-1 8746-CX.GPJ INB\_MLLR.GDT 10/7/99

# PARTICLE SIZE ANALYSIS

PROJECT: Highline Ditch TEST DATE: 9/10/99  
 JOB NO.: 8746-CX TESTED BY: JMR  
 CLIENT: Anderson Consulting TEST METHOD: ASTM D422



COBBLES	COARSE GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	SILT	CLAY
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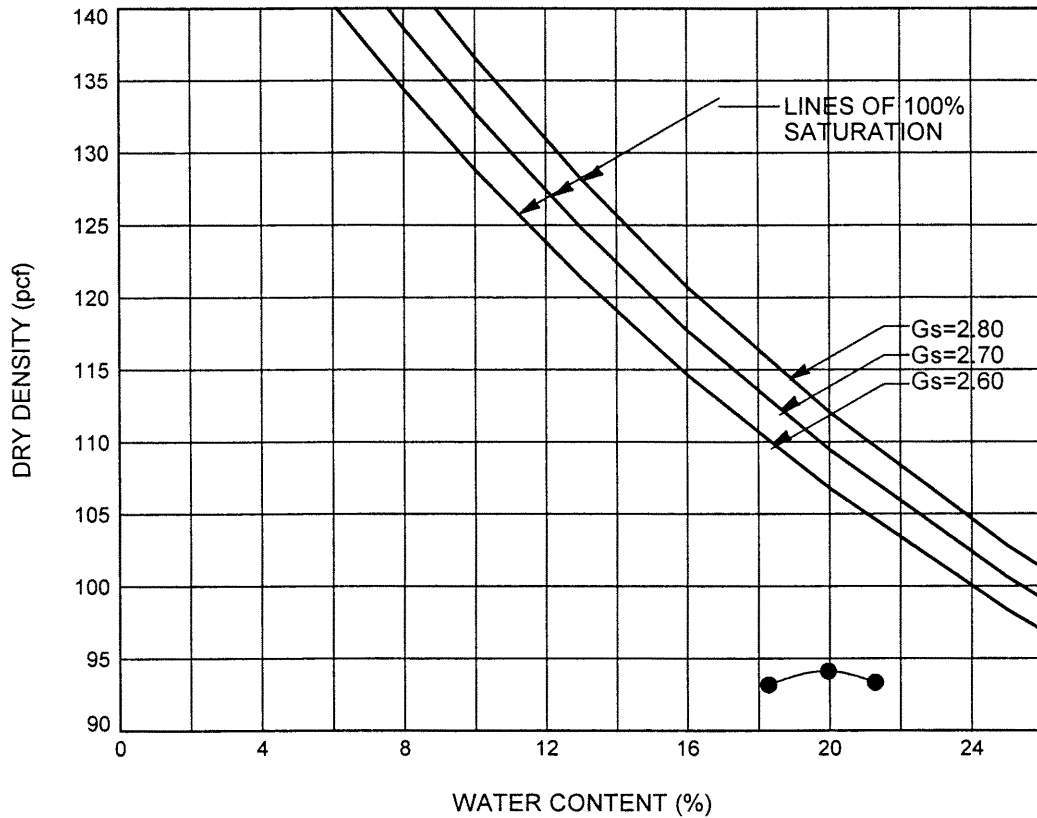
SOIL DESCRIPTION: Light Yellowish, Brown, Fine Sandy Silt SAMPLE NO.: T-1  
 SOURCE: Wiant Ditch DEPTH: 0  
 SAMPLED BY: SFM

LIQUID LIMIT: \_\_\_\_\_ PERCENT GRAVEL: 2.8  
 PLASTIC LIMIT: \_\_\_\_\_ PERCENT SAND: 35.1  
 PLASTICITY INDEX: \_\_\_\_\_ PERCENT SILT & CLAY: 62.0

