Water Conservation Project Fund
Arkansas River Corridor
Feasibility Study No. 1
South Side Ditch



Prepared for

KANSAS WATER OFFICE
The State's Water Planning Agency
AD ASTRA PER ASPERA
Water - Your Resource for Life

October 9, 2007

Burns & McDonnell
SINCE 1898

9400 Ward Parkway
Kansas City, Missouri, 64114
Project: 43995

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October 9, 2007

Ms. Diane Coe
State of Kansas
Kansas Water Office
901 South Kansas Avenue
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Water Conservation Project Fund
Arkansas River Corridor
Feasibility Study No. 1: South Side Ditch
Final Report Submittal
BMcD Project 43995

Diane:

Burns & McDonnell Engineering Company is please to present the final version of Feasibility Study No. 1: South Side Ditch for the Kansas Water Office. This feasibility study sets forth our analysis and recommendations for moving forward with the proposed improvements to the South Side Ditch System. Enclosed for your use and distribution are twenty (20) copies of the final report which contains the narrative text, exhibits and data summaries.

It has been our pleasure working with you and your staff in the completion of this report, and we appreciate the opportunity to be of future service to the Kansas Water Office. If you have any questions, please feel free to contact us at (816)822-3214.

Sincerely,

Leon J. Staab, P.E.
Project Manager

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Water Conservation Project Fund
Arkansas River Corridor
Feasibility Study 1: South Side Ditch

prepared for

Kansas Water Office
Topeka, Kansas

October 2007

Project No. 43995

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

INDEX AND CERTIFICATION

Feasibility Studies on Water Conservations
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Feasibility Study Number 1: South Side Ditch

Project 43995

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Certification

I hereby certify, as a Professional Engineer in the state of Kansas, that the information in the document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the Kansas Water Office or others without specific verification or adaptation by the Engineer.

Leon J. Staab, P.E. (KS 13580)
(Reproductions are not valid unless signed, dated, and embossed with Engineer's seal)

Burns & McDonnell SINCE 1898

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Executive Summary

EXECUTIVE SUMMARY

INTRODUCTION

This feasibility study is to provide sufficient evaluation that would enable the Director, Kansas Water Office (KWO), with input from the Chief Engineer, Kansas Department of Agriculture-Division of Water Resources (DWR), the Director of the Southwest Groundwater Management District No. 3 (GMD3), and the Arkansas River Litigation Fund Committee to determine the appropriateness of moving forward with the proposed improvements to the South Side Ditch System.

This study investigates the feasibility of creating an Alternate Delivery System (ADS) designed to divert flow from the Arkansas River at the South Side Ditch headgate. The ADS will convey flows intended for the Farmer's and Garden City Ditches through the South Side Ditch. Flows will then be returned to the Arkansas River immediately upstream of the Farmer's Ditch head gate. The intent is to bypass the Arkansas River when transit losses in the river are high by conveying irrigation water through the South Side Ditch. It is believed that transit losses could be substantially reduced (when compared to the losses in the Arkansas River) and more surface water made available to the Farmer's and Garden City Ditches.

This study also investigates the feasibility of lining the South Side Ditch to reduce transit losses. The soils along the South Side Ditch are typically comprised of sand and silt. Depending upon conditions, surface water conveyed in the ditch can infiltrate into the alluvial aquifer. To reduce these losses portions of the South Side Ditch could be lined with a more impervious material.

REGIONAL MANAGEMENT OF WATER RESOURCES

The recommendations and goals of this study are as water management projects to enhance the management and efficiency of water use in an area impacted by reduced flows in the Arkansas River entering Kansas from Colorado. The word "conservation" in state programs implies that less water will be used or that the efficiency of water use will be improved. When considering the water available for irrigation, there are two sources available: surface water and groundwater. Both sources are used within the service areas of the various ditch companies. It is assumed that the aggregate water usage will remain the same, but that the recommended improvements will cause a redistribution of water supply within the system. This project focuses on efficiency of the irrigation canals and water resource management in the area.

In recent years, the Farmer's Ditch has not received any surface water due to the inability to effectively deliver surface water to their headgates. The ADS will allow the Farmer's and Garden City ditches to receive a greater share of surface water supplies than otherwise could be delivered by the Arkansas River during certain circumstances (low river flow and depleted alluvial aquifer conditions). When surface water deliveries are curtailed, then not only do the Farmer's Ditch surface water users suffer, but also the groundwater users below the South Side Ditch headgates. There is also a portion of surface water that is applied in the Farmer's Ditch service area that provides local groundwater recharge that is lost when surface water is not applied. When conditions prevent surface water deliveries to the Farmer's Ditch, surface water is redistributed upstream.

This report discusses "transit losses" for the Arkansas River and for the South Side Ditch. It is important to note that the term "transit loss" is the movement of surface water to the underlying aquifer. The term should not be construed as the loss of water for irrigation purposes. Transit losses can be reclaimed by groundwater pumping.

ALTERNATE DELIVERY SYSTEM

Transit losses in the Arkansas River can be quite high when the water table is below the stream bed alluvial aquifer. Under certain hydrologic conditions and when the aquifer is sufficiently depleted, nearly all of the base flow in the river can infiltrate into the alluvium before it reaches the headgates of the Farmer's Ditch. This study evaluates the impacts of an ADS to the Farmer's and Garden City ditches by utilizing the main channel of the South Side Ditch to bypass the river. It is proposed to use the South Side Ditch to deliver waters directly to the Farmer's and Garden City ditches when surface water flows are limited. During periods of higher flows, surface water will remain in the river channel for delivery to the Farmer's and Garden City ditches. The study includes identification of benefits of this additional management tool to the surface water users, groundwater users and the groundwater resources.

Channel Return Alternatives

A new channel will need to be constructed to return flows in the ADS to the Arkansas River. For this study, four return options were considered. All alignments are shown on **Exhibit A3**.

- Alternate 1 recommends improvement of the existing channel return. This option would involve improvements to approximately 3,860 feet of channel that currently serves as a channel return for the South Side Ditch.

- Channel Return Alternate 2 includes the construction of a 13,640-foot ditch to return flows to the river. The project will consist of approximately 7,930 feet of improvements to the existing ditch and 4,930 feet of new channel. Channel Return Alternate 2 proposes a new return along Deerfield Lane.

- Channel Return Alternate 3 involves approximately 16,250 feet of channel improvement. 7,930 feet of the total length constitutes improvements to the existing channel and 8,320 feet consists of new channel. The proposed channel begins at the existing end of the South Side Ditch and would be routed around the irrigation circle in the NW ¼ of S24 T24S R35W. The channel would then cross County Road 243 where a new bridge would be required. The alignment would then be routed along the perimeter of the irrigation circle in the SW ¼ of S13 T24 R35. The channel would then be routed north to the Arkansas River.

- Channel Return Alternate 4 is the use of the existing channel return (same alignment as Channel Return Alternate 1) without expansion or lining of the channel. The return channel would be used in its current state. The alternate is intended to be used for comparison between constructing a channel return and taking no action.

SOUTH SIDE DITCH LINING OPTIONS

This study evaluates the lining of the South Side Ditch and its effect on water quality, ditch efficiency and groundwater recharge. Lining options considered included the following:

- Concrete
- Earthen Material
- Synthetics
- Geosynthetics
- Bentonite/Soil Matrix
- Fly Ash/Soil Matrix
- Polyacrylamides

PROJECT PHASING

The ADS and associated channel lining options will encompass approximately 19 miles of channel. As a result, funding may not be readily available to construct the entire project. Project phasing recommendations have been developed to prioritize the various aspects of the project and divide the project into four (4) manageable reaches.

Reach 1

Reach 1 encompasses the selection and subsequent construction of one of the four return channel options presented. Reach 1 begins at the Arkansas River (depending on the Channel Return Alternate selected) ends at channel station 181+50 at the existing channel return for the South Side Ditch.

Reach 2

Reach 2 entails approximately 5.6 miles of channel improvements from the end of Reach 1 (Station 181+50) to where the ditch crosses County Road 25 (Station 477+11).

Reach 3

Reach 3 includes the portion of the ditch from County Road 25 (Station 477+11) to County Road 27 (Station 757+64) and includes approximately 5.3 miles of improvements.

Reach 4

Channel Reach 4 consists of approximately 5.1 miles of improvements from County Road 27 (Station 757+64) to the South Side Ditch headgate structure (Station 1024+60).

Phasing Options

Two phasing options are presented in the report (see **Exhibit A2**). Option 1 is the standard phasing which requires improvements to be made in the upstream direction: Reach 1, Reach 2, Reach 3 and Reach 4. The priorities for the Phasing Option 1 would be to first establish a new channel return close to the Farmer's head gate and then to improve system capacity in the ADS.

Phasing Option 2 proposes the construction of Reach 2 first; thereby changing the phasing priorities. Instead of first providing a channel return close to the Farmer's head gate, this option would first increase the capacity of the ADS by expanding and lining Reach 2. The existing channel return would need to be temporarily incorporated in the ADS until the completion of Reach 1. This phasing option mimics, but improves upon, the current operation of the system.

REGIONAL WATER RIGHTS

Between the South Side and Farmer's Ditch headgates there are approximately 285 water rights in the Intensive Groundwater Use Control Area (IGUCA); 100 of which are vested. The Finney County Water Users Association (FCWUA)[1] and the Garden City Ditch Company have vested water rights which allow diversion of surface water from the Arkansas River. These vested rights allow diversion whether the surface water is released from accounts in John Martin Reservoir or from other flows. During periods of low flows in the Arkansas River, the associated alluvial aquifer becomes depleted resulting in significant losses of river flow. It is under these circumstances, the Farmer's and Garden City ditches are not able to divert surface water from the Arkansas River, or are limited in the amounts that they can divert.

[1] The Finney County Water Users Association is the owner of the Farmer's Ditch.

EFFECTS ON WATER SUPPLY

It is anticipated that the net impact on groundwater when considering regional usage will be negligible. If the recommended improvements are implemented, then recharge to the alluvial aquifer may be reduced during some years and may be increased in others. Using the ADS could result in additional alluvial aquifer drawdown under some conditions in some areas. However, when river flows recover, then the alluvial aquifer will again recharge. The overall intent of the project is to increase the availability of surface water. Both the lining options and ADS projects are designed to reduce transit losses from surface water to the underlying aquifer.

EFFECTS ON WATER QUALITY

Water quality in the Arkansas River is most affected by variations in flows. If flow rates are low then total dissolved solids (TDS) concentrations are typically high while higher flow rates tend to dilute sulfate concentrations. It can be expected that sulfate concentrations would be at the highest concentrations when the ADS would be in use. In order to maximize benefits of high flow water to improve the quality of the water recharged to the river alluvium, the ADS would need to be used only during low flow periods in the Arkansas River and only when all of the flow is diverted at the Farmer's Ditch head gate for irrigation purposes. Periods of low flows will have the highest concentrations of TDS and it will be desired to divert as much water to the fields as possible. Periods of high flow have lower concentrations of TDS and these flows will be desirable for recharge purposes.

EFFECTS ON TRANSIT LOSSES

The system simulation model described in **Section 5** was executed for 12 model alternatives. Each model run generates daily estimates of flow at each river node and diversions into each ditch system for the 26-year simulation period, a total of 9,497 days. The primary goal of this study is to investigate ways to make more efficient use of available surface water supplies so a comparison of average infiltration losses is summarized in **Table ES.1**.

The analysis concludes that the ADS could actually increase net infiltration losses if the South Side Ditch is left in its current, unlined state. However, the simulation model is believed to overstate the remaining infiltration losses in the Arkansas River for all of the alternative delivery options. This occurs because the timing and rate of releases from John Martin Reservoir are not synchronized completely with the simulated ditch diversions. Historic discharges in the Arkansas River at the Kansas-Colorado state line were not adjusted for the simulation model but these discharges are highly influenced by when calls are made for reservoir releases.

Table ES.1
Summary of Simulation Modeling Results

Alternative	Lining Method	Average Annual Net Infiltration Losses (acre-feet)		
		Arkansas River [1]	South Side Ditch	Total
Base	Unlined	38,230	3,360	41,591
	Fly Ash	38,230	711	38.942
	Other[2]	38,230	0	38.230
Alternative 1	Unlined	36,102	7,423	43,525
	Fly Ash	36,128	1,598	37,725
	Other	36,104	0	36,104
Alternative 2	Unlined	35,757	7,793	43,550
	Fly Ash	36,735	1,691	37,426
	Other	35,702	0	35,702
Alternative 3	Unlined	36,805	7,505	44,310
	Fly Ash	36,933	1,574	38,508
	Other	37,027	0	37,027

1. Estimated net infiltration losses in Arkansas River between Coolidge and Garden City gages.
2. "Other" lining methods include concrete, compacted clay, bentonite, synthetic, etc. Each has a calculated infiltration rate less than 0.1 cfs and was treated as zero.

The potential benefits of lining the South Side Ditch are clearly shown in the modeling results. Modeling suggests that a fly ash would result in an approximate reduction of 80% in ditch losses and an 8% reduction in total losses. The other lining methods, including the recommended bentonite/soil matrix lining , are estimated to virtually eliminate infiltration losses, would save near 100% of ditch losses and up to 14% of total infiltration losses.

The model examined the effects of lining the entire ADS and the percentages listed above are indicative of that assumption. The study also concluded that the western portions of the ditch were more impervious than the eastern sections. It is assumed that silts are deposited in the channel to form a natural liner. Silt deposits are expected higher at the upstream end of the system and decrease in the downstream direction.

CONCLUSIONS AND RECOMMENDATIONS

Alternate Delivery System

This report recommends improvements to the South Side Ditch to allow for its use as an ADS. The analysis described herein verifies that such a system (if lined) would provide a significant reduction in transit losses to the Arkansas River and would allow the Farmer's and Garden City Ditches to more efficiently receive water for surface irrigation.

In order for the ADS to function properly, two improvements need to be made to the existing ditch. First, portions of the ditch need to be enlarged so that a sufficient flow can be conveyed through the system. Second, those sections of the ditch that are enlarged should be lined with an impervious material to reduce transit losses. Both of these improvements need to be made or the ADS will not function as desired.

The feasibility of the ADS is best proven by past operation. It has been reported by the South Side Ditch Association that the South Side Ditch has been successfully operated as an ADS at least twice in recent history. It was reported that during these times, not enough flow could be "pushed" down the river to overcome the transit losses. By using the South Side Ditch to divert flow around the river, a successful delivery was made to the Farmer's head gate.

Reaches to Construct

For this study, the ADS was divided into four (4) reaches (see **Exhibit A2**). It is the conclusion of this report that the construction of Reaches 1 and 2 are imperative to the success and operation of the ADS. Reach 2 needs to be improved to ensure adequate capacity of the system. Reach 1 is the construction of the channel return to the river.

Reaches 3 and 4 would add some benefit to the overall project, but should be considered optional work. If kept well maintained, these reaches should generally provide the desired capacity. A few localized areas may need to be addressed.

Necessity for Lining

The ADS closely parallels the Arkansas River. Both channels are cut into the same material and both are located over the alluvial aquifer. Both channels should exhibit the same potential for transit losses as the Arkansas River. However, the existing ditch has not been disturbed in many years. The fine sediments that have been deposited over years of use act as barrier to infiltration. Theoretically, the deposition of silt should be greatest at the upstream (western) end of the ditch and should decrease in the downstream direction. Any portions of the channel that are disturbed by construction will lose this natural barrier. Once the barrier is lost, the ditch could exhibit the same transit loss characteristics of the river.

Reaches 3 and 4 (upstream end of the system) currently show the greatest amount silt deposition in the channel. Left undisturbed, these reaches should demonstrate a reasonable resistance to transit losses; one of the reasons these reaches are considered to be optional.

If constructed, Reaches 1 and 2 will need to be lined. Excavation of the channel will disturb the silt lining and any resistance to transit losses would be lost. If left unlined, newly constructed sections will exhibit transit loss potentially equal to the river.

Advantages

- The ADS would allow Finney County Water User Association and Garden City Ditch Company to retrieve their allocated portion of surface water.
- The ADS will indirectly promote groundwater recharge in the Farmer's and Garden City Ditch service areas.
- The ADS would promote a greater usage of surface water irrigation in the South Side, Farmer's and Garden City Ditch services areas. This could result in improved maintenance of the system and a cost savings of groundwater pumping.
- The project fulfills a goal of the Water Conservation Project Fund by recovering a reasonable amount of base flow.

Disadvantages

- The existing ditch will need to be expanded and could cause the loss of agricultural land to adjacent property owners.
- With the intent of the project to reduce transit losses, the project would reduce aquifer recharge.
- The operation of the ADS introduces additional complexity of the regional water management policies.
- The costs associated with operation and maintenance of the ADS will be an increased burden to the South Side Ditch Association, Finney County Water Users Association, and the Garden City Ditch Company.

Channel Return Alternates

Four options were considered for the means of returning flow to the Arkansas River (see **Section 3** for more detailed discussion). Alternate 1, 2 and 3 considered capital improvements by either improving an existing ditch or by constructing a new channel return to the river. Alternate 4 examined a "no action" option for which the existing channel return would be used in its current condition. Alternate 4 was used for comparison with the other three alternates and provides justification for construction of a channel return. When comparing the "no action" option to the other three, it is apparent that the main benefit to Alternate 4 is the cost savings of taking no action. Alternate 4 would limit the flow through the ADS and the overall system would not have the desired delivery rate. In addition, Alternate 4 does not eliminate transit losses, although past use has shown a reduction in transit losses when water delivery was possible to the Farmer's headgate using the existing South Side Ditch. Finally, the owner of the property through which the existing return is routed is adverse to the project.

There are two recommendation associated with channel return options. The first is whether or not to take action and construct a channel return. It is the conclusion of this report that construction of a new channel return (Alternate 1, 2 or 3) would be of benefit to the regional water users. Of the three options that involve construction of a new channel return, Channel Return Alternate 2 is the recommended route to return flows to the Arkansas River. The advantages and disadvantages for all channel return options are presented in **Table ES.5**. Those relating to the recommended project are listed below.

Advantages

- Alternate 2 provides the minimum conveyance requires for the ADS.
- Alternate 2 is the option that best balances cost and transit losses.
- The route proposed by Alternate 2 runs along an existing roadway and does not cause partition of any fields.
- The Alternative 2 route avoids some of the safety concerns associated with Alternate 3.
- Alternate 2 provides a significant reduction in transit losses over Alternate 1 and Alternate 4.

Disadvantages

- Alternate 2 is not the least expensive option. While Alternate 1 is the least expensive, it also would have the least improvement for transit loss reduction when compared to the other alternatives.
- Alternate 2 will require the acquisition of additional right-of-way when compared to Alternate 1.

South Side Ditch Lining Option

Based on expected performance, repair measures, lifespan and durability, the recommended lining option for the ADS is a Bentonite / Soil Matrix.

Advantages

- A bentonite/soil matrix liner would be self repairing. Minor cracks in the liner would reseal once the bentonite becomes saturated.
- Repairs to the liner could be made with equipment and materials readily available to the SSDA, but a store of bentonite would need to be kept on hand.
- With the proposed 18 inch cover layer, the liner would be protected from damage and could provide a very long life span.
- The liner would require little additional maintenance for the SSDA.

Disadvantages

- There are no sources of bentonite clay near the project. The closest source of bentonite is Wyoming. The cost to purchase bentonite and transport it to the project site significantly adds to the cost of the project.

Other Lining Options

- The concrete lining option was not recommended because of the overall cost.
- An earthen liner is cost prohibitive because of the apparent lack of suitable material in the region. If a suitable borrow source could be found in Finney County, the cost associated with the earthen liner would become the preferred recommendation. The source and cost to transport suitable borrow material is a significant uncertainty that greatly impacts the cost of the project.
- A synthetic liner was not recommended because of durability. The material would be susceptible to damage by UV degradation, traffic, cattle and burning operations.
- A geosynthetic liner promises the same susceptibility to damage as a synthetic liner, but with a higher cost.

- A fly ash/soil matrix liner is an unproven technique for channel lining applications and research do date suggests problems with environmental concerns.

- The use of Polyacrylamides to reduce infiltration is untested on a project of this scale.

Project Phasing

If either Channel Return Alternate 2 or 3 is selected, then it is recommended that Phasing Option 2 be used for construction sequencing.

Though not a recommendation of the report, if Channel Return Alternate 1 is selected, then Phasing Option 1 would be preferred.

Advantages

- Construction of Reach 2 first provides an opportunity for the expedited use of the South Side Ditch as an ADS.

- This option would first increase the capacity of the ADS by expanding and lining Reach 2.

- The existing channel return would need to be temporarily incorporated in the ADS until the completion of Reach 1.

Operation of Alternate Delivery System

The models prepared for this study are not sufficiently sophisticated to make detailed recommendations for operation of the ADS. Transit losses in the Arkansas River are dependent on numerous parameters including, but not limited to: base flow, releases from John Martin Reservoir, local rainfall, evapotranspiration, operation of the surface water irrigation systems, groundwater usage and groundwater recharge.

Given the complexities and uncertainties within the system, it is recommended that the operational decisions be established from real data rather than modeling results. One option would be to install a series of monitoring wells along the river between the South Side Ditch and Farmer's Ditch headgates. The wells would be used to monitor the levels in the alluvial aquifer. Over time an accurate relationship could be developed between flow rate at the South Side Ditch head gate, aquifer level, and transit losses.

SUMMARY OF COSTS

Table ES.2 and **ES.3** summarize the incremental costs for channel improvements and liners respectively. **Table ES.2** represents the costs of constructing the ADS and **Table ES.3** provides the incremental costs for lining the ADS. **Table ES.4** provides a summary of combined costs (ADS construction plus lining) for each lining option.

Table ES.2
Opinion of Probable Costs for Channel Improvements
(thousands of dollars)

Project Component	Reach 1	Reach 2	Reach 3	Reach 4	TOTALS
CHANNEL IMPROVEMENTS					
Channel Return Alternate 1	$401	$1,259	$1,090	$407	**$3,157**
Channel Return Alternate 2	$1,024	$1,259	$1,090	$407	**$3,780**
Channel Return Alternate 3	$1,305	$1,259	$1,090	$407	**$4,061**
Channel Return Alternate 4	$0	$1,259	$1,090	$407	**$2,756**

Table ES.3
Opinion of Probable Costs for Channel Liners
(thousands of dollars)

Project Component	Reach 1	Reach 2	Reach 3	Reach 4	TOTALS
CONCRETE					
Channel Return Alternate 1	$871	$7,102	$5,315	$5,619	**$18,907**
Channel Return Alternate 2	$3,061	$7,102	$5,315	$5,619	**$21,097**
Channel Return Alternate 3	$3,670	$7,102	$5,315	$5,619	**$21,706**
Channel Return Alternate 4	$0	$7,102	$5,315	$5,619	**$18,036**
EARTHEN					
Channel Return Alternate 1	$378	$4,288	$3,964	$3,527	**$12,157**
Channel Return Alternate 2	$1,703	$4,288	$3,964	$3,527	**$13,482**
Channel Return Alternate 3	$2,070	$4,288	$3,964	$3,527	**$13,849**
Channel Return Alternate 4	$0	$4,288	$3,964	$3,527	**$11,779**
BENTONITE / SOIL MATRIX					
Channel Return Alternate 1	$148	$1,796	$1,660	$1,463	**$5,067**
Channel Return Alternate 2	$711	$1,796	$1,660	$1,463	**$5,630**
Channel Return Alternate 3	$864	$1,796	$1,660	$1,463	**$5,783**

Table ES.3
Opinion of Probable Costs for Channel Liners
(thousands of dollars)

Project Component	Reach 1	Reach 2	Reach 3	Reach 4	TOTALS
Channel Return Alternate 4	$0	$1,796	$1,660	$1,463	**$4,919**
SYNTHETIC					
Channel Return Alternate 1	$219	$1,859	$1,718	$1,537	**$5,333**
Channel Return Alternate 2	$737	$1,859	$1,718	$1,537	**$5,851**
Channel Return Alternate 3	$877	$1,859	$1,718	$1,537	**$5,991**
Channel Return Alternate 4	$0	$1,859	$1,718	$1,537	**$5,114**
GEOSYNTHETIC					
Channel Return Alternate 1	$330	$2,647	$2,447	$2,203	**$7,627**
Channel Return Alternate 2	$1,051	$2,647	$2,447	$2,203	**$8,348**
Channel Return Alternate 3	$1,248	$2,647	$2,447	$2,203	**$8,545**
Channel Return Alternate 4	$0	$2,647	$2,447	$2,203	**$7,297**
FLYASH / SOIL MATRIX					
Channel Return Alternate 1	$133	$1,631	$1,507	$1,326	**$4,597**
Channel Return Alternate 2	$646	$1,631	$1,507	$1,326	**$5,110**
Channel Return Alternate 3	$785	$1,631	$1,507	$1,326	**$5,249**
Channel Return Alternate 4	$0	$1,631	$1,507	$1,326	**$4,464**

Table ES.4
Opinion of Probable Costs
Combined Costs for Channel Improvements and Lining
(thousands of dollars)

Lining Option	Reach 1	Reach 2	Reach 3	Reach 4	TOTALS
CONCRETE					
Channel Return Alternate 1	$1,272	$8,361	$6,405	$6,026	**$22,064**
Channel Return Alternate 2	$4,085	$8,361	$6,405	$6,026	**$24,877**
Channel Return Alternate 3	$4,975	$8,361	$6,405	$6,026	**$25,767**
Channel Return Alternate 4	$0	$8,361	$6,405	$6,026	**$20,792**
EARTHEN					
Channel Return Alternate 1	$779	$5,547	$5,054	$3,934	**$15,314**
Channel Return Alternate 2	$2,727	$5,547	$5,054	$3,934	**$17,262**

Table ES.4
Opinion of Probable Costs
Combined Costs for Channel Improvements and Lining
(thousands of dollars)

Lining Option	Reach 1	Reach 2	Reach 3	Reach 4	TOTALS
Channel Return Alternate 3	$3,375	$5,547	$5,054	$3,934	**$17,910**
Channel Return Alternate 4	$0	$5,547	$5,054	$3,934	**$14,535**
BENTONITE / SOIL MATRIX					
Channel Return Alternate 1	$549	$3,055	$2,750	$1,870	**$8,224**
Channel Return Alternate 2	$1,735	$3,055	$2,750	$1,870	**$9,410**
Channel Return Alternate 3	$2,169	$3,055	$2,750	$1,870	**$9,844**
Channel Return Alternate 4	$0	$3,055	$2,750	$1,870	**$7,675**
SYNTHETIC					
Channel Return Alternate 1	$620	$3,118	$2,808	$1,944	**$8,490**
Channel Return Alternate 2	$1,761	$3,118	$2,808	$1,944	**$9,631**
Channel Return Alternate 3	$2,182	$3,118	$2,808	$1,944	**$10,052**
Channel Return Alternate 4	$0	$3,118	$2,808	$1,944	**$7,870**
GEOSYNTHETIC					
Channel Return Alternate 1	$731	$3,906	$3,537	$2,610	**$10,784**
Channel Return Alternate 2	$2,075	$3,906	$3,537	$2,610	**$12,128**
Channel Return Alternate 3	$2,553	$3,906	$3,537	$2,610	**$12,606**
Channel Return Alternate 4	$0	$3,906	$3,537	$2,610	**$10,053**
FLYASH / SOIL MATRIX					
Channel Return Alternate 1	$534	$2,890	$2,597	$1,733	**$7,754**
Channel Return Alternate 2	$1,670	$2,890	$2,597	$1,733	**$8,890**
Channel Return Alternate 3	$2,090	$2,890	$2,597	$1,733	**$9,310**
Channel Return Alternate 4	$0	$2,890	$2,597	$1,733	**$7,220**

TABLE ES.5
PROJECT MATRIX

Item	Opinion of Cost (thousands)	Cost Ranking [1]	Recommended Project	Phasing Priority	ADVANTAGES: Reduces Tranist Losses	ADVANTAGES: Water Management Benefits	ADVANTAGES: Least Expensive	ADVANTAGES: Most Reduction in Transit Losses	ADVANTAGES: Improved Operational Efficiency	ADVANTAGES: Meets Conveyance Requirments	DISADVANTAGES: Highest Cost	DISADVANTAGES: Least Reduction in Transit Losses	DISADVANTAGES: Land Owner Opposition	DISADVANTAGES: Public Safety Concerns	DISADVANTAGES: Additional ROW Required	DISADVANTAGES: Impact to Agriculture Land	DISADVANTAGES: Existing Ditch is Impervious	DISADVANTAGES: Increased Maintenance for SSDA
Alternate Delivery System			✓		✓	✓			✓						✓	✓		✓
Reach 1																		
Channel Return Alternate 1	$401	2			✓		✓		✓	✓		✓	✓					✓
Channel Return Alternate 2	$1,024	3	✓	2	✓				✓	✓				✓	✓	✓		✓
Channel Return Alternate 3	$1,305	4			✓			✓	✓	✓	✓			✓	✓	✓		✓
Channel Return Alternate 4	$0	1					✓						✓					
Reach 2	$1,259		✓	1	✓				✓	✓								✓
Reach 3	$1,090			3	✓				✓	✓							✓	✓
Reach 4	$407			4	✓				✓	✓							✓	✓

Item	Opinion of Cost (thousands) [1]	Cost Ranking [1]	Recommended Project	Transit Loss Reduction	ADVANTAGES: Near Impervious	ADVANTAGES: Most Durable	ADVANTAGES: Long Lifespan	ADVANTAGES: Easily Maintained	ADVANTAGES: Least Expensive	ADVANTAGES: Self-Repairing	DISADVANTAGES: Least Durable	DISADVANTAGES: Most Expensive	DISADVANTAGES: Environmental Impacts	DISADVANTAGES: Unproven Technology	DISADVANTAGES: High Maintenance Costs	DISADVANTAGES: Difficult to Repair	DISADVANTAGES: No Local Supply of Lining Material	DISADVANTAGES: Increased Maintenance for SSDA
Channel Lining Options			✓															✓
Concrete	$21,097	6		**14%**	✓	✓	✓	✓				✓	✓		✓	✓		✓
Earthen	$13,482	5		**14%**	✓	✓	✓	✓		✓		✓					✓	✓
Bentonite / Soil Matrix	$5,630	2	✓	**14%**	✓	✓	✓	✓		✓							✓	✓
Synthetic	$5,851	3		**14%**	✓						✓					✓	✓	✓
Geosynthetic	$8,348	4		**14%**	✓					✓	✓					✓	✓	✓
Fly Ash / Soil Matrix	$5,110	1		**8%**					✓				✓	✓		✓		✓
Polyacrylamide	--	--	--	--										✓				✓

1. Opinion of cost shown in table represent the total lining cost of the ADS using Channel Return Alternate 2
2. Cost Rankings are from least expensive to most expensive

Section 1
General Information

1.0 GENERAL INFORMATION

The following narrative originates from the Request for Proposal and is reiterated (with minor revisions) in this report for convenience.

1.1 PURPOSE

The purpose of this feasibility study is to collect and analyze data, and to further examine the costs and potential resource benefits, as well as the potential interaction and complementary effects of multiple projects. This feasibility study is to provide sufficient evaluation that would enable the Director, Kansas Water Office (KWO), with input from the Chief Engineer, Kansas Department of Agriculture-Division of Water Resources (DWR), the Director of the Southwest Groundwater Management District No. 3 (GMD3), and the Arkansas River Litigation Fund Committee to determine the appropriateness of moving forward with the proposed improvements to the South Side Ditch System.

This study has been funded from the Water Conservation Project Funds (WCPF) Reserve Account. The WCPF funds projects that contribute to water conservation efficiency in the Upper Arkansas River valley in Kansas from Garden City west to the Colorado state line. Kansas statute (K.S.A. 82a-1803) designates the KWO to administer the WCPF. The KWO is committed to administering the WCPF for the conservation and water use efficiency efforts in the area directly impacted by Colorado's Compact violations for six (6) specific items. These items include the following:

- Efficiency improvements to canals or laterals owned by a ditch company or projects to improve the operational efficiency or management of such canals or laterals;
- Water use efficiency devices, tailwater systems or irrigation system efficiency upgrades;
- Water measurement flumes, meters, gauges, data collection platforms or related monitoring equipment;
- Artificial recharge or purchase of water rights for stream recovery or aquifer restoration;
- Maintenance of the Arkansas river channel; and
- Monitoring and enforcement of Colorado's compliance with the Arkansas River Compact.

The economically impacted area was defined for parts of Hamilton, Kearny and Finney counties through the litigation process. Therefore, the WCPF may address stream and groundwater resources in the affected area.

Figure 1.1
Arkansas River at Lakin, Kansas

Implementation of innovative and effective programs to increase water use efficiencies, encourage irrigation water conservation, minimize ground water declines through education, and positive incentive-based methods in the Arkansas River Intensive Groundwater Use Control Area (IGUCA) have been a part of the *Kansas Water Plan* for many years. Recovery of a reasonable amount of base flow in selected reaches of the Arkansas River has also been a basin goal. Under the provisions of the WCPF, the director of KWO and the Chief Engineers, Kansas Department of Agriculture-Division of Water Resources (DWR), shall give priority to: (1) projects that achieve the greatest water conservation efficiency for the general good; and (2) projects that have been required by the DWR. A strategic plan for implementation of projects will be based on the outcomes of the feasibility studies.

1.2 REPORT CONTRIBUTORS

Diane Coe
Kansas Water Office

Mike Meyer
Kansas Department of Agriculture – Division of Water Resources

Randy Hayzlett
Kansas Water Office / South Side Ditch Association

George Austin
Kansas Department of Agriculture – Division of Water Resources

Kevin Salter
Kansas Department of Agriculture – Division of Water Resources

Mark Rude
Southwest Kansas Groundwater Management District No. 3

1.3 GENERAL BACKGROUND INFORMATION

The Kansas-Colorado Arkansas River Compact (Compact) was negotiated in 1948 between the States of Kansas and Colorado. Article I of the Compact provides the following:

- Settle existing disputes and remove causes of future controversy between the states of Colorado and Kansas, and between citizens of one and citizens of the other state, concerning the waters of the Arkansas River and their control, conservation and utilization for irrigation and other beneficial purposes.

- Equitably divide and apportion between the states of Colorado and Kansas the waters of the Arkansas River and their utilization as well as the benefits arising from the construction, operation and maintenance by the United States of John Martin Reservoir Project for water conservation purposes.

The Compact does not allocate specific quantities of water to each state, but rather provides for maximum release rates for each State from the conservation pool. A provision of the Compact requires releases from John Martin Reservoir (reservoir) be applied directly to beneficial use, without storage.

The reservoir is located approximately 60 miles west of the Stateline and has an available capacity for irrigation water supply of approximately 338,000 ac-ft. The reservoir has an effective priority date in Colorado of 1948, though the Compact operations are not subject of a Colorado Water Court Decree.

Additionally, the Arkansas River Compact Administration (ARCA) adopted a Resolution Concerning an Operating Plan for John Martin Reservoir (1980 Operating Plan) as amended which established separate accounts for users in Colorado and for Kansas along with related operating provisions. ARCA also adopted a Resolution Concerning an Offset Account in John Martin Reservoir for Colorado Pumping as Amended March 30, 1998 (Offset Account). The Offset Account is provided to replace stream flow depletions caused by post-compact pumping. As such, the Offset Account is not an additional water supply, but water that Kansas should have received if not for the groundwater pumping in Colorado. The 1980 Operating Plan and Offset Account resolutions are available upon request.

General WCPF project goals include the following objectives:

- Maximize general public good (public interest);
- Maximize efficiency of water diverted for ditch irrigation (e.g., reducing transit losses);
- Maximize benefits of high flow water to improve recharge and mitigate water quality problems in surface and groundwater;
- Reduce consumptive use of water to help stabilize the system, as well as improve the stability of the hydrologic system for remaining irrigators;

- Other considerations for use of the WCPF include:
  - The reduction of transit losses or reduction in consumptive use,
  - The protection of public water supply (water quality and/or ground water declines),
  - Stabilization of ground water levels,
  - The improvement of surface water availability,
  - Continued economic activity and diversity in community,
  - Compliance with the intensions of the Intensive Groundwater Use Control Area (IGUCA) and Kansas Water Plan objectives.

A Reconnaissance Study[2], completed in August 2005, was authorized by GMD3 to evaluate initial project alternatives developed by the Arkansas River Litigation Fund Committee. The study includes four elements:

- The identification of the engineering elements of project alternatives identified by the local stakeholder group;
- A preliminary assessment of these alternatives;
- Identification of other projects that should also be considered;
- A description of subsequent steps for implementation of feasible alternatives.

The Arkansas River Litigation Funds Committee recommended, and the Director, KWO, and Chief Engineers, KDA-DWR, have concurred; that priority for a feasibility study should be given to the South Side Project, including the southern alternative delivery system and lining of the South Side Ditch.

1.4 DITCH COMPANIES

1.4.1 South Side Ditch

The South Side Ditch is owned and operated by South Side Ditch Association. The Association is comprised of shareholders who own land within the service area of the ditch system. The system provides irrigation for approximately 10,000 acres of irrigated land and the total number of shares in the association is 10,000. Shares are apportioned according to acreage and not all land within the service area is eligible for irrigation.

[2] Spronk Water Engineers, Inc., (2005), *Upper Arkansas River Conservations Project Reconnaissance Study*. Denver: Author.

The South Side Ditch begins approximately 8.5 miles west of Lakin, Kansas and ends near Deerfield, Kansas. The total length of irrigation ditches within the system is about 42 miles. An overview of the South Side Ditch system can be found on **Exhibit A2**.

1.4.2 Farmer's Ditch

The Farmer's Ditch System is owned and operated by the Finney County Water Users Association and is comprised of approximately 40 miles of irrigation channels. The Finney County Water Users Association is comprised of shareholders who are apportioned shares according to the area of irrigated land.

The Farmer's Ditch head gate structure (the beginning of the system) is located just south of Deerfield, Kansas. Diverted water is conveyed east and the primary distribution system is north of Garden City, Kansas. **Exhibit A1** provides an overall view of the system.

1.4.3 Garden City Ditch

The Garden City Ditch is a system comprised of approximately 7.5 miles of irrigation ditches as shown on **Exhibit A1**. The Garden City Ditch does not have a point of diversion on the Arkansas River. Rather, flow in the river is diverted at the Farmer's Ditch head gate structure and conveyed a short distance through the Farmer's Ditch to another point of diversion. While both ditch systems share a common point of diversion, they are considered to be independent systems with independent ownership and water rights.

1.5 REGIONAL MANAGEMENT OF WATER RESOURCES

The recommendations and goals of this study are as water management projects to enhance the management and efficiency of water use in an area impacted by reduced flows in the Arkansas River entering Kansas from Colorado. The word "conservation" in state programs implies that less water will be used or that the efficiency of water use will be improved. When considering the water available for irrigation, there are two sources available: surface water and groundwater. Both sources are used within the service areas of the various ditch companies. It is assumed that the aggregate water usage will remain the same, but that the recommended improvements will cause a redistribution of water supply within the system. This project focuses on efficiency of the irrigation canals and water resource management in the area.

In recent years, the Farmer's and Garden City Ditches have not received any surface water due to the inability to effectively deliver surface water to their headgates. The Alternate Delivery System (ADS) will allow the Farmer's and Garden City ditches to receive a greater share of surface water supplies than otherwise could be delivered by the Arkansas River during certain circumstances (low river flow and depleted alluvial aquifer conditions). When surface water deliveries are curtailed, then not only do the Farmer's and Garden City Ditches surface water users suffer, but also the groundwater users below the South Side Ditch headgates. There is also a portion of surface water that is applied in the Farmer's Ditch service area that provides local groundwater recharge that is lost when surface water is not applied. When conditions prevent surface water deliveries to the Farmer's Ditch, surface water is redistributed upstream.

This report discusses "transit losses" for the Arkansas River and for the South Side Ditch. It is important to note that the term "transit loss" is the movement of surface water to the underlying aquifer. The term should not be construed as the loss of water for irrigations purposes. Transit losses can be reclaimed by groundwater pumping.

1.6 STUDY OBJECTIVES

This feasibility study evaluates the South Side Ditch projects proposed in the Reconnaissance Study against goals of the Water Conservation Project Fund (WCPF) to determine a group of implementation projects for funding. Project evaluations include cost estimates of the recommended project and alternatives. The project also identifies benefits and potential obstacles to implementation.

1.6.1 Alternate Delivery System

This study will investigate the feasibility of diverting surface water flow from the Arkansas River during low flow conditions into the South Side Ditch to convey this water to a point in the river which is close to the Farmer's and Garden City Ditch headgate. It is believed that if the South Side Ditch could be improved, transit losses could be substantially reduced (when compared to the losses in the Arkansas River) enabling the Farmer's and Garden City Ditches to utilize more surface water. Without the Alternative Delivery System, these ditches have been historically unable to receive either the water released from John Martin Reservoir or other flows in the Arkansas River. Thus, the ability to distribute the water between all irrigation ditches will be facilitated with this project.

1.6.2 Lining of South Side Ditch

The soils along the South Side Ditch are comprised of sand and silt and, depending upon conditions, surface water can infiltrate into the alluvial aquifer. This water is considered lost to the surface users that make up the various ditch companies. To reduce these losses alluvial portions of the South Side Ditch could be lined with a more impervious material. This study will consider the following lining alternatives:

- Concrete

- Earthen Liner
- Bentonite Matrix
- Fly Ash Matrix
- Synthetic Liner
- Geosynthetic Liner
- Polyacrylamide (PAM)

1.7 Information Provided by Client

In the preparation of this report, the information provided by the Client was used to make certain assumptions with respect to conditions which may exist in the future. While Burns & McDonnell believes the assumptions made are reasonable for the purposes of this report, Burns & McDonnell makes no representation that the conditions assumed will, in fact, occur. In addition, while Burns & McDonnell has no reason to believe that the information provided by the Client, and on which this report is based, is inaccurate in any material respect, Burns & McDonnell has not independently verified such information and cannot guarantee its accuracy or completeness. To the extent that actual future conditions differ from those assumed herein or from the information provided to Burns & McDonnell, the actual results will vary from those forecast.

1.8 ESTIMATES AND PROJECTIONS

The estimates prepared by Burns & McDonnell relating to construction costs, schedules, operation and maintenance costs, and modeling results are based on our experience, qualifications and judgment as a professional consultant. Because Burns & McDonnell has no control over weather; cost and availability of labor, material and equipment; labor productivity; construction contractor's procedures and methods; unavoidable delays; construction contractor's methods of determining prices; economic conditions;, government regulations and laws (including the interpretation thereof); competitive bidding or market conditions and other factors affecting such estimates or projections, Burns & McDonnell does not guarantee that actual costs, performance, schedules, etc., will not vary from the estimates and projections prepared.

1.8.1 Alternate Delivery System

For the purposes of this report, the ADS is defined as the main channel of the South Side Ditch as it currently exists. It includes the portion of the channel from the headgate structure to the system terminus near County Rd Y-22. This definition excludes the laterals that distribute flow to the service area and most existing channels that return flow to the river. One exception is the existing channel return at Station 181+00 which is the basis for Channel Return Alternate 1.

The cost opinions associated with ADS are divided into two primary areas of consideration: the cost to improve the channel so that it can convey the authorized discharge, and the additional costs that would be associated with each of the seven (7) lining options discussed herein.

1.8.2 Channel Return Options

There are three (3) options presented in this report that will allow flow in the ADS to return to the Arkansas River. The cost opinions associated with each of the three Channel Return Options are also divided into two primary areas of consideration: the cost to improve/construct the channel so that it can convey the authorized discharge, and the additional costs that would be associated with each of the seven (7) lining options discussed herein.

1.8.3 Disclaimer

Opinions of cost were developed from information available at the time of the study. No detailed topography of the area was available for which to estimate excavation and backfill quantities. Should this project proceed into the design phase, a detailed topographical survey will be required to better ascertain quantities. To account for unknown circumstances and to increase the level of conservatism in the cost opinions, a contingency factor of 30% was incorporated. When better information becomes available, the contingency can be reduced.

1.8.4 Right of Way Acquisition

Opinions of cost do not include costs associated with the acquisition of additional right of way or easements needed to construct the proposed channel improvements.

Section 2
Field Reconnaissance

2.0 FIELD RECONNAISSANCE

2.1 GENERAL

Field reconnaissance was conducted by Burns & McDonnell personnel the week of November 27, 2006. Survey grade GPS data was collected to ascertain the physical features of the South Side Ditch main channel. No data was collected on the lateral diversion ditches.

The field survey was conducted to obtain necessary channel conveyance information and the physical dimensions of the hydraulic structures. Surveying is referenced to Kansas State Plane Coordinates and the North American Datum of 1988 (NAD88).

Figure 2.1 – Field Reconnaissance

2.2 PROJECT BENCHMARK

Table 2.1
Project Benchmark Information

Name	P91
Date Established	1935
Location	Northeast Corner of Kansas Highway 25 and County Line Road, Kearny, County, Kansas
Vertical Datum	North American Datum 1988 (NAD88)
Latitude	37 44 10.51828
Longitude	101 21 49.27344
Northing	1714510.178
Easting	484355.250
Elevation	937.90
Condition	Monumented

2.3 CULVERT AND BRIDGE SURVEYS

Culvert and bridge information was collected where the main ditch crossed county roads and state highways. The field survey was conducted using GPS or conventional survey techniques. Information collected was used to define the conveyance opening of the structure, and included the following information:

- One (1) channel cross-section at the upstream face of the structure.
- Structure opening information, including location of piers, location of abutments, culvert invert, headwall types, culvert dimensions, etc.
- Low chord and top of road elevations.
- Roadway or crossing top of road centerline elevation section to define weir flow overtopping the structure.