SIZE ANALYSIS-1 8746-CX-GPJ INB\_MLLR.GDT 10/7/99

# MOISTURE-DENSITY ANALYSIS

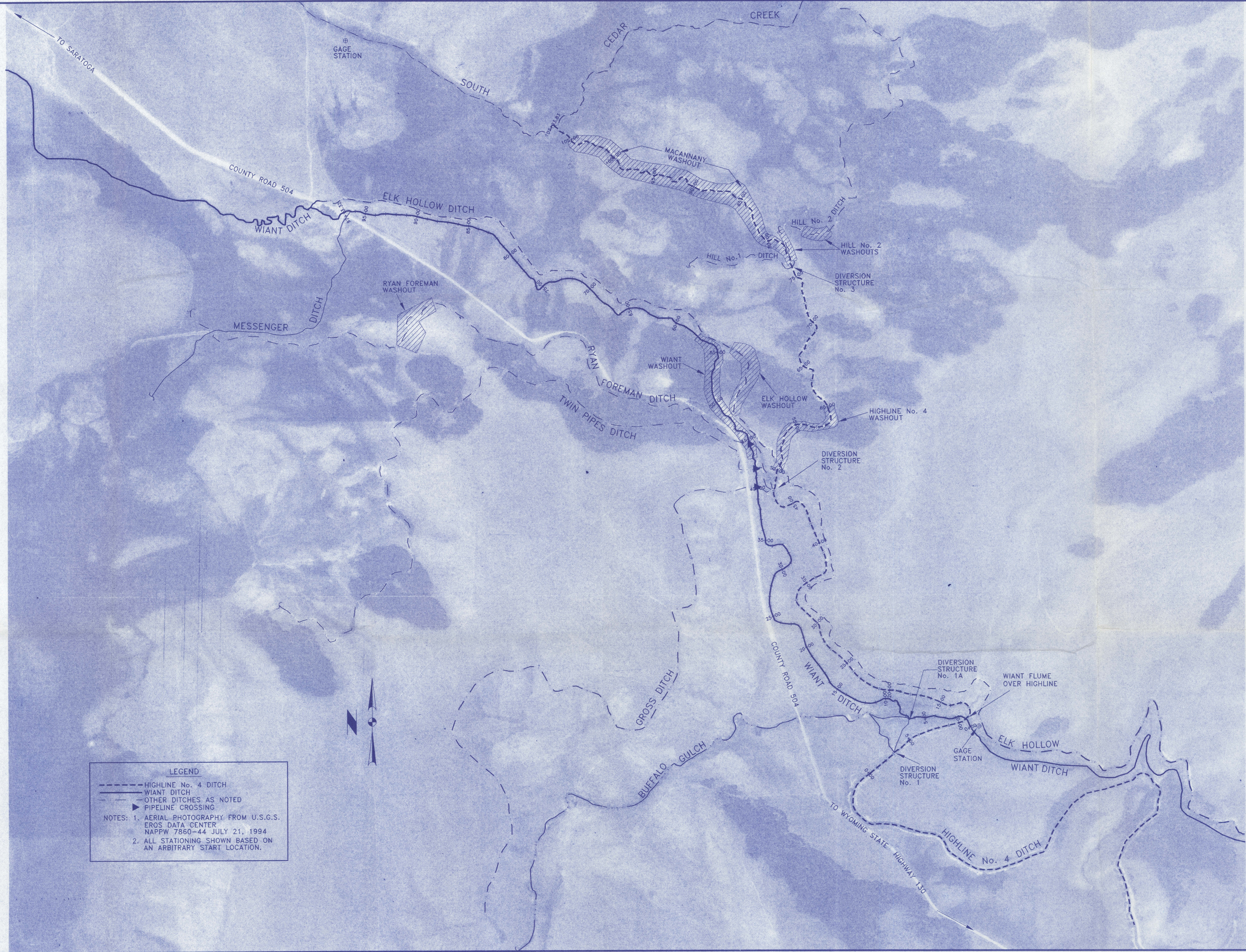
PROJECT: Highline Ditch TEST DATE: 9/3/99  
 JOB NO.: 8746-CX TESTED BY: RDB  
 CLIENT: Anderson Consulting TEST METHOD: D698A



SAMPLE NO.: S-8 SOIL DESCRIPTION: Light Brown, Silty Fine Sand  
 SAMPLED BY: SFM  
 DEPTH: 0 SOURCE: Wiant Ditch

PASSING #200 SIEVE: 35.6 %  
 LIQUID LIMIT: \_\_\_\_\_ OPTIMUM WATER CONTENT: 20.5 %  
 PLASTICITY INDEX: \_\_\_\_\_ MAXIMUM DRY DENSITY: 95.0 pcf

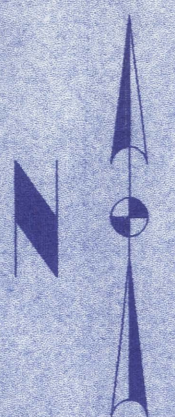
PROCTOR 8746-CX.GPJ INB\_MLLR.GDT 10/7/99



**LEGEND**

- HIGHLINE No. 4 DITCH
- WIANT DITCH
- OTHER DITCHES AS NOTED
- ▶ PIPELINE CROSSING

NOTES: 1. AERIAL PHOTOGRAPHY FROM U.S.G.S. EROS DATA CENTER NAPPW 7860-44 JULY 21, 1994  
 2. ALL STATIONING SHOWN BASED ON AN ARBITRARY START LOCATION.



PROJECT NUMBER:	WYWDC 14
ACAD FILE:	ALLPOINTS-BW
DATE:	9/29/99
DRAWN BY:	MRC
DESIGNED BY:	CJP/JDS
CHECKED BY:	

**EXISTING SYSTEM INVENTORY**

**HIGHLINE WATERSHED IMPROVEMENT DISTRICT DITCH PROJECT LEVEL II**