For this study, approximately seventeen (17) bridges and culverts were surveyed.

2.4 DITCH CROSS SECTIONS

At various points along the ditch, a cross section was surveyed to provide a representative cross section for conveyance calculations.

2.5 SPRINKLER BRIDGES

In past years, some farmers have converted from flood irrigation to center pivot irrigation systems. Because the South Side Ditch meanders without respect to field boundaries, many wheel tracks cross the ditch. At these locations, small bridges have been placed to allow the center pivot to traverse the ditch. Sprinkler bridges have been installed by individual farmers and are not the responsibility of the South Side Ditch Company.

An inventory of these bridges was estimated from visible wheel tracks apparent from the aerial photography.

2.6 DITCH DIVERSIONS

Randy Hayzlett, consultant for the Kansas Water Office (KWO), provided a map showing the approximate locations of historic diversions from the main channel of the South Side Ditch (see **Exhibit A2**).

2.7 SOUTH SIDE DITCH COMPANY SERVICE AREA

Randy Hayzlett, consultant for the KWO, provided a map showing the approximate service area of the South Side Ditch Company. The service area boundaries were determined from Mr. Hayzlett's experience and by interviewing several farmers within the service area (see **Exhibit A2**).

Section 3
Alternate Delivery System

3.0 ALTERNATE DELIVERY SYSTEM

3.1 INTRODUCTION

During periods of prolonged low flows, transit losses in the Arkansas River can be quite high due to depletion of the alluvial aquifer and other factors. When the alluvial aquifer is sufficiently depleted, nearly all of the base flow in the river can infiltrate into the alluvium before it reaches the headgates of the Farmer's Ditch. This study evaluates the impacts of an Alternate Delivery System (ADS or ditch) to the Farmer's and Garden City ditches by utilizing the main channel of the South Side Ditch to bypass the river. This study also investigates the conditions under which the ADS should be operated. It is proposed to use the South Side Ditch to deliver waters directly to the Farmer's and Garden City ditches during low flows of the Arkansas River and allow higher flows to remain in the river channel. Specific areas addressed by this study include:

- An analysis of operational needs, capacities, and engineering costs for conveyance facilities needed to deliver waters directly to the Farmer's and Garden City ditches
- Quantification of the benefits of water savings, benefits to the water supply and potential impact to water rights;
- Identification of the project's effects on ground water quality;
- Determination of design flow; verification of existing capacities on a structure-by-structure and reach-by-reach basis; and include recommendations to change these where necessary.
- Recommendations for the construction of ditch "connectors" and channel return;
- Design flow variations that include the artificial recharge. (Evaluation of the net effect of the proposed Southern ADS on current ground water recharge and ground water rights.)
- Consideration of impacts of lining of the South Side Ditch with this project.
- Evaluation of water right implications and other regulatory requirements;
- Identification of cooperative parties needed, such as the State Highway Department, County road departments, railroads, oil and gas companies, other subsurface utility owners; identification of additional costs of modifications necessary to increase

conveyance capacity, such as new bridges, culverts, modified grade control structures, property owner cooperation, utilities, jurisdictional wetlands, unsuitable soils; and

- Evaluation of groundwater and surface water quality effects of the ADS versus the status quo. The study should include recommendations for the operation of the ADS related to water quality impacts.

3.2 HYDRAULIC ANALYSIS

The hydraulic analysis of the South Side Ditch was performed using the U.S. Army Corps of Engineer's HEC-RAS (Version 4.0) computer model. HEC-RAS is a widely accepted computer program used to calculate water surface profiles for steady, gradually varied flow in natural and improved open channels. The model is also used to evaluate the effects of various obstructions such as bridges, culverts, weirs, and structures within the ditch.

3.3 AUTHORIZED CAPACITIES

The ditches are regulated by the Kansas Department of Agriculture, Division of Water Resources under the KWAA. Additionally, the Associated Ditches have adopted *Rules and Regulations Governing the Rotation, Diversion and Use of Water for Irrigation Purposes from the Arkansas River by Irrigation Companies in Kearny and Finney Counties, Kansas*, herein referred to as the *Rules and Regulations*, the rotation schedule and agreed upon water usage are as summarized in **Table 3.1**.

Table 3.1
Summary of Water Usage

Order of Rotation	Name of Ditch Company	Decreed Rotation Rights (acre-ft)	Maximum Annual Volume (acre-ft)	Max. Authorized Diversion Rate (cfs)
1	Amazon Ditch (KE-79)	3000	31,000	200
2	South Side Ditch (KE-78)	3000	20,000	200
3	Great Eastern Ditch (KE-77)	5312.5	60,000	300
4	Farmer's Ditch (KE-76)	3937.5	20,000	250
5	Garden City Ditch (FI-217)	500	4,000	80

The Farmer's Ditch diverts water for the Garden City Ditch at the Farmer's headgates and delivers that water to a drop just ahead of the Farmer's Ditch flow measuring station. Therefore, the potential maximum conveyance thru the Alternative Delivery System would as follows:

- 330 cfs, if considering maximum authorized water right
- Approximately 275 cfs, if considering existing capacities of the Garden City and Farmer's Ditches.

It would be beneficial to the Farmer's and Garden City Ditches if the Chief Engineer would allow a diversion of more than 200 cfs in the South Side Ditch when it is used as an ADS. The South Side Ditch's capacity is limited to 200 cfs by an agreement or adjudication of the rights of the Associated Ditches. However, under the KWAA the Farmer's and Garden City Ditches may be able to add to their points of diversion to the South Side Ditch and all three water rights could be carried within an expanded ditch. This option may be subject to some limitations as adjudicated between the ditches in their original court decree and so may require further legal consultation. In the event that greater capacities are authorized, the SSDA's headgate structure is adequate. However the Parshall flume used to measure the flow rates through the headgate structure only has capacity for the 200 cfs maximum diversion.

For these reasons, this report assumes that the maximum authorized capacity of the ADS will be 200 cfs.

The issue of flow rates may not be such a detriment to the project. After all, it is the volume of water that can be used for irrigation that is the true measure of the system's performance. The capacity of the ditch system only defines the amount of time needed to route the authorized volume through the system. For example, if the Farmer's Ditch is allotted 20,000 acre-feet of water, then under its authorized capacity of 263 cfs, it would take 920 hours (38 days, 8 hours) to deliver the full allocation.

$$3937.5 \text{ acre-ft} \times \frac{43560 \text{ ft}^2}{\text{acre}} \times \frac{\text{second}}{263 \text{ ft}^3} \times \frac{\text{minute}}{60 \text{ seconds}} \times \frac{\text{hour}}{60 \text{ minutes}} = 181 \text{ hours}$$

If the delivery rate is limited to 200 cfs by the capacity of the South Side Ditch, then it would take approximately 1210 hours (50 days, 10 hours) to deliver the full allocation. One rotation would take approximately 9.91 days.

$$3937.5 \text{ acre-ft} \times \frac{43560 \text{ ft}^2}{\text{acre}} \times \frac{\text{second}}{200 \text{ ft}^3} \times \frac{\text{minute}}{60 \text{ seconds}} \times \frac{\text{hour}}{60 \text{ minutes}} = 238 \text{ hours}$$

3.4 DITCH CAPACITY CONSIDERATIONS

The SSDA holds Vested Water Right, KE-078, that provides a maximum diversion rate of 200 cfs (for the South Side Ditch). Under the KWAA, the Farmer's and Garden City Ditches may be able to add to their points of diversion and all three water rights could be carried within an expanded ditch. This option may be subject to some limitations as adjudicated between the ditches in their original court decree and so may require further legal consultation. For the purposes of this report, it was assumed that the maximum diversion rate of the South Side Ditch would remain at 200 cfs.

There are many factors that contribute to the capacity of a channel (i.e., channel shape, channel slope, depth of flow, and channel roughness) and certain assumptions must be made when estimating capacity. The following paragraphs discuss the parameters and assumptions associated with the design of a channel.

The simplest way to estimate channel capacity is by using Manning's Equation:

$$Q = \frac{1.486}{n} \cdot A \cdot R^{2/3} \cdot S^{1/2}$$

Where

Q = flow rate in cfs

A = area of flow in ft^2

R = hydraulic radius in ft

S = channel slope in ft/ft

n = Manning's roughness coefficient

Of the four parameters, the area of flow and the hydraulic radius are a function of the depth of flow and shape of the channel. Manning's roughness coefficient is determined by the conditions within the channel and for this study, the slope of the channel is fixed.

3.4.1 Channel Shape

Channels come in a variety of shapes. Channel cross sections can be trapezoidal, "V-shaped," square, curved, elliptical, irregular or natural. For the purposes of this study, a trapezoidal-shaped channel was the only shape considered for channel improvements.

From a capacity standpoint, the shape of channel determines the wetted perimeter. The wetted perimeter is amount of ground surface in contact with the flowing water. With greater wetted perimeter comes a greater amount of friction, slower flow velocities, and greater depths of flow. When designing channels, it is desired to minimize the wetted perimeter by striking a balance between depth of flow and width of channel. A trapezoidal shape fits these conditions.

A trapezoidal channel has a flat bottom of a given width and has uniform side slopes. Slopes are measured as a ratio of horizontal offset to vertical offset. For example a 3:1 side slope means that for every 3 feet of horizontal distance, the side slope of the ditch will rise 1 foot.

3.4.2 Channel Slope

Of all the parameters that affect capacity, channel slope is the most understandable. The steeper the channel the more flow it can carry. As the slope of a channel increases, the depth of flow decreases and flow velocity increases.

For the South Side Ditch, the slope of the channel varies, but the average slope is approximately 0.0013 feet/foot or 7 feet/mile. This is generally considered to a very flat or mild sloping channel. Flow velocities will typically be low, and the average flow velocity for the authorized flow rate is about 3 feet/second. A flow rate of 3 feet/second is generally considered non-erosive and the channel should be able to remain stable without significant vegetative cover.

3.4.3 Channel Roughness

Channel roughness is a parameter used to measure friction losses in a channel. Manning's n value is the empirical number used to estimate channel roughness. Channel roughness is an estimated value based on published information and engineering judgment. Table 3.2 provides a summary of channel roughness coefficients considered for this study. As indicated by the table, the South Side Ditch falls into a number of channel descriptions. The table indicates a fairly wide range of values that could be applied when assessing the capacity of the ditch. If the ditch were in pristine condition (mowed short, no weeds) then the Manning's n value could be as low as 0.025. Under the worst conditions (assuming the ditch is filled with tumble weeds) a value of 0.140 might be justified.

Table 3.2
Channel Roughness Coefficients

Description of Channel	Minimum	Normal	Maximum
Natural streams, clean, straight, full, no rifts or deep pools.	0.025	0.030	0.033

Table 3.2
Channel Roughness Coefficients

Description of Channel	Minimum	Normal	Maximum
Lined or built up channels, vegetal lining	0.030	0.040	0.050
Excavated or dredged channel, earth, straight and uniform, with short grass, few weeds	0.022	0.027	0.033
Channels not maintained, weeds & brush, clean bottom, brush on sides	0.040	0.050	0.080
Channels not maintained, weeds & brush, dense brush, high stage.	0.080	0.100	0.140

For the purposes of this study, a Manning's n value of 0.040 was assumed to determine the capacity of the existing channel and proposed improvements. Given the level of maintenance that occurs on the ditch, it is reasonable to assume that the bottom would remain fairly clean and that the side of the channel will have some brush and weeds. Figure 3-1 illustrates the general condition of the ditch as it existed at the time of the study. It is understood that the ditch is burned prior to use.

Figure 3.1
South Side Ditch Vegetative Cover
November 2006

3.4.4 Depth of Flow

When the original ditch was constructed, excess material excavated from the ditch was wasted along the sides of the channel forming low embankments or artificial levees. These embankments allow the water in the ditch to be higher than the level of the adjacent fields. While this is a necessity when the system is used for irrigation, it would be undesirable during a diversion event.

These embankments are comprised of sand, silt and loam; materials not suitable to act as a levee. An extended inundation with a sustained head of water could weaken the embankments and cause a failure. Therefore, the capacity of the channel is defined by this report to a depth of flow where the water in the channel is at or below the natural ground level. Only that water which can be conveyed below the natural ground surface is considered to contribute to the channel capacity.

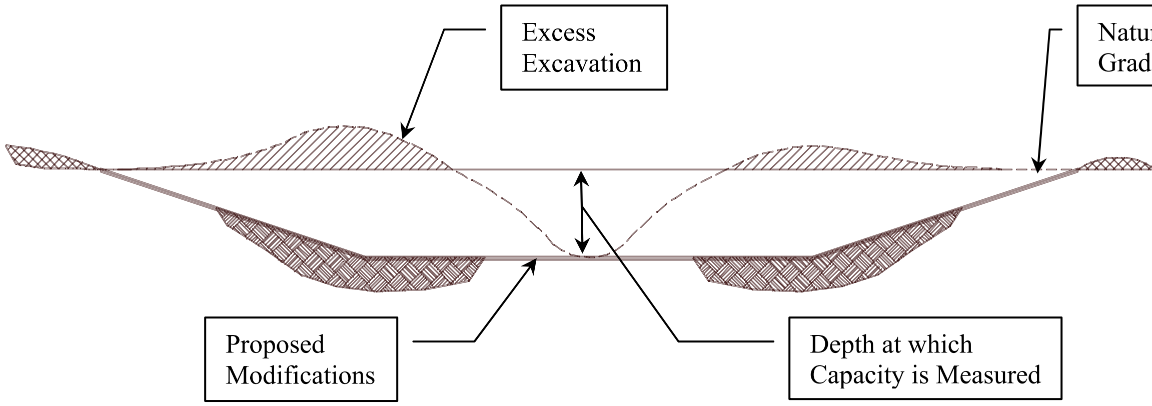


Figure 3.2 - Typical Channel Cross Section

3.5 EXISTING DITCH CAPACITY

As discussed above, the capacity of the existing South Side Ditch is somewhat interpretive. Assumptions regarding allowable depth of flow and channel conditions play a large role in estimating the actual capacity. From conversations with representatives of the South Side Ditch Company, it is understood that the condition of the ditch varies greatly from season to season and from year to year. Clearing of vegetation and debris is the responsibility of the SSDA.

Rather than providing a definitive capacity, this report provides a range of capacities for various conditions in the ditch. **Table 3.3** presents the estimated capacity of the ditch at numerous points along its alignment. Shaded values indicate those portions of the ditch which have the capacity to carry the authorized flow.

Table 3.3
South Side Ditch Capacity

River Station	Channel Capacity				
	n=0.025	n=0.030	n=0.035	n=0.040	n=0.10
▼ PHASE 4 ▼					
102597	0	10	10	10	0
102312	200	180	160	140	50
101827	200	200	200	170	60
93965	200	200	200	200	170
93915	200	200	200	200	160
90396	200	200	200	200	200
90306	200	200	200	200	200
87017	200	200	200	200	100
85436	200	200	200	200	200
82559	200	200	200	200	110
81515	200	200	200	200	200
79455	100	90	70	60	20

Table 3.3
South Side Ditch Capacity

River Station	Channel Capacity				
	n=0.025	n=0.030	n=0.035	n=0.040	n=0.10
75902	130	110	90	80	30
75795	140	110	100	80	30
▲ PHASE 4 ▲					
▼ PHASE 3 ▼					
73597	200	200	200	200	200
71984	200	200	200	200	110
71954	200	200	200	200	120
70070	200	170	150	130	50
67470	80	60	50	40	10
65977	200	200	200	200	180
65922	200	200	200	200	200
62510	200	200	200	200	140
62432	200	200	200	200	140
60260	200	200	200	200	160
60215	200	200	200	200	180
59703	200	200	200	200	100
58670	200	200	200	190	70
57559	200	200	200	190	70
56894	200	200	200	200	100
56411	170	140	120	110	40
56080	200	200	200	200	110
56034	200	200	200	200	150
55602	200	200	200	190	70
54573	200	200	200	190	70
54473	200	200	200	200	80
49368	200	200	200	190	70
47818	200	200	200	200	190
▲ PHASE 3 ▲					
▼ PHASE 2 ▼					
47703	200	200	200	200	200
46530	200	200	200	200	140
46436	200	200	200	200	150
41706	130	110	90	80	30
40381	120	100	80	70	30
40287	130	100	90	80	30
37625	70	60	50	40	10
37495	70	60	50	40	10
33933	110	90	80	70	20
33883	110	100	80	70	30
30756	200	180	150	130	50
25326	180	160	140	120	40
25294	200	170	140	120	50
24773	90	80	60	60	20
22063	200	170	140	130	60
21933	200	170	140	130	60

Table 3.3
South Side Ditch Capacity

River Station	Channel Capacity				
	n=0.025	n=0.030	n=0.035	n=0.040	n=0.10
20590	200	160	140	120	30
18225	80	70	70	60	30
▲ PHASE 2 ▲					
▼ PHASE 1 ▼					
14560	200	200	200	200	20
10316	20	20	10	10	0
10226	20	20	20	10	0
▲ PHASE 1 ▲					

Channel Roughness	Description of Channel Conditions
n=0.025	Excellent Conditions, channel is straight, no vegetation
n=0.030	Very Good Condition, bottom of ditch is clean, side slopes mowed short.
n=0.035	Good Conditions, bottom of ditch is clean, some weeds and brush on side slopes
n=0.040	Fair Conditions, bottom of ditch is clean, but side slopes have weeds and brush
n=0.100	Very Poor Conditions, ditch filled with tumbleweeds and heavy vegetation

Ditch capacity generally decreases from upstream to downstream. This is not an unexpected finding given the nature of the system. When irrigating, water is diverted from the main channel and flow decreases in the downstream direction of flow. While this is acceptable under the current operation plan, it will not be adequate for the operation of an ADS.

The capacity of the entire system is limited to the lowest capacity of a given reach. Modeling indicates that the maximum flow rate that the system can convey is about 40 to 50 cfs assuming "fair" to "good" conditions within the ditch. In general, the channel downstream of River Station 37193 is too small.

Table 3.3 also shows the importance of maintenance. Because the slope of the ditch is so mild, the capacity of the ditch is very sensitive to its condition. **Table 3.3** suggests that when the ditch is clean and free from excess vegetation, the capacity will be roughly 2 times as when the ditch is in "fair" conditions.

3.6 SCOUR AND EROSION

3.6.1 Improved Channel

Through interviews with the SSDA, it was determined that scour and erosion within the ditch is a concern. With the proposed increase in flow rates through the main channel, it is the concern of the SSDA that additional maintenance may be required. The hydraulic modeling prepared for the ADS predicts that flow velocities will typically be between 2 and 3 feet per second for a flow rate of 200 cubic feet per second. This range of velocities is generally considered to be non-erosive and nominal ground cover should be sufficient to stabilize the channel.

3.6.2 Bridges and Culverts

Flow velocities near bridges and culverts do increase significantly as the water speeds up to pass through the structure. Depending on the type of lining selected, some local channel protection may be warranted at bridges and culverts. The highest velocities predicted by modeling are around 7 feet per second. In these areas, riprap or turf reinforcement matting would be sufficient to prevent erosion.

3.6.3 Channel Slope

The main channel is not a uniform slope which may contribute to areas erosion and deposition. Changes in slope and shape impact the velocity of flow in the channel. However, the slope of the South Side Ditch is considered to be very mild and the effect of channel slope changes should not significantly impact erosion and deposition of material.

3.7 BRIDGES AND CULVERTS

Figure 3.3 shows a typical county road bridge along the ADS. Existing bridges vary in design and construction, but most are single span bridges supported by steel girders. Several bridges and culverts will need to be replaced to meet the capacity requirements of the improved ditch. It is anticipated that most of existing bridges will not have to be replaced. The hydraulic analysis showed that most bridges can convey the authorized flow without overtopping the road. However, the bridges will need to be cleaned of the debris and sediment that have occurred over years of operation, in an effort to maximize the bridge opening.

Figure 3.3
Typical County Road Bridge

During field reconnaissance, it was observed that several of the county road bridges were in need of repair or replacement. Figure 3.4 shows an existing bridge at County Road P that has adequate capacity, but has questionable structural integrity. It was not the purpose of this study to make a structural evaluation of the existing bridges. In order to provide opinions of costs, it has been assumed that bridges and culverts that cannot adequately convey 200 cfs will be removed and replaced. Replacement of bridges that can convey the authorized flow, but which have suspected structural integrity will need a plan for replacement.

Figure 3.4
County Road Bridge in Need of Repair

3.8 SPRINKLER BRIDGES

There are approximately fifty (50) sprinkler bridges that exist along the ADS. It is likely that some of these bridges will need to be removed and replaced in areas where the existing ditch is enlarged. Because the proposed channel restoration will include widening, the existing bridges will not likely be able to span the new channel.

Figure 3.5
Sprinkler Bridges

It is understood that sprinkler bridges have been installed by individual landowners and are not the responsibility of the SSDA. This report assumes that the costs associated with the bridge replacement will fall to the landowner. The cost for sprinkler bridges average about $1200 each. That price includes fabrication of the bridge and delivery to the location. The installation is at the expense of the farmer.

3.9 DIVERSION STRUCTURES

There are approximately twenty-two (22) diversion structures along the ADS (see **Exhibit A2**). **Figures 3.6** through **3.9** provide an example of diversion structures along the system. Though the actual date of construction varies from structure to structure, most seem to have been constructed in the 1930's and 1940's. With the age of most of the structures approaching 100 years, it is doubtful that simple modifications could be made in an effort to save costs. Because the proposed channel improvements associated with the ADS will widen the channel, it has been assumed that all of the existing structures are not sufficiently wide and will need to be replaced. New diversion structures are expected to cost about $60,000 each.

Figure 3.6
Diversion Structure

Figure 3.7
Diversion Structure

Figure 3.8
Diversion Structure

Figure 3.9
Diversion Structure

3.10 CHANNEL MODIFICATIONS

Existing channel capacity is less than adequate and a significant portion of the flow in the ditch is lost to infiltration. Improvements will be needed if the authorized flow rate of 200 cfs is to be conveyed in the ditch and if infiltration losses are to be reduced. The improvements include modifying the channel by increasing its size and shape, and/or lining the ditch to reduce infiltration. This section specifically addresses the channel modifications necessary to convey the authorized flow. The considerations for channel lining are addressed in **Section 4** of this report.

The channel improvements presented by this study are intentionally simple. No channel realignments or major changes in slope are proposed. Channel widths and slopes are held constant between the roadways that cross the system. This is primarily due to the limited information available. Given better survey information and topography, the channel improvements could be optimized to minimize the amount of excavation and backfill. This could reduce the overall cost of the project, but would require more detailed engineering plans.

Table 3.4 shows the recommended channel improvements for the ADS. River Stations are labeled from downstream to upstream and are shown on **Exhibit A2**.

Table 3.4
Summary of Channel Modifications

River Station	Original Channel Invert (feet)	LOB Length	Channel Length	ROB Length	Center Station	Bottom Width (feet)	Proposed Channel Invert (feet)	Cut Area (sq ft)	Fill Area (sq ft)
102597	3049.50	285.38	285.38	285.38	0	30	3049.50	53.50	
102312	3053.09	485.00	485.00	485.00	0	30	3050.09	132.00	
101827	3051.44	7862.00	7862.00	7862.00	0	30	3051.44	21.70	
93965	3042.78	50.00	50.00	50.00	0	20	3042.78	19.30	
93940	Bridge								
93915	3042.48	3519.00	3519.00	3519.00	0	20	3042.48	11.10	
90396	3041.01	90.00	90.00	90.00	0	20	3041.01	19.70	
90351	Bridge								
90306	3040.87	3289.00	3289.00	3289.00	0	20	3040.87	30.60	
87017	3038.92	1581.00	1581.00	1581.00	0	20	3038.92	21.90	
85436	3037.44	2877.00	2877.00	2877.00	0	20	3037.44	16.40	
82559	3031.44	1044.00	1044.00	1044.00	0	20	3031.44	50.80	
81515	3030.12	2060.00	2060.00	2060.00	0	20	3030.12	152.00	
79455	3028.70	3553.05	3553.05	3553.05	0	20	3028.70	72.60	
75902	3027.21	107.00	107.00	107.00	0	20	3027.21	75.00	
75849	Bridge								
75795	3027.21	2197.98	2197.98	2197.98	0	20	3027.21	75.10	
73597	3025.19	1613.01	1613.01	1613.01	0	20	3022.07	277.00	
71984	3018.29	30.00	30.00	30.00	0	20	3018.29	143.00	
71969	Bridge								
71954	3018.29	1884.00	1884.00	1884.00	0	20	3018.29	143.00	
70070	3017.01	2600.00	2600.00	2600.00	0	20	3016.36	136.00	
67470	3014.73	1492.98	1492.98	1492.98	0	20	3013.71	118.00	
65977	3012.18	55.00	55.00	55.00	0	20	3012.18	136.00	
65950	Bridge								
65922	3012.18	3411.94	3411.94	3411.94	0	20	3012.18	136.00	
62510	3004.47	78.00	78.00	78.00	0	20	3004.47	31.90	
62471	Bridge								
62432	3004.47	2171.97	2171.97	2171.97	-1	20	3004.47	30.20	
60260	3002.47	45.00	45.00	45.00	0	10	3002.47	50.30	

Table 3.4
Summary of Channel Modifications

River Station	Original Channel Invert (feet)	LOB Length	Channel Length	ROB Length	Center Station	Bottom Width (feet)	Proposed Channel Invert (feet)	Cut Area (sq ft)	Fill Area (sq ft)
60237	Bridge								
60215	3002.57	512.01	512.01	512.01	0	10	3002.57	29.70	
59703	2998.67	1033.00	1033.00	1033.00	0	10	2998.67	52.40	
58670	2997.50	1111.00	1111.00	1111.00	0	10	2997.67	63.70	0.21
57559	2996.82	665.01	665.01	665.01	0	10	2996.59	48.00	
56894	2995.90	483.00	483.00	483.00	0	10	2995.94	76.40	0.01
56411	2996.00	331.00	331.00	331.00	0	10	2995.47	38.50	
56080	2995.15	46.00	46.00	46.00	0	10	2995.15	77.30	
56057	Bridge								
56034	2995.39	432.00	432.00	432.00	0	10	2995.15	39.50	
55602	2994.90	1029.00	1029.00	1029.00	0	10	2994.90	36.40	
54573	2993.53	100.00	100.00	100.00	0	10	2993.53	48.80	
54523	Bridge								
54473	2993.53	5105.10	5105.10	5105.10	0	25	2993.53	135.00	
49368	2989.28	1550.00	1550.00	1550.00	0	25	2989.28	69.20	
47818	2986.83	115.00	115.00	115.00	0	25	2986.83	87.90	
47760	Bridge								
47703	2986.83	1173.00	1173.00	1173.00	0	25	2986.83	88.00	
46530	2982.19	94.00	94.00	94.00	0	25	2982.19	189.00	
46483	Culvert								
46436	2982.19	4730.05	4730.05	4730.05	0	30	2982.19	221.00	
41706	2976.73	1325.00	1325.00	1325.00	0	30	2977.40	104.00	2.74
40381	2976.06	94.00	94.00	94.00	0	30	2976.06	118.00	
40334	Bridge								
40287	2976.06	2662.00	2662.00	2662.00	0	30	2976.06	118.00	
37625	2972.72	130.00	130.00	130.00	0	30	2972.72	182.00	
37560	Culvert								
37495	2972.72	3562.05	3562.05	3562.05	0	30	2972.72	182.00	
33933	2968.62	50.00	50.00	50.00	0	30	2968.62	106.00	
33908	Bridge								
33883	2968.62	3127.02	3127.02	3127.02	0	30	2968.62	106.00	
30756	2964.37	5430.00	5430.00	5430.00	0	30	2964.58	125.00	0.18
25326	2957.56	32.00	32.00	32.00	0	30	2957.56	108.00	
25310	Bridge								
25294	2957.56	521.01	521.01	521.01	0	30	2957.56	108.00	
24773	2956.22	2710.00	2710.00	2710.00	0	30	2956.70	125.00	1.61
22063	2952.23	130.00	130.00	130.00	0	30	2952.23	144.00	
21998	Culvert								
21933	2952.23	1342.98	1342.98	1342.98	0	30	2952.23	144.00	
20590	2949.66	2365.00	2365.00	2365.00	0	30	2950.41	73.60	4.90
18225	2946.54	3665.00	3665.00	3665.00	0	30	2346.54	107.00	
14560	2941.71	4244.05	4244.05	4244.05	0	30	2942.25	83.30	1.23
10316	2936.51	90.00	90.00	90.00	0	30	2936.51	72.00	
10271	Bridge								

Table 3.4
Summary of Channel Modifications

River Station	Original Channel Invert (feet)	LOB Length	Channel Length	ROB Length	Center Station	Bottom Width (feet)	Proposed Channel Invert (feet)	Cut Area (sq ft)	Fill Area (sq ft)
10226	2936.51	226.00	226.00	226.00	0	30	2936.51	72.00	
10000	2935.88	3868.00	3868.00	3868.00	0	30	2935.88	69.90	
6132	2925.17	1619.00	1619.00	1619.00	0	30	2925.17	13.40	
4513	2918.00	0.00	0.00	0.00	0	30	2914.50	142.00	

3.11 CHANNEL RETURN ALTERNATE 1

3.11.1 General Information

A new channel will need to be constructed to direct the South Side Ditch flows (alternate delivery) to the downstream Farmer's Ditch. One option is to improve the existing return channel to direct flows back into the Arkansas River (see **Exhibit. A3**). Channel Return Alternate 1 would involve improvements to approximately 3,860 feet of channel that currently serves as a channel return for the South Side Ditch.

The existing return channel will need to be improved to a 30-foot flat bottom ditch with 3:1 channel side slopes. Material excavated from the channel will be spread in the fields adjacent to the channel. The Opinion of Cost has no costs associated with hauling the material off site. Fill (Excess Material) will be graded to allow its future use as cropland or pasture.

It is assumed that the bridge at County Road 243 will be adequate to convey the authorized flows and will not need to be replaced.

The Opinion of Cost reflects pricing for two (2) new bridges. One will be associated with a new cattle crossing and the other will be associated with a private road crossing.

A new diversion structure will need to be constructed to control return flow back to the Arkansas River. Then need for flow monitoring equipment that would allow better accounting of water returned to the river is anticipated and included in the cost for the return structure.

3.11.2 Advantages

- This primary advantage to Channel Return Alternate 1 is cost. The proposed alignment is along an existing channel return. The costs associated with this project are significantly less than Alternates 2 and 3 because this project entails modifications to an existing channel.

3.11.3 Disadvantages

- The point of return to the Arkansas River is approximately three miles from the Farmer's Ditch headgate. This alternate proposes the greatest distance of travel along the Arkansas River and will exhibit the highest degree of transit losses of all channel return routes proposed.

- It has also been reported that the existing property owner utilizes the existing bridge under County Road 243 as a cattle crossing. If the ditch is improved and used to convey flows more frequently, the landowner will lose cattle access to both sides of the road. According to the representative of the SSDA, one of the conditions for using the ditch as part of the ADS would be to construct a new cattle crossing.

3.11.4 Opinion of Cost

The opinion of cost associated with the construction of Alternate 1 is **$401,000** and does not include the costs associated with lining. Additional detail can be found in **Appendix E**. Lining options are not included and can be found in **Section 4** and **Appendix E**.

3.12 CHANNEL RETURN ALTERNATE 2

3.12.1 General Information

Channel Return Alternate 2 includes the construction of a 13,640-foot ditch to return flows to the river. The project will consist of approximately 7,930 feet of improvements to the existing ditch and 4,930 feet of new channel. As shown on **Exhibit A3**, Channel Return Alternate 2 proposes a new return along Deerfield Lane. Deerfield Lane is a north-south road that crosses the South Side Ditch at the far downstream end. A new channel could be constructed parallel to the road and continue north to the Arkansas River.

Exhibit A3 shows the proposed channel return on both sides of Deer Field Lane. The southern portion of the channel was routed along the west side to avoid the "Areas of Safety Concerns" introduced by the farmsteads at the intersection of Deerfield Lane and County Road Y-22. Once past the farmsteads, the proposed channel is then directed to the east side of Deerfield Lane where it continues to the river. This was done because the landowner on the east side of Deerfield Lane is more amicable to the project. Conditions for right-of-way acquisition may be more favorable if the channel is on the east side of Deerfield Lane.

It is important to note that there are many available options associated with Alternate 2. The routing shown on **Exhibit A3** is but one feasible solution. The route of the channel (whether or not it is routed along the east or west side of Deerfield Lane) neither affects the feasibility nor the opinion of cost for the project. The overall channel length and number of bridges is the same. The final design of the channel should be given the latitude to consider land acquisition costs, cooperation of landowners, public safety concerns, impacts to existing pivot irrigation, and obstacles that may be realized once a detailed topographic survey is obtained.

The opinion of cost for Channel Return Alternate 2 assumes the new return channel will need to be improved to a 30-foot flat bottom ditch with 3:1 channel side slopes. It is assumed that material excavated from the channel will be spread in the fields adjacent to the channel. The Opinion of Cost has no costs associated with hauling the material off site. Fill (Excess Material) will be graded to allow its future use as cropland or pasture.

It is anticipated that Channel Return Alternate 2 will require three (3) new bridges at the following locations if the ditch is located on the west side of Deerfield Lane:

- County Road Y-22
- West River Road.
- Deerfield Road

However if the ditch is located on the east side of Deerfield Lane, the existing bridge on West River Road could be used reducing the bridge need to two.

Bridges are assumed to be single span, steel girder bridges similar to those found elsewhere along the system.

A new diversion structure will be constructed to control return flow back to the Arkansas River. The need for flow monitoring equipment that would allow better accounting of water returned to the river is anticipated and included in the cost for the return structure.

The opinion of cost does not address property or right of way acquisition.

3.12.2 Advantages

- Of the three options presented in this report, Channel Return Alternate 2 provides a moderate solution. The cost of the project is neither the highest nor the lowest.

- Of the options presented, Channel Return Alternate 2 provides a point of return to the Arkansas River moderately close Farmer's Ditch head gate. The distance from the point of return to the head gate is approximately 1.2 miles.

- The proposed route is along Deerfield Lane. The route will require additional right of way and will take agricultural land out of service. However, the route runs along the edge of existing fields and will not fragment any existing fields.

- Channel Return Alternate 2 can be routed to avoid close contact to farmsteads and safety issues are more easily addressed with this option.

3.12.3 Disadvantages

- Channel Return Alternate 2 requires the construction of the three (3) bridges. Bridges add to the cost of the project and disrupt traffic in the area.

- Channel Return Alternate 2 does not provide the closest point of return to the Farmer's Ditch headgate. Therefore, transit losses are not minimized by the selection of this option.

3.12.4 Opinion of Cost

The opinion of cost associated with the construction of Alternate 2 is **$1,024,000** and does not include the costs associated with lining. This cost may be reduced if the bridge on West River Road is not needed. Additional detail can be found in **Appendix E**. Lining options are not included and can be found in **Section 4** and **Appendix E**.

3.13 CHANNEL RETURN ALTERNATE 3

3.13.1 General Information

Channel Return Alternate 3 encompasses approximately 16,250 feet of channel improvement. Of this 7,930 feet of the total length constitutes improvements to the existing channel and 8,320 feet consists of new channel. **Exhibit A3** shows the proposed alignment for Channel Return Alternate 3. The proposed channel begins at the existing end of the South Side Ditch and would be routed around the irrigation circle in the NW ¼ of S24 T24S R35W. The channel would then cross County Road 243 where a new bridge would be required. The alignment would then be routed along the perimeter of the irrigation circle in the SW ¼ of S13 T24 R35. The channel would then be routed north to the Arkansas River. This option is the most expensive of the three channel returns proposed, but also provides the greatest reduction in transit losses with a distance of 2050 feet from the return to the Farmer's Ditch head gate.

It is assumed that the new return channel will need to be a 30-foot flat bottom ditch with 3:1 channel side slopes. Material excavated from the channel will be spread in the fields adjacent to the channel. The Opinion of Cost has no costs associated with hauling the material off site. Fill (Excess Material) will be graded to allow its future use as cropland or pasture.

Four (4) new bridges will be required at the following locations:

- County Road Y-22
- West River Road.
- Deerfield Lane
- Private Road (near the center of S13 T24S R35W)

Bridges are assumed to be single span, steel girder bridges similar to those elsewhere along the system.

A new diversion structure will be constructed to control return flow back to the Arkansas River. As with the other options, consideration should be given to installing flow monitoring equipment with the diversion structures that would allow better accounting of water returned to the river.

The opinion of cost does not address property or right of way acquisition.

3.13.2 Advantages

- Channel Return Option 3 provides the closest point of return to the Farmer's Ditch head gate. As a result, this option provides the minimum amount of transit losses in the Arkansas River of all options proposed.

3.13.3 Disadvantages

- Channel Return Alternate 3 requires the construction of the three (3) bridges. Bridges add to the cost of the project and disrupt of traffic in the area.

- The proposed alignment passes near two farmsteads. The project may introduce public safety liability that could be avoided by selecting another route.

- Channel Return Alternate 3 is the longest of the three options proposed and is consequently the most expensive option.

3.13.4 Opinion of Cost

The opinion of cost associated with the construction of Alternate 3 is **$1,305,000** and does not include the costs associated with lining. Additional detail can be found in **Appendix E**. Lining options are not included and can be found in **Section 4** and **Appendix E**.

3.14 CHANNEL RETURN ALTERNATE 4

3.14.1 General Information

Channel Return Alternate 4 is the use of the existing channel return (same alignment as Channel Return Alternate 1) without expansion or lining of the channel. The return channel would be used in its current state.

3.14.2 Advantages

- There is no cost associated with this option.

3.14.3 Disadvantages

- The size of the existing channel will limit flow rates through the ADS. The system would not be able to convey the desired flow rates.

- This option does not maximize opportunities for transit loss reduction.

- It has also been reported that the existing property owner utilizes the cattle crossing under County Road 243. If the ditch is used as an ADS, the landowner will need cattle access to both sides of the road.

3.14.4 Opinion of Cost

This option recommends no action. There are no costs associated with Channel Return Alternate 4.

3.15 SUMMARY OF COSTS

Table 3.5 shows the opinion of probable costs for the work associated with improving the South Side Ditch to function as an ADS. With further detail provided in Appendix E, the costs associated with the table generally include excavation, backfill, compaction, seeding, return structures, diversion structures, demolition and construction of new bridges. The cost represents the work necessary to expand the existing ditch to meet capacity requirements.

The table does not include any costs associated with the lining options discussed in **Section 4**. These two costs have been kept separate in the body of the report. **Table 3.5** provides a summary of combined costs.

Table 3.5
Opinion of Probable Costs for Alternate Delivery System
(thousands of dollars)

Project Component	Reach 1	Reach 2	Reach 3	Reach 4	TOTALS
CHANNEL IMPROVEMENTS					
Channel Return Alternate 1	$401	$1,259	$1,090	$407	**$3,157**
Channel Return Alternate 2	$1,024	$1,259	$1,090	$407	**$3,780**
Channel Return Alternate 3	$1,305	$1,259	$1,090	$407	**$4,061**
Channel Return Alternate 4	$0	$1,259	$1,090	$407	**$2,756**

Section 4
Lining of South Side Ditch

4.0 LINING OF SOUTH SIDE DITCH

4.1 INTRODUCTION

This study evaluates the lining the South Side Ditch and its effects on water quality, ditch efficiency and groundwater recharge. This alternative is also considered to be a part of the Alternate Delivery System (ADS) discuss in **Section 3**. Lining options considered include concrete, earthen material, synthetics, geosynthetics, bentonite/soil matrix, fly ash/soil matrix and polyacrylamides.

This study addresses the following considerations for lining:

- Operation and Maintenance
- Portions of ditch to line
- Lining materials
- Benefit analysis for lining the ditch including efficiency of delivery, effects on ground water and nearby water right holders.

4.2 OPERATION AND MAINTENANCE

The operation and maintenance practices of the South Side Ditch Company and the farmers that use the ditch will have a strong influence on the alternatives recommended by this report. It is the goal of this study to recommend a feasible solution that does not encumber the current operation and maintenance practices. The practices of concern are discussed below.

4.2.1 Vegetation Control

The current means of vegetation control are herbicide application and burning. These two control measures are a result of the shape and operation of the ditch. Mowing is not an option because the side slopes of the ditch are too steep and irregular. The field reconnaissance conducted with this study indicated that portions of the ditch have side slopes steeper than 1.2 horizontal to 1 vertical. In order to provide safe access for equipment, side slopes should not be any steeper than 3 horizontal to 1 vertical.

Vegetation within the ditch is mainly comprised of weeds and other volunteer plants. No attempt has been made to establish turf within the ditch. Under normal conditions, the ditch is dry, but when a call for water is made, the ditch could be inundated with water for weeks at a time. The inundation deprives the established vegetation of oxygen, and most of it dies during periods of irrigation. The vegetation that is reestablished after every irrigation cycle is volunteer growth.

The SSDA implements a regular vegetative maintenance program. The program involves application of herbicides and mowing of the right of way. Typically the ditch is cleared of vegetation by burning in early spring before a call for water is made.

The accumulation of tumbleweeds in the ditch is unavoidable. This vegetation is not grown in the ditch; it is blown in from elsewhere. No maintenance practice would diminish this problem and the method of removal by burning will likely remain a practice well into the future. The lining option will need to account for the practice of burning.

4.2.2 Cattle Operations

Though most of the service area is cropland, some farmers do run cattle on their fields during the winter months. Temporary fences are constructed, but no heed is given the ditch. The ditch right of way is not typically fenced and cattle have full access to the ditch.

A lining option will need to consider the potential damage that could be done by livestock.

4.2.3 Access

The route taken by the existing ditch is without consideration of property boundaries. The ditch meanders through fields and follows the topography of the area. As a result, many fields are fragmented by the presence of the ditch. A lining option should consider the need for access across the ditch with farm equipment.

A lining option should also consider access by the equipment needed to maintain the ditch.

4.2.4 Maintenance Responsibility

The South Side Ditch Company employs one person (known as the Ditch Rider) to oversee the operation and maintenance of the system. When the ditches are prepared to accept water, the task of removing the vegetation is too great for one person. Therefore a grass roots effort is made by the stockholders to clear the ditch. Each farmer who has installed sprinkler bridges across the ditch is responsible for clearing the ditch running through the entire length of the property.

4.3 PROTECTIVE BUFFER

Given the operation and maintenance practices that are existing practices, it is the recommendation of this report that any liner selected for this project (with the exception of concrete) should be buried to a minimum depth of 18 inches. 18 inches is a nominal depth which should provide a sufficient protective buffer above any liner selected. Benefits of the protective buffer include the following:

- A geosynthetic liner's lifespan will be maximized when exposure to ultraviolet light is minimized.

- A geosynthetic liner could easily be punctured by the hooves of cattle. The protective buffer would protect the liner and still allow cattle to have access to the ditch.

- A geosynthetic liner could not be directly exposed to the intense heat created when the ditch is cleared by burning. It is believed that the 18 inches of cover would be adequate to insulate the liner from heat generated by burning for short durations. Therefore the practice of burning could continue.

- With a protective buffer, vehicular access across the ditch would be feasible without damaging the liner.

- For earthen, bentonite matrix, and fly ash matrix liners (see discussion below), an 18 inch buffer would protect the lining material from erosion. If left at the surface, these liners would gradually be eroded away by the water being conveyed.

- For any liner option, the best means of protection and extended life of the liner is by burying it. This approach undoubtedly will yield a higher initial cost. However, the environment to which the liner is to be installed is hostile, and the lifespan of an unprotected liner could be short. Because the SSDA desires to maintain its current operation and maintenance protocols, a buried liner is the most practical solution.

4.4 CONCRETE LINER

4.4.1 General Description

A trapezoidal ditch lined with concrete would greatly improve the conveyance characteristics of the ditch and significantly reduce transit losses. This report assumes the construction of a 10 to 30 -foot trapezoidal channel with 3:1 side slopes. For estimating purposes it was assumed that the concrete liner would be 6 inches thick with 6x6–W1.4 x W1.4 welded wire reinforcement. More detailed geotechnical information and a complete structural design will need to be conducted before the final concrete thickness and means of reinforcement is determined.

4.4.2 Advantages

- A concrete liner would offer a durable solution and would be resistant to traffic, cattle and erosion.

- A well maintained concrete liner would be nearly impervious and transit losses would be minimized.

4.4.3 Disadvantages

- The primary disadvantage to a concrete liner is the cost of materials and construction. Of the lining options considered, concrete proved to be the most expensive by a factor of three.

- A concrete liner would require joints and will likely crack and settle over time. Joints and cracks would introduce opportunities for transit losses and would need to be maintained (sealed) regularly to minimize transit losses. Given the extent of the ADS (approximately 19 miles in length), the costs to seal and repair cracks could be significant.

- Concrete is not considered to be environmentally friendly and could be difficult to permit.

4.4.4 Opinion of Cost

Table 4.1 provides a summary of costs associated with a concrete liner. Opinions of cost do not reflect the channel improvements needed to increase capacity as described in **Section 3** of this report. Project totals are summarized in **Table ES.2** and **ES.3**. More detailed cost information can be found in **Appendix E**.

Table 4.1
Opinion of Probable Costs for Concrete Liner
(thousands of dollars)

Lining Option	Phase 1	Phase 2	Phase 3	Phase 4	TOTALS
Channel Return Alternate 1	$871	$7,102	$5,315	$5,619	**$18,907**
Channel Return Alternate 2	$3,061	$7,102	$5,315	$5,619	**$21,097**
Channel Return Alternate 3	$3,670	$7,102	$5,315	$5,619	**$21,706**
Channel Return Alternate 4	$0	$7,102	$5,315	$5,619	**$18,036**

4.5 EARTHEN LINER

4.5.1 General Description

An earthen liner consists of a layer of impermeable soil (typically clay) to reduce infiltration. For the construction of an earthen liner, the top 30 inches of native material would be excavated. This assumes

18 inches for the protective buffer and 12 inches for the earthen liner. The actual depth of the liner would need to be determined by analyzing samples of the borrow material used. A 12-inch liner thickness was assumed for estimated purposes. The earthen liner would need to be comprised of a clay material or clay mix with low permeability. **Figure 4.1** shows a typical the installation of a typical earthen liner.

Once the earthen liner has been placed, the excavated material would then be replaced over the clay liner and compacted to a depth of 18 inches.

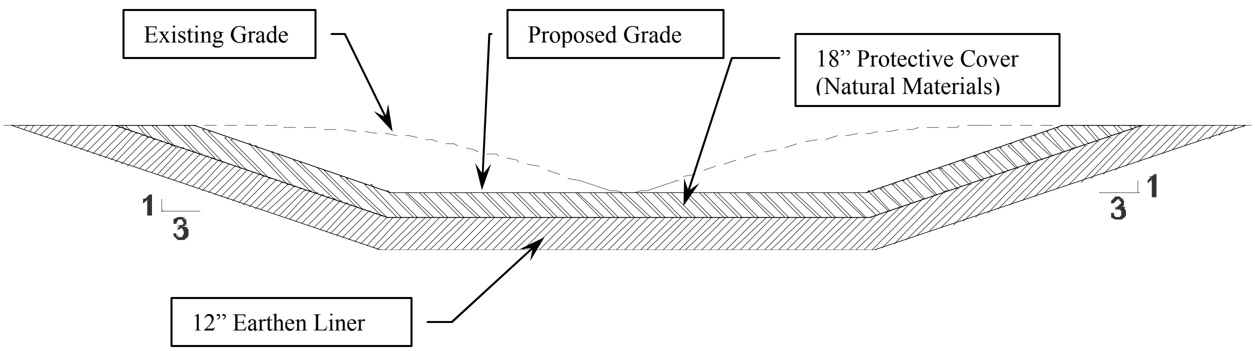


Figure 4.1
Typical Earthen Liner

It should be noted that no suitable borrow site is evident by the soils mapping available from either the USGS or the NRCS. The costs associated with constructing an earthen liner may be cost prohibitive because of the hauling distances needed to bring suitable material to the site.

4.5.2 McKinney Lake Borrow Source

It is possible that an acceptable borrow source for the earthen liner would be found in the Lake McKinney bed. Geotechnical information is available for the lake area that suggests that the lake bed may be suitable for use[3]. While the geotechnical investigation was intended to assess conditions in the dam, it does state the following about the foundation soil:

The foundation soils beneath the dikes generally classify, according to ASTM D 2487, as lean clay with sand (CL), with some fat clay with sand (CH) and silty sand (SM) encountered in TH-4. These soils are likely relatively shallow sediments that have been recently deposited in Lake McKinney reservoir prior to construction of the dikes. The implication is that the clay material covers the entire lake bed and is suitable for use as a liner. Use of the material would be subject to additional geotechnical analysis.

[3] Michael W. West and Associates, Inc. (2007). Geotechnical Investigation, Lake McKinney Dam, Kearny County, Kansas. P. 8.

If the lake bed can be used as a borrow sources, the option to use an earthen liner becomes a more cost effective option:

- Using an earthen liner, the 18 inches of protective overburden could be removed from the project at a cost savings of $1,689,000.
- The opinion of cost for this option assumes that borrow material would need to be purchased from another borrow source. Because additional storage capacity is desired within Lake McKinney, it is assumed that the material would not need to be purchased. The cost savings to the project would be approximately $2,218,000[4].
- The opinion of cost assumes a 40 mile round trip for hauling borrow material. The round trip haul distance from the project to Lake McKinney would average around 10 miles. Savings to the project would be about $3,732,000.

The above changes would bring the total estimated opinion of cost to line the proposed ADS with an earthen liner to approximately $8,600,000.

4.5.3 Advantages

- An earthen liner would be self repairing. Minor cracks in the liner would reseal once the soil becomes saturated.
- Repairs to the liner could be made with equipment and materials readily available to the SSDA.
- With the proposed 18 inch cover layer, the liner would be protected from damage and could provide a very long life span.
- The liner would require little additional maintenance for the SSDA.

4.5.4 Disadvantages

- With the exception of McKinney Lake, there are no obvious sources of earthen material near the project that would facilitate the construction of an earthen liner. The cost to purchase the borrow material and haul it to the project site may be cost prohibitive when considering this option.

[4] $6.00/CY was assumed for the price of borrow material.

4.5.5 Opinion of Cost

Table 4.2 provides a summary of costs associated with an earthen liner. Opinions of cost do not reflect the channel improvements needed to increase capacity as described in **Section 3** of this report. Project totals are summarized in **Table ES.2** and **ES.3**. More detailed cost information can be found in **Appendix E**.

The opinion of cost assumes a 40 mile round trip for hauling of borrow material. This is likely an optimistic assumption. Soils maps of the County indicate no suitable material and the cost for hauling may be understated.

Table 4.2
Opinion of Probable Costs for Earthen Liner
(thousands of dollars)

Lining Option	Phase 1	Phase 2	Phase 3	Phase 4	TOTALS
Channel Return Alternate 1	$378	$4,288	$3,964	$3,527	**$12,157**
Channel Return Alternate 2	$1,703	$4,288	$3,964	$3,527	**$13,482**
Channel Return Alternate 3	$2,070	$4,288	$3,964	$3,527	**$13,849**
Channel Return Alternate 4	$0	$4,288	$3,964	$3,527	**$11,779**

4.6 BENTONITE/SOIL MATRIX

4.6.1 General Description

Bentonite has become increasingly popular for uses in decorative ponds and other man-made water features. The high clay content of bentonite helps to reduce seepage losses in these applications. For this reason, it can also be used to reduce the high infiltration rates common to the Arkansas River alluvium.

Several types of bentonite are available, but only sodium bentonite is recommended for use. Another form, calcium bentonite, can have a harmful effect on the environment. It can lead to rapid changes in

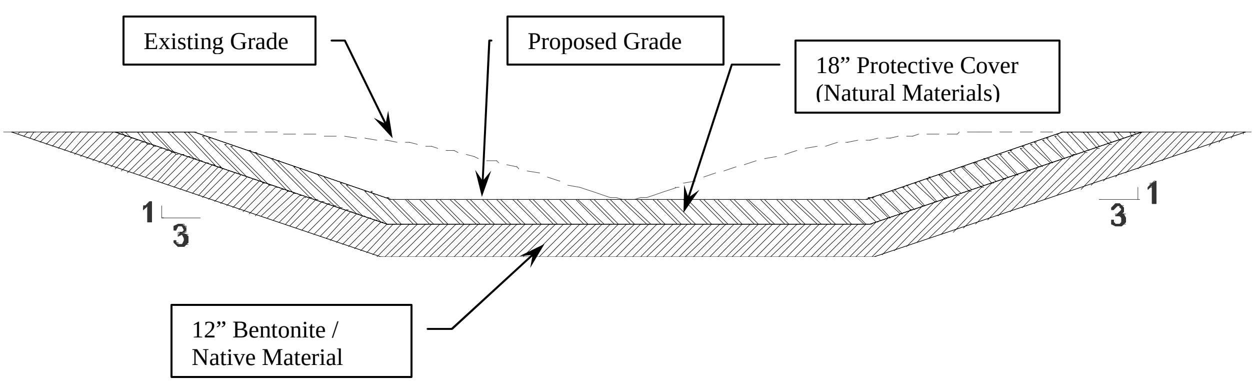


Figure 4.2
Typical Bentonite/Soil Matrix Liner

water's pH which results in fish kills. Sodium bentonite also has the ability to exchange nutrients with native soils, an advantage over synthetic liners which may result in a build up of nutrients.

Bentonite can be applied in two ways. The first is known as the blanket method. In this method, the first four to six inches of soil is removed. Bentonite is then spread over the exposed soil and the removed material is replaced and compacted over the bentonite layer. The blanket method of application was not considered for this report.

Another method that can be used is known as the mixing method or soil matrix (see **Figure 4.2**). For this method, the bentonite is mixed into a 12 inch layer of soil and then compacted. Regardless of the method used, bentonite should always be added to dry, rather than wet, soils to enhance performance.

A disadvantage to this liner is that clay has a high shrink/swell potential. When wet, Bentonite swells and expands to fill cracks in the soil effectively sealing it against infiltration loss. In this case, the high shrink/swell characteristics could prove to be an advantage as the liner would be self repairing if damaged. During hot summer months, when the ditch is dry, the seal may have a tendency to shrink and crack. The ditch would need to be closely monitored for such conditions as they will not effectively prohibit water infiltration until the clay material becomes completely saturated. The 18 inch protective cover would provide some degree of protection from shrink / swell by reducing the amount of moisture lost to evaporation.

4.6.2 Advantages

- A bentonite/soil matrix liner would be self repairing. Minor cracks in the liner would reseal once the bentonite becomes saturated.
- Repairs to the liner could be made with equipment and materials readily available to the SSDA, but a store of bentonite would need to be kept on hand.
- With the proposed 18 inch cover layer, the liner would be protected from damage and could provide a very long life span.
- The liner would require little additional maintenance for the SSDA.

4.6.3 4.6.3 Disadvantages

- There are no sources of bentonite clay near the project. The closest source of bentonite is Wyoming. The cost to purchase bentonite and transport it to the project site significantly adds to the cost of the project.

4.6.4 Opinion of Cost

Table 4.3 provides a summary of costs associated with a bentonite/soil matrix liner. Opinions of cost do not reflect the channel improvements needed to increase capacity as described in **Section 3** of this report. Project totals are summarized in **Table ES.2** and **ES.3**. More detailed cost information can be found in **Appendix E**.

Table 4.3
Opinion of Probable Costs for Bentonite/Soil Matrix Liner
(thousands of dollars)

Lining Option	Phase 1	Phase 2	Phase 3	Phase 4	TOTALS
Channel Return Alternate 1	$148	$1,796	$1,660	$1,463	**$5,067**
Channel Return Alternate 2	$711	$1,796	$1,660	$1,463	**$5,630**
Channel Return Alternate 3	$864	$1,796	$1,660	$1,463	**$5,783**
Channel Return Alternate 4	$0	$1,796	$1,660	$1,463	**$4,919**

One of the parameters that could greatly impact the costs associated with this lining option is the location of the bentonite supplier. Bentonite is abundant in Wyoming and the Opinion of Cost assumes that the material will be transported from Wyoming. The costs of shipping will vary on quantity and mode of transportation available to the construction contractor. It may be more cost effective to transport large quantities by rail and smaller quantities by truck. Therefore, the decision to phase the projects may have an impact on the overall cost of this option.

4.7 SYNTHETIC LINER

4.7.1 General Description

Synthetic liners are typically constructed using either polyvinyl chloride (PVC) or high density polyethylene (HDPE) products. HDPE and PVC liners have several advantages and disadvantages. They come in large sheets that are easy to install and may be more readily available if adequate earthen materials are not on site. However, there is some debate as the durability of the product.

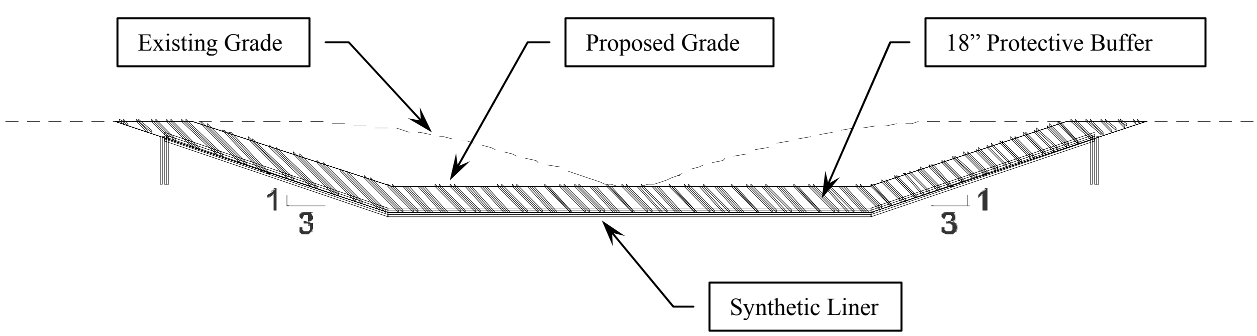


Figure 4.3
Typical Synthetic Liner

A Geosynthetic Clay Liner (GCL) is a composite bentonite and geotextile fabric typically used for lining ponds, landfills, canals and other applications. GCL's are usually constructed of two layers of geosynthetics stitched together enclosing a layer of clay. Woven and/or non-woven textile geosynthetics can be used. Bentonite clays, specifically Montmorillonite, are preferred and are most common. While geosynthetic liners are more expensive, the clay materials would allow the liner to be self-repairing for minor tears and punctures.

4.7.2 Advantages

- A geosynthetic liner would be self-repairing with respect to small tears and holes.
- Repairs to the liner could be made with equipment and materials readily available to the SSDA, but a store of liner material would need to be kept on hand.
- With the proposed 18 inch cover layer, the liner would be protected from damage and could provide a reasonably long life span.
- Once installed the liner would require little additional maintenance for the SSDA.

4.7.3 Disadvantages

- A synthetic liner would not be self repairing. Holes and tears in the liner would need to be excavated and repaired. Because the liner will be buried, the presence of holes and tears will not be obvious.

4.7.4 Opinion of Cost

Tables 4.4 and 4.5 provide a summary of costs associated with synthetic and geosynthetic liners. Opinions of cost do not reflect the channel improvements needed to increase capacity as described in **Section 3** of this report. Project totals are summarized in **Table ES.2** and **ES.3**. More detailed cost information can be found in **Appendix E**.

Table 4.4
Opinion of Probable Costs for Synthetic Liner
(thousands of dollars)

Lining Option	Phase 1	Phase 2	Phase 3	Phase 4	TOTALS
Channel Return Alternate 1	$219	$1,859	$1,718	$1,537	**$5,332**
Channel Return Alternate 2	$737	$1,859	$1,718	$1,537	**$5,850**
Channel Return Alternate 3	$877	$1,859	$1,718	$1,537	**$5,991**
Channel Return Alternate 4	$0	$1,859	$1,718	$1,537	**$5,114**

Table 4.5
Opinion of Probable Costs for Geosynthetic Liner
(thousands of dollars)

Lining Option	Phase 1	Phase 2	Phase 3	Phase 4	TOTALS
Channel Return Alternate 1	$330	$2,647	$2,447	$2,203	**$7,627**
Channel Return Alternate 2	$1,051	$2,647	$2,447	$2,203	**$8,347**
Channel Return Alternate 3	$1,248	$2,647	$2,447	$2,203	**$8,544**
Channel Return Alternate 4	$0	$2,647	$2,447	$2,203	**$7,297**

4.8 FLY ASH/SOIL MATRIX

4.8.1 General Description

Fly ash is a by product of burning coal that has typically been used to enhance concrete products. Its use as a soil liner is a relatively new technology. Fly ash has a natural cementitious quality that historically has increased the durability of concrete. This quality is now being applied to soils. Fly ash is an admixture that would be mixed in with the existing soils to create an impermeable liner and reduce infiltration.

4.8.2 Environmental Issues

There is some discussion as to potential harmful environmental effects of fly ash liners. Some studies believe that fly ash liners will leach metals and salts into the environment. However there is still much research to be done in this area before any definitive conclusions can be reached. Carlson[5] makes notes of a study prepared for the City of Holcomb, Kansas which evaluated the leachate characteristics of a water lagoon lined with a fly ash/native soil liner.

> *Sulfate, (SO_4) Chloride (Cl), Iron (Fe), pH, and Manganese (Mn) were all detected in the initial leachate at concentrations above the Federal Secondary Maximum Contaminant Levels (SMCLs). Similar to the Landfill Liner Study, concentrations of Sulfate (SO_4) and Manganese (Mn) were both observed to decrease consistently with increasing pore volumes eluted; Chloride (Cl), Iron (Fe), pH were observed to either stabilize and/or no discernable pattern could be observed.*

[5] James R. Carlson, (2002). Leachate Characteristics from Two Laboratory Fly Ash Column Tests. Kansas State University.

Practically speaking, the two fly ash leachate constituents likely to be of concern to the environmental community are Sulfate and Chromium. As the EPA further implements the Threshold Maximum Daily Loading (TMDL) leg of the National Pollution Discharge Elimination System (NPDES) Program, Sulfates are likely to be a thorny issue for both Dischargers and Regulators alike. Chromium, like Mercury (which was not detected in this study) is likely to be more of a political issue than an actual threat – however, more research into what actually may need to be done to confirm (or dissuade) any [perceived] threats posed by Chromium should still be undertaken.

4.8.3 Constructability Issues

Carlson[6] reported several constructability issues associated with using fly ash as a liner: maintaining consistent water content, quickness in cure times following batch mixing, substantial variations in permeability, and problems with interconnecting vertical and horizontal lifts. Carlson also indicated that the rapid cure time of fly ash mixtures also present field constructability problems which needed additional research.

4.8.4 Available Sources

Currently, a 360 megawatt coal-fired plant is located near Holcomb. Sunflower Electric has announced plans to construct two new 600 megawatt coal-fired power plants nearby. This could increase the availability (and decrease cost) of fly ash for local soil liner applications.

Construction of a fly ash soil matrix would be similar to that of the bentonite soil matrix shown in **Figure 4.2**. The installation would involve removal of the top 18 inches of natural material and then mixing fly ash into the 18 inches of natural material.

4.8.5 Advantages

- There is an available source of fly ash material within 15 miles of the project.
- A fly ash / soil matrix liner provide the least expensive alternative.

4.8.6 Disadvantages

- There are potential environmental hazards associated with a fly ash liner.
- Studies indicate construction difficulties and the need for strict quality control measures.

[6] James R. Carlson, (2000). Comparison of Bentonite and Fly Ash Materials on Low Permeability Liner Applications. Kansas State University.

- Fly ash is not a self repairing liner. Once cracked or damaged, the area will need to be re-lined.

4.8.7 Opinion of Cost

Table 4.6 provides a summary of costs associated with a fly ash/soil matrix liner. Opinions of cost do not reflect the channel improvements needed to increase capacity as described in **Section 3** of this report. Project totals are summarized in **Table ES.2** and **ES.3**. More detailed cost information can be found in **Appendix E**.

Table 4.6
Opinion of Probable Costs for Fly Ash/Soil Matrix Liner
(thousands of dollars)

Lining Option	Phase 1	Phase 2	Phase 3	Phase 4	TOTALS
Channel Return Alternate 1	$133	$1,631	$1,507	$1,326	**$4,596**
Channel Return Alternate 2	$646	$1,631	$1,507	$1,326	**$5,110**
Channel Return Alternate 3	$785	$1,631	$1,507	$1,326	**$5,249**
Channel Return Alternate 4	0$	$1,631	$1,507	$1,326	**$4,464**

One of the parameters that could impact the costs associated with this lining option is the location of the fly ash supplier. Fly ash is produced at the Holcomb Power Station approximately 15 miles east of the project. The Opinion of Cost assumes that fly ash would be available from this source. However, the availability of fly ash from Holcomb Power Station is not guaranteed. The costs of shipping will vary on quantity and mode of transportation available to the construction contractor.

4.8.8 Conclusions

Of all the liner options considered in this report, fly ash would provide one of the least expensive options for channel lining. A source for fly ash is within 15 miles of the project and has undergone some study and field testing near the project area. However, those studies identified potential problems with constructability and water quality. The studies also identified the need for additional research.

The use of fly ash as a liner is not a recommendation of this report because of the uncertainties involved and because the use of fly ash as a lining material is considered a new technology. It would not be advisable to use a project of this magnitude as a test case.

With that said, there may be some opportunity for the State to develop a small pilot study to work out constructability, environmental and permeability issues.

4.9 POLYACRYLAMIDES

4.9.1 General Description

Polyacrylamide (PAM) is a synthetic polymer that dissolves in water and is used to control soil erosion caused by irrigation. It comes in several forms including dry powder, block, or liquid. PAM is dissolved in water where it then attracts and bonds to sediment particles which then settle out of suspension. This results in reduced erosion and some believe decreased seepage rates.

Recent studies have been made to evaluate the performance of PAM as an infiltration inhibiter. PAM does not seal the natural soils. Rather, the introduction of the polymer into flowing, sediment-laden water causes suspended sediments to deposit in the bottom of the channel. It is this layer of fine material that decreases permeability. It is in this context that this report considers the use of PAM as a ditch lining option.

4.9.2 Canal Seepage Reduction Demonstration

Valliant[7] has documented his results of using polymers to seal the Catlin Canal on the Arkansas River near La Junta, Colorado. The report addresses the use of two different polymers used to seal an earthen ditch along the Arkansas River. The ditch was divided into three sections; the first section was left untreated, PAM was applied to the second section, and another polymer (HYDROGEL) was applied along the third section. Four (4) wells were dug in each section to monitor the amount of seepage occurring in the field.

The HYDROGEL was applied to the bottom and sides of a section of the test canal in 1998. The sides of the ditch continued to erode and water levels in the monitoring well did not change after the application of the HYDROGEL. It was determined that HYDROGEL alone was not sufficient to seal the ditch and reduce seepage losses.

Valliant then applied PAM to another section of the canal with varying application rates. However no conclusion was provided as to the optimum application rate. After the PAM was applied, water levels in the monitoring wells dropped in comparison to the untreated section of canal.

Seepage losses between each section were also calculated and recorded throughout the three year study. Losses in the section of canal treated with PAM were reduced dramatically. It was reported that before any seal was applied seepage losses were 0.76 gpm/ft. The following day (after applying PAM), seepage

[7] Valliant, Jim. (Dec 2000). Final Report, Canal Seepage Reduction Demonstration, Using Polyacrylamides in the Ditch and Water, Arkansas River Valley of Colorado, Phases I, II, and III. Colorado State University Cooperative Extension.

losses were 0.36 gpm/ft. The last recording of the study was performed two years after the initial application with a seepage loss of 0.02 gpm/ft. Total seepage loss was reduced by 84.1% in 1998, 95.1% in 1999, and 92.3% in 2000.

In Valliant's study, PAM was applied to the canal four (4) times in both 1998 and 1999, but only once in 2000. Sedimentation had a profound effect on the amount of sealant required and the report estimates as much as 12.8 pounds per linear foot of ditch was deposited. PAM has a natural characteristic which encourages suspended sediment to collect and settle. PAM was often most effective during irrigation season or abnormally high flows, as the excess sediment was encouraged to settle out and helped to seal the ditch naturally.

4.9.3 Other Studies and Water Infiltration

Valliant's report concluded that PAM is an effective means at reducing water infiltration loss in earthen canals. However, there is still some debate as to whether PAM does actually decrease infiltration, or if it increases it. The United States Department of Agriculture's Agricultural Research Service, Northwest Irrigation and Soils Research Lab (NWIRSL) have performed numerous studies on PAM and its reports contain some of the most recent and pertinent information available regarding PAM. Many of the reports referenced on the site indicate that PAM generally increases net infiltration – by as much as 60%. Other studies that follow the same conclusion are listed below:

- Trenkel, J., D. Burton, and C. Shock. 1996. PAM and/or Low Rates of Straw Furrow Mulching to Reduce Soil Erosion and Increase Water Infiltration in a Furrow Irrigated Field, 1995 Trial. OSU, Malheur Experiment Station Special Report 964:167-175.

- Burton., J. Trenkel, and C.C. Shock. 1996. *Effects of Polyacrylamide Application Method on Soil Erosion and Water Infiltration.* OSU, Malheur Experiment Station Special Report 964:186-191.

- R.E. Sojka*, R.D. Lentz, C.W. Ross and T.J. Trout. *Net and Tension Infiltration Effects of PAM in Furrow Irrigation.* Proceedings of the 1996 PAM Conference, Twin Falls, ID; May 6-8, 1996.

Lentz[8] attempts to explain the possible diverging theories on PAM's effect on water infiltration. Lentz is a leading researcher in the study of PAM and its effects. His study concludes that PAM's influence on infiltration is dependent on soil type, application protocol, and concentration of PAM used.

In the past, PAM has primarily been used to control erosion in irrigation furrows. It was determined to reduce erosion best in silty or clayey soils. However, this type of soil is also where it had a tendency to increase infiltration rates. Previous research had shown that PAM increased infiltration rates when concentrations of 20-500 parts per million were applied to dry soils just before irrigation. Lentz's study discovered that increasing the concentration to 1000 parts per million and applying it to coarser soils (such as sand or loam), resulted in decreased infiltration.

4.9.4 Advantages

- The use PAM may offer the least expensive solution to inhibiting transit losses.
- SSDA personnel could be trained to implement a PAM application program.

4.9.5 Disadvantages

- PAM would need to be applied several times and likely on a continual, annual basis. The available literature did not present a recommended application program. It only documented the procedures of the study.
- The use a PAM as an infiltration inhibiter is a new concept and not been tried on a large scale project. Very little research has been done, but the studies that have been made suggest promising results.
- The success of PAM is dependent on site conditions (type of soil and, water quantity and water quality). There is no evidence that the polymer will provide successful results within the South Side Ditch.

4.9.6 Opinion of Cost

There is no set application for PAM and no firm guidance as to how much and how often applications should be made. Valliant reported a cost of $0.44 per linear foot of canal per application. However, the scope of his study was limited to 235 feet of canal with a flow rate of 9000 gpm (20 cfs). The scope of the ADS is on a far greater scale and there is no real comparison between the costs. Application rates are

[8] Lentz, R.D. Inhibiting Water Infiltration with Polyacrylamide and Surfactants: Applications for Irrigated Agriculture, Journal of Soil and Water Conservation. September/October 2003 : 290-300.

project specific and depend on parameters such as soils type, volume of water, treatment period, flow velocity, and sediment load. We found no information that would provide a firm opinion of cost for the application of PAM.

4.9.7 Conclusions and Recommendation

Based on results of previous studies, PAM may be considered a viable option in the lining of the South Side Ditch. However, PAM has historically been used as a means to prevent soil erosion and its use as a soil sealant is considered a new application of the product. There are very few projects to serve as an example for cost and performance and most of the studies reviewed indicate a need for additional research. With the research that has been conducted to date on polyacrylamides, there is no conclusive evidence that the application will (or will not) reduce transit losses in the South Side Ditch. It can only be said that a field study in eastern Colorado had favorable results which might be duplicated for this project.

It is important to note that PAM does not seal the natural soils. The studies suggest that adding the chemical causes suspended sediments to deposit in the bottom of the channel. It is this layer of fine material that decreases permeability. The soil samples gathered with this report (see paragraph 4.10.2) suggest this process is occurring in the South Side Ditch without the use of PAM. The samples indicate higher amounts of silt in the western (upstream) portions of the ditch. This implies that sediments are deposited along the ditch as water flows from west to east. It also implies that the farther east the water flows, the cleaner it becomes.

Previous studies examined short reaches where sediment concentrations were constant. When completed, the ADS will be approximately 18.5 mile long; or about 400 times as long as the studied reach.

If PAM is dependent on sediment laden water to deposit a layer of fine material, then there may be application problems with the South Side Ditch. The portion of the channel that is least impervious (the eastern portion) also has the cleanest water and less fine material available. The underlying question is whether or not there will be sufficient sediment left in the water for the PAM to be effective when applied.

If this option is to merit further consideration, it is the recommendation of this report to conduct a pilot study to develop an application program of PAM in the South Side Ditch. The pilot study should be conducted in the Phase 1 or Phase 2 portions of the projects were the highest permeability rates are expected. A study within the Phase 2 portion may yield better results because flow rates are typically higher. It would also be desirable to construct a portion of the proposed channel improvements to ascertain the performance of the PAM program with disturbed soils.

4.10 PROJECT PHASING

4.10.1 Regional Mean Permeability Data

Exhibit A5 shows regional soils permeability as estimated by the U.S. Geological Survey in Lawrence, Kansas. While not intended to be used for design purposes, the data provides a general overview for soil permeability within the region. The figure indicates that the entire South Side Ditch System is within an area having "rapid" mean soil permeability. There are some areas along the system that may exhibit "very rapid" and "moderately rapid" permeability. **Exhibit A5** was developed for this report to show that in general, the soils along the ditch are uniform in nature; all having potential for high transit losses. **Exhibit A5** suggests that there is no section of the channel that would benefit more from lining than any other section.

4.10.2 Collected Soil Samples

During the field reconnaissance phase of this study, five grab samples were taken along the South Side Ditch. **Exhibit A2** shows the location of each sample. Samples were taken from the bottom of the channel a grain size distribution was determined for each. Based on the grain size distribution, a permeability rate was established based on the D_{10} particle size. The results are shown in **Table 4.7**.

Table 4.7
Summary of Soil Samples

Sample	Description	D_{10} (mm)	Permeability (in/hr)	Seepage (gal/ft^2/hr)
1	Silty sand, SM	--		
2	Poorly graded sand, SP	0.26	95.8	59.73
3	Poorly graded sand with silt and gravel, SP-SM	0.206	60.1	37.49
4	Silty sand, SM	0.0025	0.009	0.01
5	Silty sand, SM	0.0037	0.019	0.01

The soil testing contradicts the information found on **Exhibit A5** in that it suggests that the permeability of the channel bottom is less in the western portions of the ditch. The information also suggests that the portion of the channel south of County Road 27 may not require lining. The results of the soil samples are speculative and more geotechnical investigation is warranted before the need for channel lining is determined. Because the grab samples were taken at the bottom of the channel, they may not be representative of the surrounding material. If the silt found in these areas were deposited from irrigation water, then the permeability values would not represent natural materials.

4.10.3 Reach 1

Reach 1 encompasses the selection and subsequent construction of one of the three return channel options presented. Reach 1 begins at the Arkansas River (depending on the Channel Return Alternate selected) ends at channel station 181+50 at the existing channel return for the South Side Ditch.

Construction of Reach 1 would provide a means of flow return to the river, but would not improve the capacity of the system. As indicated in **Table 3.3**, if Reach 1 were constructed, the capacity of the system would be limited by portions of the ditch scheduled for improvement with Reach 2. If only Reach 1 were to be constructed, the capacity of the ADS would be approximately 50 to 100 cfs.

4.10.4 Reach 2

Reach 2 entails approximately 5.6 miles of channel improvements from the end of Reach 1 (Station 181+50) to where the ditch crosses County Road 25 (Station 477+11). According to **Table 3.3**, this section is of the ditch consistently lacks the capacity to convey the 200 cfs design flow and will need to be enlarged. With the exception of a few locations, the ditch upstream of County Road 25 can convey the design flows and channel improvements are not as critical to the overall level of service provided by the system.

4.10.5 Reach 3

Reach 3 includes the portion of the ditch from County Road 25 (Station 477+11) to County Road 27 (Station 757+64) and includes approximately 5.3 miles of improvements. Based on the existing capacity and in-situ soil characteristics, the need to expand and line the channel south and west of County Road 27 is questionable. Reshaping of the channel would be required to install a liner and would promote a stable, more maintainable channel section. Reach 3 is considered a low priority project.

4.10.6 Reach 4

Channel Reach 4 consists of approximately 5.1 miles of improvements from County Road 27 (Station 757+64) to the South Side Ditch headgate structure (Station 1024+60). As discussed in **Section 3**, channel improvements west of County Road 25 may not be necessary to increase capacity. However, reshaping of the channel would be required to install a liner and would promote a stable, more maintainable channel section.

4.10.7 Phasing Options

For whatever lining option is selected, construction of the liner should be done in conjunction with the channel improvements necessary to increase capacity. It would not be cost effective to do each project separately.

4.10.7.1 Phasing Option 1

It is common practice to construct channel improvements beginning at the downstream end of the system and proceeding upstream. This ensures that the system upstream of the construct area always limits the amount of flow able to enter the system. When improvements are made to the downstream end of the first, the system has a greater capacity for exiting flows than entering flows. This approach tends to reduce flooding problems interior to the system.

The priorities for the Phasing Option 1 (in order of importance) are as follows:

- Establishing a new return close to the Farmer's head gate
- Improving system capacity in the ADS

For Phasing Option 1 the construction sequence of reaches would be as follows:

- Reach 1
- Reach 2
- Reach 3
- Reach 4

4.10.7.2 Phasing Option 2

Phasing Option 2 suggests the construction of Reach 2 first; thereby changing the phasing priorities. Instead of first providing a channel return close to the Farmer's head gate, this option would first increase the capacity of the ADS by expanding and lining Reach 2. The existing channel return would need to be temporarily incorporated in the ADS until the completion of Reach 1. This phasing option mimics, but improves upon, the current operation of the system.

The priorities for the Phasing Option 2 (in order of importance) are as follows:

- Improving system capacity in the ADS

- Establishing a new return close to the Farmer's head gate

For Phasing Option 2 the construction sequence of reaches would be as follows:

- Reach 2
- Reach 1
- Reach 3
- Reach 4

4.10.7.2.1 Advantages:

- This option would allow for a more expedited, overall project. It will take time to design and acquire the right-of-way needed for the new channel in Reach 1. Reach 2 is within the SSDA's existing right-of-way and work could be started sooner.
- Expansion and lining of Reach 2 could be done by the SSDA without involvement from an outside contractor.

4.10.7.2.2 Disadvantages:

- Despite the expansion of Reach 2, the capacity of the existing channel return will still limit the capacity of the ADS. Reach 2 could be constructed with no appreciable difference in ADS capacity.
- As previously discussed in Section 3, the point of return to the Arkansas River is approximately three miles from the Farmer's Ditch headgate. This option offers an immediate solution to transit losses in the river with respect to current operations.
- The existing property owner utilizes the existing bridge under County Road 243 as a cattle crossing. If the existing return is to be more frequently (albeit temporarily) used as part of the ADS, then the landowner will lose cattle access to both sides of the road. According to the representative of the SSDA, one of the conditions for using the ditch as part of the ADS would be to construct a new cattle crossing.

Section 5
System Simulation Model

5.0 SYSTEM SIMULATION MODEL

This report section discusses the hydrologic system simulation model for the Arkansas River and ditch systems of Kearny and Finney counties that was developed for the project area. The balance of this section describes the historic data used to develop the model, adjustments made to these data, the assumptions incorporated into the simulation model and modeling results.

5.1 HISTORIC FLOW DATA

The historic flow data used in development of the simulation model were collected by the U.S. Geological Survey (USGS) and Kansas Department of Agriculture, Division of Water Resources (DWR) at gauging stations on the Arkansas River and ditch diversion structures.

5.1.1 Arkansas River Discharge

Mean daily discharge data are available for a number of stream gauging stations on the Arkansas River in the project area. Some of these gages are still active and others have been discontinued. Table 5.1 lists these stream gages and their respective periods of record. The locations of these gauging stations are shown on **Exhibit A1**.

Table 5.1
Arkansas River Stream Gauging Stations

		Period of Record	
Number	**Name**	**Start**	**End**
07137500	Arkansas River near Coolidge, KS	10/01/1950	Present
07138000	Arkansas River at Syracuse, KS	08/21/1902 06/01/1921	09/30/1906 Present
07138020	Arkansas River at Kendall, KS	04/13/1979 06/01/2000	09/30/1982 Present
07138062	Arkansas R. bl. Amazon Div., KS	12/13/1977	10/06/1982
07138065	Arkansas River at Lakin, KS	04/07/1978	10/06/1982
07138070	Arkansas River at Deerfield, KS	10/01/1998	Present
07139000	Arkansas River at Garden City, KS	06/21/1922 01/01/1980	06/30/1970 Present

Declines in alluvial groundwater levels have been observed throughout the project area. These declines have occurred for various reasons including decreased stream flow and increased groundwater usage. Many of the groundwater supply systems in use today were developed during the 1960s and 1970s. The groundwater systems that are used for irrigation provide both supplemental supplies to lands served by surface water from one of the existing ditch systems and also irrigate lands not served by one of these ditches. The lack of stream flow and use of groundwater has caused the Arkansas River to become a losing stream between the Kansas-Colorado state line and Garden City some of the time, which significantly alters the flow regime in the river. Therefore, only those flow data collected since the development of these groundwater systems (post-1970s) are considered representative of current and future conditions.

Daily flow data for the stream gages listed in **Table 5.1** were retrieved from the USGS's National Water Information System. A summary of these flow data by month for calendar years 1980–2005 is included in **Appendix D**.

Within the project study area, the flow in the Arkansas River is highly regulated by John Martin Reservoir These annual flow volumes near the state line have ranged from a low of 26,338 acre-feet in 2003 to a

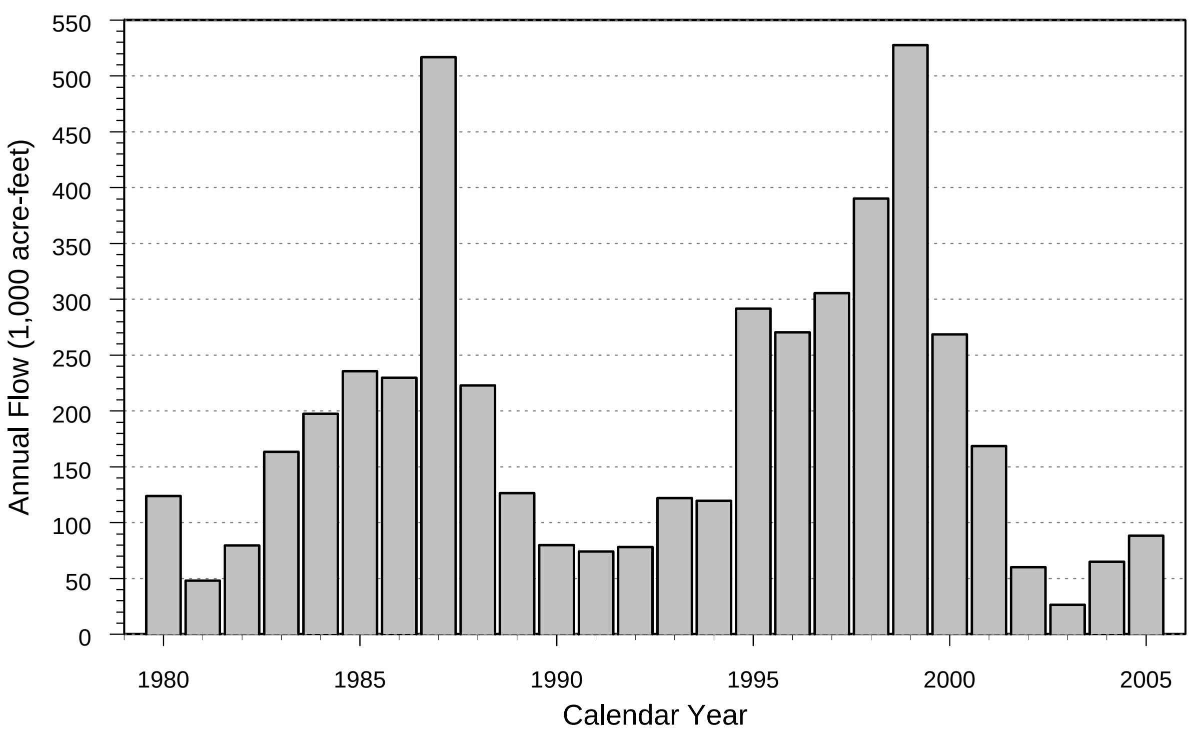


Figure 5.1
Annual Flow in Arkansas River near Coolidge, Kansas

high 527,744 acre-feet in 1999. These flows do not reflect the additional water that would have been available, had it not been for Colorado's lack of Compact compliance.[9]

5.1.2 Ditch Diversions

Historic daily diversions into the five ditch systems of Kearny and Finney counties were provided by DWR for calendar years 1980–2005. Monthly summaries of these ditch diversions are provided in **Appendix D**. **Table 5.2** lists average monthly and annual diversions for the five ditch systems for the available 26-year period of record. These same data are shown graphically in **Figure 5.2**.

Figure 5.2 gives an indication of the typical seasonal distribution of ditch diversions. As expected, the highest average diversions are concentrated during the growing season, particularly during the summer months of June, July and August. All of the ditches are shown to have significant average diversions from April through October. Also, the Great Eastern Ditch is the only ditch with significant diversions outside of the typical growing season. These winter-time diversions are used to build inventory in Lake McKinney for the upcoming irrigation season.

Table 5.2
Average Monthly Ditch Diversions for Calendar Years 1980–2005

Month	Amazon (acre-feet)	South Side (acre-feet)	Great Eastern (acre-feet)	Farmer's (acre-feet)	Garden City (acre-feet)
Jan	0	0	770	0	0
Feb	1	0	1,280	7	9
Mar	583	39	1,684	353	8
Apr	2,105	936	1,744	1,319	178
May	1,768	973	1,618	1,720	127
Jun	2,390	1,223	2,816	1.556	228
Jul	5,676	2,478	4,314	2,898	510
Aug	3,363	2,173	2,736	2,230	363
Sep	1,153	1,286	1,236	1,587	222
Oct	1,220	976	373	551	136
Nov	75	340	429	382	34
Dec	0	80	353	33	5
Annual	**18,334**	**10,505**	**19,352**	**12,636**	**1,820**

[9] An additional factor to consider is Colorado's violation of the Compact, which denied Kansas Stateline flows: The States stipulated to 328,505 AF of depletions for the period of 1950 to 1985 and the Special Master found that depletions of usable Stateline flow amounted to 91,565 acre-feet for the 1986 to 1994 period. Average depletions for the 1950 to 1985 period is 9,390 acre-feet per year and for the 1986 to 1994 period is 11,400 acre-feet.

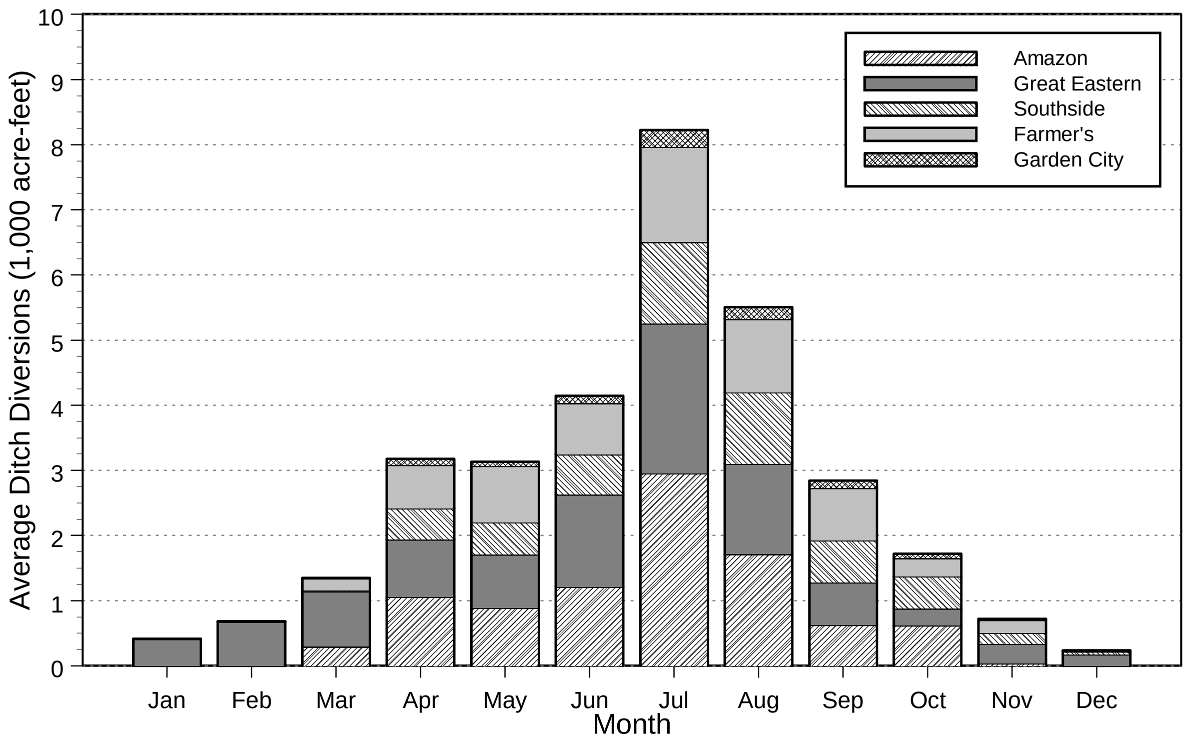


Figure 5.2
Average Monthly Ditch Diversions, 1980–2005

5.1.3 Discussion of Losing Stream Conditions

Historically, the Arkansas River was considered to be a gaining stream below the Colorado state line. Groundwater levels in the alluvial aquifer were typically near the surface so there was a net discharge from the aquifer to the river. However, due to the decreased flows and utilization of groundwater along the river valley and associated declines in groundwater level, the Arkansas River is now more often than not a losing stream.

Evidence of this is given by a simple comparison of Syracuse and Deerfield stream gages. The Syracuse Gage[10] is located upstream of the Bear Creek Fault and the Deerfield Gage[11] is located in towards the downstream end of the South Side Ditch (See **Exhibit A1**). Both monitor flows on the Arkansas River and the difference between the two correlates to the transit losses in the river. If the flow rates at the downstream gage (Deerfield) are lower than the upstream gage (Syracuse), then river is considered to be a losing stream.

[10] USGS 07138000 Arkansas River at Syracuse, KS
[11] USGS 07138070 Arkansas River at Deerfield, KS

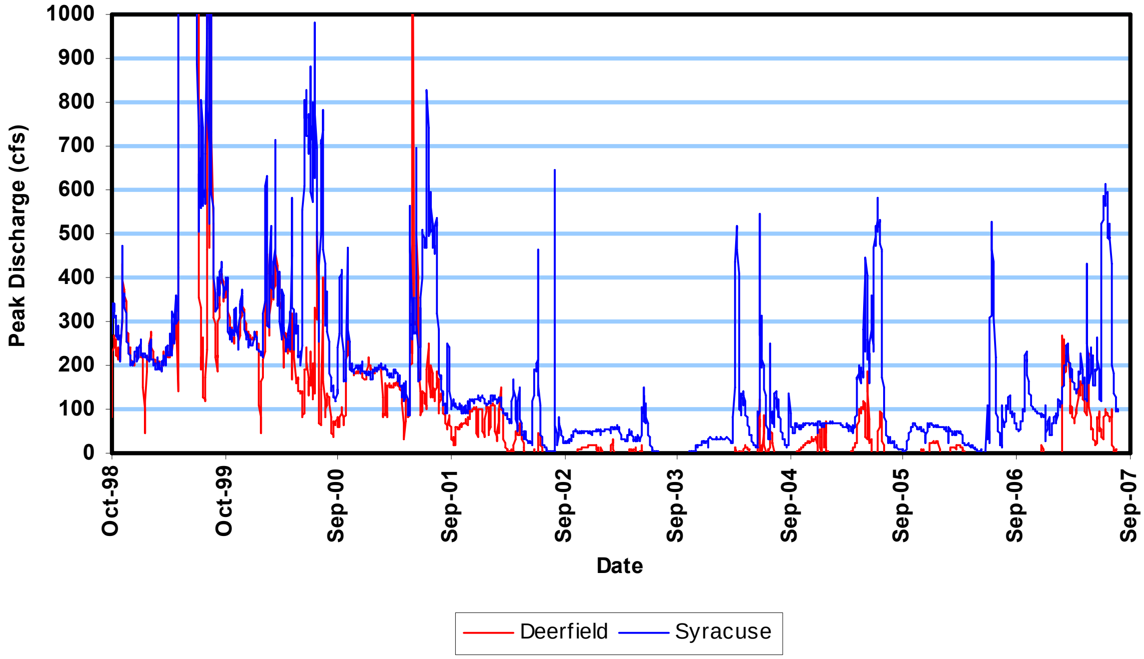


Figure 5.3
Syracuse and Deerfield Gage Data

Figure 5.3 shows the average daily peak flows for the USGS Gages at Syracuse and Deerfield. From October 1, 1998 through August 22, 2007 the gage data provides the following statistics:

Total number of days:	3248
Number of days with no flow at Syracuse Gage:	0
Number of days with no flow at Deerfield Gage:	1147
Percentage of time where no flow is observed at Deerfield Gage (annual average):	35%
Percentage of time where no flow is observed at Deerfield Gage (June through September average):	47%
Percentage of time where flow at Deerfield is greater than at Syracuse (340 days) Gage:	10%

The data also shows a worsening trend since 2002. From September 1, 2002 through August 22, 2007 the gage data provides the following statistics:

Total number of days:	1817
Number of days with no flow at Syracuse Gage:	0
Number of days with no flow at Deerfield:	1073
Percentage of time where no flow is observed at Deerfield Gage (annual average):	59%
Percentage of time where no flow is observed at Deerfield Gage (June through September average):	71%
Percentage of time where flow at Deerfield is greater than at Syracuse (78 days)	4%

The correlation of flow rates at the Syracuse Gage and the Deerfield Gage indicate two things. First, the Arkansas River between the Bear Creek Fault and Deerfield, Kansas is usually a losing stream. The historical gage data suggests that since October 1, 1998 (the period of record for the Deerfield Gage), the reach of the river loses water (primarily through consumption or to the alluvial aquifer) about 90 percent of the time. This statement is based on a comparison of gage data for the Deerfield and Syracuse Gages where 340 of 3248 gage readings showed the flow at the Deerfield Gage to be greater than the Syracuse Gage. This suggests that on average, conditions for a losing stream are present around 90% of the time.

Secondly, the data suggests a trend where conditions for losing a losing stream are increasing. From September 1, 2002 to August 22, 2007 there were 78 gage readings out of 1817. Within the last 5 years, the conditions for which the conditions are favorable for a losing stream have increased to 96%.

5.1.4 Arkansas River Infiltration Losses

The alluvial aquifer in the upper Arkansas River valley consists of sand, gravel and lesser amounts of silt and clay. The less permeable silt and clay sediments are generally found near the base of the alluvium. West of the Bear Creek fault in Hamilton and western Kearny counties (**Exhibit A1**), the alluvial aquifer is underlain by bedrock, which tends to confine groundwater to the alluvium itself. East of the Bear Creek fault however, the alluvial aquifer is underlain by the deep, unconsolidated deposits of the Ogallala, or High Plains, aquifer. The silt and clay deposits at the base of the alluvium may separate it from the

Ogallala aquifer and tend to limit the hydraulic connection between these two aquifer systems in places; however, these silt and clay layers are relatively thin and discontinuous west of Dodge City, allowing some groundwater to percolate downward out of the alluvium.

There are a number of factors that influence the timing and rate at which flow in the river may infiltrate into the alluvial aquifer at any given point. Among these factors are the following:

- Discharge rate of surface flow
- Local groundwater levels in the alluvium
- The current pumping rate of wells that draw from the alluvial aquifer
- Length of time that water has been flowing in the river

All of these factors tend to be very dynamic, varying both spatially and temporally so making accurate predictions of infiltration rates is difficult. For this reason, a simplistic analysis method was adopted that considers only the flow distance between points.

Reviewing the available periods of record for the Arkansas River stream gages (Table 5.1) shows there are only three gages that have data available for the entire study period (calendar years 1980-2005). These are the gages near Coolidge, at Syracuse and at Garden City. Therefore, the infiltration rate analysis was based on data from these gages only. The focus of this analysis was to estimate the flow available for diversion into each of the five ditch systems so this analysis concentrated on the river reach between the Syracuse and Garden City gages. All of the five ditch systems divert from the Arkansas River reach between these two gages.

For each day during the 26-year period of record, a simple water balance was developed to estimate the incremental flow gain or loss between Syracuse and Garden City. These incremental gain/loss values were calculated from the following equation:

$$I = Q_{GC} - Q_S + \sum_{i=1}^{5} D_i$$

Where I is the incremental gain/loss, Q_{GC} and Q_S are the respective discharge rates at the Garden City and Syracuse gages, and D_i are the current diversion rates for the five ditch systems. With this equation, a positive incremental river gain/loss indicates a net gain and a negative value a net loss in this river reach.

In a typical river system, the flow will increase in a downstream direction, after adjustments for significant diversions. However, the resulting daily gain/loss values for this reach of the Arkansas River range from -2,330 cfs (a net loss) to 1,250 cfs, and average -65.6 cfs. A large positive gain value would be expected during a significant local storm event but it is unlikely that the river would ever lose over 2,300 cfs to infiltration between Syracuse and Garden City. This anomaly could be due to measurement or transcription errors. **Figure 5.4** is a duration curve for the calculated incremental gain/loss values between Syracuse and Garden City. Examination of this graph shows that the Arkansas River suffers a net loss in flow about 80 percent of the time (net flow gain/loss is negative).

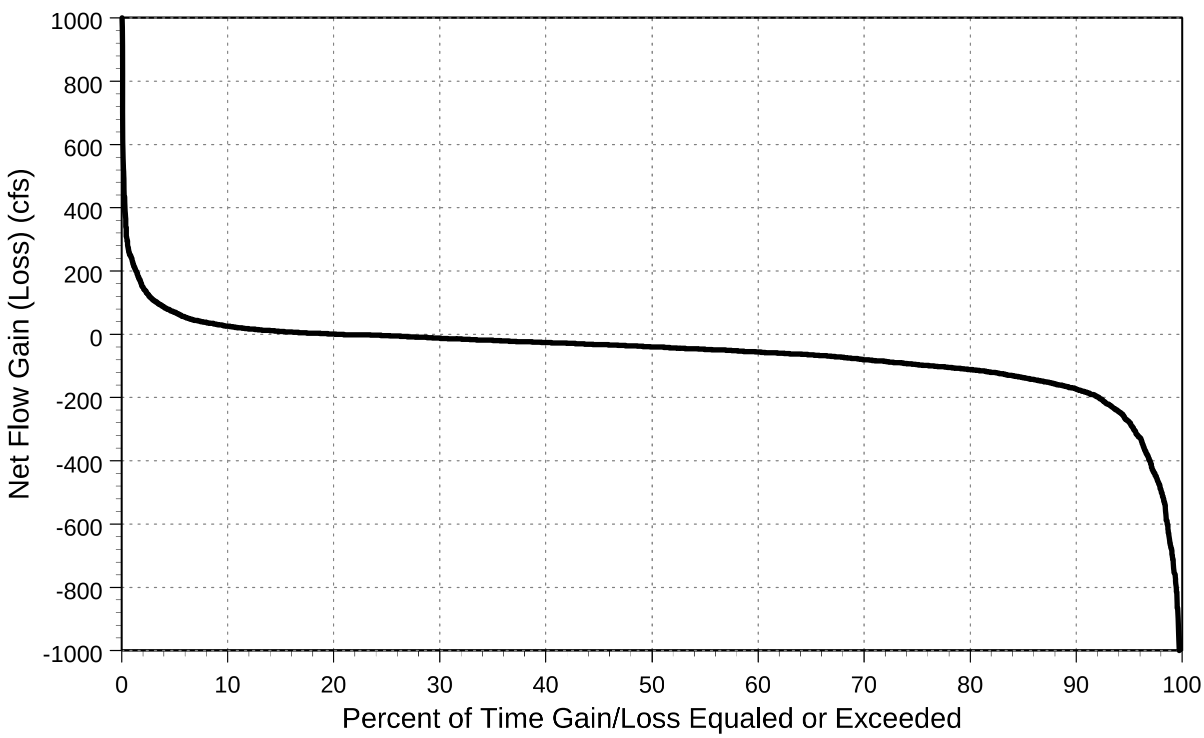


Figure 5.4
Duration Curve for Net River Gain/Loss between Syracuse and Garden City

The primary goal of this analysis was to estimate infiltration losses so the complete dataset of incremental gain/loss values was filtered to include only days with a net loss (negative value). This dataset was then further filtered to include only days during the primary irrigation season (April through September). These filters excluded approximately 64 percent of the available data values. The revised infiltration statistics with these modifications yield a range of -2,330 cfs to -0.3 cfs, and an average of -131.9 cfs. Because the flow at Garden City is often zero, many of the calculated infiltration rates are less than the potential infiltration in this river reach. To account for this underestimation effect, the 75th percentile value (152.0 cfs) was adopted as a reasonable estimate of the potential infiltration in this reach Syracuse and Garden City. With an approximate distance between these two river stations of about 59.5 miles, the potential linear infiltration loss is calculated to be approximately 2.6 cfs/river mile.

Basing potential infiltration estimates on a typical linear loss rate is a simplistic approach. However, the available mean daily discharge data do not themselves provide an efficient means for more sophisticated analyses. Review of the daily infiltration loss data described above show these rates are directly related to the available flow at the Syracuse gage. On average, the best-fit regression line for infiltration loss vs. discharge at Syracuse has an intercept of 39.0 cfs, a slope of 0.26 and a R^2 of 0.41. These results indicate the principal factor controlling infiltration loss is simply the amount of water available for infiltration. On average, about a quarter of the flow at Syracuse is lost to infiltration.

5.2 SIMULATION MODEL DISCHARGE DATA

The purpose of the simulation model is to estimate the impacts of the various alternative delivery and channel lining options. Therefore, it is necessary to adjust the historic flow data to estimate flows in the Arkansas River without any ditch diversions. These adjusted flows are then used as the base input data for the simulation model.

The adjusted historic flow data were developed using the following assumptions:

- The historic flows in the Arkansas River at the Coolidge and Syracuse gages are not affected by downstream ditch diversions so these values were not adjusted.
- Between Syracuse and Garden City any estimated flow gains or losses are assumed to be distributed linearly based on reach length.
- On any day with a calculated net loss between Syracuse and Garden City and a nominal "no flow" reading at Garden City (less than 1.0 cfs); the estimated potential infiltration loss (152.0 cfs) was substituted for the actual calculated loss.
- The adjusted flow at any point between Syracuse and Garden City is calculated as the flow at Syracuse plus or minus the incremental flow gains or losses (actual or potential) between Syracuse and this point. If the adjusted available flow at this point is less than the historic ditch diversions at this same point, then the incremental gain/loss is adjusted accordingly and the discharge below this diversion point is set to zero.

As stated in one of the assumptions above, flow gains and losses were distributed proportionately based on reach lengths. The estimated reach lengths between each model node are listed in Table 5.3.

Table 5.3
Arkansas River Reach Lengths

River Reach	Reach Length (miles)
Coolidge Gage→Syracuse Gage	19.19
Syracuse Gage→Kendall Gage	13.71
Kendall Gage→Amazon Ditch	6.86
Amazon Ditch→South Side Ditch	3.88
South Side Ditch→Lakin Gage	10.37
Lakin Gage→Alternative 1 Return	8.30
Alternative 1 Return→Deerfield Gage	1.00
Deerfield Gage→Alternative 2 Return	0.68
Alternative 2 Return→Farmer's Ditch	0.98
Farmer's Ditch→Garden City Gage	13.68

With these assumptions, adjusted daily flow estimates were made for each river node used in the simulation model. **Table 5.4** presents a comparison of the historic and adjusted incremental gain/loss between points and total flows at each of these points. The historic average flows at the Syracuse and Garden City gages are 249.6 and 97.3 cfs, respectively. With intervening average ditch diversions of 87.3 cfs, the average net infiltration loss between the Coolidge and Garden City gages is estimated to be 74.5 cfs. For the adjusted flow data, there are assumed to be no ditch diversions. The average discharge at the Garden City gage increases to 176.2 cfs with total losses of 84.0 cfs. Average total river losses increase for the adjusted data because eliminating the ditch diversions leaves more water in the river to infiltrate.

Table 5.4
Comparison of Historic and Adjusted Average Flow Data, 1980–2005

River Station or Node	Historic		Adjusted	
	Incr. G/L (cfs)	Total (cfs)	Incr. G/L (cfs)	Total (cfs)
Coolidge Gage	---	259.1	---	259.1
Syracuse Gage	-9.5	249.6	-9.5	249.6
Amazon/Great Eastern Diversion	---	---	-31.2	218.3
South Side Diversion	---	---	-5.0	213.03
Alternative 1 Return	---	---	-23.9	189.4

Table 5.4
Comparison of Historic and Adjusted Average Flow Data, 1980–2005

River Station or Node	Historic Incr. G/L (cfs)	Historic Total (cfs)	Adjusted Incr. G/L (cfs)	Adjusted Total (cfs)
Alternative 2 Return	---	---	-1.9	187.5
Farmer's Diversion	---	---	+1.1	188.6
Garden City Gage	-152.3	97.3	-15.3	173.2
Total Ditch Diversions	---	87.3	---	---
Total Gain/Loss→Coolidge–Garden City	-74.5		-85.9	---

5.3 SIMULATION MODEL ASSUMPTIONS

The hydrologic system simulation model for the project area was developed using Microsoft's Excel spreadsheet software. The basic goal of this simulation model was to investigate the potential impacts of various development alternatives on the delivery efficiency of the South Side and other ditches in the project area.

5.3.1 Ditch Operations

The ditch systems of Kearny and Finney counties are operated under a complex set of rules established by court order and agreements between the Associated Ditch companies. Each of the ditches has an assigned capacity, or authorized diversion rate, and a rotation order and volume. The rotation orders can come into play whenever the flow available for diversion from the Arkansas River is less than the total desired by all of the ditches. Most often these ditch systems are operated by mutual agreement but if two or more of the ditch associations request that DWR implement the rotation system, the ditches then take turns diverting water. The rotation order establishes the order in which they take turns and the rotation volume is the total volume they can divert before passing their turn on to the next ditch. When stream flows are sufficient, it is often possible for two or more of the ditches to divert simultaneously. **Table 5.5** lists the authorized diversion rate, rotation order and rotation volumes assigned to each of the five ditches.

Table 5.5
Ditch Operating Assumptions

Ditch	Authorized Diversion Rate	Rotation Order	Rotation Volume (acre-feet)
Amazon	200	1	3,000.0
South Side	200	2	3,000.0
Great Eastern	354	3	5,312.5
Farmer's	263	4	3,937.5

Table 5.5
Ditch Operating Assumptions

Ditch	Authorized Diversion Rate	Rotation Order	Rotation Volume (acre-feet)
Garden City	33	5	500.0

There are many other rules the can modify the basic ditch rotation process under certain situations. For example, if the amount of flow available for diversion into a ditch is less than 10 percent of its capacity, its diversion under the current rotation is canceled and the balance of its rotation volume is added to its next rotation. This and the other modifying rules are intended to promote the most efficient use of the available water.

Another factor controlling ditch diversions is the demand for irrigation water. Generally, most of the ditches divert water only during the active growing season. As previously described, the historic diversion data shows that only the Great Eastern ditch routinely diverts during the non-growing season to build inventory in Lake McKinney for use during the upcoming irrigation season. Based upon review of the historic diversion data, ditch demands were assigned by month as shown in **Table 5.6**.

Table 5.6
Ditch Demand by Month

	Ditch Demand (percent of capacity)				
Month	Amazon	South Side	Great Eastern	Farmer's	Garden City
Jan	0	0	100	0	0
Feb	0	0	100	0	0
Mar	0	0	100	0	0
Apr	100	100	100	100	100
May	100	100	100	100	100
Jun	100	100	100	100	100
Jul	100	100	100	100	100
Aug	100	100	100	100	100
Sep	100	100	100	100	100
Oct	100	100	100	100	100
Nov	0	0	0	0	0
Dec	0	0	0	0	0

As shown in **Table 5.6**, all of the ditches are assumed divert up to 100 percent of their capacity whenever water is available for the months of April through October. In addition, the Great Eastern ditch is assumed to divert at up to 100 percent in January, February and March. During the months of November and December, none of the ditches are assumed to divert. These monthly demand rates were assumed to apply each and every year, with no attempt to modify demands based on historic precipitation amounts.

In the system simulation model, a simplified procedure was used to model the operation of the five ditches. Given the demand assumptions presented above, each ditch would want to divert 100 percent of its authorized diversion rate continuously during its respective irrigation season. Under these conditions, it is unlikely there would be sufficient water supplies in the river to satisfy all demands. Therefore, to ration the available supplies, the basic ditch rotation system was assumed to be active at all times. In any month when a ditch has an irrigation demand (**Table 5.6**), diversions are allocated based on this rotation system wherein each ditch has an assigned rotation order and volume (**Table 5.5**). The additional modifying rules, such as when to cancel a ditch's current rotation, were not considered in the simulation model.

5.3.2 South Side Ditch Infiltration Rates

In addition to losses in the Arkansas River channel between Coolidge and Garden City, the simulation model also considers infiltration losses from the South Side Ditch. Infiltration losses from the other ditches were not evaluated in this study. Infiltration rates were estimated for the main South Side ditch only, and not for its laterals, with various alternatives for channel lining. For each of the lining alternatives, it was assumed that the entire ditch would be lined.

The infiltration loss estimates for the South Side main ditch are summarized in **Table 5.7**. The rates listed in this table are for the entire main ditch. With its daily time step, the simulation model assumes that the main ditch is either empty (dry) on days with no diversions to the ditch, or full along its entire length on days with diversions.

Table 5.7
South Side Ditch Infiltration Estimates

Model Alternative [1]	Main South Side Ditch Infiltration Loss (cfs) Unlined [2]	Fly Ash	Other [3]
Base	33.7	6.7	0.0
Alternate No. 1	32.1	6.4	0.0
Alternate No. 2	34.8	7.0	0.0
Alternate No. 3	35.9	7.2	0.0

Table 5.7
South Side Ditch Infiltration Estimates

Model Alternative [1]	Main South Side Ditch Infiltration Loss (cfs)		
	Unlined [2]	Fly Ash	Other [3]

1. Model alternatives are discussed below in **Section 5.4**.
2. Existing conditions.
3. All other lining alternatives considered — concrete, compacted clay, bentonite, synthetic, etc. — have calculated infiltration rates less than 0.1 cfs so these rates were all treated as zero.

5.3.3 Model Architecture

In the simulation model, eight river stations, or nodes, were identified on the Arkansas River in the project area. These eight nodes represent the locations of existing flow gages, ditch diversion points and alternative ditch return locations for the South Side Ditch. These river nodes are the same ones listed in **Table 5.4**:

- Coolidge Gage
- Syracuse Gage
- Amazon and Great Eastern Diversion
- South Side Diversion
- South Side Ditch Return–Alternative 1
- South Side Ditch Return–Alternative 2
- Farmer's Diversion and South Side Ditch Return–Alternative 3
- Garden City Gage

For each of these river nodes, the simulation model tracks the following flow rates or volumes:

- Total adjusted gain/loss between upstream and current node with no ditch diversions (**Section 5.2**)

- Total adjusted flow at node from upstream with no ditch diversions (**Section 5.2**)
- Actual gain/loss between upstream and current node after applicable upstream diversions
- Actual flow at node from upstream after applicable upstream diversions
- Ditch diversions from this node
- Ditch returns to this node (from South Side Ditch only)
- Flow from upstream that is allocated to satisfy downstream diversions and intervening channel losses below node
- Downstream flow

The main processing loop of the simulation model performs the following steps for each day during the 26-year period of record:

- Determine first ditch in rotation order for current day—next ditch in rotation with nonzero demand rate in current month.
- Calculate actual and allocated flows at each river node.
- Starting with the first ditch in rotation, calculate its diversion rate as the lesser of the flow available for diversion (actual minus allocated flow), its capacity, and the volume required to satisfy its remaining rotation volume deficit.
- If this ditch's rotation volume is satisfied, zero its rotation account for the next rotation and make the next ditch in rotation the first ditch.
- Re-calculate actual and allocated flows after diversions to the first ditch.
- Jump to next ditch in rotation order and repeat three prior steps.
- Continue looping through each of the ditches in order until no further diversions are possible on this day.
- Write model results to worksheet and continue with next day.

5.4 MODEL ALTERNATIVES

The various model alternatives considered in this study are described in this section. These alternatives include combinations of four alternative configurations for the South Side Ditch and three alternatives for lining this ditch, for a total of 12 model alternatives. The four ditch configuration alternatives are as follows:

- Base – The South Side Ditch is used in its current state for delivery of irrigation water to its members only.
- Alternative 1 – Under Alternative 1, the Southside Ditch is used both for delivery of water to its members and as an alternative delivery route for flows intended for the Farmer's and Garden City ditches. Under Alternative 1, all deliveries for the downstream ditches are routed through the Southside Ditch and returned to the Arkansas River through the existing return canal.
- Alternative 2 – Alternative 2 is similar to Alternative 1 except that returns to the river would occur through construction of a new canal that parallels Deerfield Lane.
- Alternative 3 – Alternative 3 is also similar to Alternatives 1 and 2 but returns to the Arkansas River would occur through an extension of the existing main Southside Ditch. This ditch extension would merge with the river immediately upstream of the diversion point for the Farmer's and Garden City ditches.

The three modeled lining options for the South Side main ditch are the same as those listed in **Table 5.7**: unlined (existing conditions), lined with fly ash/soil mixture, and all other lining methods with very low infiltration rates (for example, concrete, clay, bentonite, synthetics, etc.).

5.5 MODELING RESULTS

The system simulation model described above was executed for each of the 12 model alternatives. Each model run generates daily estimates of flow at each river node and diversions into each ditch system for the 26-year simulation period, a total of 9,497 days. Because of the large amount of data generated by the model, all of these model runs will be provided to the Kansas Water Office (KWO) in an electronic format. The intent of this report section is to summarize the most important results from these model runs. The primary goal of this study is to investigate ways to make more efficient use of available surface water supplies so a comparison of average infiltration losses is provided in **Table 5.8** for each model run. Figure 5.4 is a graphical representation of these same data.

Review of **Table 5.8** and **Figure 5.4** shows that the alternate delivery alternatives (Alternatives 1, 2 and 3) could actually increase net infiltration losses if the South Side Ditch is left in its current, unlined state. However, the simulation model is believed to overstate the remaining infiltration losses in the Arkansas River for all of the alternative delivery options. This occurs because the timing and rate of releases from John Martin Reservoir are not synchronized completely with the simulated ditch diversions. Historic discharges in the Arkansas River at the Kansas-Colorado state line were not adjusted for the simulation model but these discharges are highly influenced by when calls are made for reservoir releases. Under the alternative delivery options, the goal is to divert all river flows through the South Side Ditch to reduce infiltration losses in the river channel itself. However, because reservoir releases are not synchronized with these diversions, there are periods when the following occurs:

- Maximum allowable diversions (200 cfs) are being made through the South Side Ditch.
- The other upstream ditches (Amazon and Great Eastern) have satisfied their allowed diversion volumes under the current rotation so they are at the end of the rotation order and currently restricted from any further diversions.

The flow in the Arkansas River at the South Side Ditch's diversion exceeds 200 cfs so there is a net flow past this diversion point.

Because there is still flow in the river reach between the South Side and Farmer's diversions under the stated conditions, there may be little or no simulated reductions in river channel infiltration losses on this date even though most of the potential river flow has been rerouted through the South Side Ditch. In addition to these continuing river channel losses, additional flow losses are incurred as the rerouted flow passes through the South Side Ditch. In actual operation, reservoir releases and upstream ditch diversions would be optimized to divert 100 percent of the river flow at the Southside diversion whenever possible, resulting in an additional reduction in transit losses over those shown in the simulation model. In an attempt to account for this phenomenon, the allowable diversion rates shown in **Table 5.5** were increased by 50 percent in the simulation model because the simulation model is not sophisticated enough to re-regulate river flows or override the ditch rotation process when required to minimize transit losses. Given that the total net Arkansas River infiltration losses are likely overstated in the simulation model, the alternative delivery options are likely more advantageous than portrayed in **Table 5.8** and **Figure 5.5**.

Table 5.8
Summary of Simulation Modeling Results

Alternative	Lining Method	Average Annual Net Infiltration Losses (acre-feet) Arkansas River [1]	South Side Ditch	Total
Base	Unlined	38,230	3,360	41,591
	Fly Ash	38,230	711	38.942
	Other [2]	38,230	0	38.230
Alternate 1	Unlined	36,102	7,423	43,525
	Fly Ash	36,128	1,598	37,725
	Other	36,104	0	36,104
Alternate 2	Unlined	35,757	7,793	43,550
	Fly Ash	36,735	1,691	37,426
	Other	35,702	0	35,702
Alternate 3	Unlined	36,805	7,505	44,310
	Fly Ash	36,933	1,574	38,508
	Other	37,027	0	37,027

1. Estimated net infiltration losses in Arkansas River between Coolidge and Garden City gages.
2. "Other" lining methods include concrete, compacted clay, bentonite, synthetic, etc. Each has a calculated infiltration rate less than 0.1 cfs and was treated as zero.

The potential benefits of lining the South Side Ditch are clearly shown in the modeling results. Modeling indicates that a fly ash liner would result in approximately an 80% reduction in ditch losses and an 8% reduction in total losses.

Lining methods such as a soil/bentonite matrix, earthen matrix and synthetic liners are estimated to virtually eliminate infiltration losses, would save near 100% of ditch losses and up to 14% of total infiltration losses.

Section 6
Project Impacts

6.0 PROJECT IMPACTS

6.1 INTRODUCTION

This section outlines some of the impacts associated with the channel lining and construction of the Alternate Delivery System (ADS) proposed by this report. Impacts may include, but are not necessarily limited to the following:

- Identification of beneficiaries
- Effect on water rights
- Effect on water quality
- Construction and permitting
- Public Safety

6.2 WATER RIGHT IMPLICATIONS

6.2.1 Regional Water Rights

Between the South Side and Farmer's headgates, there are approximately 285 water rights in the IGUCA, one hundred (100) of which are vested. The Finney County Water Users Association (FCWUA), owners of the Farmer's Ditch, and the Garden City Ditch Company (owners of the Garden City Ditch) have vested water rights which allow them to divert surface water from the Arkansas River. These vested rights allow surface water to be diverted from the Arkansas River, whether the surface water is released from accounts in John Martin Reservoir or from other flows. During periods of low flows in the Arkansas River, the associated alluvial aquifer becomes depleted resulting in significant losses of river flow. It is under these circumstances, the Farmer's and Garden City ditches are not able to divert surface water from the Arkansas River, or are limited in the amounts that they can divert.

6.2.1.1 Water Rights Terms

A **water right** is any vested right or appropriation right under which a person may lawfully divert and use water. It is a real property right appurtenant to and severable from the land on or in connection with which the water is used and such water right passes as an appurtenance with a conveyance of the land by deed, lease, mortgage, will, or other voluntary disposal, or by inheritance.

A **point of diversion** is the location at which water is diverted or withdrawn from a source of water supply.

The **Chief Engineer** refers to the position of chief engineer of the Division of Water Resources of the Kansas Department of Agriculture.

A **vested right** pertains to a person under a common law or statutory claim to continue the use of water having actually been applied to any beneficial use, including domestic use, on or before June 28, 1945. These water rights were those in existence prior to the acceptance of the KWAA of 1945. This group of users includes all of the Associated Ditches and some groundwater users.

An **appropriation right** gives a person the right to divert from a definite water supply a specific quantity of water at a specific rate of diversion, provided such water is available in excess of the requirements of all vested rights that relate to such supply and all appropriation rights of earlier date that relate to such supply, and to apply such water to a specific beneficial use or uses in preference to all appropriations right of later date. Appropriated rights pertain to points of diversion that were developed after and in accordance with the KWAA of 1945.

6.2.2 Point of Diversion

6.2.2.1 Accounting of Water

The operation of ADS would create a fairly unique situation. When operated, water would be diverted at the SSDA's point of diversion, routed through the South Side Ditch, returned to the Arkansas River, routed down the river, and then diverted again at the Farmer's Ditch's point of diversion. With diverted flow closely monitored at the headgate of the South Side Ditch, flows diverted on behalf of the Farmer's Ditch would be subtracted from the SSDA's water appropriation. The same flows would again be subtracted from the FCWUA's water appropriation.

Figure 6.1
South Side Ditch Parshall Flume

A more complex procedure for accounting will be necessary to monitor and fairly appropriate water between the two ditch companies. A new flow monitoring structure will need to be added where flow in the South Side Ditch is returned to the river.

When the ditch is being used as the ADS, flow measurements at the South Side Ditch headgate (inflow) would be subtracted from the SSDA's water appropriation. Flow measurements at the return (outflow) would be credited back the SSDA's account. The inflows will always be higher than the outflows due to transit losses in the ditch. Transit losses should not be deducted from the SSDA's allocation when the water diverted is not for their use. Transit losses without using the ADS would occur prior to diversion from the river itself. However, transit losses will serve the benefit of the water users in the area by recharging the aquifer.

6.2.2.2 Responsibility of the Chief Engineer

Water right options that could be considered:

- Create an alternate point of diversion for the Farmer's and Garden City Ditches that coincides with the SSDA's point of diversion.

- The SSDA diverts water on behalf of the Farmer's Ditch, with SSDA being credited for the amount returned to the river. The Chief Engineer may need to put conditions on the SSDA that there is an operational agreement with the FCWUA before credits are given.

Regardless of the diversion scheme selected, a detailed operational plan will need to be developed that addresses the conditions for which an alternate diversion can be made and how water is accounted. These options should be utilized only at times where the alluvial aquifer is significantly depleted and operation of the ADS results in the reduction of large transit losses in the main Arkansas River channel between the South Side and Farmer's headgates

6.2.3 Alternate Delivery System Agreement

An agreement between the SSDA, the FCWUA and Garden City Ditch Company would be useful for a fair and equitable plan of operations should the ADS be implemented. The following are items offered for consideration.

- The Agreement should state that the three associations are subject to the terms and conditions of the *Rules and Regulations, the Compact, and any other appropriate documents, all of which shall* take precedent over those of the new Agreement.

- The Agreement should clarify that the authorized capacity of the South Side Ditch is 200 cfs. This is less than the 250 cfs authorized for the Farmer's Ditch. The Alternate Deliver System will not be able to convey the full rate needed for the Farmer's Ditch.

- The SSDA should not be required to guarantee the amount or quality of water that reaches the head structure of the Farmer's Ditch.

- The SSDA should maintain senior rights to use of the system. The ADS will not have the capacity to allow simultaneous operation by both parties.

- The Agreement should state that when an alternate delivery is being made to the FCWUA, the SSDA cannot divert water from the system. Terms of the agreement should pay special attention to the restrictions put on the SSDA. The SSDA should not be restricted from diversion under all conditions (i.e. if extra water was available in the system.)

- FCWUA should participate in the annual maintenance and operation costs of the ADS. If annual fee is imposed on the FCWUA, it is recommended that a budget be established and agreed upon by both parties that is particular to just the ADS. This would earmark FCWUA's contribution to the maintenance of the ADS and not the entire South Side Ditch. An annual operating budget could be negotiated every year.

- The Agreement should define those portions of the South Side Ditch System that comprise the ADS. This would be the main channel from the headgate to where the water is returned to the river near Deerfield. Laterals and other returns would be excluded from the definition.

- It has been suggested that the Agreement provide guidelines that prescribe when the South Side Ditch should be used for alternate delivery. Given the complexity of operational conditions, it is recommended not to include too much detail on this subject in the Agreement itself.

- The Agreement should clarify that water accounting for the FCWUA will continue to be conducted at the headgate structure for the Farmer's Ditch.

- It is recommended that the term of the Agreement be for an extended period of time. The improvements needed to upgrade the system will be quite expensive and both parties should be held to a long term investment in the operation and maintenance. A minimum specified term of agreement guarantees the period for which the improvements made to the South Side Ditch benefit the region. It is reasonable to assume that the life of the project will be 20 to 25 years. After that time, a major effort could be expected to rehabilitate the ditch. Therefore it is recommended that the minimum term of the agreement also be 20 to 25 years.

- The Agreement should set forth minimum standards for maintenance of the ADS. Consideration should be given to joint annual inspections with both parties having the opportunity to identify maintenance needs. These needs could then be used to establish the year's maintenance budget.

- The Agreement should establish terms of indemnification. It is recommended that indemnification be established for both parties. The SSDA should be held harmless if the ADS fails to provide water due to circumstances beyond its control. Considerations should also be given to insurance and worker's compensations. For example, if the SSDA's ditch rider were to be injured on the Alternate Deliver System, would the FCWUA be partially liable?

6.3 EFFECT ON WATER SUPPLY

It is anticipated that the net impact on groundwater when the considering regional usage will be negligible. If the recommended improvements are implemented, then recharge to the alluvial aquifer may be reduced during some years and may be increased in others. Using the ADS could result in additional alluvial aquifer drawdown under some conditions in some areas. However, when river flows recover, then the alluvial aquifer will again recharge. The overall intent of the project is to increase the availability of surface water. Both the lining options and ADS projects are designed to reduce transit losses from surface water to the underlying aquifer.

6.4 EFFECT ON WATER QUALITY

The Arkansas River at the Colorado/Kansas State line has been recognized by the Colorado Department of Public Health and Environment (CDPHE) and Kansas Department of Health and Environment (KDHE) as one of the most saline fresh water rivers in the U.S., with total dissolved solids (TDS) concentrations of 3,000 to 4,000 mg/L common. Upper Arkansas Basin Total Maximum Daily Loads (TMDLs) have been or are being prepared by the KDHE for sulfate, fecal coliform bacteria, pH, boron, fluoride, ammonia, and nutrient oxygen demand.[12]

[12] Spronk Water Engineers, Inc., Wright Water Engineers, Inc., Upper Arkansas River Conservations Project Reconnaissance Study (Denver, 2005), 9.

Water quality in the Arkansas River is most affected by variations in flows. If flow rates are low the TDS concentrations are typically high while higher flow rates tend to dilute sulfate concentrations. It can be expected that sulfate concentrations would be at the highest concentrations when the ADS would be in use. As discussed previously in this report, the improvements recommended by this study will only result in a redistribution of water between the surface and the alluvial aquifer. With this project there are no changes in demands, no change in water quality entering the state, no treatment of flows once diverted from the river and no overall reduction in salts within the system. Thus the amount of salts entering the system will remain unchanged. Because the project will inhibit recharge of the alluvial aquifer when the Alternative Delivery System is in use, a slight improvement to water quality could be achieved in the alluvium in the reach between the South Side diversion and the return to the river. However, this improvement within the aquifer would come at the expense of surface conditions. High TDS concentrations would be moved to the fields away from the river alluvium.

In order to maximize benefits of high flow water to improve the quality of the water recharged to the river alluvium the ADS would need to be used only during low flow periods in the Arkansas River and only when all of the flow is diverted at the Farmer's Ditch head gate for irrigation purposes. Periods of low flows will have the highest concentrations of TDS and it will be desired to divert as much water to the fields as possible. Periods of high flow have lower concentrations of TDS and these flows will be desirable for recharge purposes.

6.5 PUBLIC SAFETY

There are two (2) areas that present safety concerns to land owners along the ditch. The areas are indicated on **Exhibit A3**. Both areas are at the downstream end of the existing system where the channel is small and the flow rates are very low because of low demand. The construction of Channel Return Alternates 3 will introduce a large channel adjacent to two existing farmsteads. Safety measures such as fencing and/or signage would need to be constructed to prohibit access to the ditch. Realignment of the channel return is another option, but that would require additional encroachment into agricultural land.

6.6 BENEFICIARIES AND COOPERATIVE PARTIES

This section identifies those parties that may be impacted by the project. Impacts may be beneficial or adverse.

6.6.1 Finney County Water Users Association and Garden City Ditch Company

The FCWUA operates and maintains the Farmer's ditch system and the Garden City Ditch Company operates and maintains the Garden City Ditch system, both shown on **Exhibit A1**. The Farmer's Ditch delivers water from its headgates to a drop structure that provides water to the Garden City Ditch. These two associations are the primary benefactors of the ADS and channel lining projects.

6.6.2 South Side Ditch Association

The SSDA owns and operates the South Side Ditch System, for which improvements in this feasibility study are proposed. The SSDA will benefit from the project with improvements to their diversion structures and irrigation ditches.

6.6.3 Groundwater Management District 3

Groundwater Management District 3 (GMD3) is a quasi-governmental organization created to properly manage groundwater resources, promote conservation of groundwater resources, and prevent economic deterioration with respect to agriculture and groundwater resources. For purposes of this study, GMD3 represents the groundwater users in the region. GMD3 desires to see flows in the river maximized because of the groundwater recharge benefits whenever possible. However, it does not want to see administration of groundwater wells in order to protect surface water deliveries, if there are alternatives. Without the project, DWR may need to administer water rights to protect senior surface water rights along the river. GMD3 is willing to accept reduced alluvial aquifer recharge in some years to sustain the most benefit of the water resource to all users.

6.6.4 Kansas Department of Transportation

The Kansas Department of Transportation has infrastructure where the ADS crosses State Highway 25 south of Lakin. The hydraulic analysis suggests that the existing bridge is adequate to convey the authorized discharged, so replacement of the bridge will not likely be necessary.

Construction access to and from Highway 25 will require approval from KDOT. Depending on the lining option selected, KDOT may be concerned with excessive truck traffic and the impacts to the highway. Pavement repair of Highway 25 may be an additional cost associated with the project.

6.6.5 Kearny County, Kansas

All of the work associated with the project will occur in the unincorporated area of Kearny County, Kansas. The ADS crosses many of the County's roads. Several bridges and culverts will need to be replaced to meet the capacity requirements of the improved ditch. Some new bridges may be necessary for the new channel return to the Arkansas River. The Kearny County Public Works Department will require the construction contractor to obtain a permit for all work within the County right of way.

The County Public Works Department will be concerned with haul routes and the impacts of excessive truck traffic on its infrastructure. The County has no set criteria for road repair associated with projects of this nature. When construction activities begin to impact roads, the County Public Works Department will encourage the construction contractor to make repairs. Repair of county roads may be an additional cost associated with the project.

The County Zoning/Building Office has regulating authority for work within the County. The Zoning Office was contacted in preparation of this report. The County currently requires no special permits for a project of this nature. The County would like to have a copy of the contract between the State and the Contractor.

A project of this nature does not have modern precedent. Large scale construction projects are not common in Kearny County and local codes and ordinances do not address projects of this nature.

6.6.6 Private Land Owners

Private landowners are identified as sources of additional costs necessary to increase conveyance capacity of the ADS. Currently, the South Side Ditch lies within a 60 foot right of way. This allows the SSDA the right of egress to operate and maintain the existing system. Given the channel improvements proposed by this report, the 60 foot right of way may not be a sufficient width. The need for additional land is likely for both construction and permanent maintenance of the system. Additional right of way may be required to accommodate the new channel improvements and temporary construction easements may be required.

Other anticipated costs associated with private landowners may include the following items:

- Compensation for crop loss
- Restoration of land to pre-construction conditions
- Relocation of irrigation equipment
- Repair of damage to irrigation equipment
- Repair of private roads
- Temporary easements for staging areas necessary for construction activities
- Removal and replacement of sprinkler bridges would be a cost to the landowner

For Alternates 2 and 3 of the Channel Return scenarios, no existing right of way exists and the property would need to be secured from landowners who are beyond the service area of the South Side Ditch System.

6.6.7 Railroad

The railroad infrastructure lies on the north side of the Arkansas River. No impacts are expected as a result of this project.

6.6.8 Utility Companies

6.6.8.1 Electric

A review of the mapping provided by the Kansas Corporation Commission mainly shows aerial distribution lines in the area along the ADS. Buried distribution lines would present the opportunity for utility relocations, but there appear to be none within the project area. One 115KV transmission main will cross the project in W½ S36 T24S R36W.

6.6.8.2 Other Utilities

No detailed information was found pertaining to gas, communications and water lines impacted by the proposed project. It is assumed that any conflicting utilities would be identified when detailed topography is collected for the design phase of the project. Utilities are expected to consist of small mains and service connection which would need to be adjusted to accommodate widening of the channel. As the area is primarily agricultural, utilities are expected to be concentrated near roads.

Costs associated with utility relocation are assumed to be minor with respect to the overall project and are included in the contingency amount.

Section 7
Recommendations & Conclusions

7.0 RECOMMENDATIONS AND CONCLUSIONS

7.1 ALTERNATE DELIVERY SYSTEM

This report recommends improvements to the South Side Ditch to allow for its use as an ADS. The analysis described herein verifies that such a system (if lined) would provide a significant reduction in transit losses to the Arkansas River and would allow the Farmer's and Garden City Ditches to more efficiently receive water for irrigation.

In order for the ADS to function most efficiently, two improvements need to be made to the existing ditch. First, portions of the ditch need to be enlarged so that a sufficient flow can be conveyed through the system. Second, those sections of the ditch that are enlarged would need to be lined with an impervious material. While the ADS would function without a lining, both expansion and lining will be needed for optimal management of water.

The feasibility of the ADS is best proven by past operation. It has been reported by the South Side Ditch Association that the South Side Ditch has been successfully operated as an ADS at least twice in recent history. It was reported that during these times, not enough flow could be "pushed" down the river to overcome the transit losses. By using the South Side Ditch to divert flow around the river, a successful delivery was made to the Farmer's head gate.

7.1.1 Reaches to Construct

For this study, the ADS was divided into four (4) reaches (see **Exhibit A2**). It is the conclusion of this report that the construction of Reaches 1 and 2 are imperative to the success and operation of the ADS. Reach 2 needs to be improved to ensure adequate capacity of the system. Reach 1 is the construction of the channel return to the river.

Reaches 3 and 4 would add some benefit to the overall project, but should be considered optional work. If kept well maintained, these reaches should generally provide the desired capacity. A few localized areas may need to be addressed.

7.1.2 Necessity for Lining

If constructed, Reaches 1 and 2 will need to be lined to prohibit transit losses. Modeling suggests that if left unlined, the reaches could exhibit the same transit loss potential as the Arkansas River.

The existing ditch has not been disturbed in many years. The fine sediments that have been deposited over years of use act as barrier to infiltration. Any portions of the channel that are disturbed by construction will lose this natural barrier. Once the barrier is lost, the ditch could exhibit the same transit loss characteristics of the river.

Reaches 3 and 4 currently show the greatest amount silt deposition in the channel. Left undisturbed, these reaches should demonstrate a reasonable resistance to transit losses; one of the reasons these reaches are considered to be optional.

7.1.3 Advantages

- The ADS would allow Finney County Water User Association and Garden City Ditch Companies to retrieve their allocated portion of surface water.
- The ADS will allow more efficient use of Kansas's allocation of Arkansas River Compact surface water.
- Reduce groundwater pumping associated with lands irrigated by the ditch companies.
- The ADS will indirectly promote groundwater recharge in the Farmer's and Garden City Ditch service areas.
- The ADS would promote a greater usage of surface water irrigation in the South Side, Farmer's and Garden City Ditch services areas. This could result in improved maintenance of the system and a cost savings of groundwater pumping.
- The ADS will provide an additional tool for water resource management in the area.
- The project fulfills a goal of the Water Conservation Project Fund by recovering a reasonable amount of base flow.

7.1.4 Disadvantages

- The existing ditch will need to be expanded and could cause the loss of agricultural land to adjacent property owners.
- With the intent of the project to reduce transit losses, the project would reduce aquifer recharge.
- The operation of the ADS introduces additional complexity of the regional water management policies.

- The costs associated with operation and maintenance of the ADS will be an increased burden to the South Side Ditch Association, Finney County Water Users Association, and the Garden City Ditch Company.

7.2 CHANNEL RETURN ALTERNATE

Four options were considered for the means of returning flow to the Arkansas River (see **Section 3** for more detailed discussion). Alternates 1, 2 and 3 are considered capital improvements by either improving an existing ditch or by constructing a new channel return to the river. Alternate 4 examined a “no action” option for which the existing channel return would be used in its current condition. Alternate 4 was used for comparison with the other three alternates and provides justification for construction of a channel return. When comparing the “no action” option to the other three, it is apparent that the only real benefit to Alternate 4 is the cost savings of taking no action. Alternate 4 would limit flow through the ADS and the overall system would not have the desired delivery rate. In addition, Alternate 4 does not help to reduce transit losses. Finally, the owner of the property through which the existing return is routed is adverse to the project.

There are two recommendations associated with channel return options. The first is whether or not to take action and construct a channel return. It is the conclusion of this report that construction of a new channel return (Alternate 1, 2 or 3) would be of benefit to the regional water users. Of the three options that involve construction of a new channel return, Channel Return Alternate 2 (see **Exhibit A3**) is the recommended route to return flows to the Arkansas River because it is the option that best balances benefits and costs. The advantages and disadvantages for all channel return options are presented in **Section 3**. Those relating to the recommended project are listed below.

7.2.1 Advantages (Alternate 2)

- Alternate 2 is the option that best balances cost and transit losses.
- The route proposed by Alternate 2 runs along an existing roadway and does not cause partition of any fields.
- The Alternative 2 route avoids some of the safety concerns associated with Alternate 3.
- Alternate 2 provides a significant reduction in transit losses over Alternate 1.

7.2.2 Disadvantages (Alternate 2)

- Alternate 2 is not the least expensive option. Alternate 1 is the least expensive, but does the least to reduce transit losses.

- Alternate 2 will require the acquisition of additional right-of-way when compared to Alternate 1.

7.3 SOUTH SIDE DITCH LINING OPTION

Based on expected performance, repair measures, lifespan and durability, the recommended lining option for the ADS is a Bentonite / Soil Matrix.

7.3.1 Advantages

- A bentonite/soil matrix liner would be self repairing. Minor cracks in the liner would reseal once the bentonite becomes saturated.

- Repairs to the liner could be made with equipment and materials readily available to the SSDA, but a store of bentonite would need to be kept on hand.

- With the proposed 18 inch cover layer, the liner would be protected from damage and could provide a very long life span.

- The liner would require little additional maintenance for the SSDA.

7.3.2 Disadvantages

- There are no sources of bentonite clay near the project. The closest source of bentonite is Wyoming. The cost to purchase bentonite and transport it to the project site significantly adds to the cost of the project.

7.3.3 Other Lining Options

- The concrete lining option was not recommended because of the overall cost.

- An earthen liner is cost prohibitive because of the apparent lack of suitable material in the region. If a suitable borrow source could be found in Finney County, the cost associated with the earthen liner would become the preferred recommendation. The source and cost to transport suitable borrow material is a significant uncertainty that greatly impacts the cost of the project.

- A synthetic liner was not recommended because of durability. The material would be susceptible to damage by UV degradation, traffic, cattle and burning operations.

- A geosynthetic liner promises the same susceptibility to damage as a synthetic liner, but with a higher cost.

- A fly ash/soil matrix liner is an unproven technique for channel lining applications and research to date suggests problem with environmental concerns.

- The use of Polyacrylamides to reduce infiltration is untested on a project of this scale.

7.4 PROJECT PHASING

If either Channel Return Alternate 2 or 3 is selected, then it is recommended that Phasing Option 2 be used the plan for construction sequencing, improving Reach 2 first.

Though not a recommendation of the report, if Channel Return Alternate 1 is selected, then Phasing Option 1 would be preferred.

7.4.1 Advantages

- Construction of Reach 2 first provides an opportunity for the expedited use of the South Side Ditch as an ADS.

- This option would first increase the capacity of the ADS by expanding and lining Reach 2.

- The existing channel return would need to be temporarily incorporated in the ADS until the completion of Reach 1.

7.5 OPERATION OF ALTERNATE DELIVERY SYSTEM

The models prepared for this study are not sufficiently sophisticated to make detailed recommendations for operation of the ADS. Transit losses in the Arkansas River are dependent on numerous parameters including, but not limited to: base flow, releases from John Martin Reservoir, local rainfall, evapotranspiration, operation of the surface water irrigation systems, groundwater usage and groundwater recharge.

Given the complexities and uncertainties within the system, it is recommend that the operational decisions be established from real data rather than modeling results. One option would be to install a series of monitoring wells along the river between the South Side Ditch and Farmer's Ditch headgates. The wells could be used to monitor the levels in the alluvial aquifer. In conjunction with river gage data, an accurate relationship could be developed between flow rate at the South Side Ditch head gate, aquifer level, and transit losses over time.

Section 8
Glossary of Terms

8.0 GLOSSARY OF TERMS

Appropriation Right: The right to divert from a definite water supply a specific quantity of water at a specific rate of diversion, provided such water is available in excess of the requirements of all vested rights that relate to such supply and all appropriation rights of earlier date that relate to such supply, and to apply such water to a specific beneficial use or uses in preference to all appropriations right of later date.

Chief Engineer: The chief engineer of the Division of Water Resources of the Kansas Department of Agriculture.

Finney County Water Users Association (FCWUA): An association of shareholders who own and operate the Farmer's Ditch.

Intensive Groundwater Use Control Area (IGUCA): An intensive groundwater use control area is defined in the Kansas Statutes in what is known as the Groundwater Management District Act.

Parshall Flume: A flume that has a special shaped open channel flow section that may be installed in a ditch ,canal, or lateral to measure the flow rate.

Point of Diversion: The point at which water is diverted or withdrawn from a source of water supply.

Polyacrylamide (PAM): A synthetic polymer that dissolves in water and is used to control soil erosion.

South Side Ditch Association (SSDA): An association of shareholders who own and operate the South Side Ditch.

Transit Loss: The movement of surface water to the underlying aquifer by infiltration.

Vested Rights: The right of a person under a common law or statutory claim to continue the use of water having actually been applied to any beneficial use, including domestic use, on or before June 28, 1945.

Water Right: Any vested right or appropriation right under which a person may lawfully divert and use water. It is a real property right appurtenant to and severable from the land on or in connection with which the water is used and such water right passes as an appurtenance with a conveyance of the land by deed, lease, mortgage, will, or other voluntary disposal, or by inheritance.

- - Acronyms - -

ADS: Alternate Delivery System

ARLFC: Arkansas River Litigation Fund Committee

DWR: Kansas Department of Agriculture, Division of Water Resources

FCWUA: Finney County Water Users Association

GCL: Geosynthetic Clay Liner

GMD3: Southwest Groundwater Management District No. 3

IGUCA: Intensive Groundwater Use Control Area

KDOT: Kansas Department of Transportation

KWAA: Kansas Water Appropriations Act

KWO: Kansas Water Office

PAM: Polyacrylamide

SSDA: South Side Ditch Association

TDS: Total Dissolved Solids

TMDL: Total Maximum Daily Loads

WCPF: Water Conservation Project Fund

USGS: U.S. Geological Survey

Appendix A
Exhibits

Water Conservation Project Fund

Arkansas River Corridor

Feasibility Study 1 South Side Ditch

Legend

- County Boundary
- Cities
- Major Roads
- Railroad
- Arkansas River
- McKinney Lake
- Farmer's Ditch
- Amazon Ditch
- Frontier Ditch
- Alluvial Aquifer
- Garden City Ditch
- Great Eastern Ditch

South Side Ditch

- Alternate Delivery System
- Lateral
- USGS Gaging Stations

N

0 1.5 3 Miles

Exhibit A1

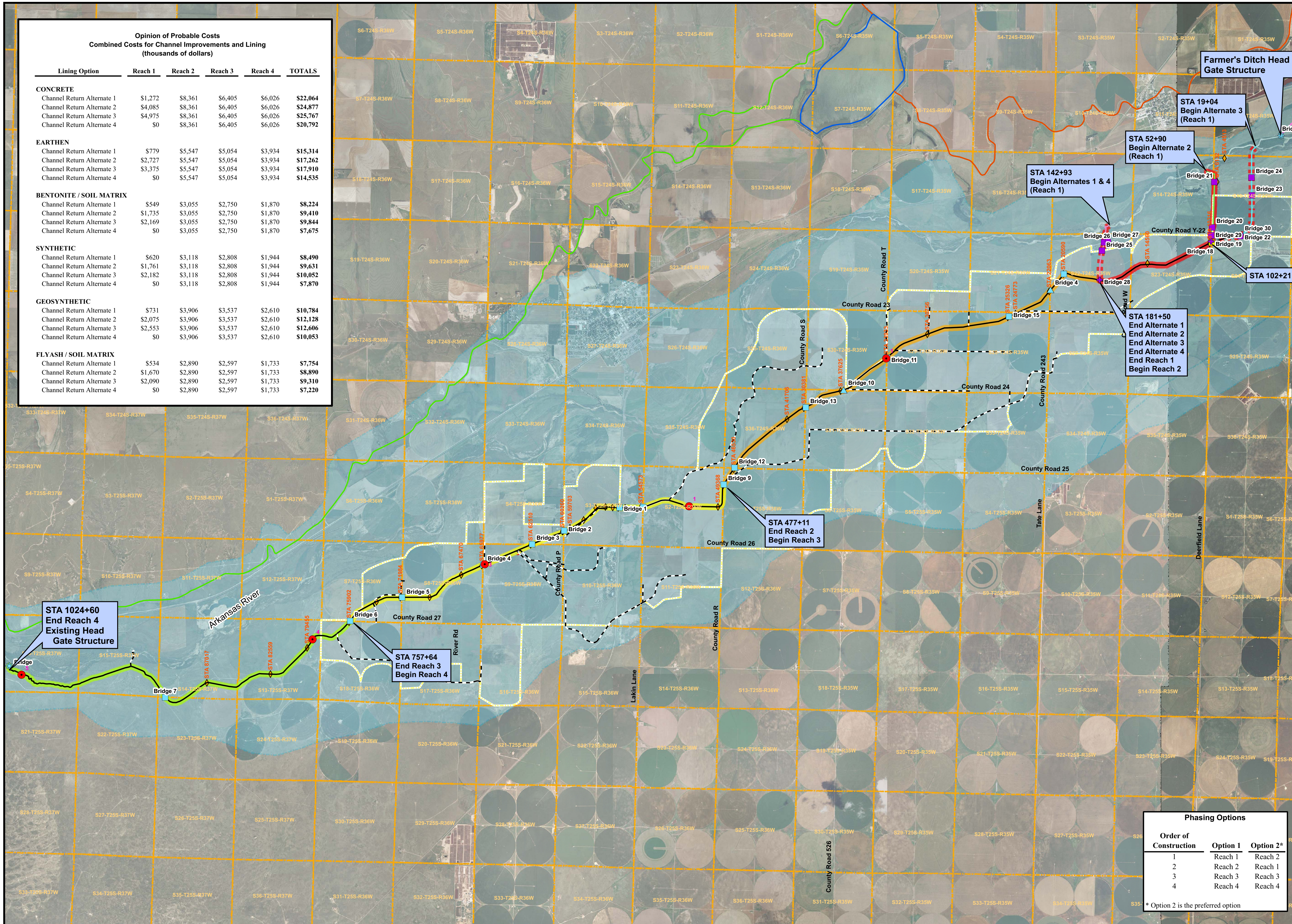
Finney and Kearny County Irrigation Systems

October 2007

Burns & McDonnell SINCE 1898

Opinion of Probable Costs
Combined Costs for Channel Improvements and Lining
(thousands of dollars)

Lining Option	Reach 1	Reach 2	Reach 3	Reach 4	TOTALS
CONCRETE					
Channel Return Alternate 1	$1,272	$8,361	$6,405	$6,026	**$22,064**
Channel Return Alternate 2	$4,085	$8,361	$6,405	$6,026	**$24,877**
Channel Return Alternate 3	$4,975	$8,361	$6,405	$6,026	**$25,767**
Channel Return Alternate 4	$0	$8,361	$6,405	$6,026	**$20,792**
EARTHEN					
Channel Return Alternate 1	$779	$5,547	$5,054	$3,934	**$15,314**
Channel Return Alternate 2	$2,727	$5,547	$5,054	$3,934	**$17,262**
Channel Return Alternate 3	$3,375	$5,547	$5,054	$3,934	**$17,910**
Channel Return Alternate 4	$0	$5,547	$5,054	$3,934	**$14,535**
BENTONITE / SOIL MATRIX					
Channel Return Alternate 1	$549	$3,055	$2,750	$1,870	**$8,224**
Channel Return Alternate 2	$1,735	$3,055	$2,750	$1,870	**$9,410**
Channel Return Alternate 3	$2,169	$3,055	$2,750	$1,870	**$9,844**
Channel Return Alternate 4	$0	$3,055	$2,750	$1,870	**$7,675**
SYNTHETIC					
Channel Return Alternate 1	$620	$3,118	$2,808	$1,944	**$8,490**
Channel Return Alternate 2	$1,761	$3,118	$2,808	$1,944	**$9,631**
Channel Return Alternate 3	$2,182	$3,118	$2,808	$1,944	**$10,052**
Channel Return Alternate 4	$0	$3,118	$2,808	$1,944	**$7,870**
GEOSYNTHETIC					
Channel Return Alternate 1	$731	$3,906	$3,537	$2,610	**$10,784**
Channel Return Alternate 2	$2,075	$3,906	$3,537	$2,610	**$12,128**
Channel Return Alternate 3	$2,553	$3,906	$3,537	$2,610	**$12,606**
Channel Return Alternate 4	$0	$3,906	$3,537	$2,610	**$10,053**
FLYASH / SOIL MATRIX					
Channel Return Alternate 1	$534	$2,890	$2,597	$1,733	**$7,754**
Channel Return Alternate 2	$1,670	$2,890	$2,597	$1,733	**$8,890**
Channel Return Alternate 3	$2,090	$2,890	$2,597	$1,733	**$9,310**
Channel Return Alternate 4	$0	$2,890	$2,597	$1,733	**$7,220**



Phasing Options

Order of Construction	Option 1	Option 2*
1	Reach 1	Reach 2
2	Reach 2	Reach 1
3	Reach 3	Reach 3
4	Reach 4	Reach 4

* Option 2 is the preferred option

Water Conservation Project Fund

Arkansas River Corridor

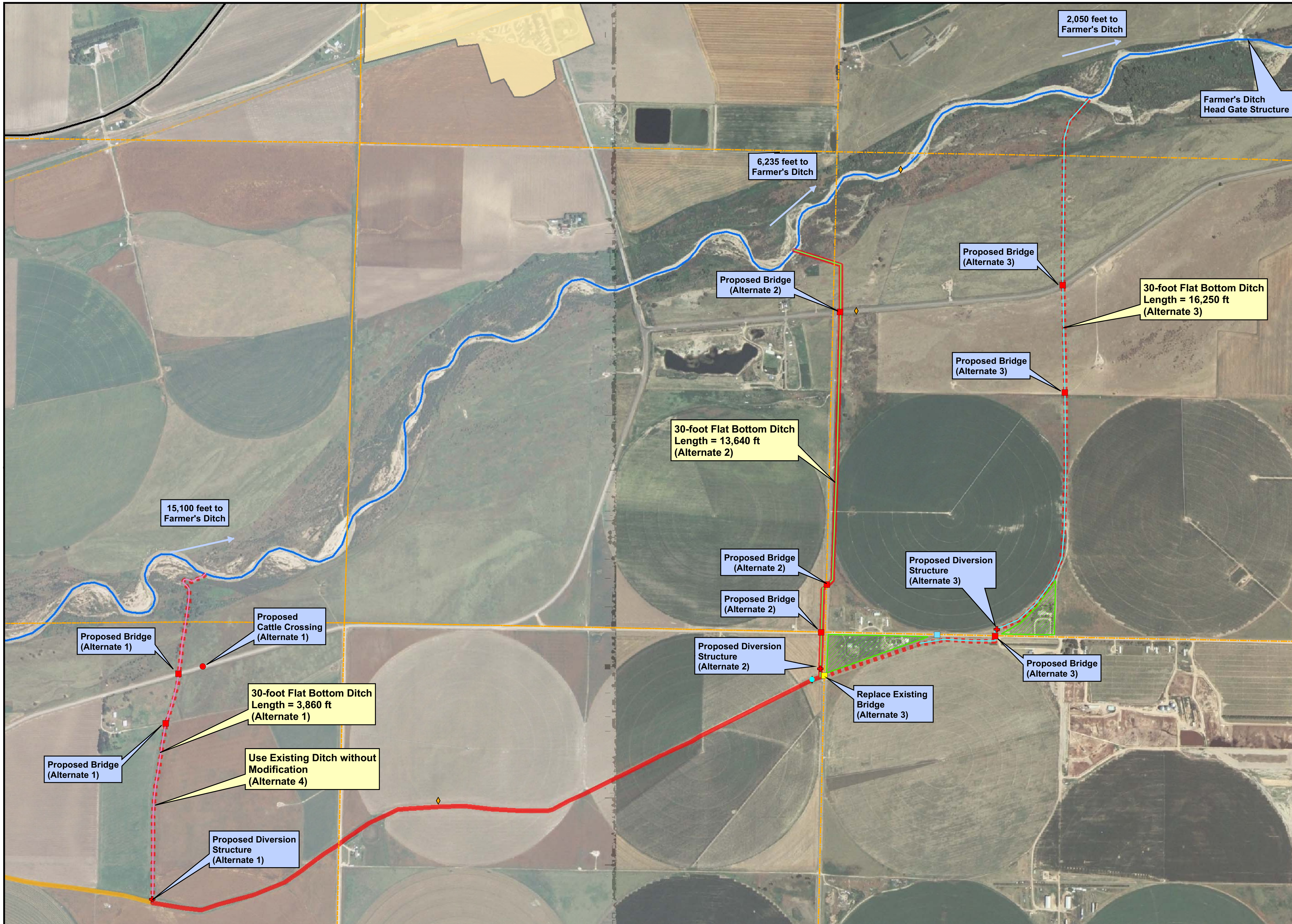
Feasibility Study 1 South Side Ditch

Exhibit A2

South Side Ditch System Overview

October 2007

Burns & McDonnell
SINCE 1898



Water Conservation Project Fund

Arkansas River Corridor

Feasibility Study 1 South Side Ditch

Legend

- County Boundary
- Cities
- Section Lines
- Minor Highways
- Major Roads
- Railroad
- Arkansas River

Phasing Options

- Reach 1
- Reach 1 Alt
- Reach 2
- Reach 3
- Reach 4

Channel Returns

- Alternates 1 and 4
- Alternate 2
- Alternate 3
- Areas of Safety Concerns

Structures

Type

- Existing Bridge
- Existing Culvert
- Proposed Bridge
- Proposed Cattle Crossing
- Proposed Diversion
- Replace Bridge

N

0 250 500 1,000 Feet

Exhibit A3

Channel Return Options

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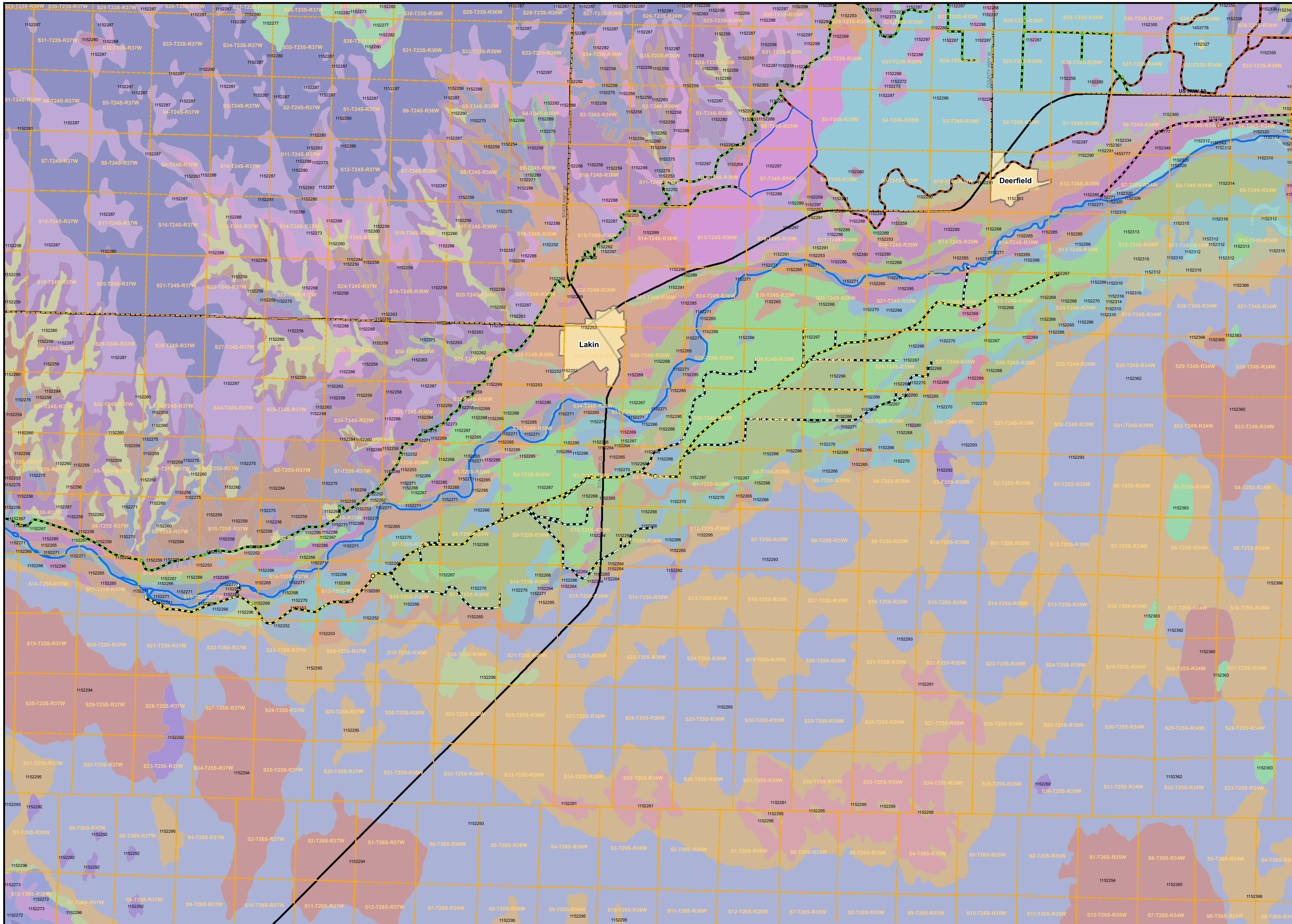

Water Conservation Project Fund

Arkansas River Corridor

Feasibility Study 1 South Side Ditch

Legend

- Cities
- Major Roads
- Soil Samples
- Arkansas River
- McKinney Lake
- Farmer's Ditch
- Amazon Ditch
- Frontier Ditch
- Garden City Ditch
- Great Eastern Ditch

South Side Ditch

- Alternate Delivery System
- Lateral

N

0 2,000 4,000 8,000 Feet

Exhibit A4

Regional Soils Information

October 2007

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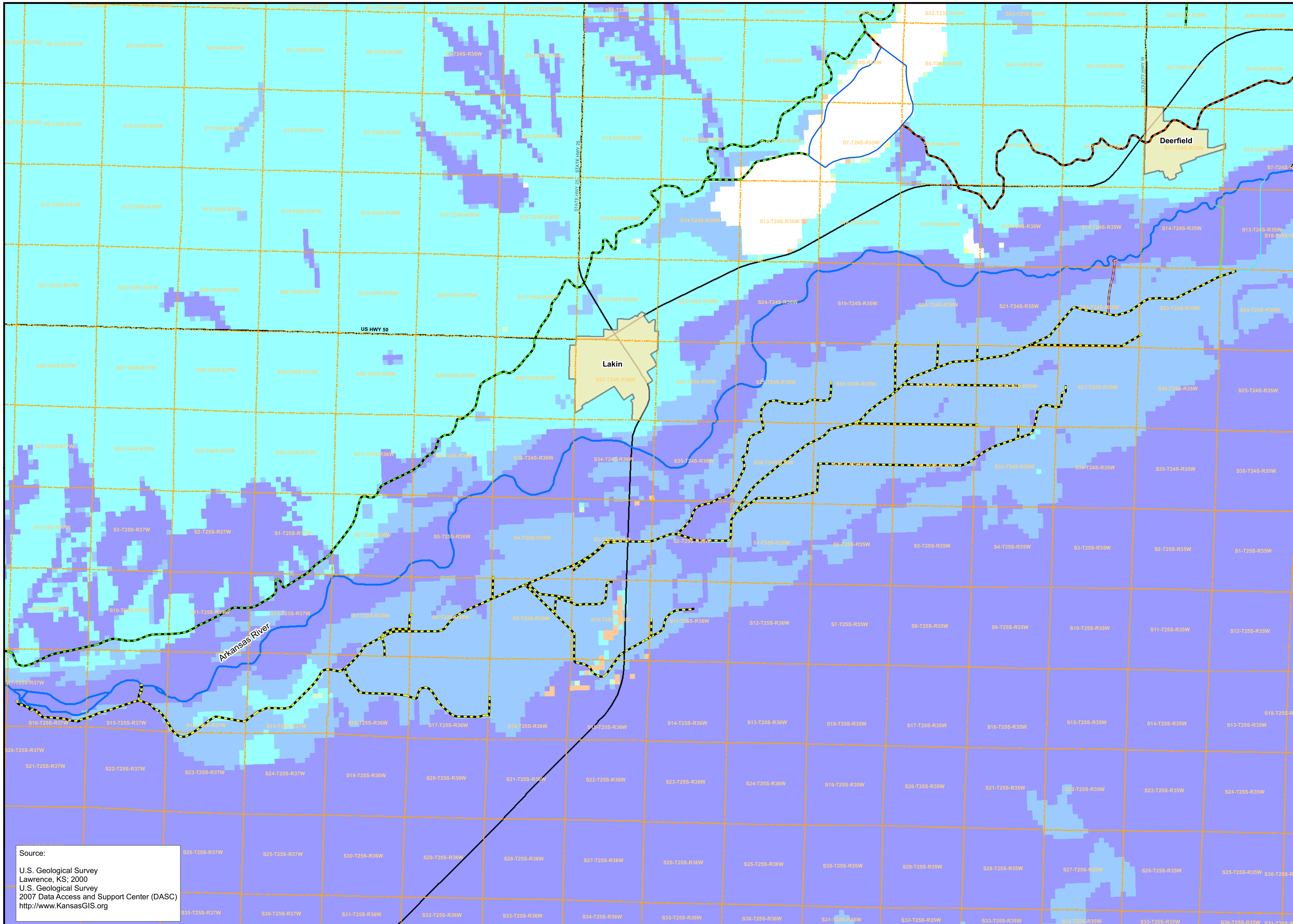


Water Conservation Project Fund

Arkansas River Corridor

Feasibility Study 1 South Side Ditch

Legend

- Cities
- Section Lines
- Major Roads
- Soil Samples
- Arkansas River
- McKinney Lake
- Farmer's Ditch
- Amazon Ditch
- Frontier Ditch
- Garden City Ditch
- Great Eastern Ditch
- South Side Ditch

Channel Returns

- Alternate 1
- Alternate 2
- Alternate 3

Mean Soil Permeability

- No Data
- Very Slow
- Slow
- Moderately Slow
- Moderately Rapid
- Rapid
- Very Rapid

N

0 1,500 3,000 6,000 Feet

Exhibit A5

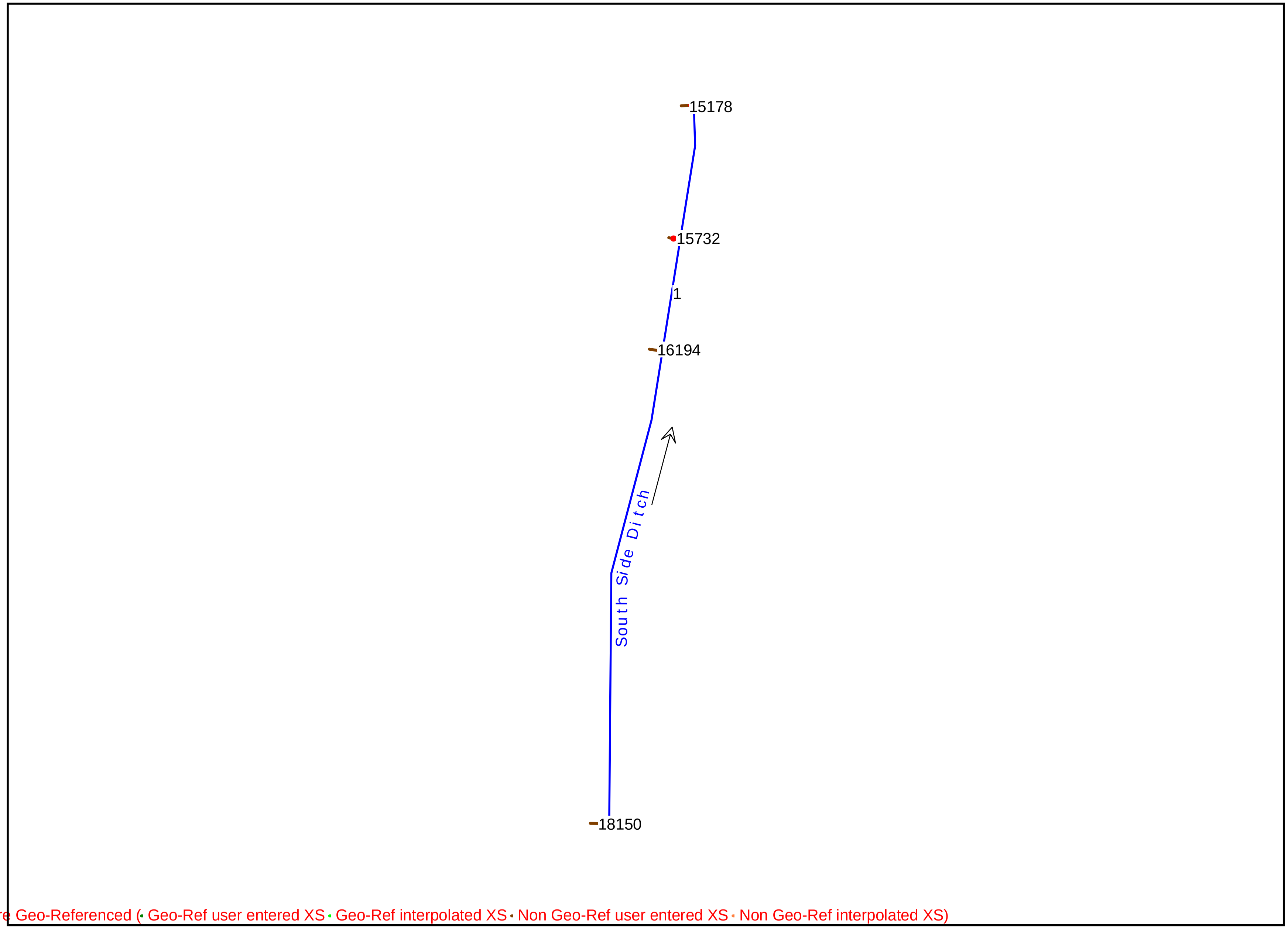
Regional Soils Permeability

October 2007

Burns & McDonnell
SINCE 1898

Appendix B
Hydraulic Analysis

Existing Conditions



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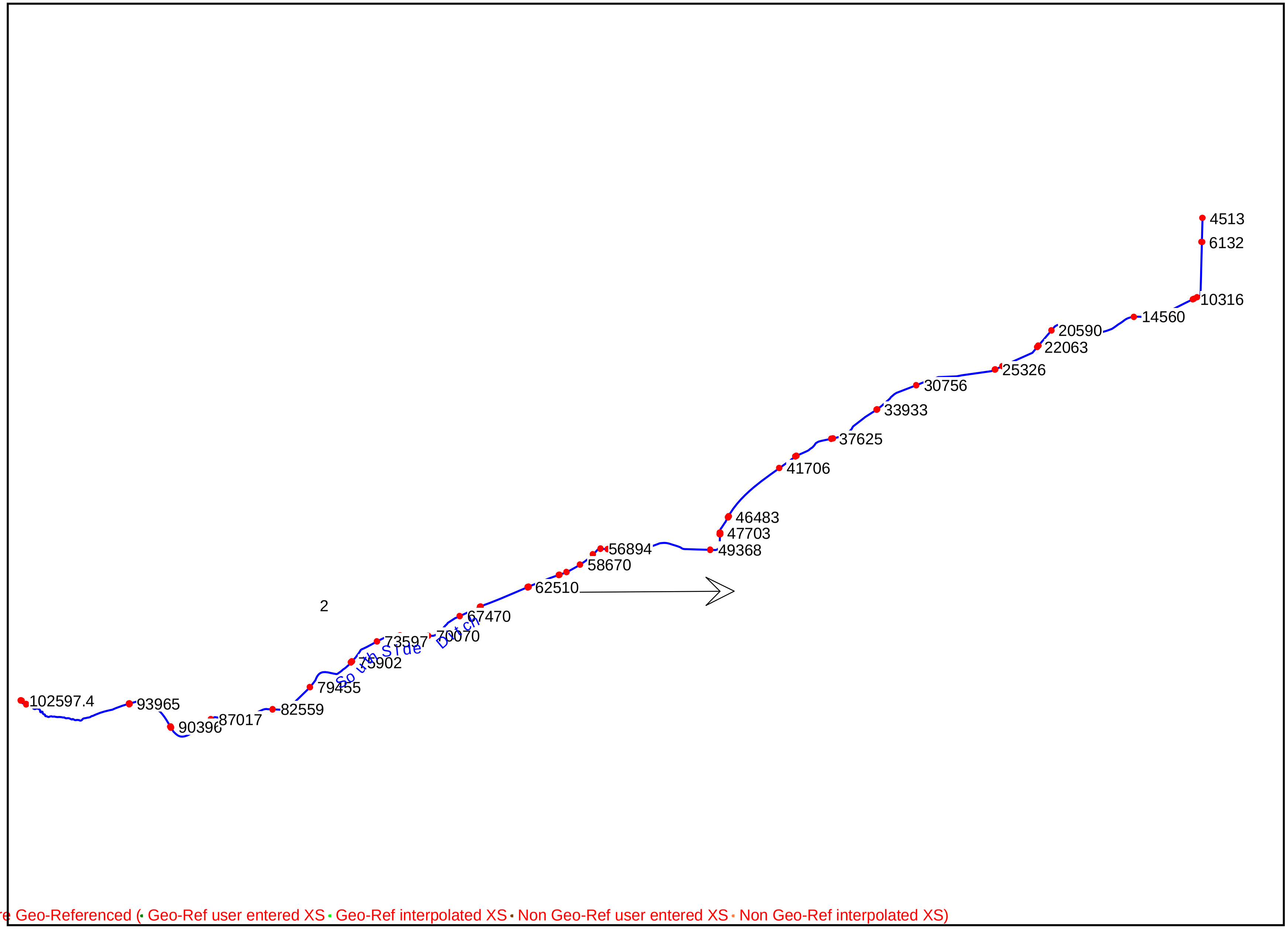

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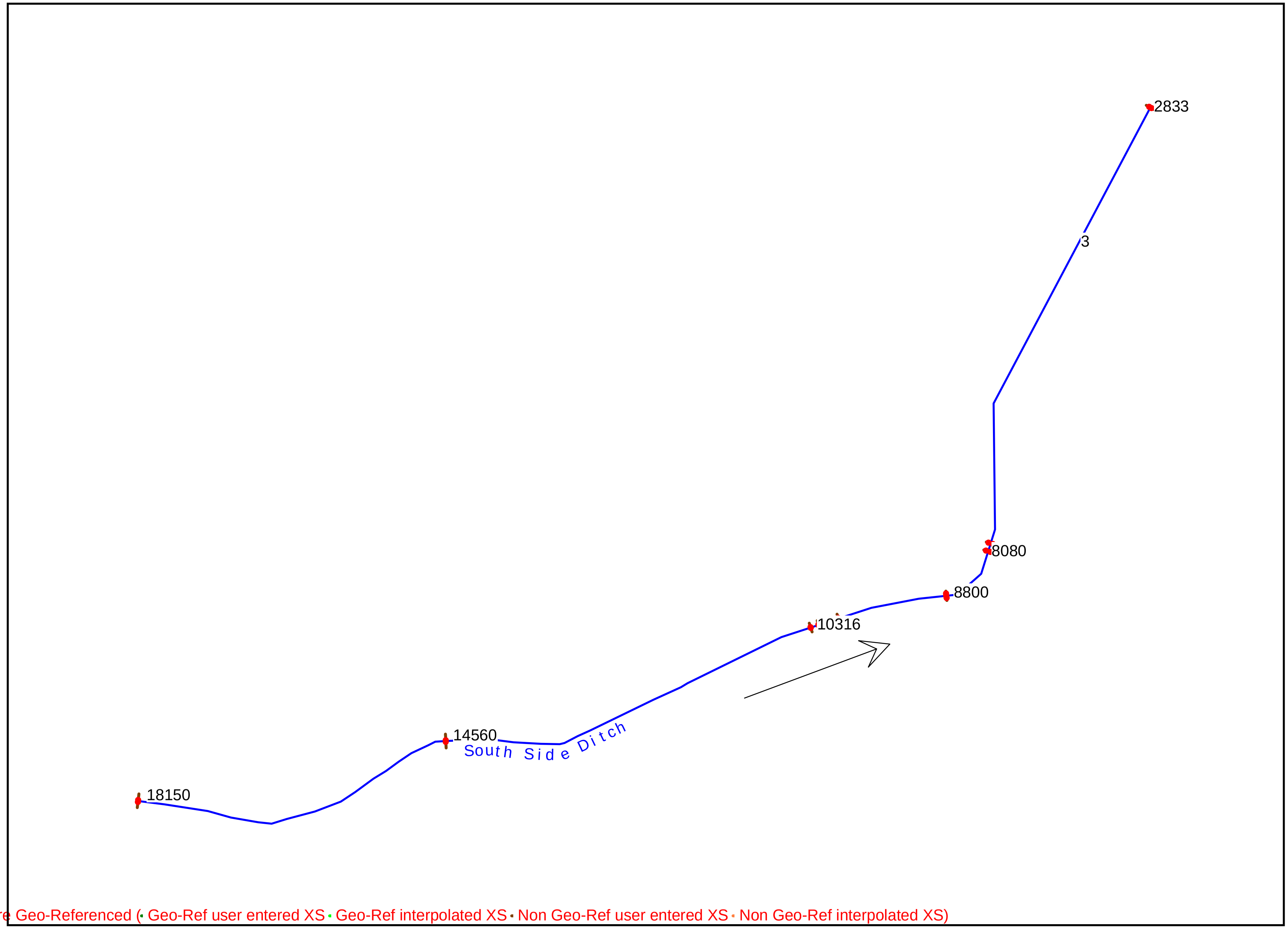

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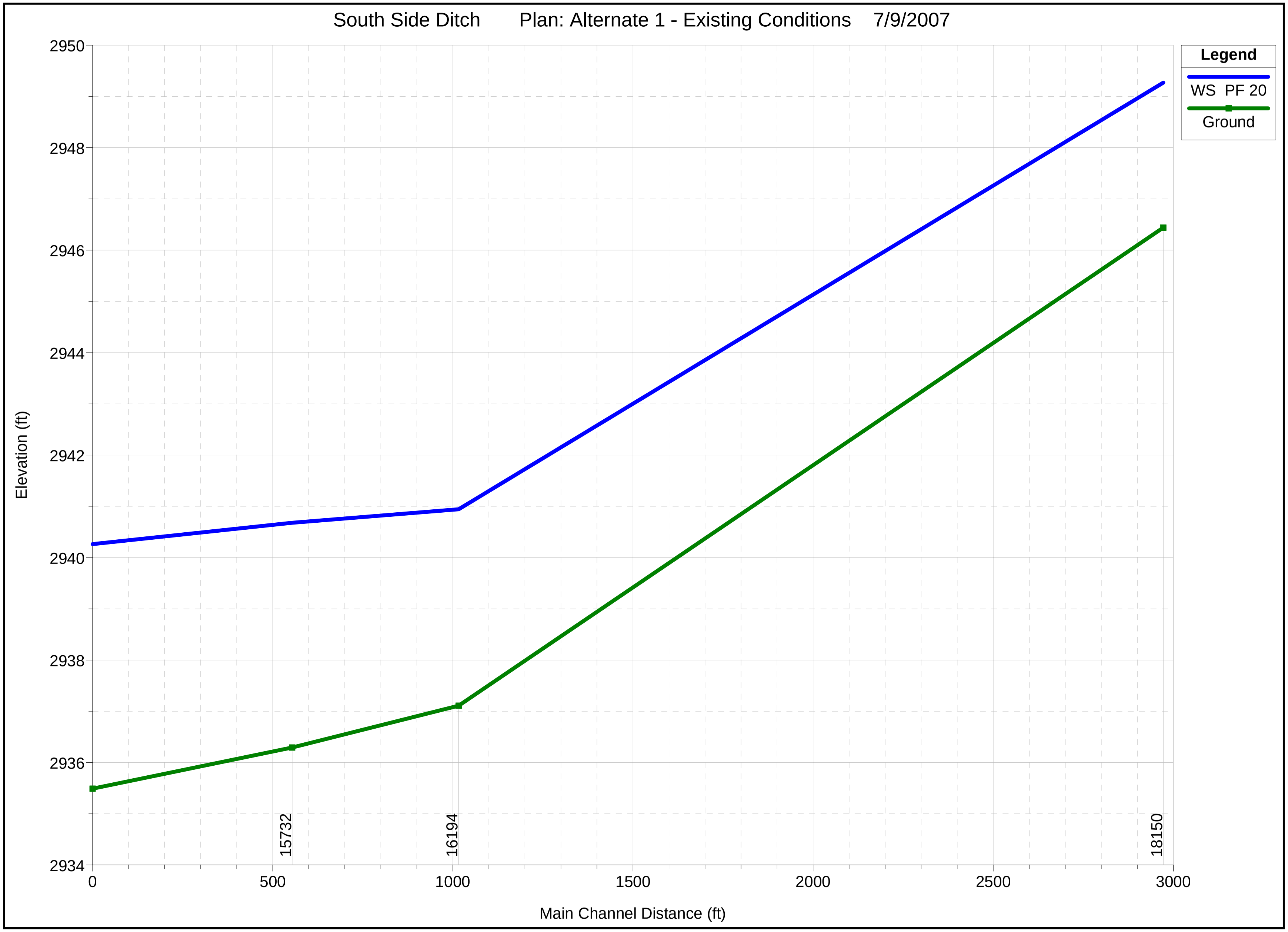
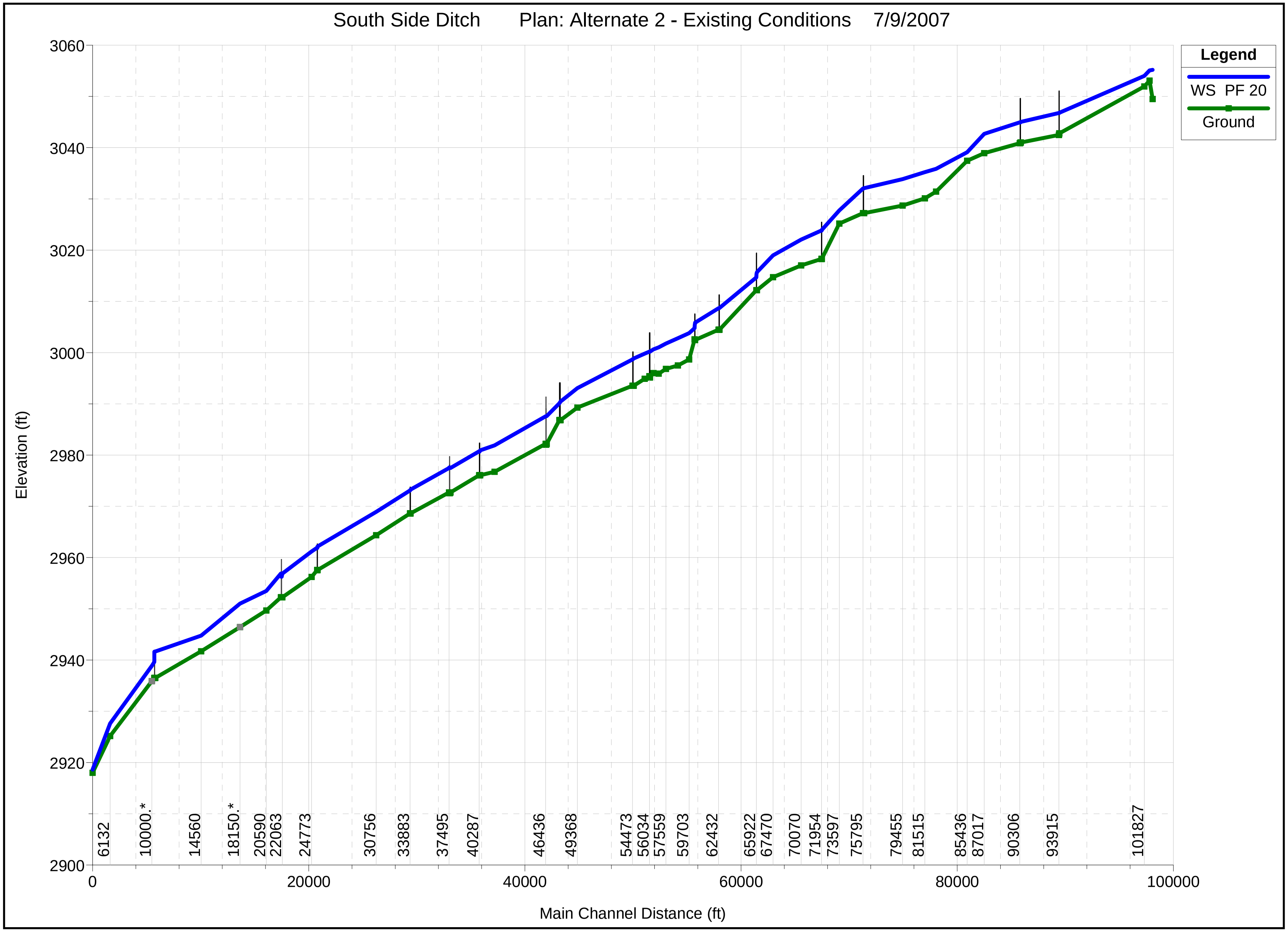


South Side Ditch Plan: Alternate 1 - Existing Conditions 7/9/2007
Legend
WS PF 20
Ground
Elevation (ft)
2950
2948
2946
2944
2942
2940
2938
2936
2934
0
500
1000
1500
2000
2500
3000
Main Channel Distance (ft)
15732
16194
18150


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
Legend
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Ground
Elevation (ft)
Main Channel Distance (ft)
3060
3040
3020
3000
2980
2960
2940
2920
2900
0
20000
40000
60000
80000
100000
6132
10000.*
14560
18150.*
20590
22063
24773
30756
33883
37495
40287
46436
49368
54473
56034
57559
59703
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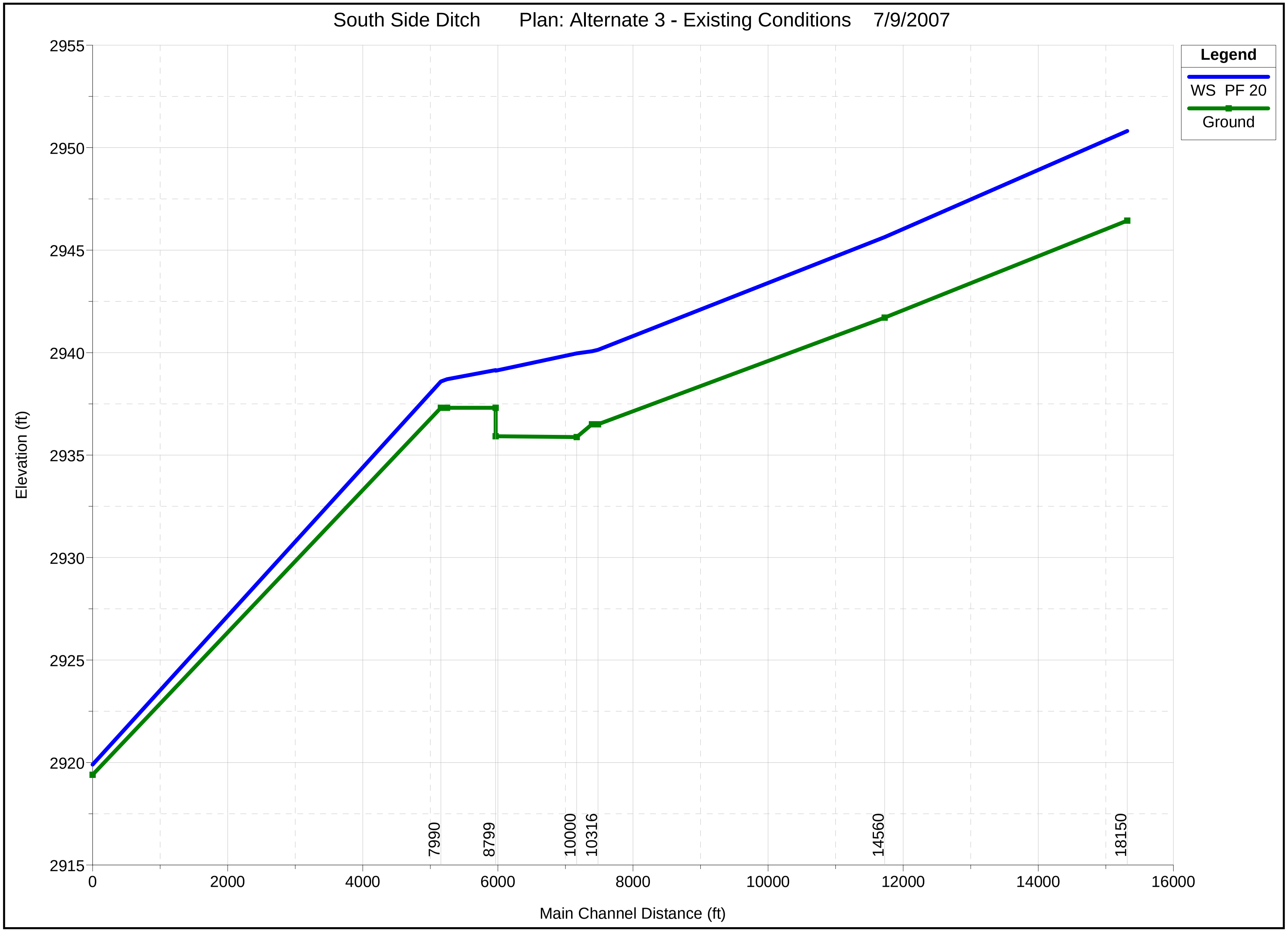
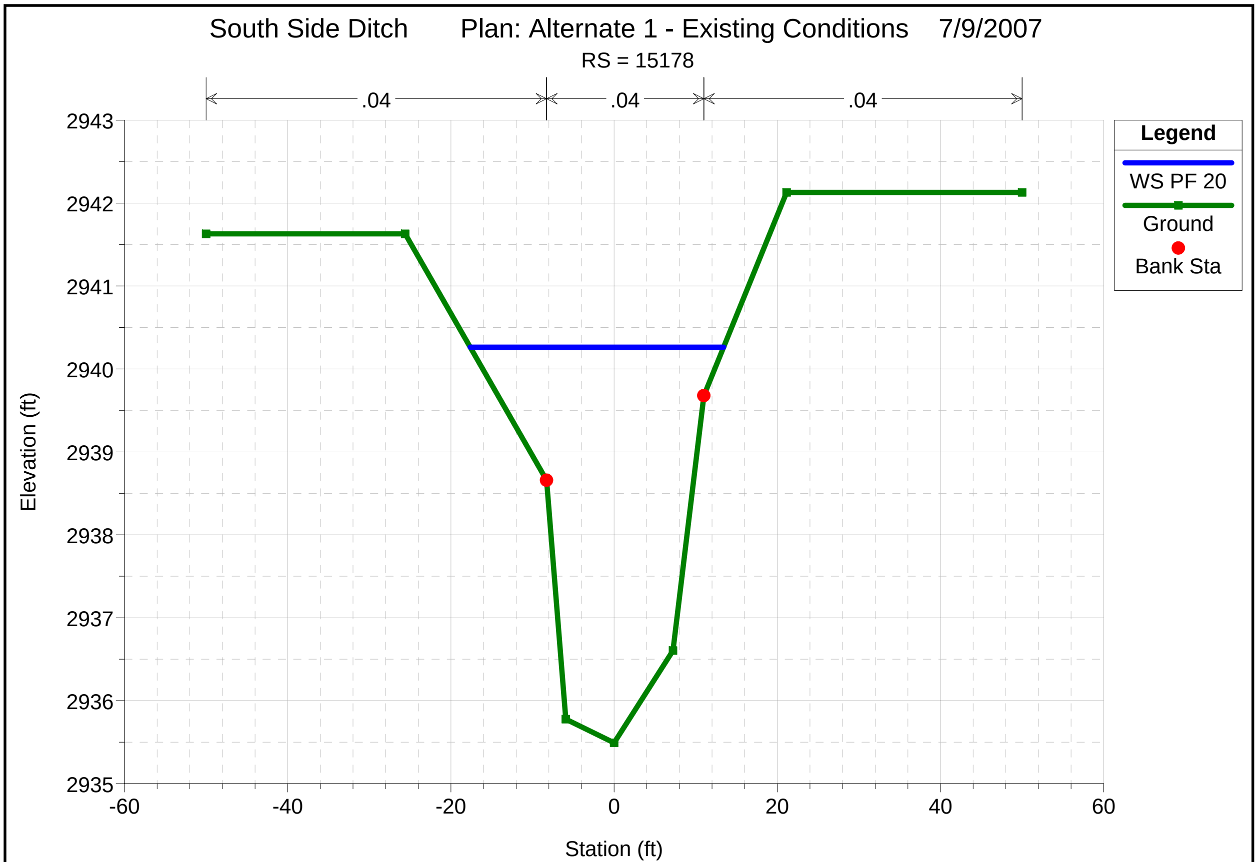
90306
93915
101827


South Side Ditch Plan: Alternate 3 - Existing Conditions 7/9/2007
Legend
WS PF 20
Ground
Elevation (ft)
2955
2950
2945
2940
2935
2930
2925
2920
2915
0
2000
4000
6000
8000
10000
12000
14000
16000
7990
8799
10000
10316
14560
18150
Main Channel Distance (ft)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.04
.04
Legend
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Ground
Bank Sta
Elevation (ft)
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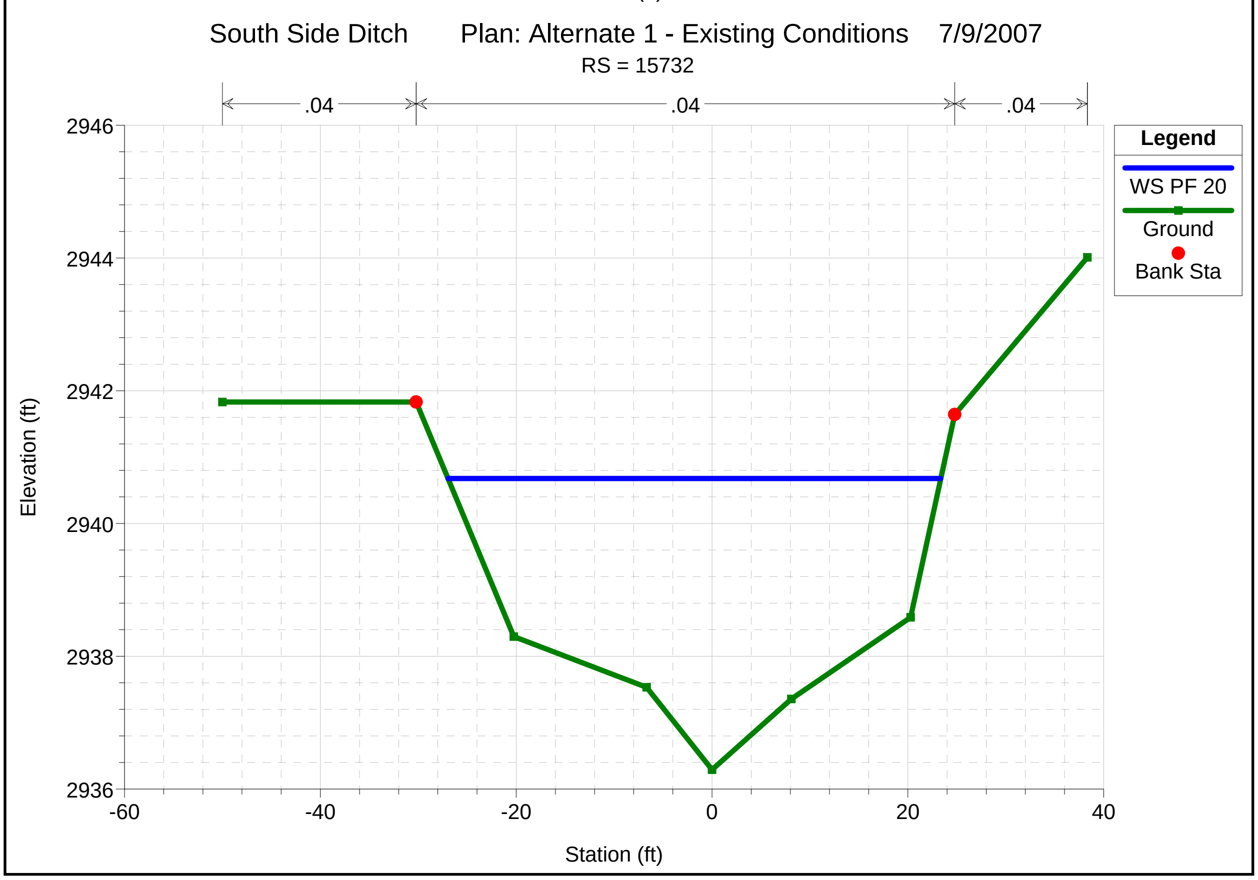
2942
2941
2940
2939
2938
2937
2936
2935
-60
-40
-20
0
20
40
60
Station (ft)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Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
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2944
2942
2940
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2936
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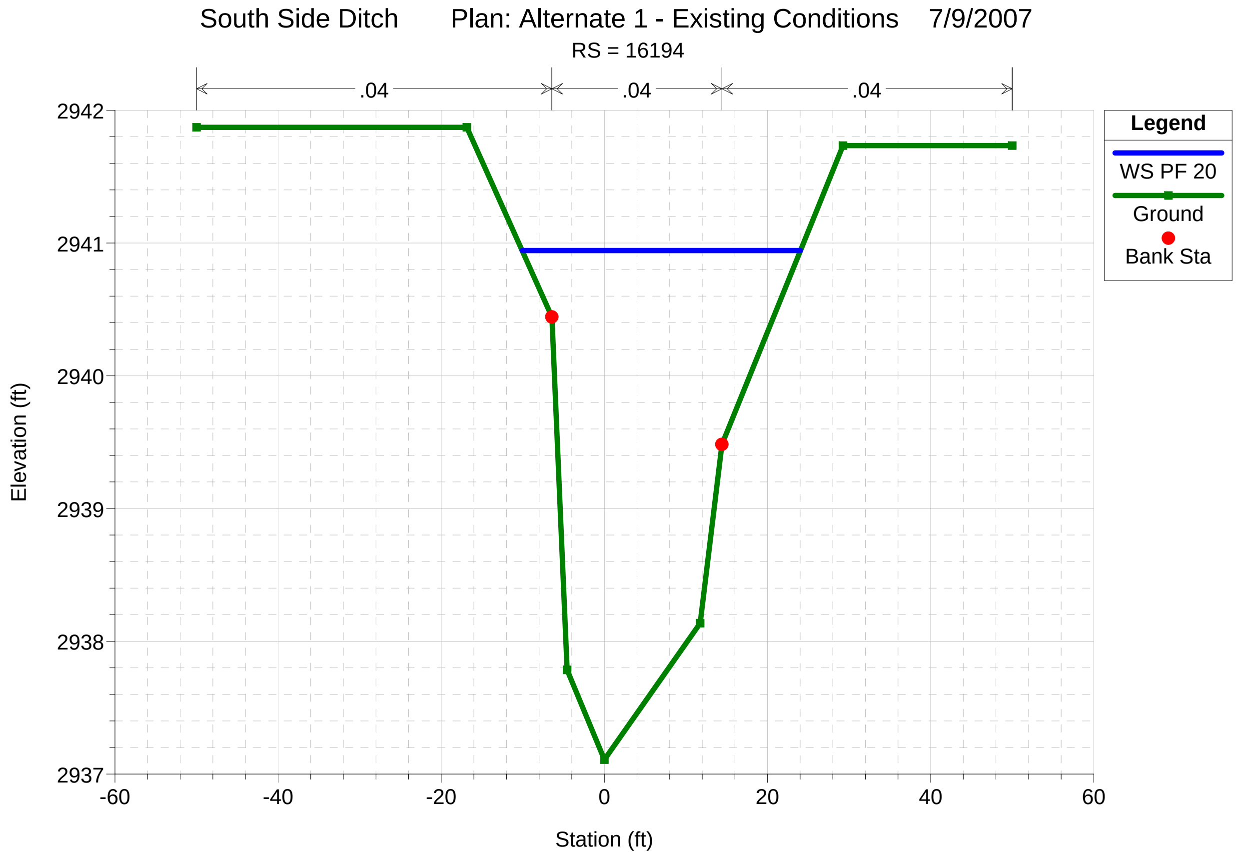
-40
-20
0
20
40
Station (ft)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Plan: Alternate 1 - Existing Conditions
7/9/2007
RS = 16194
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Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
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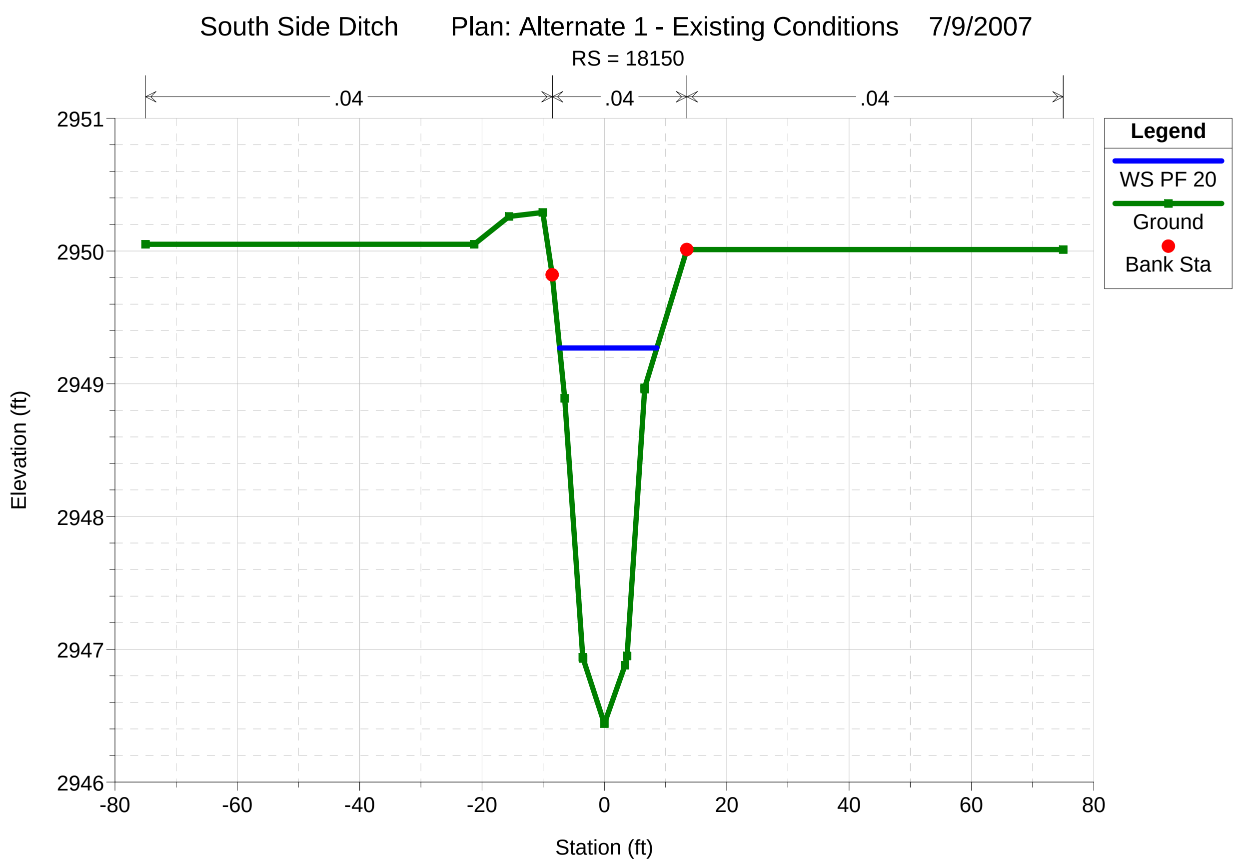
2941
2940
2939
2938
2937
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch
Plan: Alternate 1 - Existing Conditions
7/9/2007
RS = 18150
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.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
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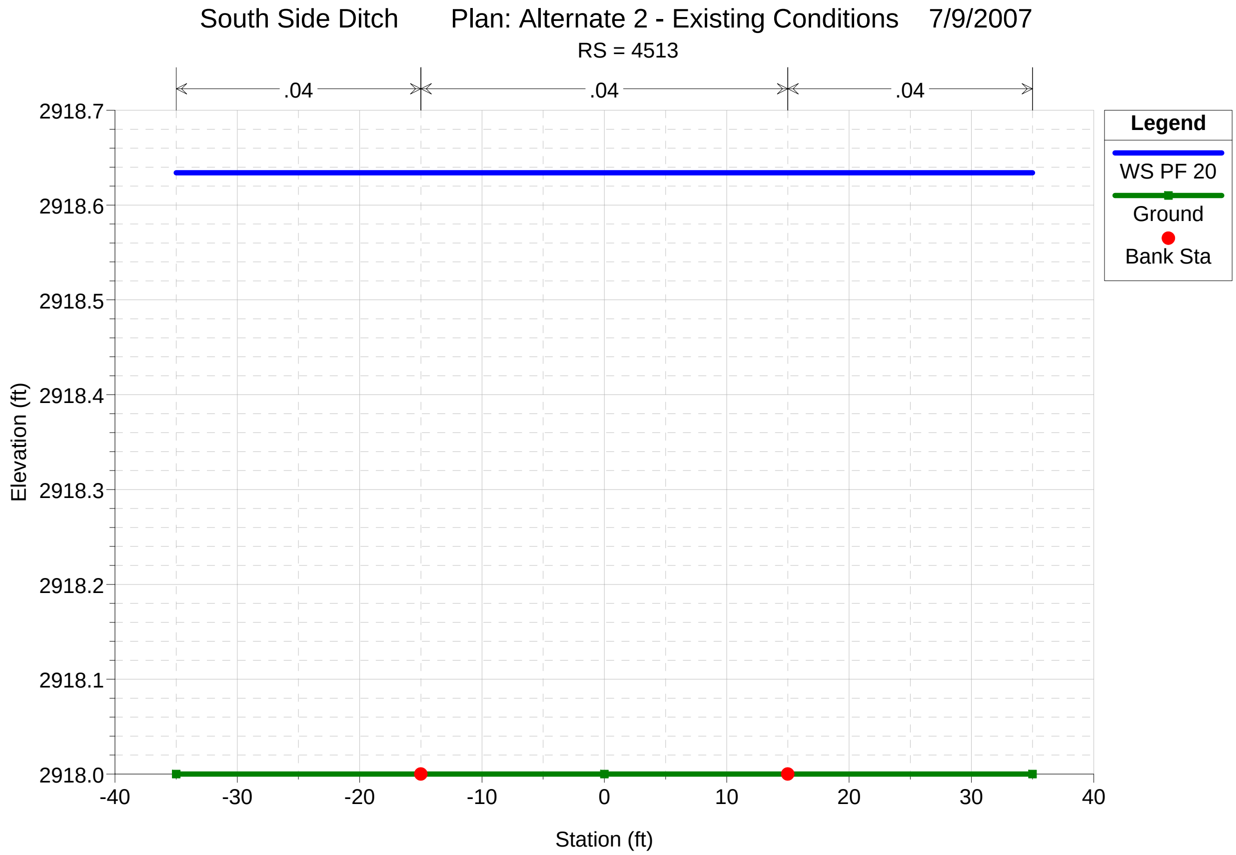
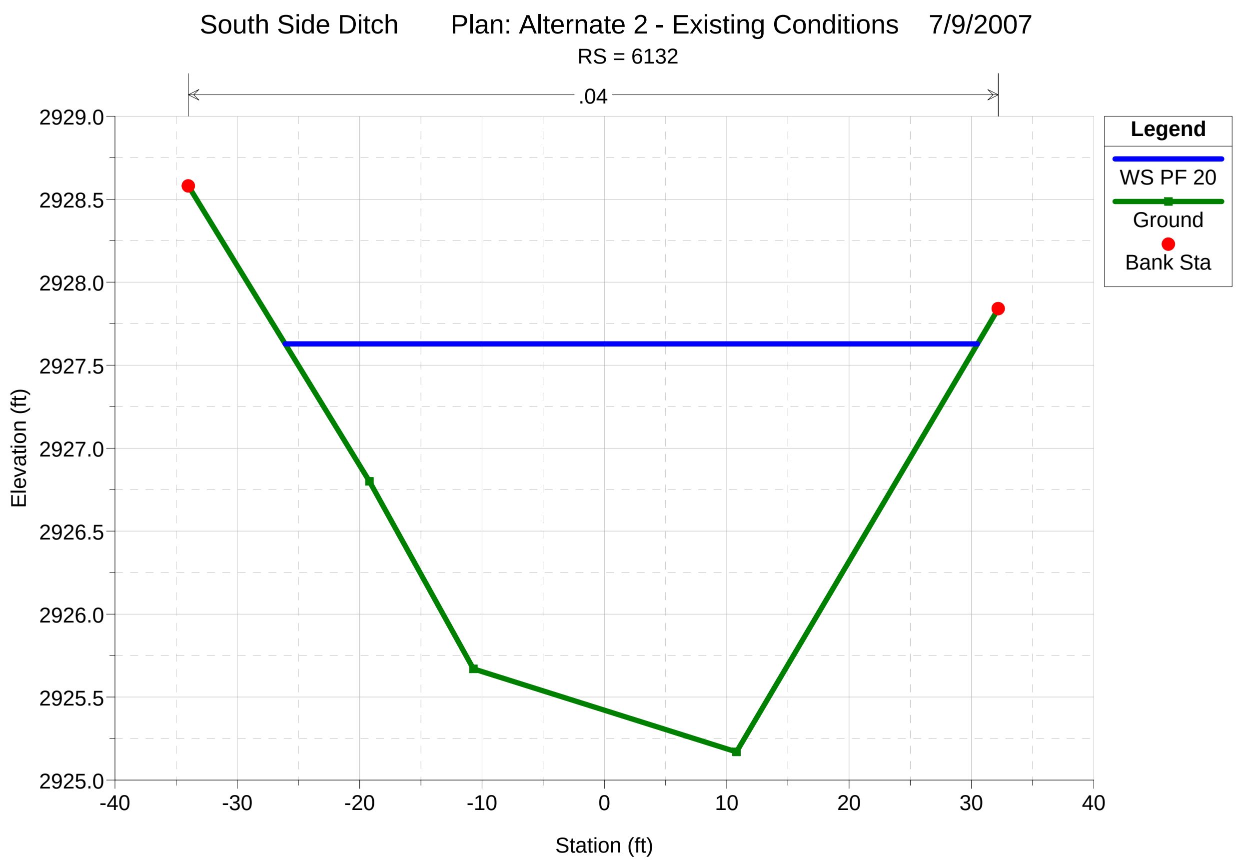
2949
2948
2947
2946
-80
-60
-40
-20
0
20
40
60
80
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 4513
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2918.7
2918.6
2918.5
2918.4
2918.3
2918.2
2918.1
2918.0
-40
-30
-20
-10
0
10
20
30
40
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
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Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
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2928.0
2927.5
2927.0
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2925.5
2925.0
-40
-30
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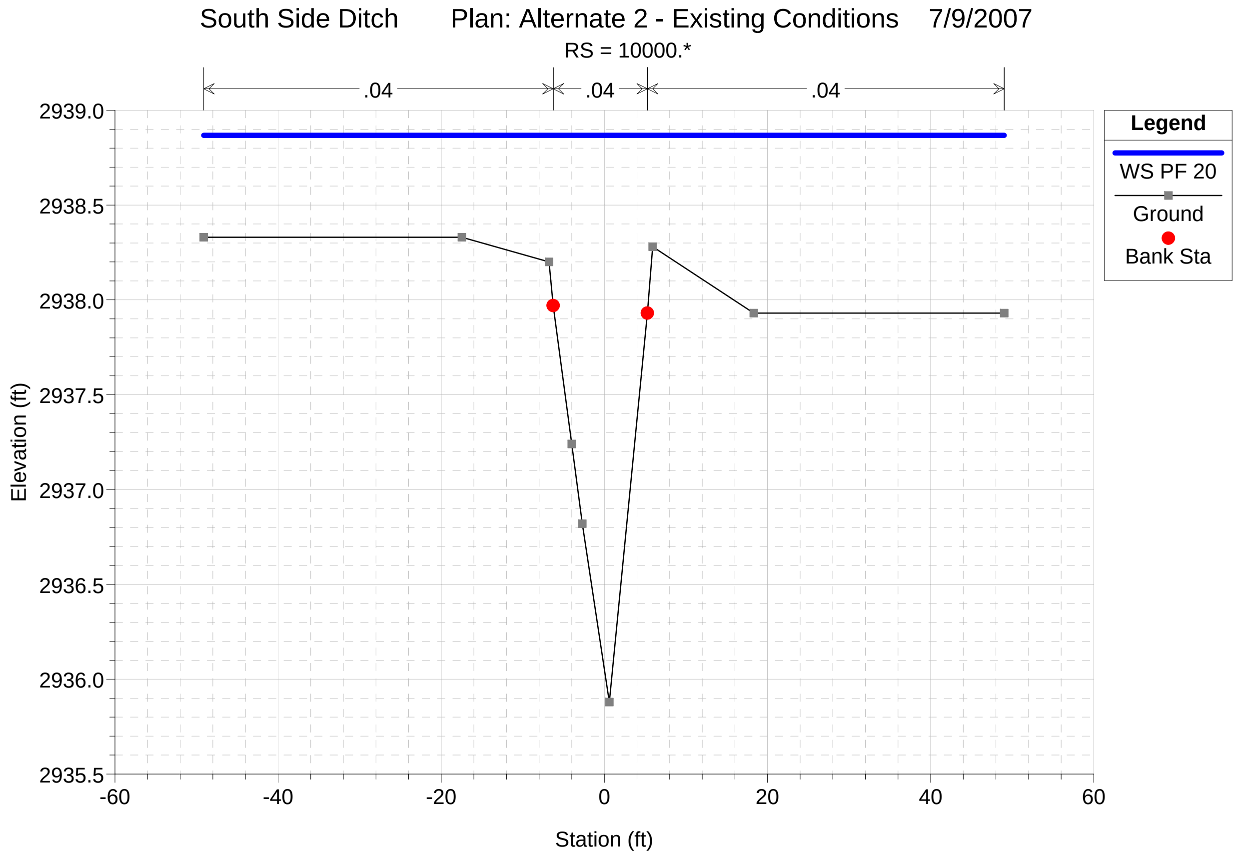
-10
0
10
20
30
40
Station (ft)


South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 10000.*
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
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2938.5
2938.0
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2936.0
2935.5
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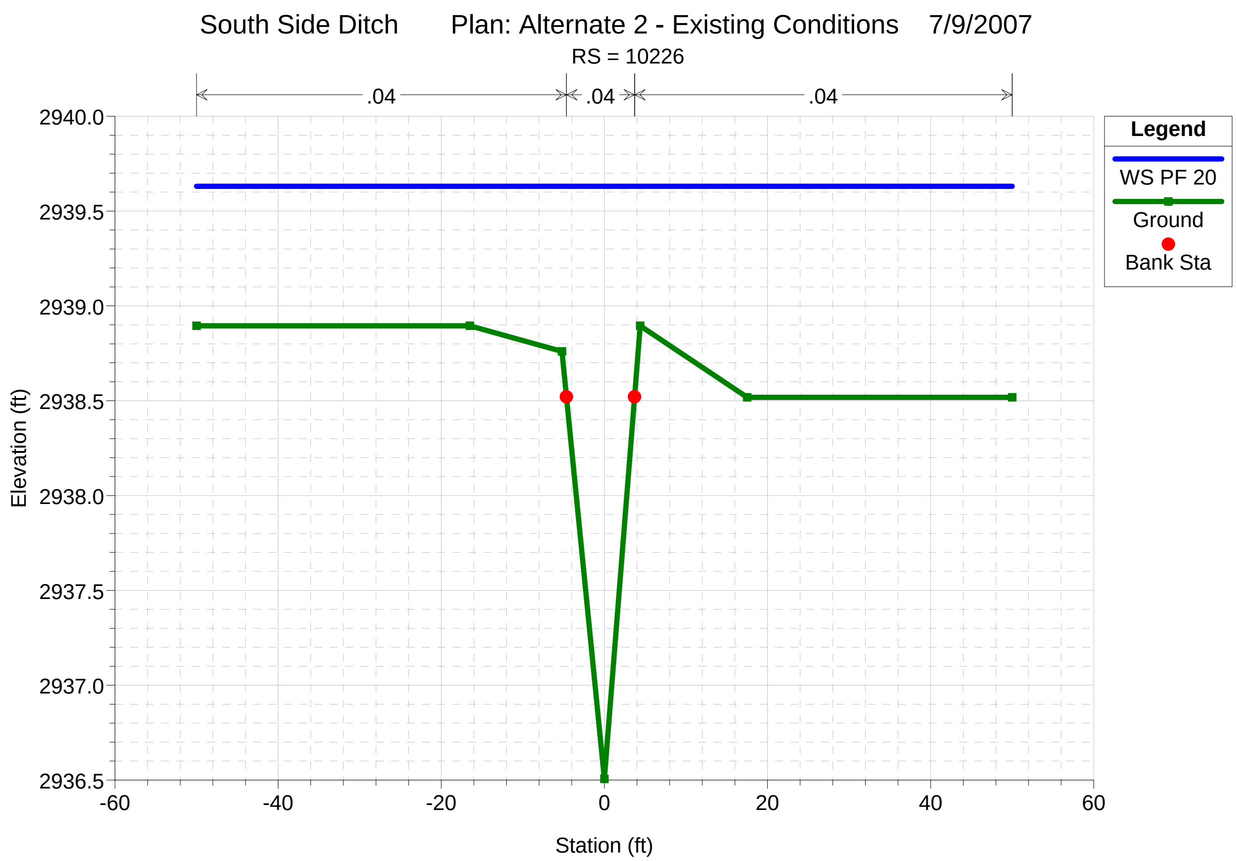
-20
0
20
40
60


South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
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Legend
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Ground
Bank Sta
Elevation (ft)
Station (ft)
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2937.0
2936.5
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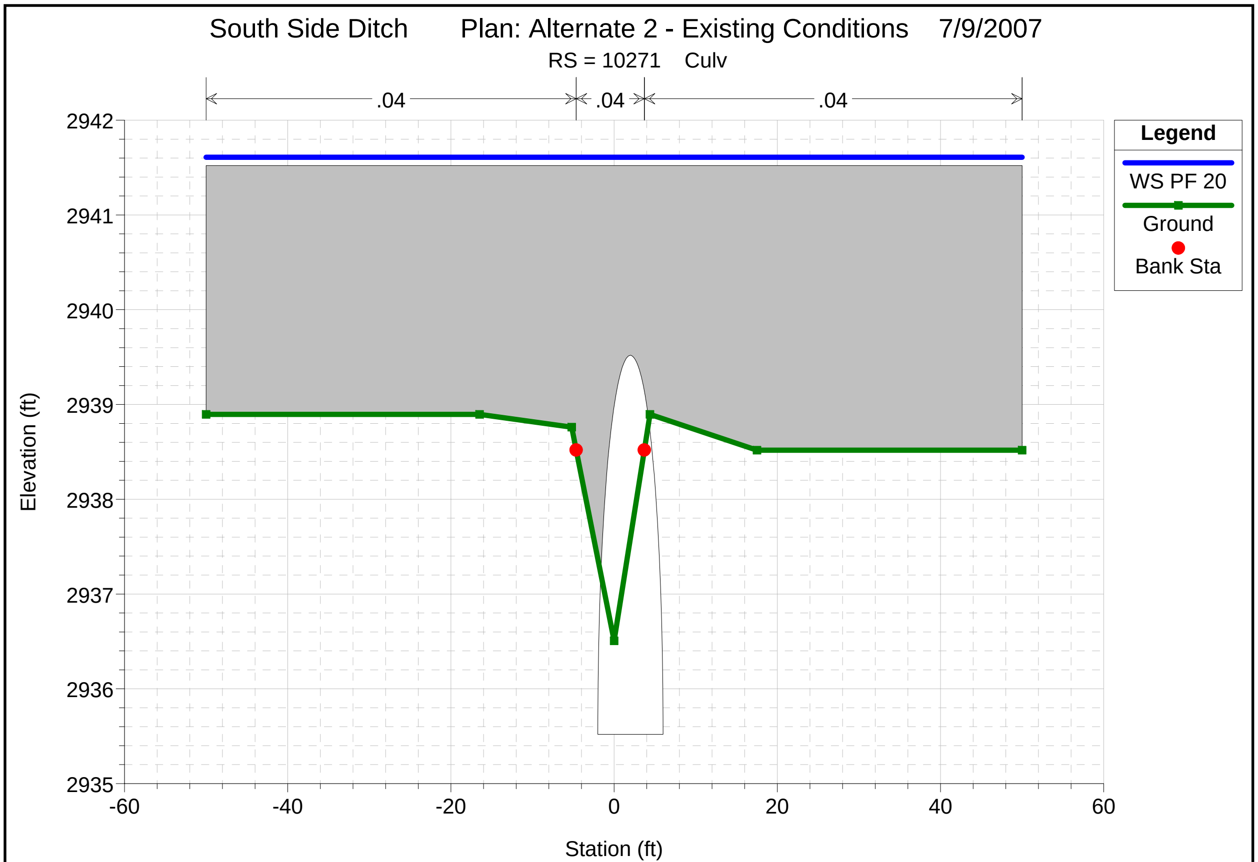
0
20
40
60



South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
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.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
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2940
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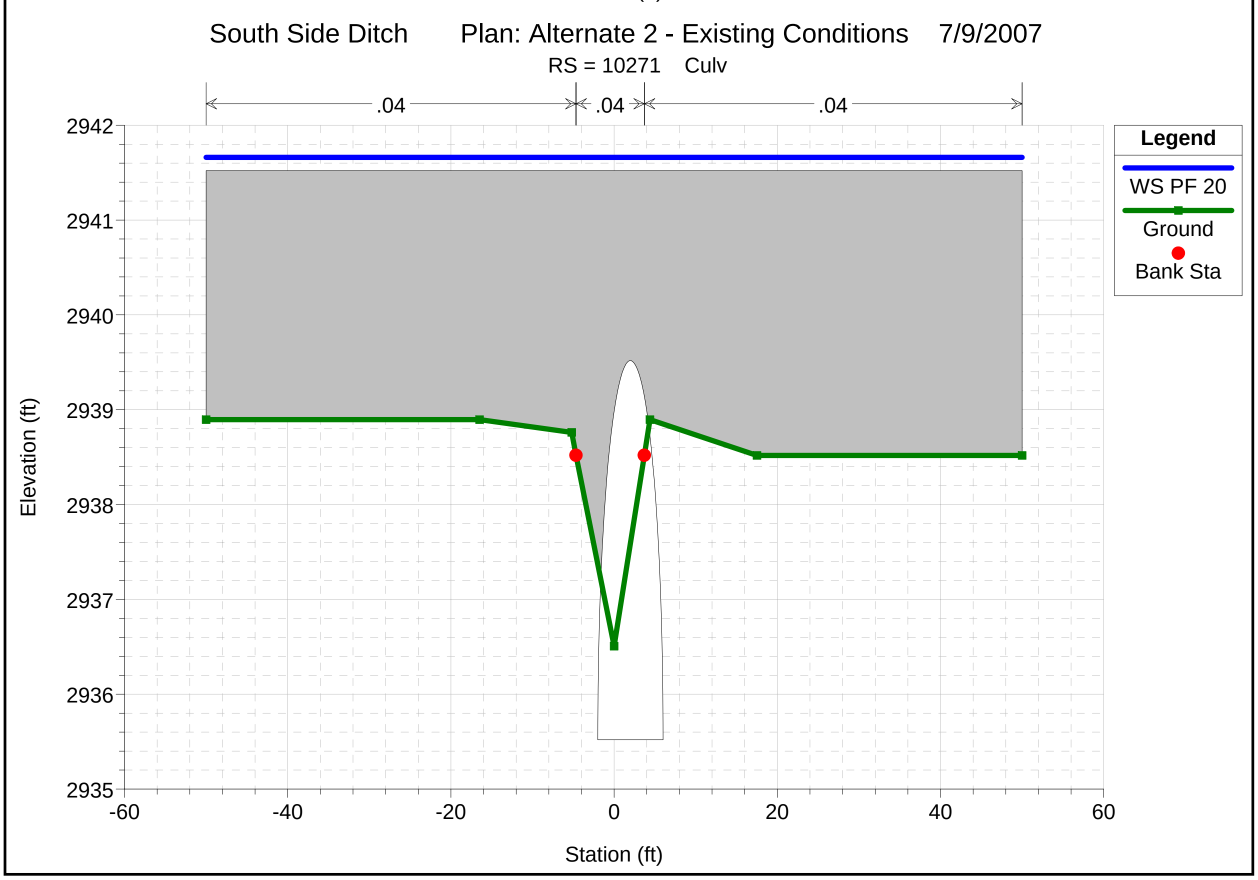
2938
2937
2936
2935
-60
-40
-20
0
20
40
60
Station (ft)



South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
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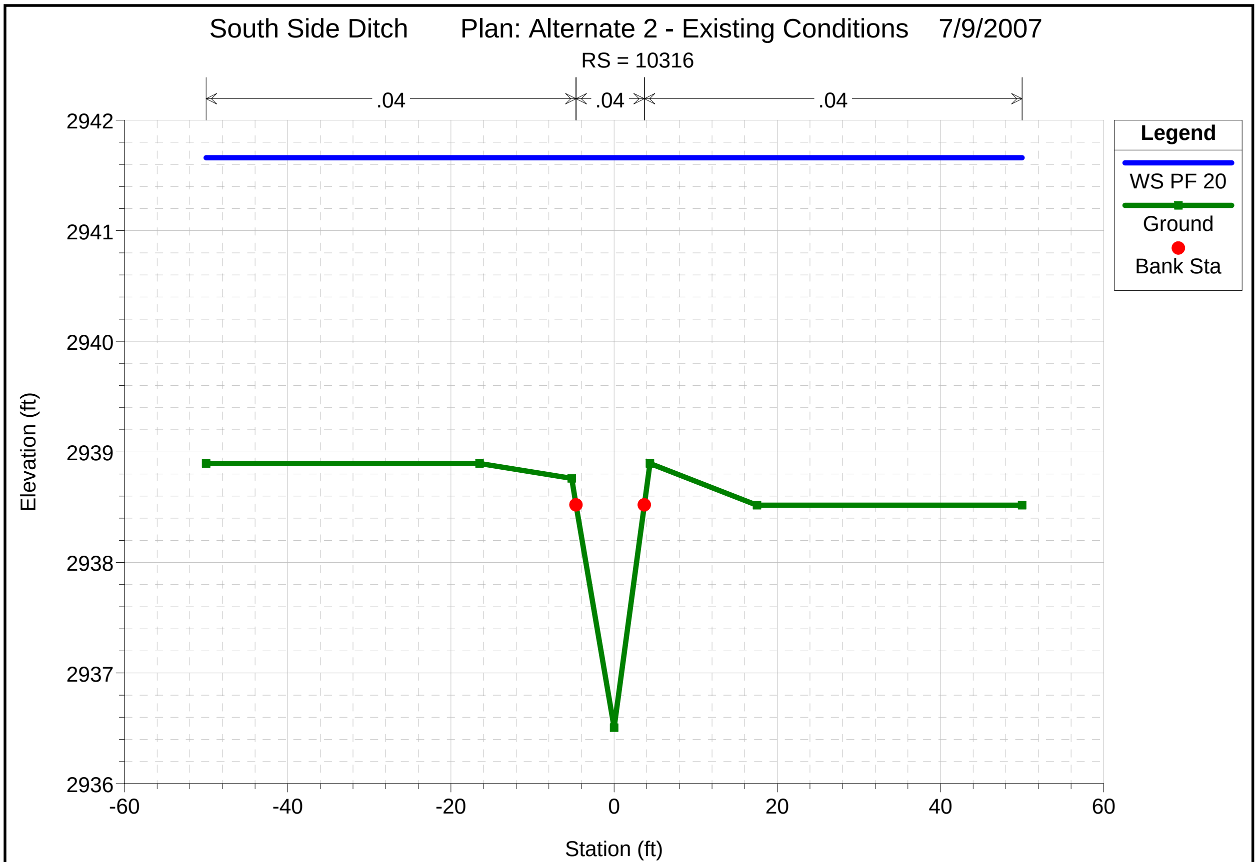
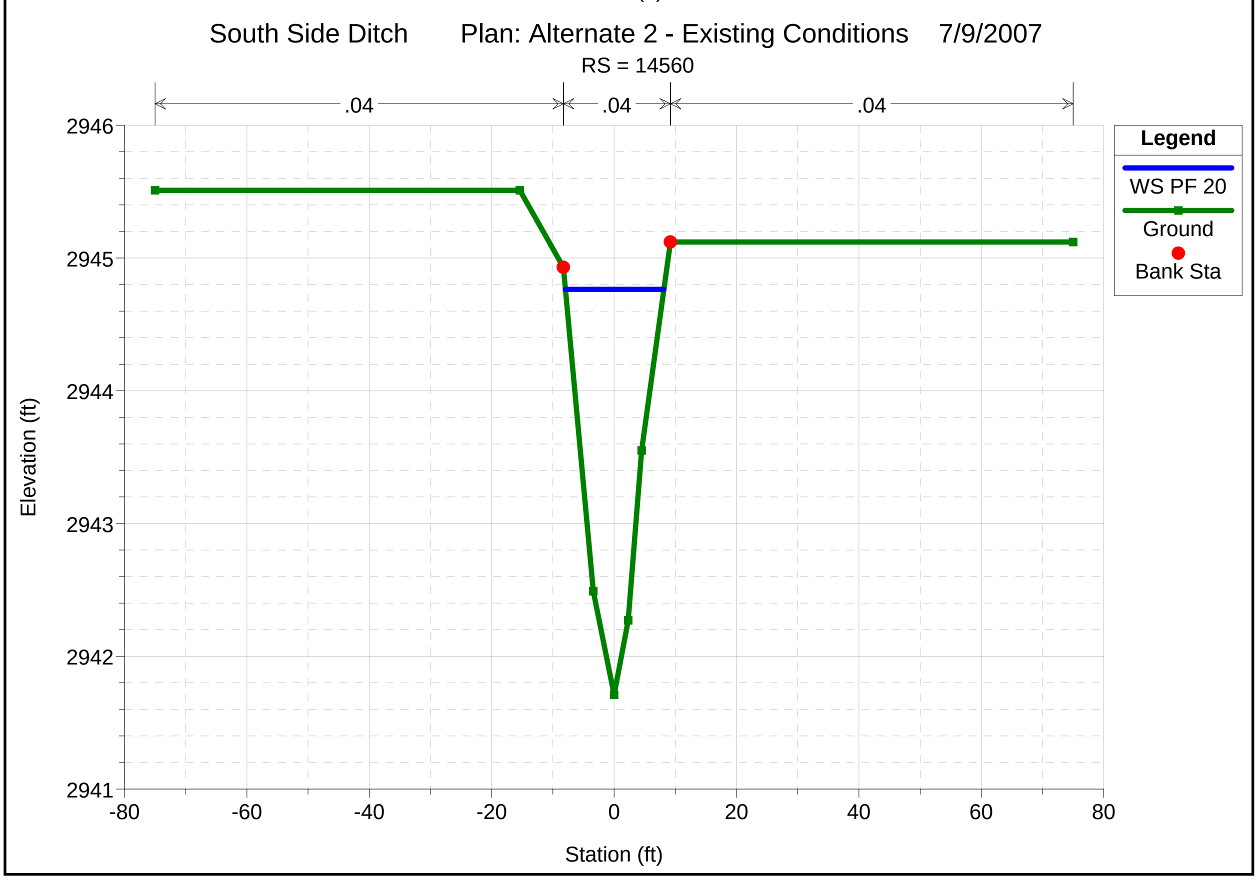
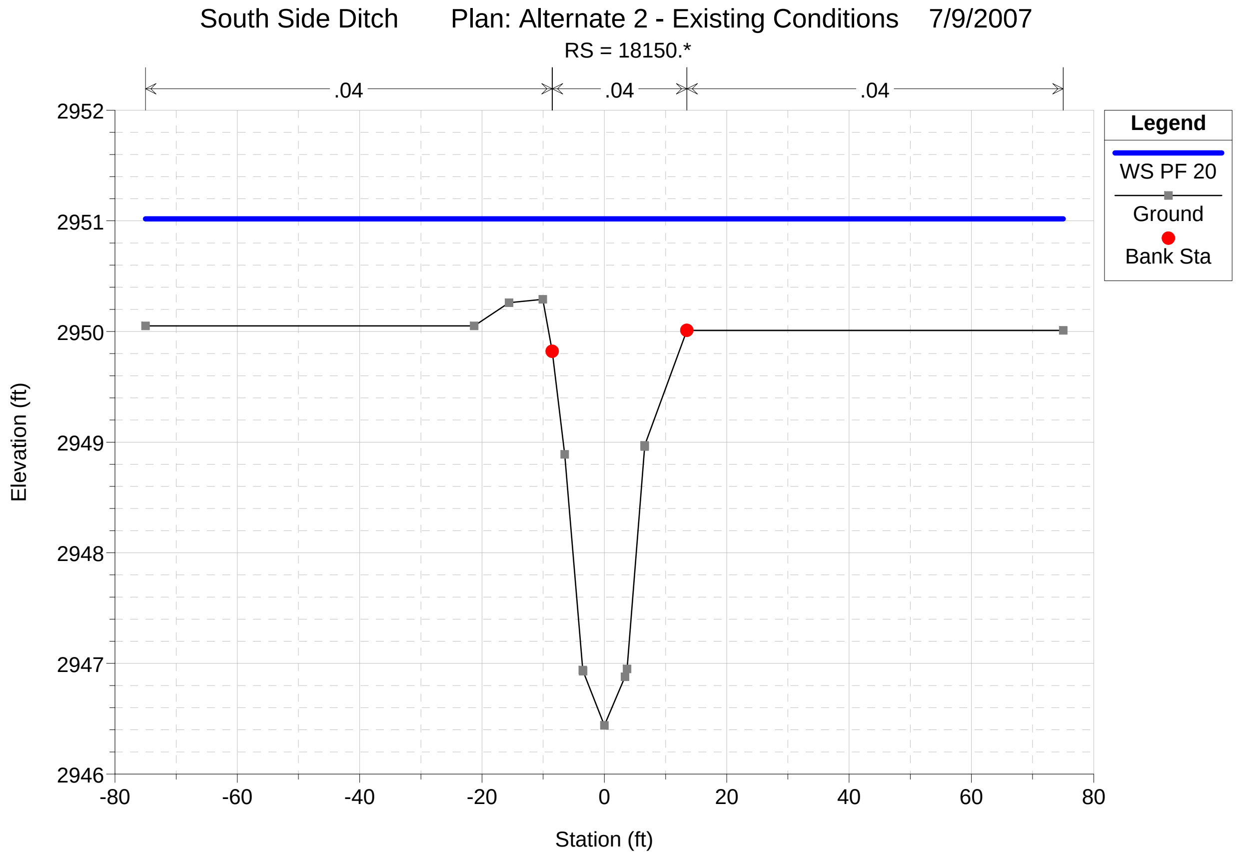
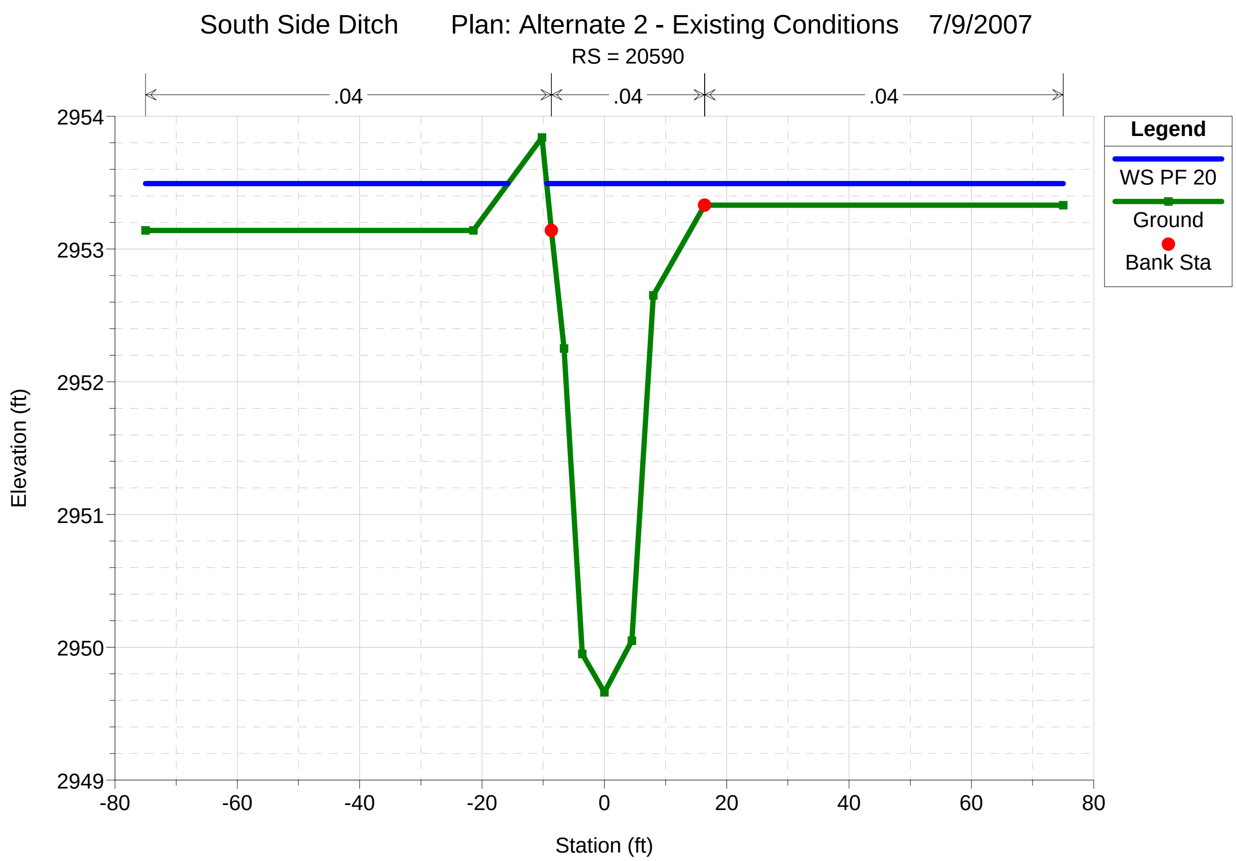
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2942
2941
2940
2939
2938
2937
2936
2935
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 10316
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2942
2941
2940
2939
2938
2937
2936
-60
-40
-20
0
20
40
60
Station (ft)

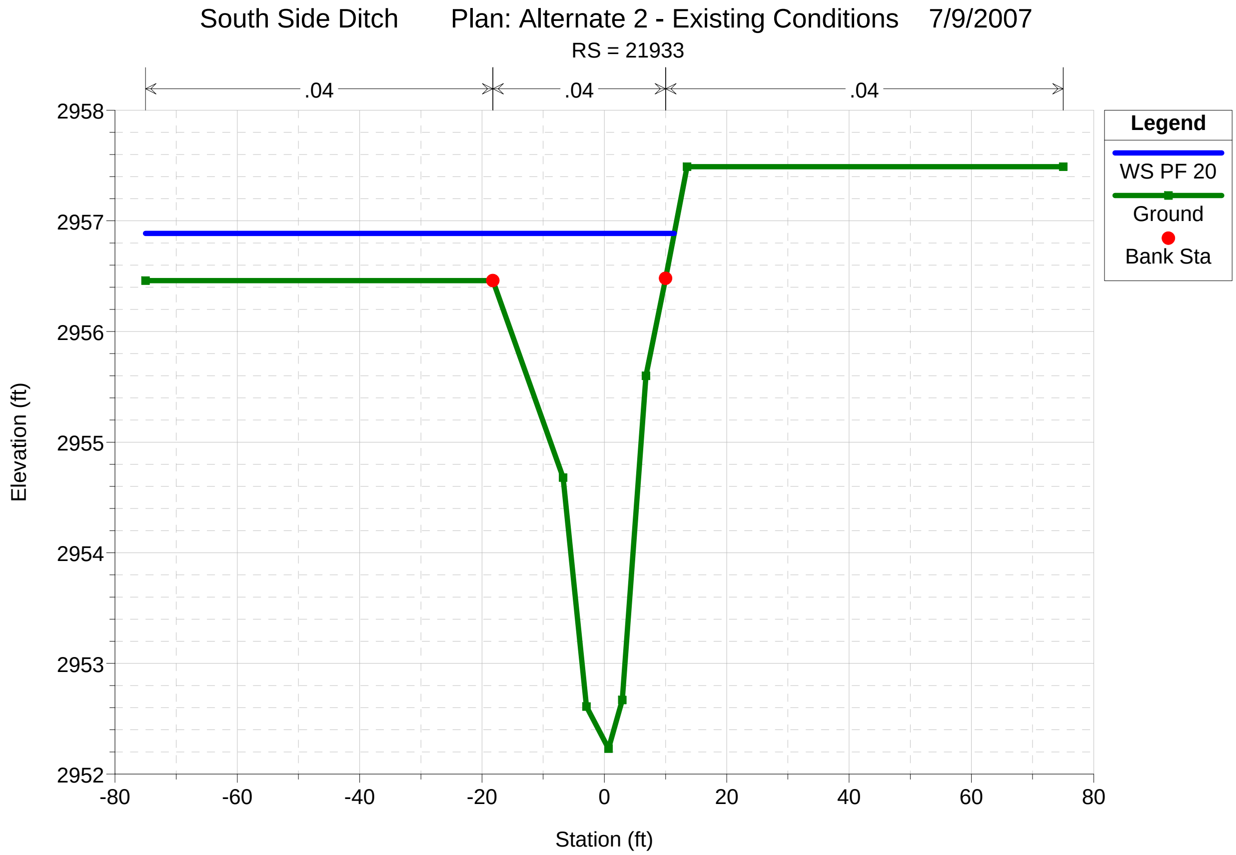

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 14560
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2946
2945
2944
2943
2942
2941
-80
-60
-40
-20
0
20
40
60
80
Station (ft)

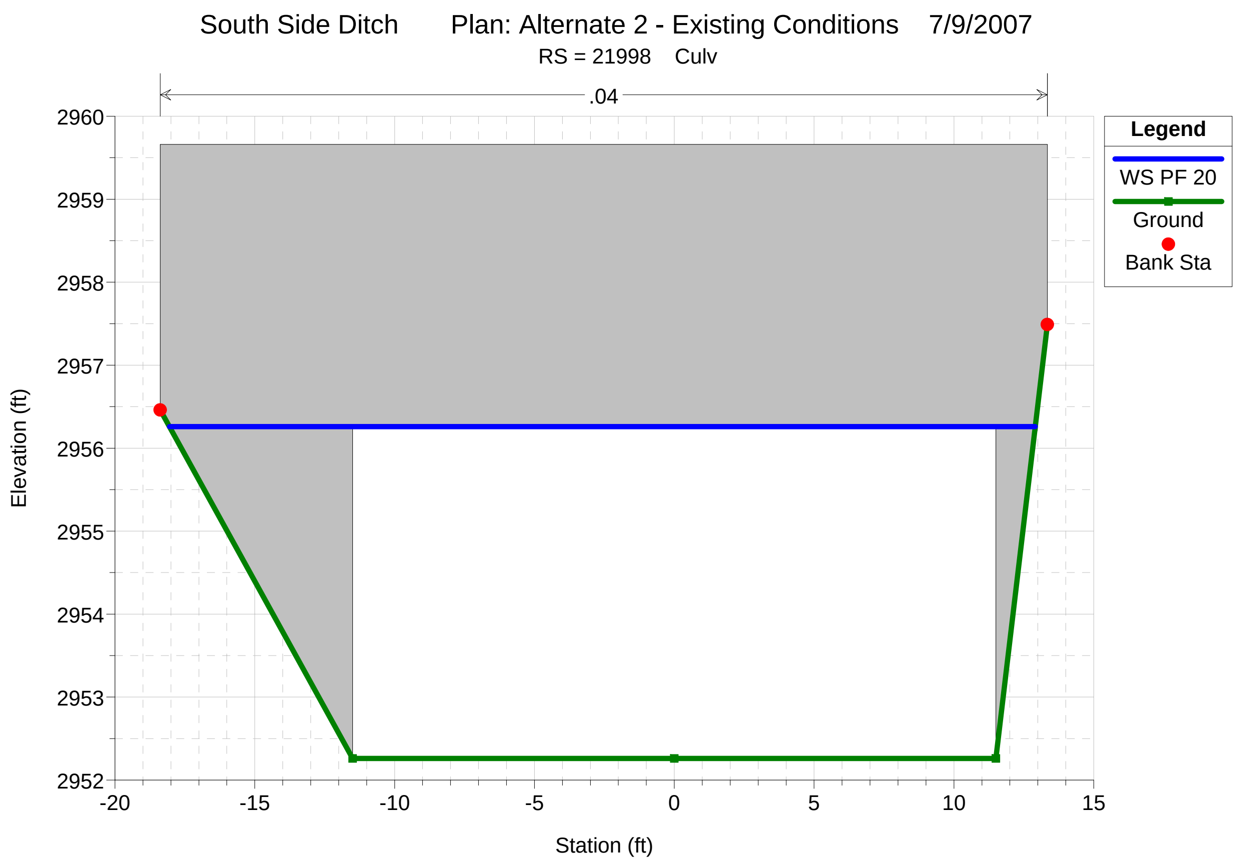


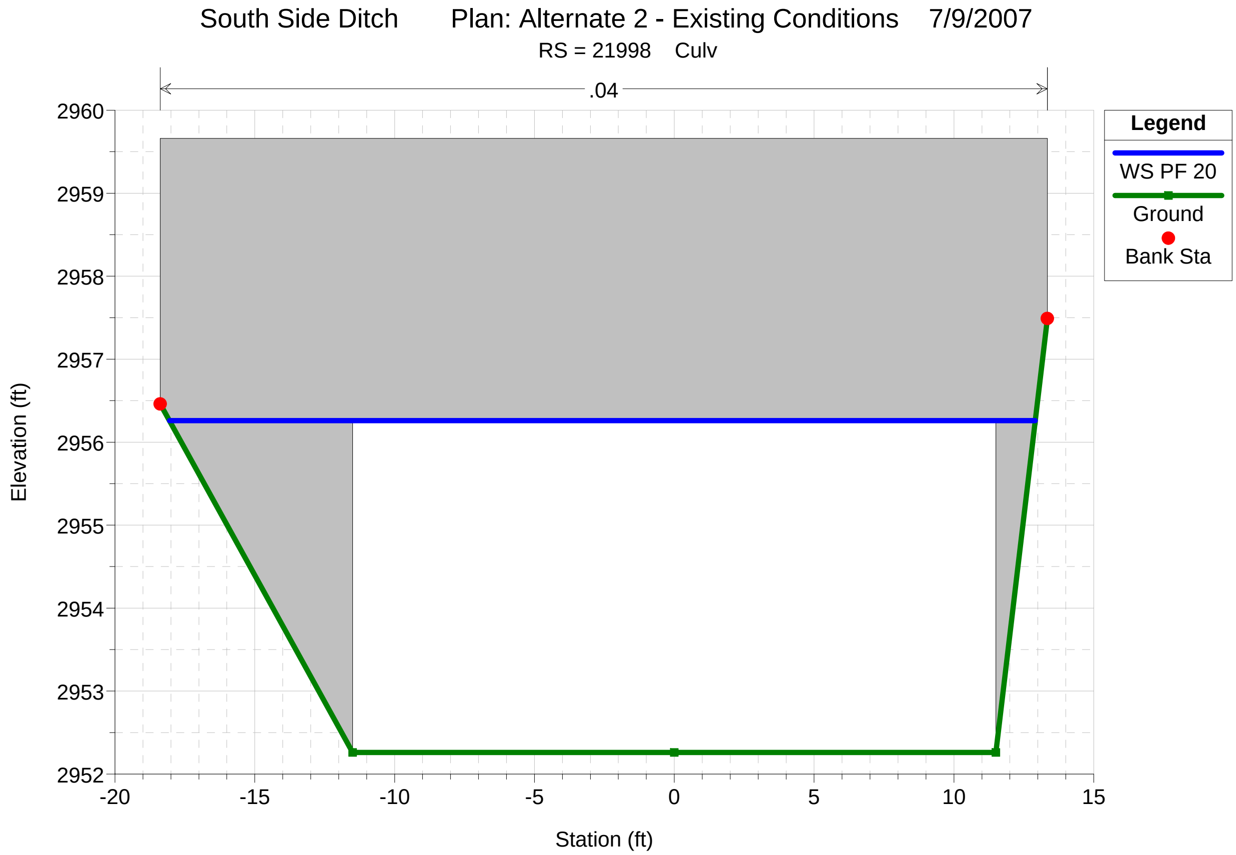
South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 18150.*
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
2952
2951
2950
2949
2948
2947
2946
-80
-60
-40
-20
0
20
40
60
80

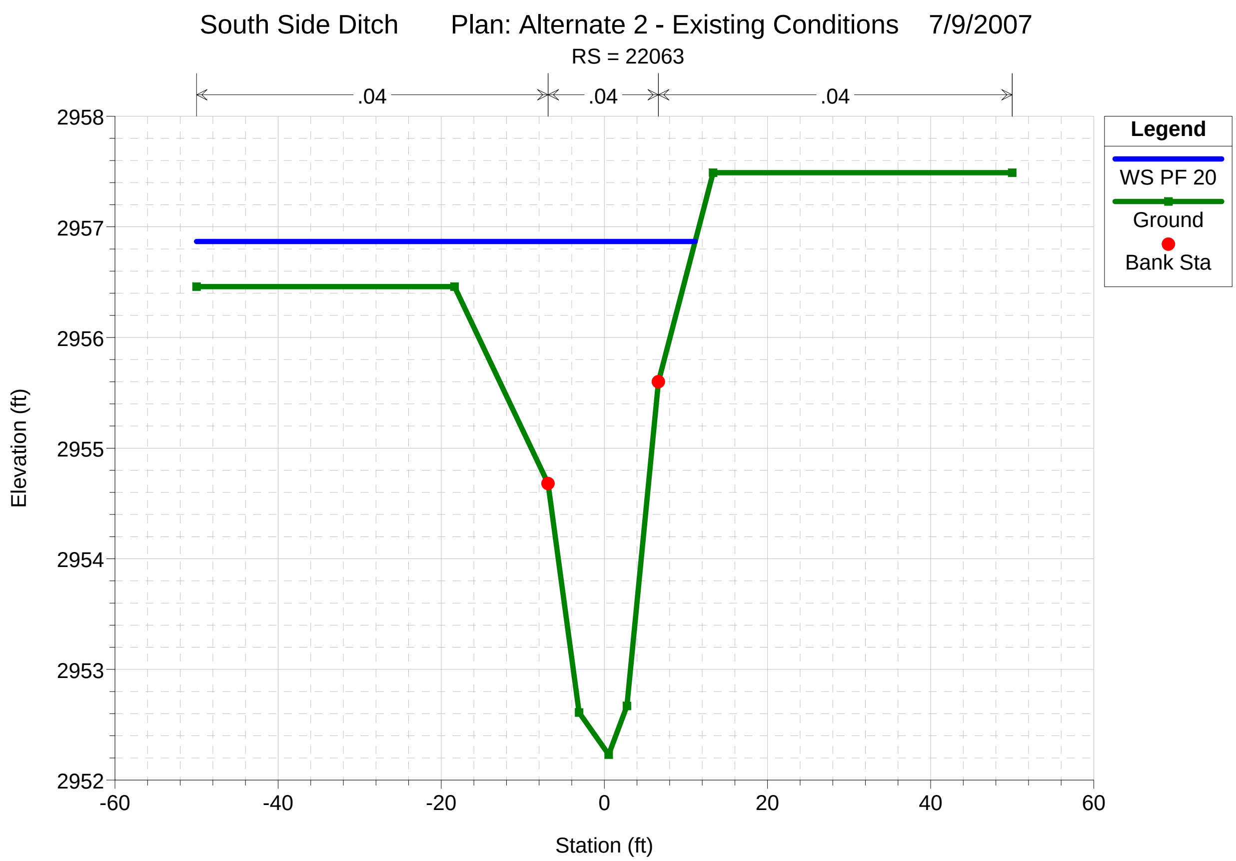


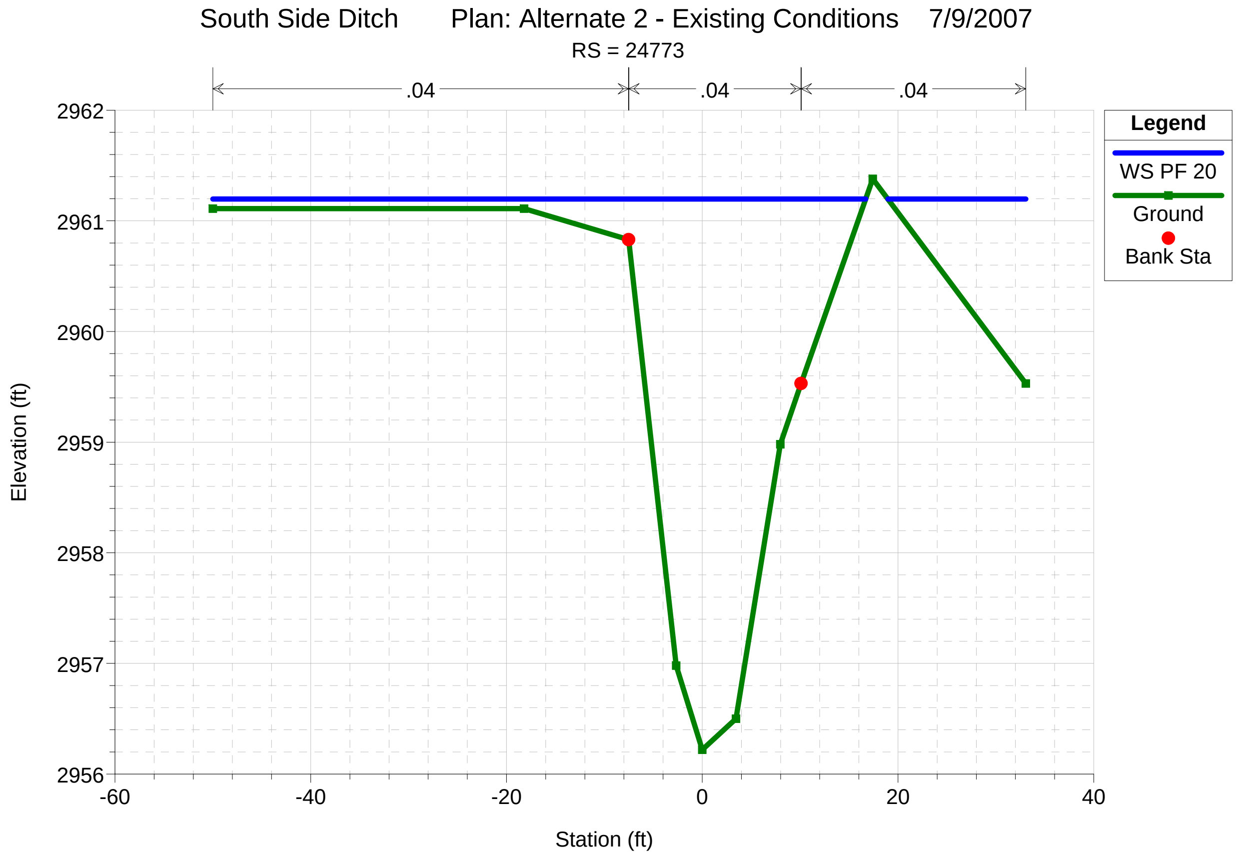
South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 20590
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
2954
2953
2952
2951
2950
2949
-80
-60
-40
-20
0
20
40
60
80

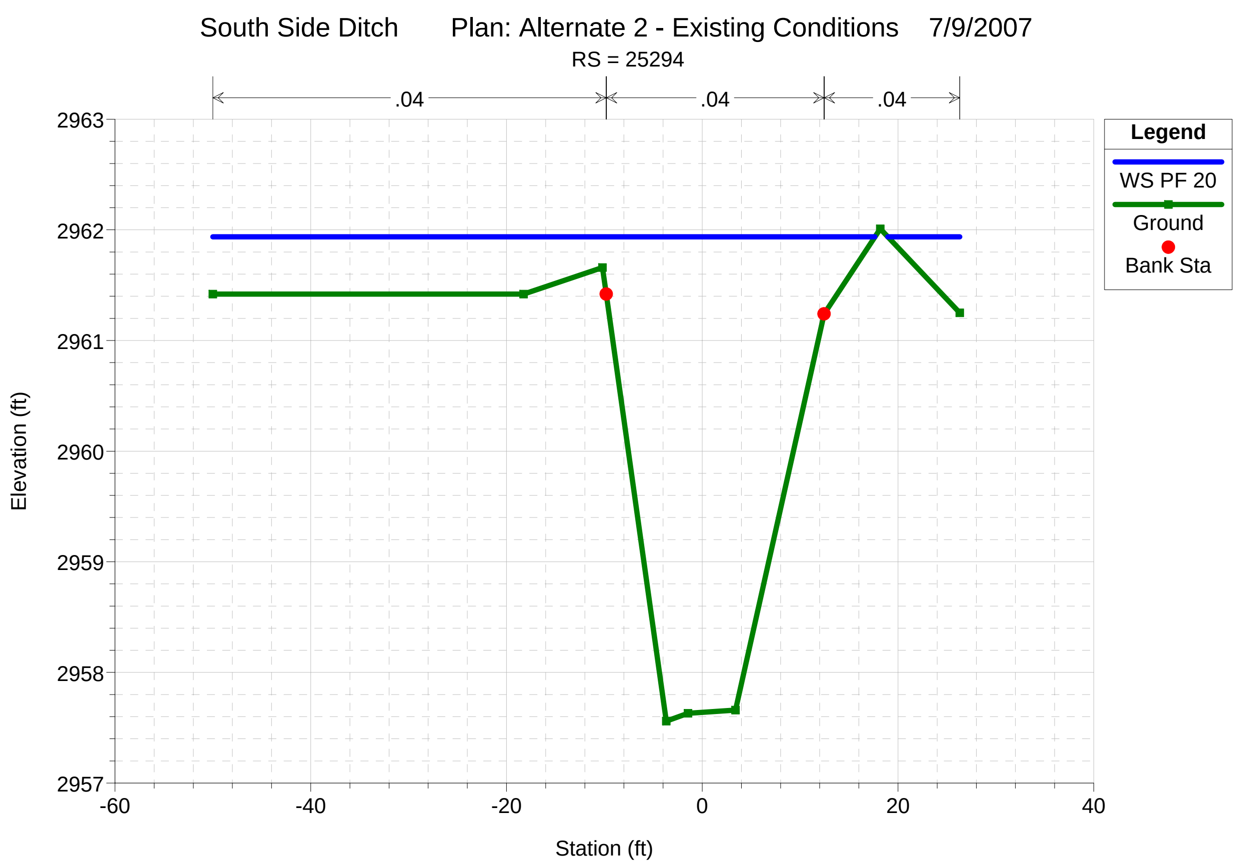

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 21933
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2958
2957
2956
2955
2954
2953
2952
-80
-60
-40
-20
0
20
40
60
80
Station (ft)

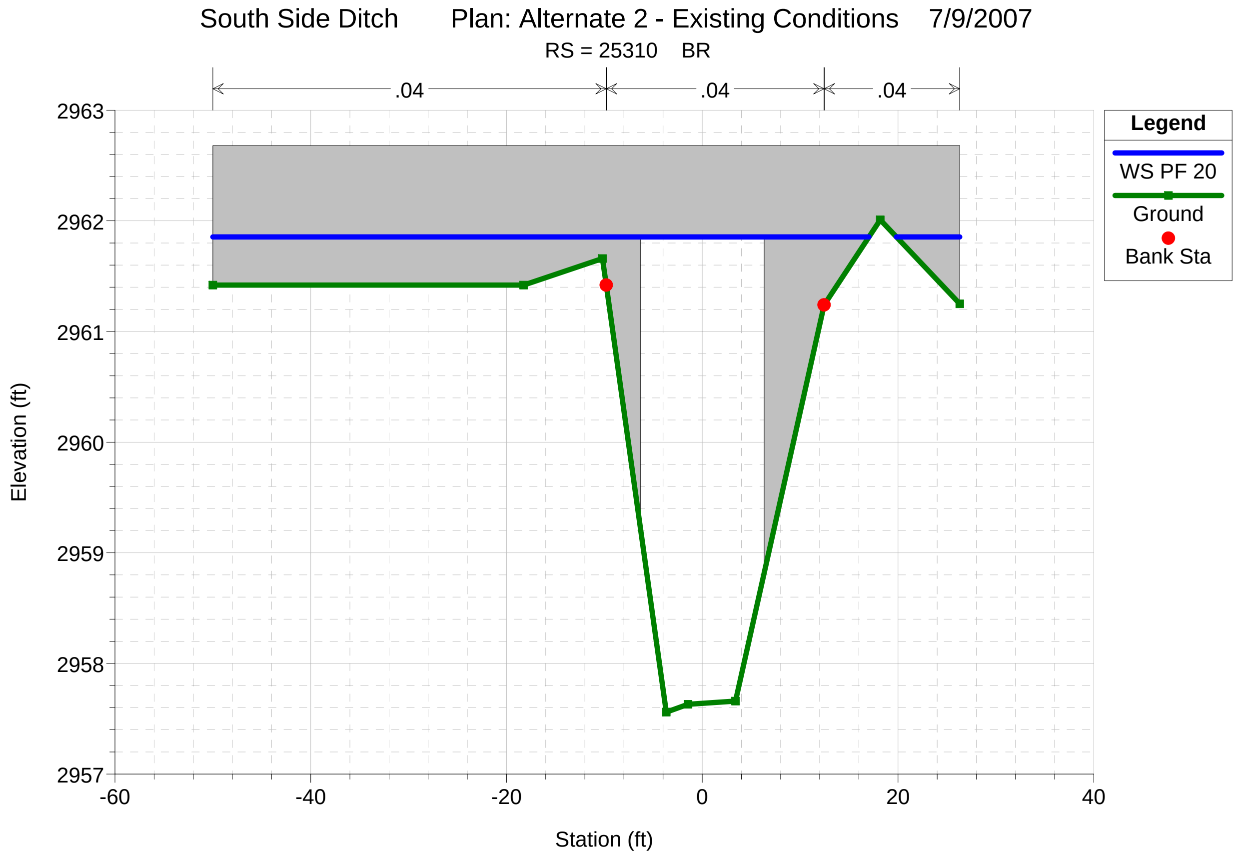

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 21998 Culv
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2960
2959
2958
2957
2956
2955
2954
2953
2952
-20
-15
-10
-5
0
5
10
15
Station (ft)

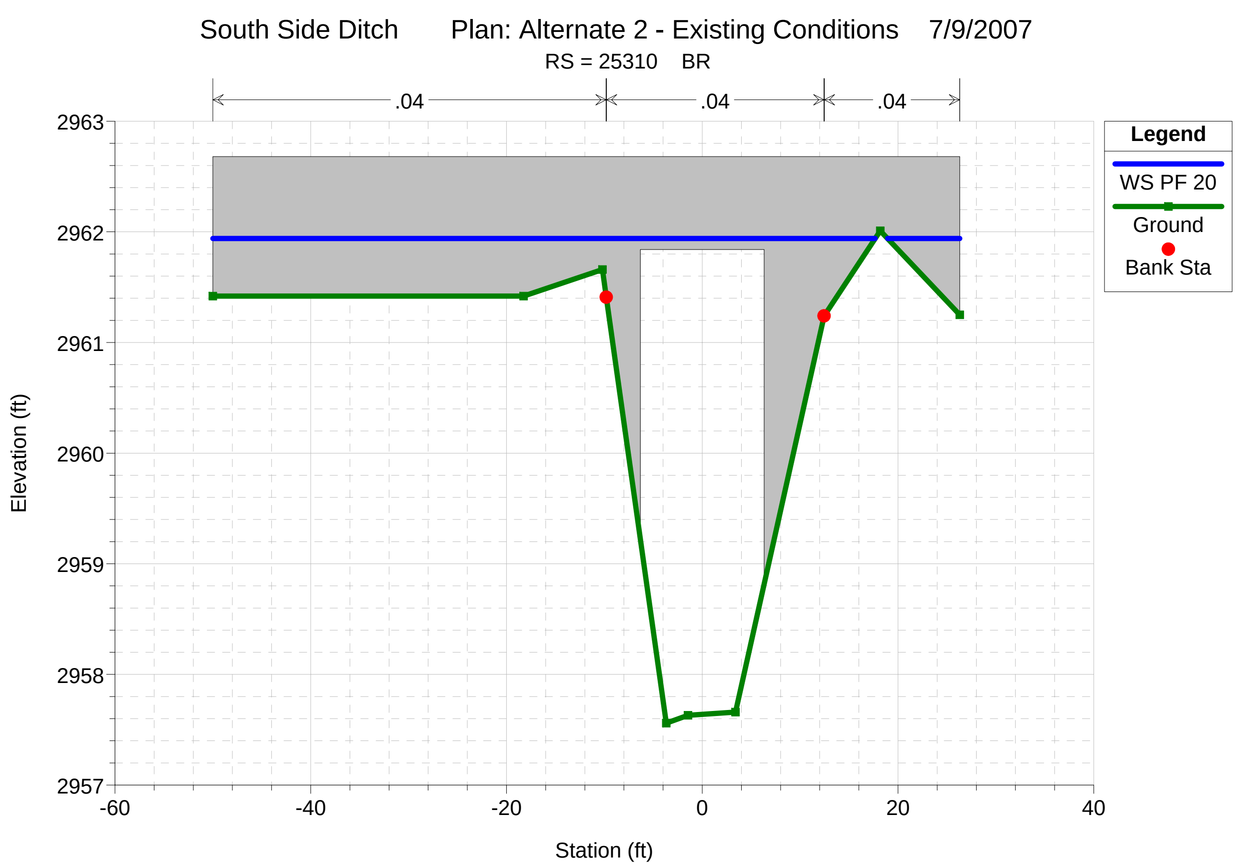

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 21998 Culv
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2960
2959
2958
2957
2956
2955
2954
2953
2952
-20
-15
-10
-5
0
5
10
15
Station (ft)

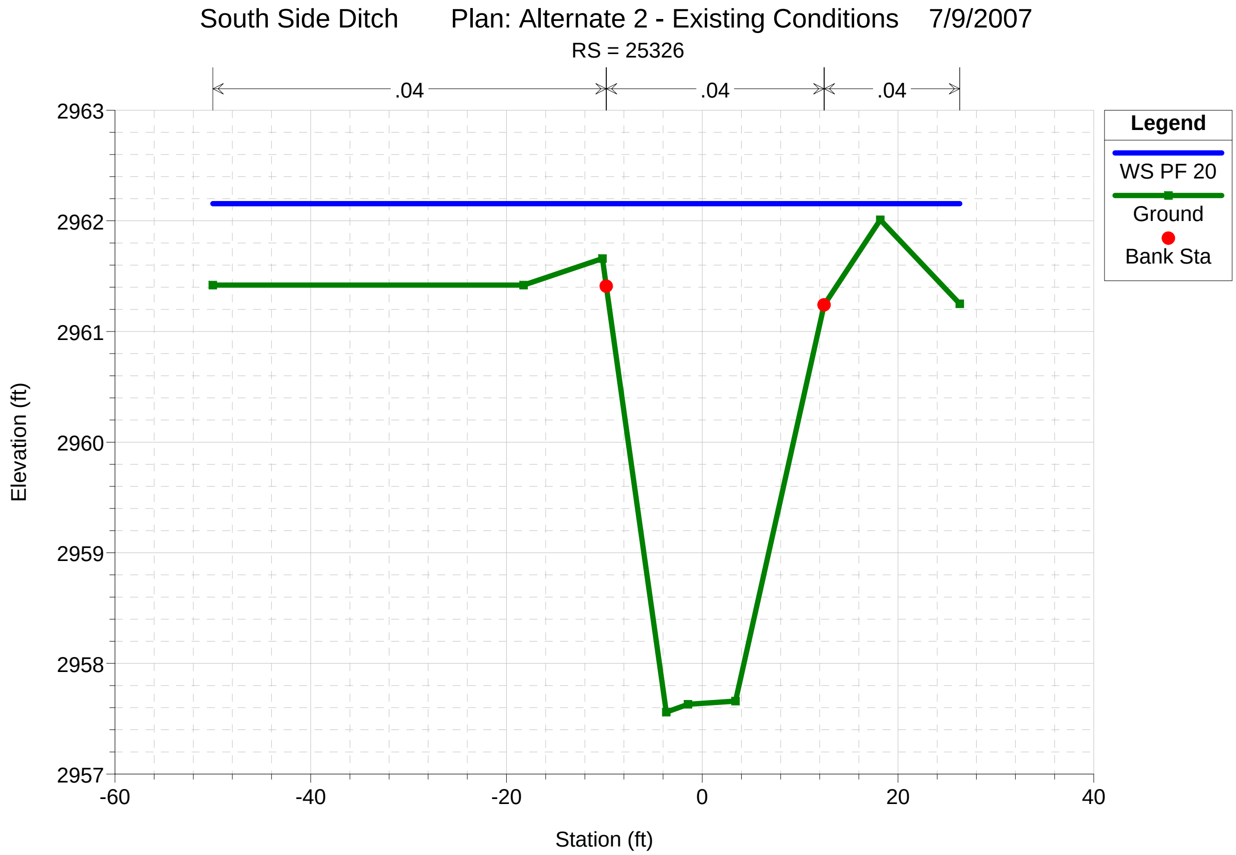

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 22063
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2958
2957
2956
2955
2954
2953
2952
-60
-40
-20
0
20
40
60
Station (ft)

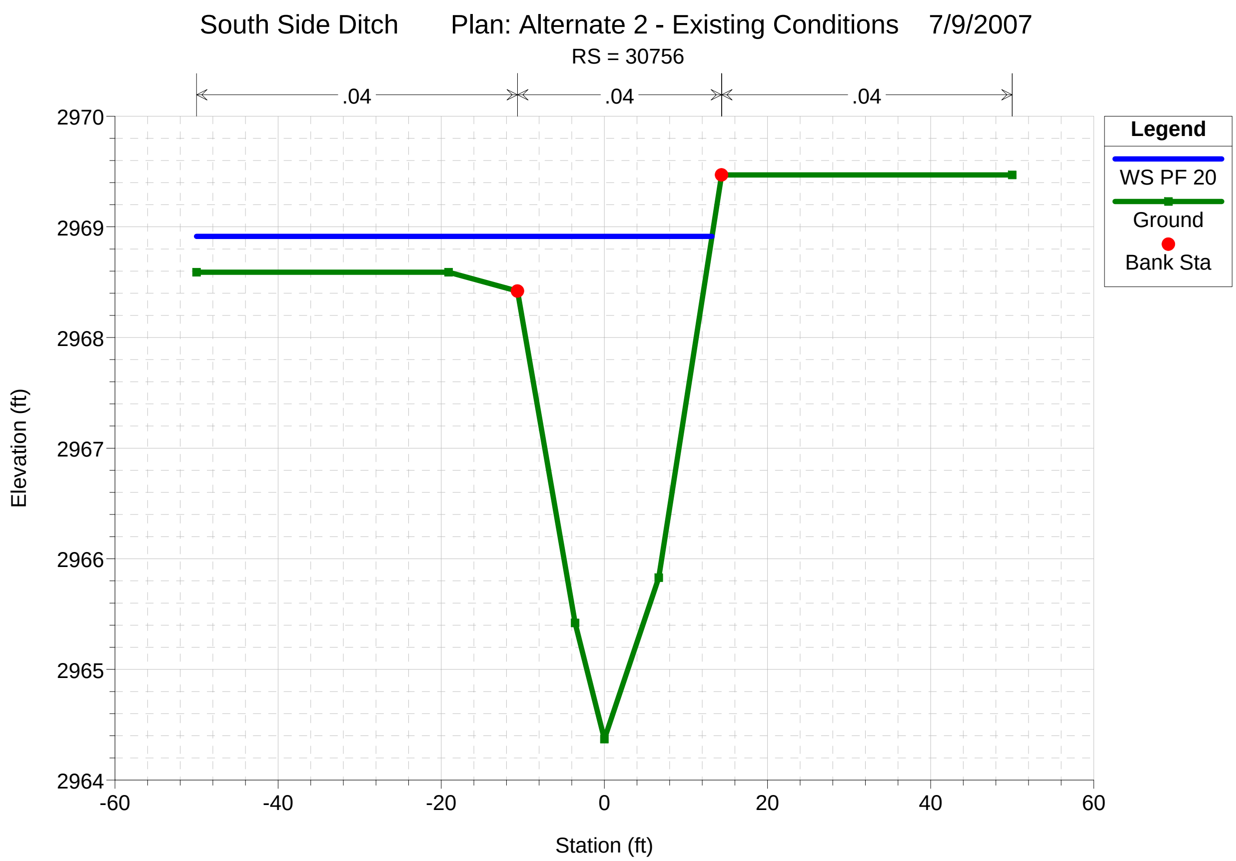

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 24773
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2962
2961
2960
2959
2958
2957
2956
-60
-40
-20
0
20
40
Station (ft)

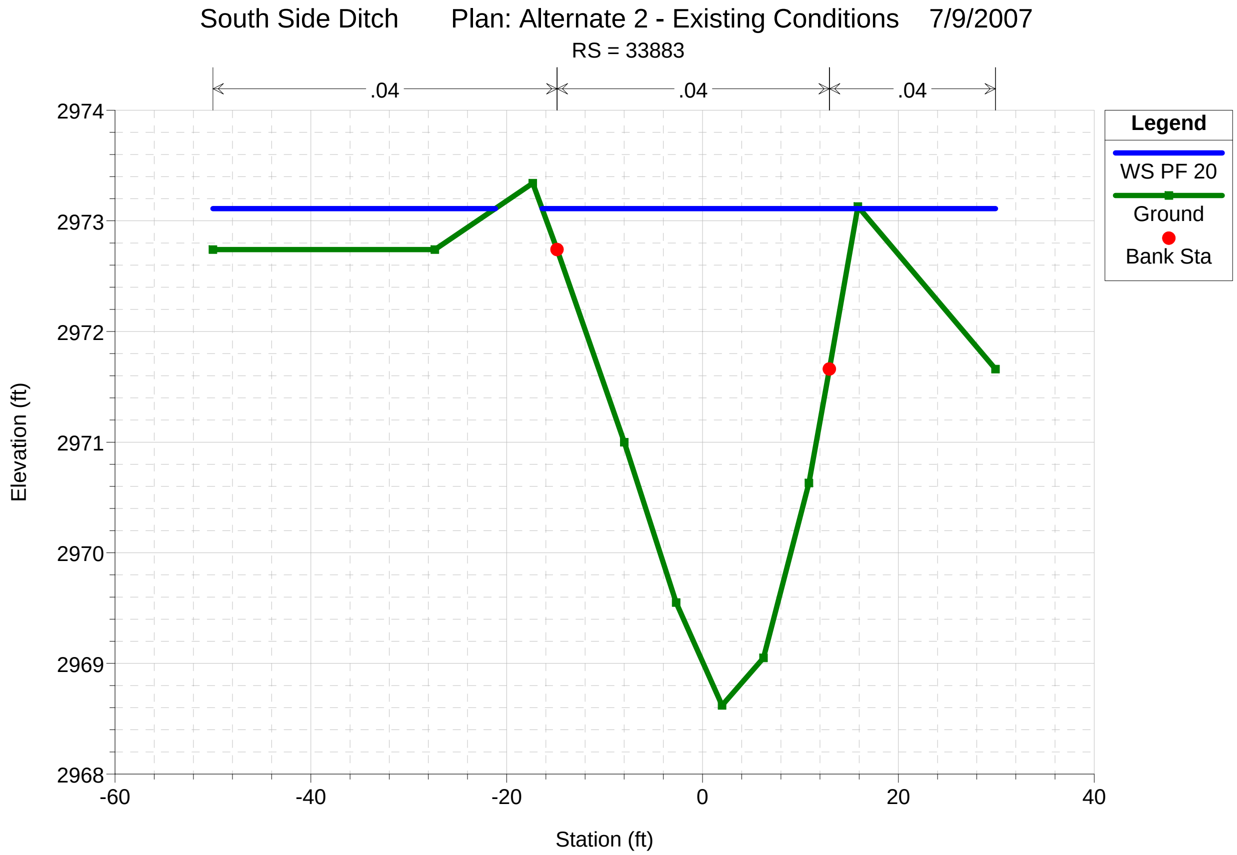

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 25294
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2963
2962
2961
2960
2959
2958
2957
-60
-40
-20
0
20
40
Station (ft)

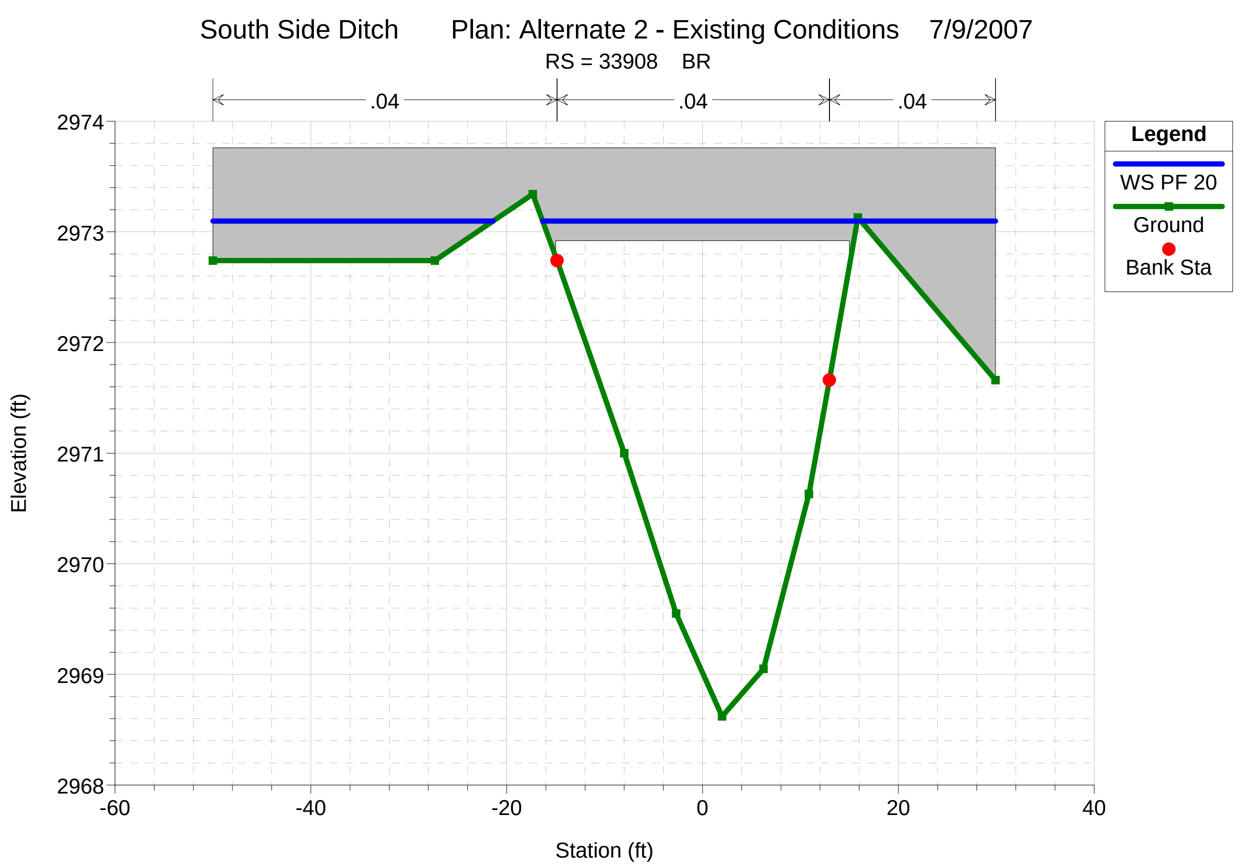

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 25310 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2963
2962
2961
2960
2959
2958
2957
-60
-40
-20
0
20
40
Station (ft)

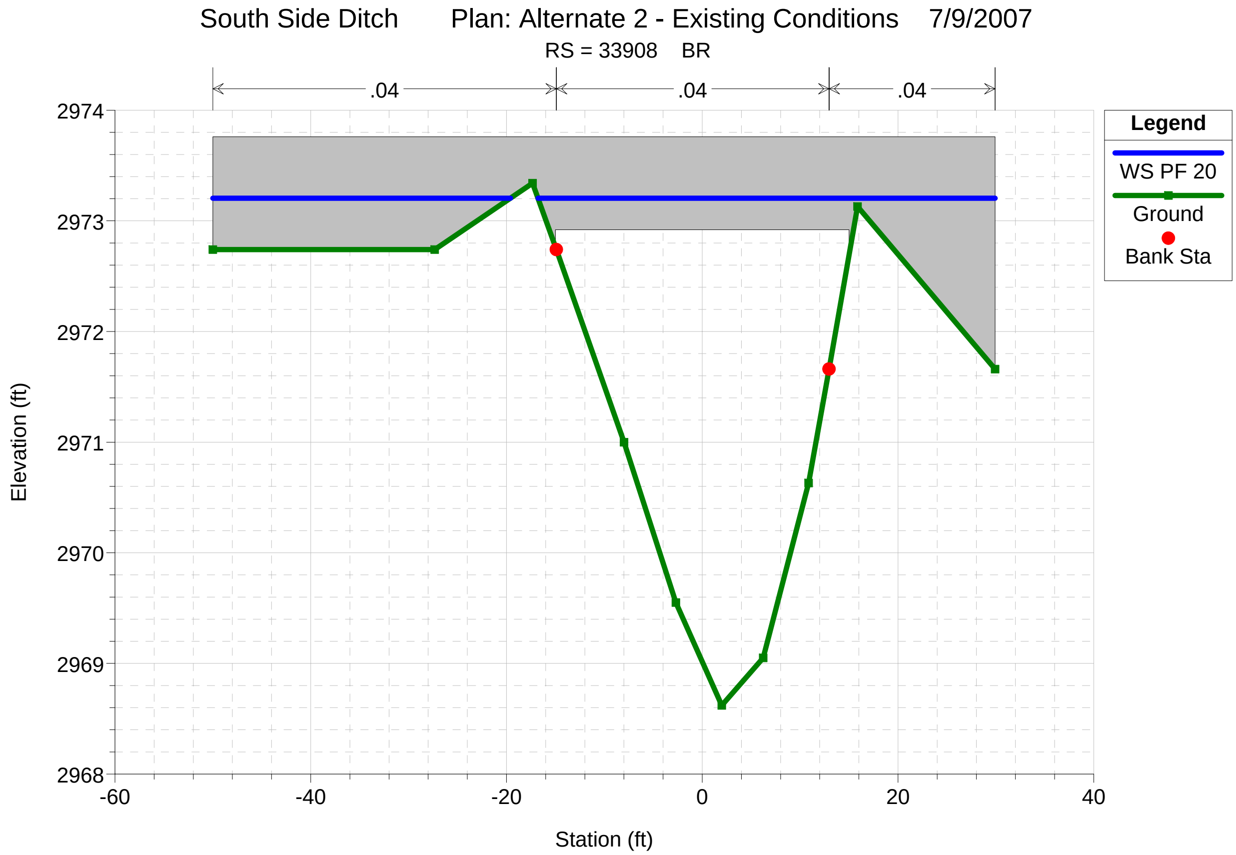

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 25310 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2963
2962
2961
2960
2959
2958
2957
-60
-40
-20
0
20
40
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 25326
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2963
2962
2961
2960
2959
2958
2957
-60
-40
-20
0
20
40
Station (ft)

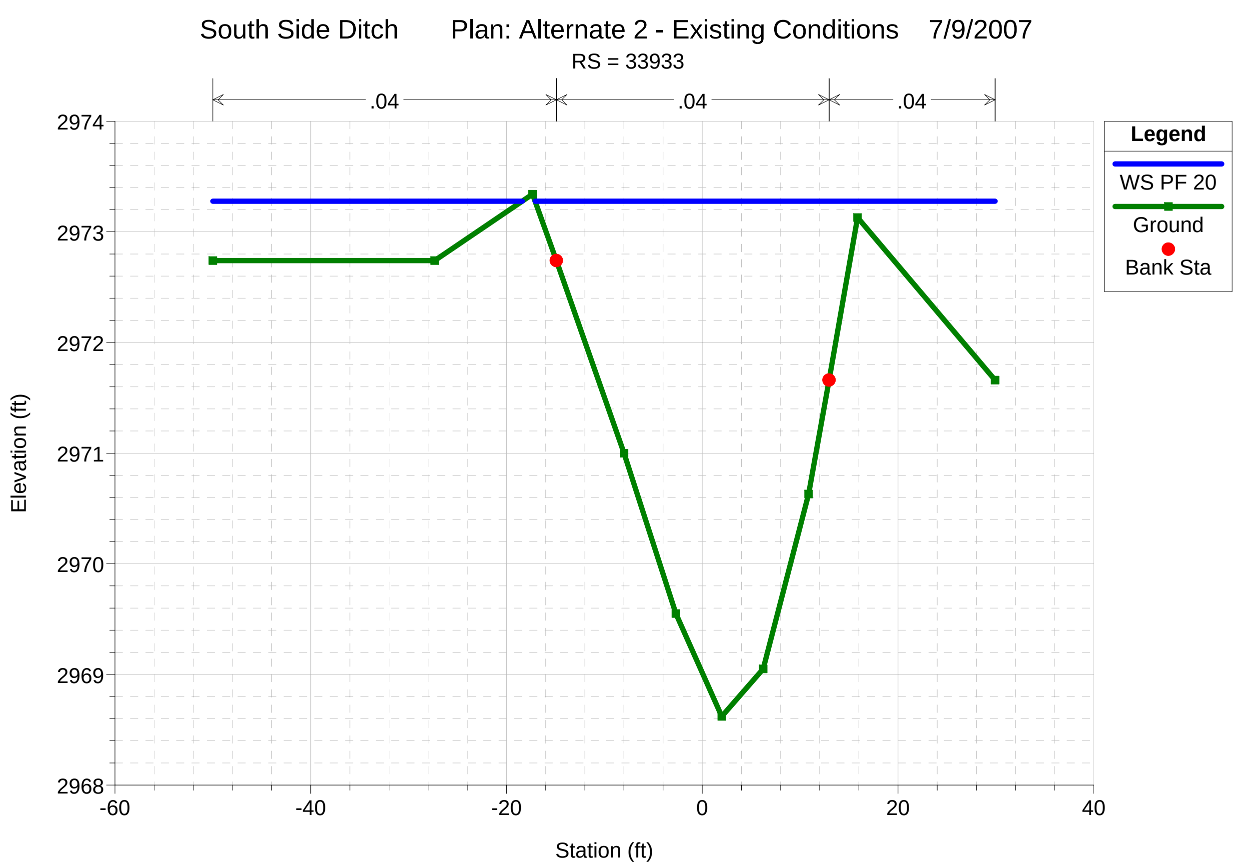

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 30756
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2970
2969
2968
2967
2966
2965
2964
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 33883
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2974
2973
2972
2971
2970
2969
2968
-60
-40
-20
0
20
40
Station (ft)

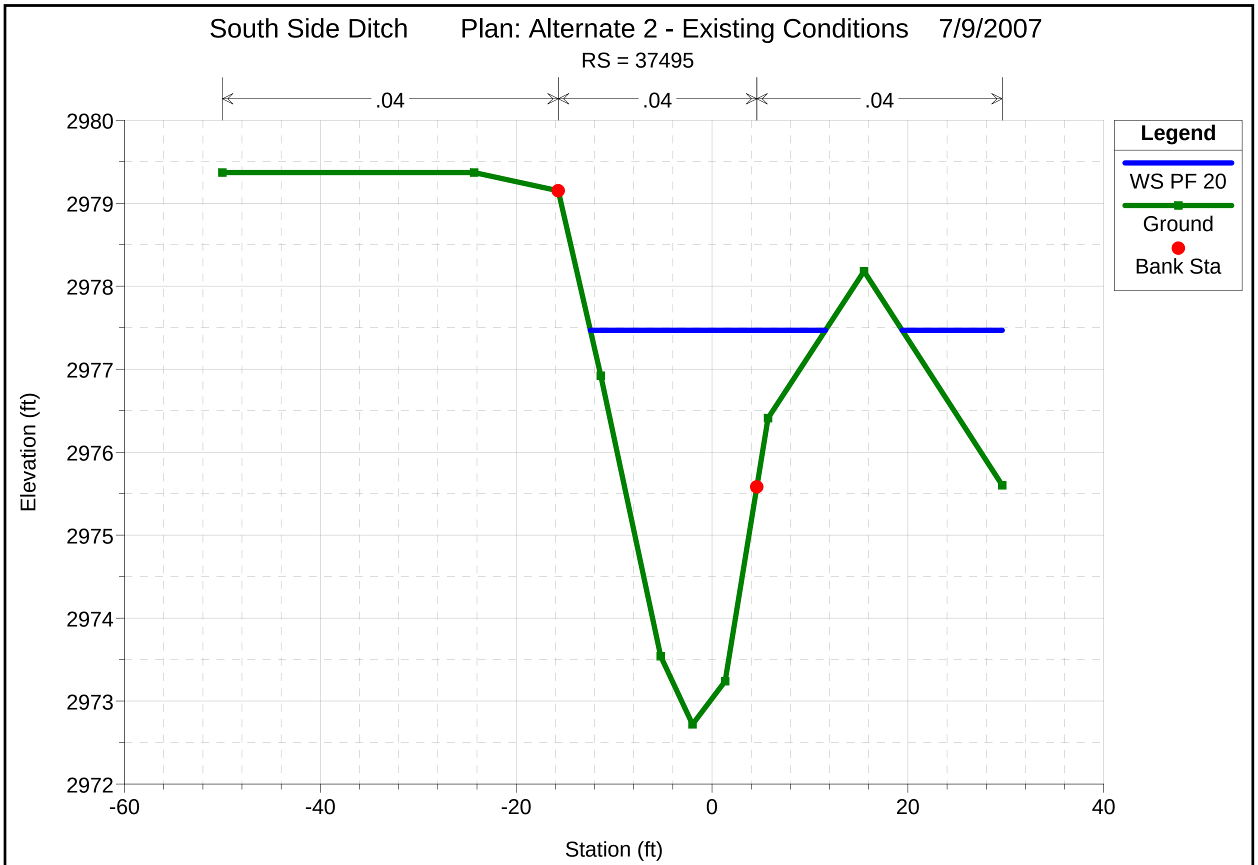

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 33908 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2974
2973
2972
2971
2970
2969
2968
-60
-40
-20
0
20
40
Station (ft)

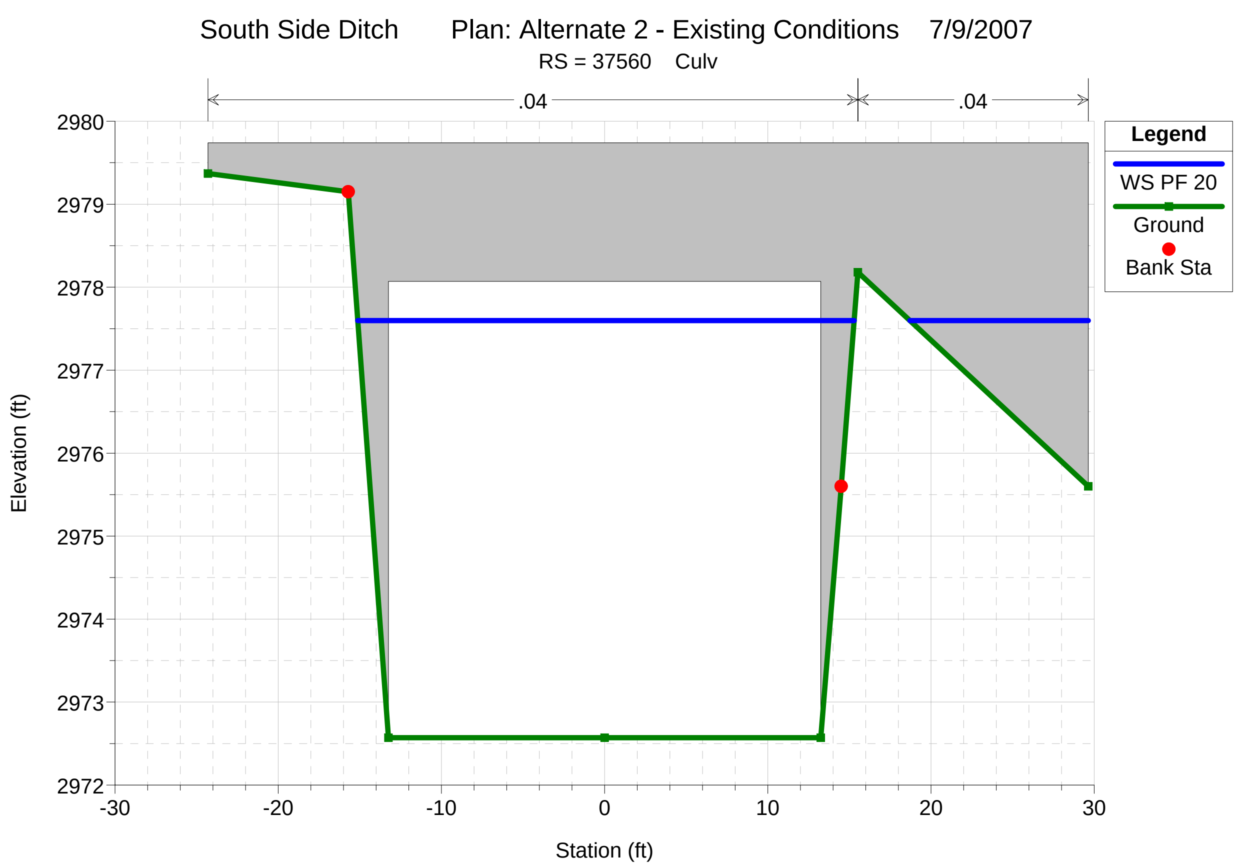


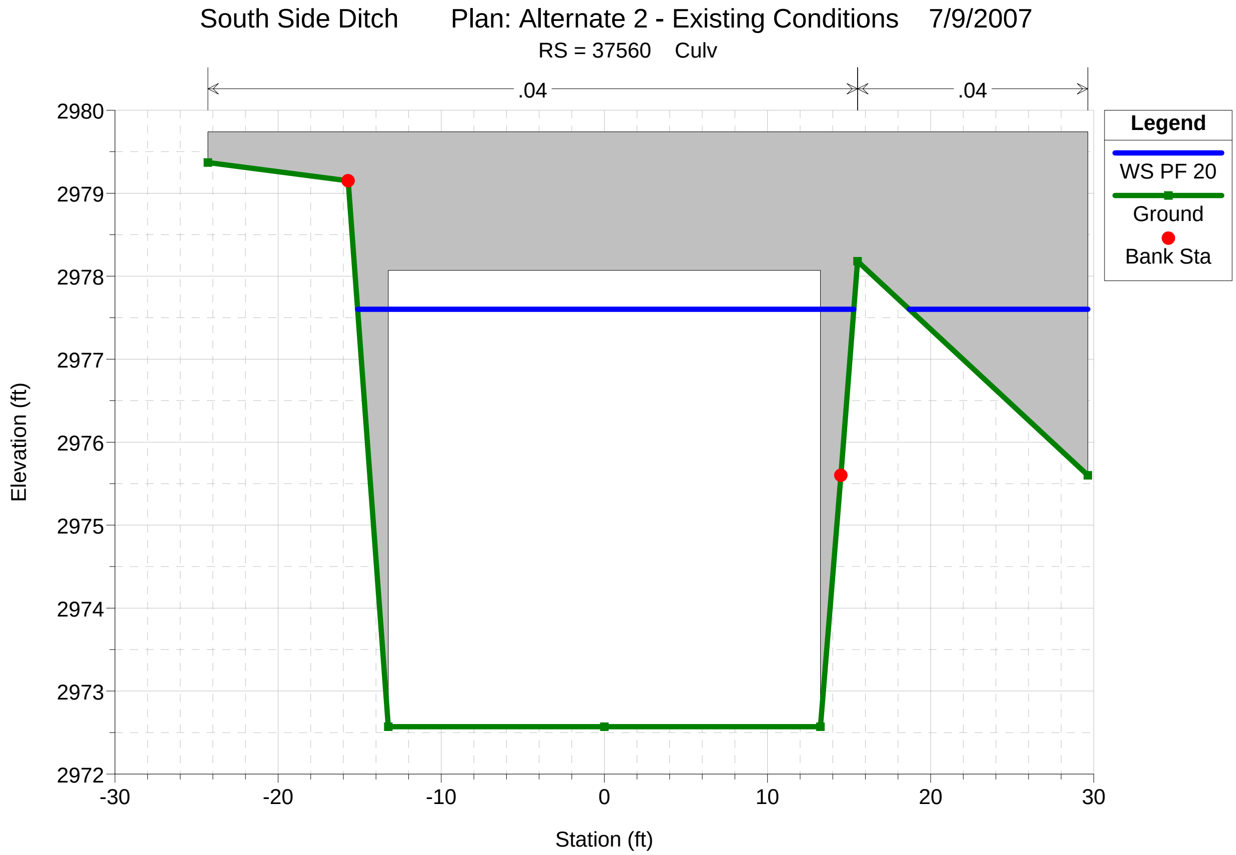
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 33908 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2974
2973
2972
2971
2970
2969
2968
-60
-40
-20
0
20
40
Station (ft)

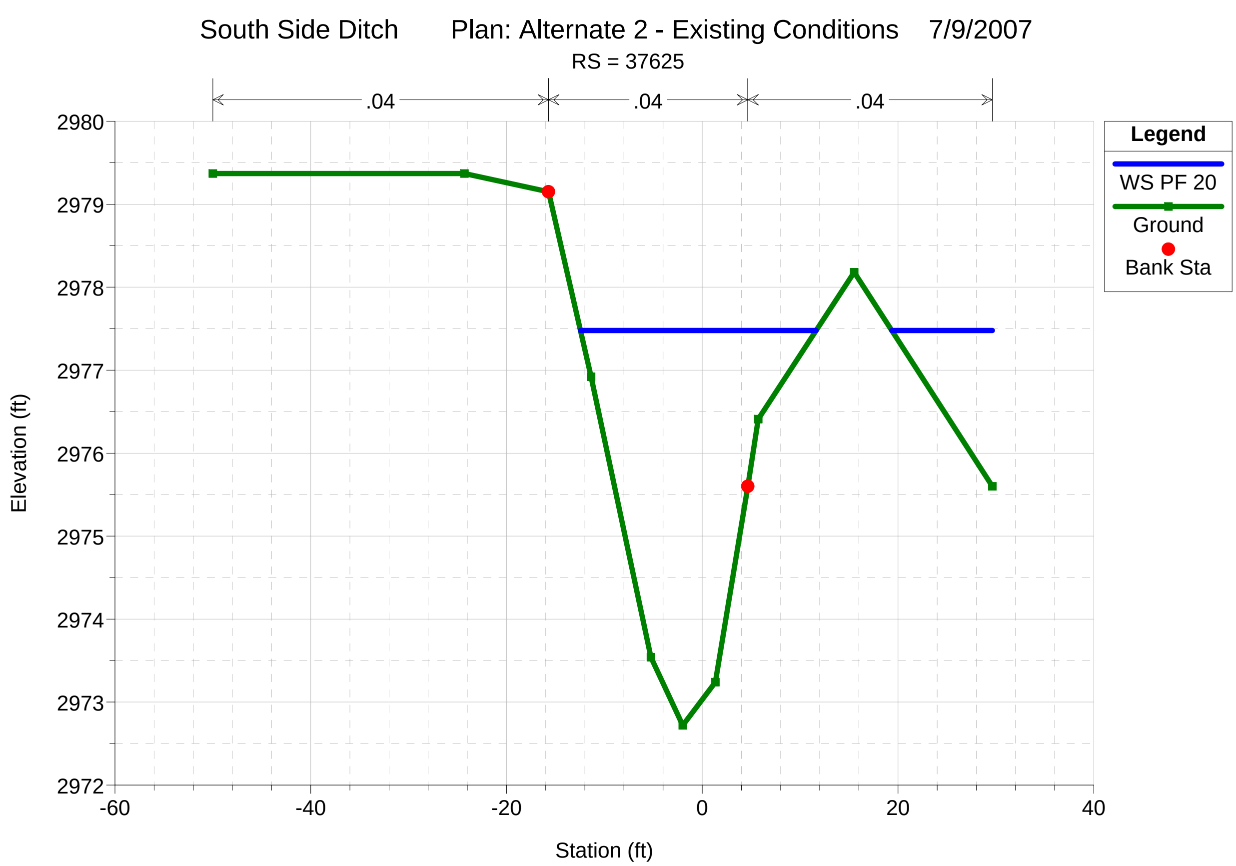


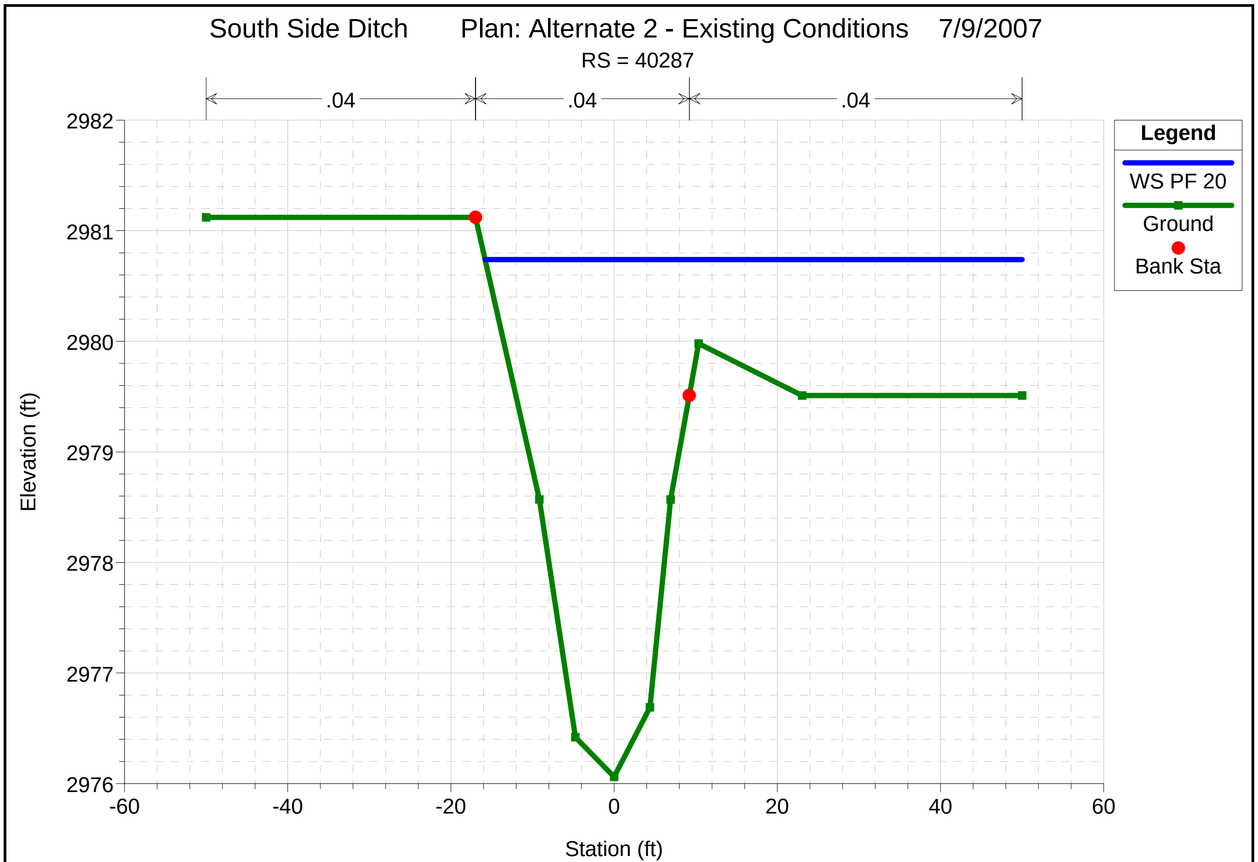
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 33933
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2974
2973
2972
2971
2970
2969
2968
-60
-40
-20
0
20
40
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 37495
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2980
2979
2978
2977
2976
2975
2974
2973
2972
-60
-40
-20
0
20
40
Station (ft)

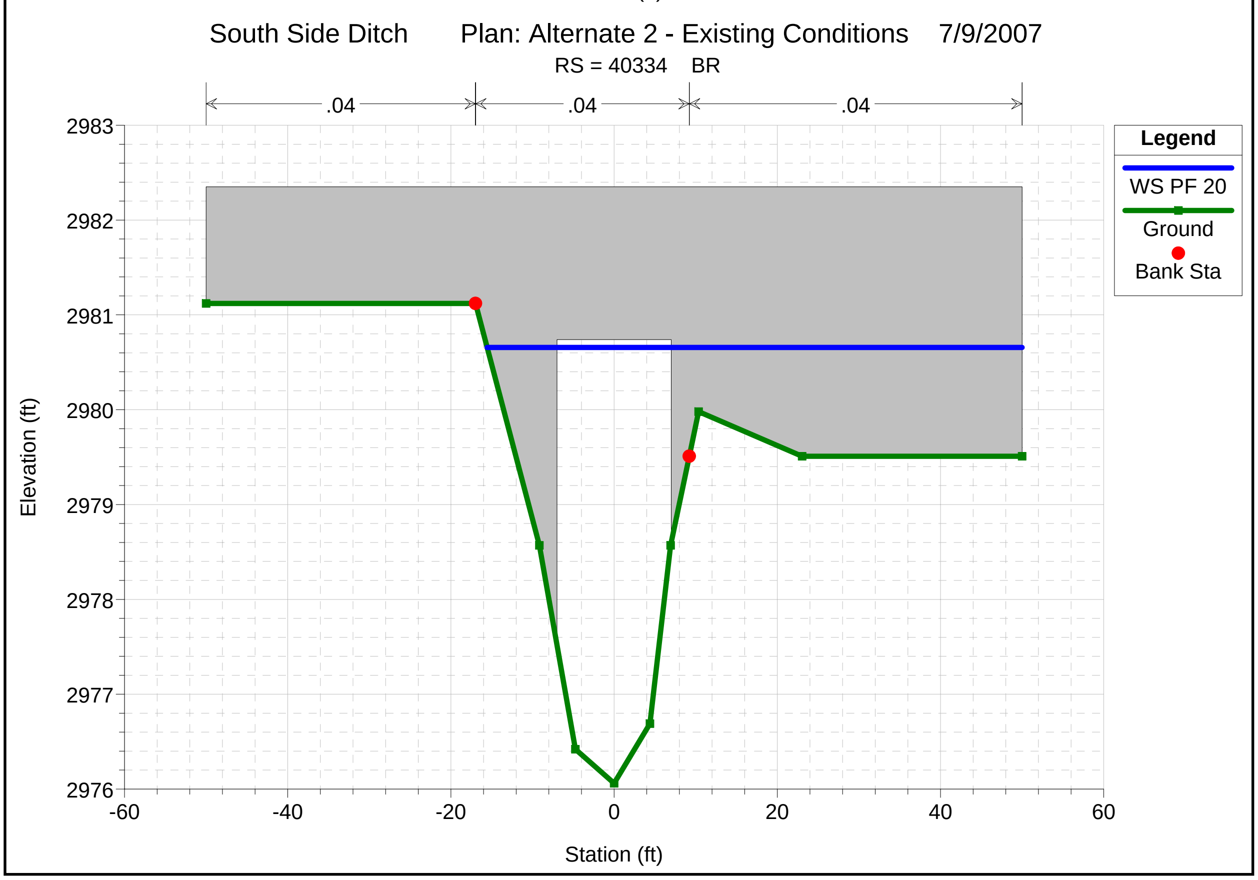

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 37560 Culv
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2980
2979
2978
2977
2976
2975
2974
2973
2972
-30
-20
-10
0
10
20
30
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 37560 Culv
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2980
2979
2978
2977
2976
2975
2974
2973
2972
-30
-20
-10
0
10
20
30
Station (ft)

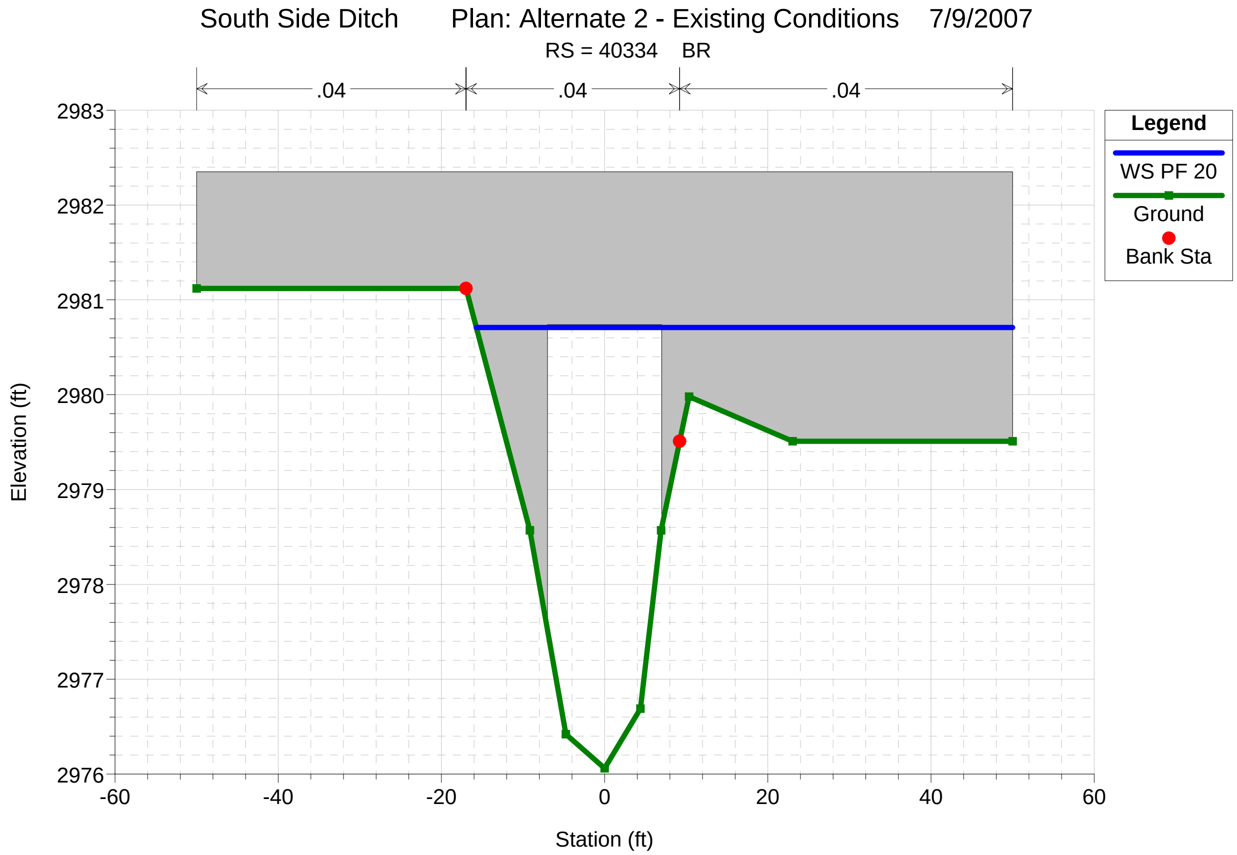

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 37625
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2980
2979
2978
2977
2976
2975
2974
2973
2972
-60
-40
-20
0
20
40
Station (ft)

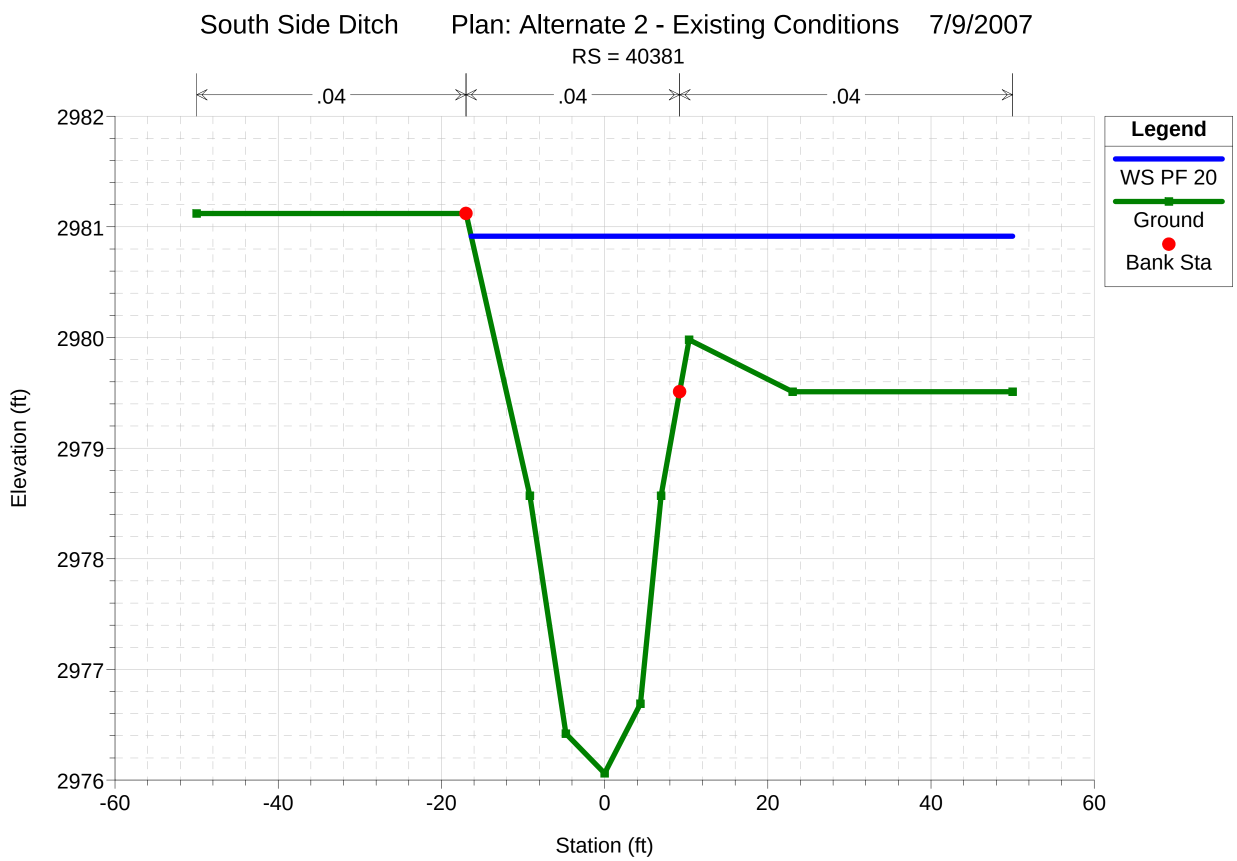


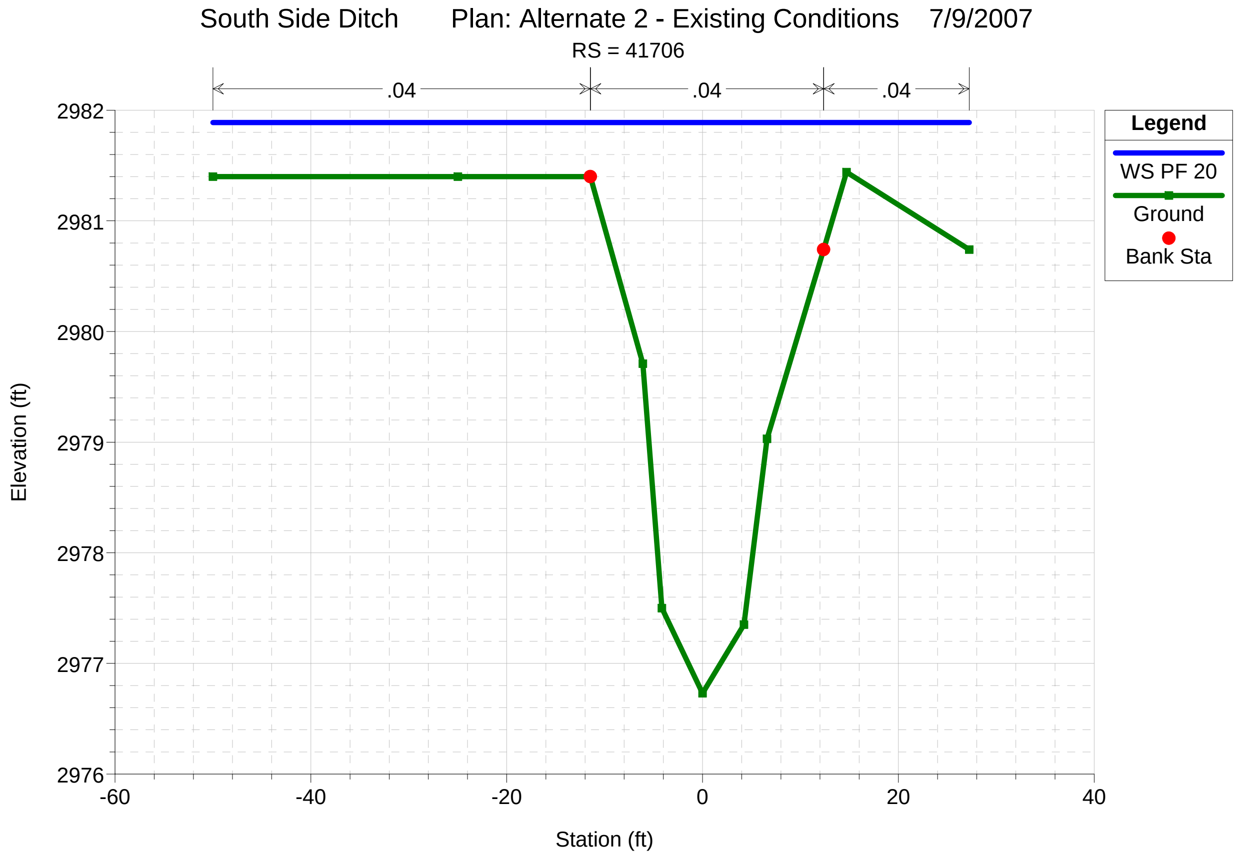
South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 40287
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
60
Station (ft)

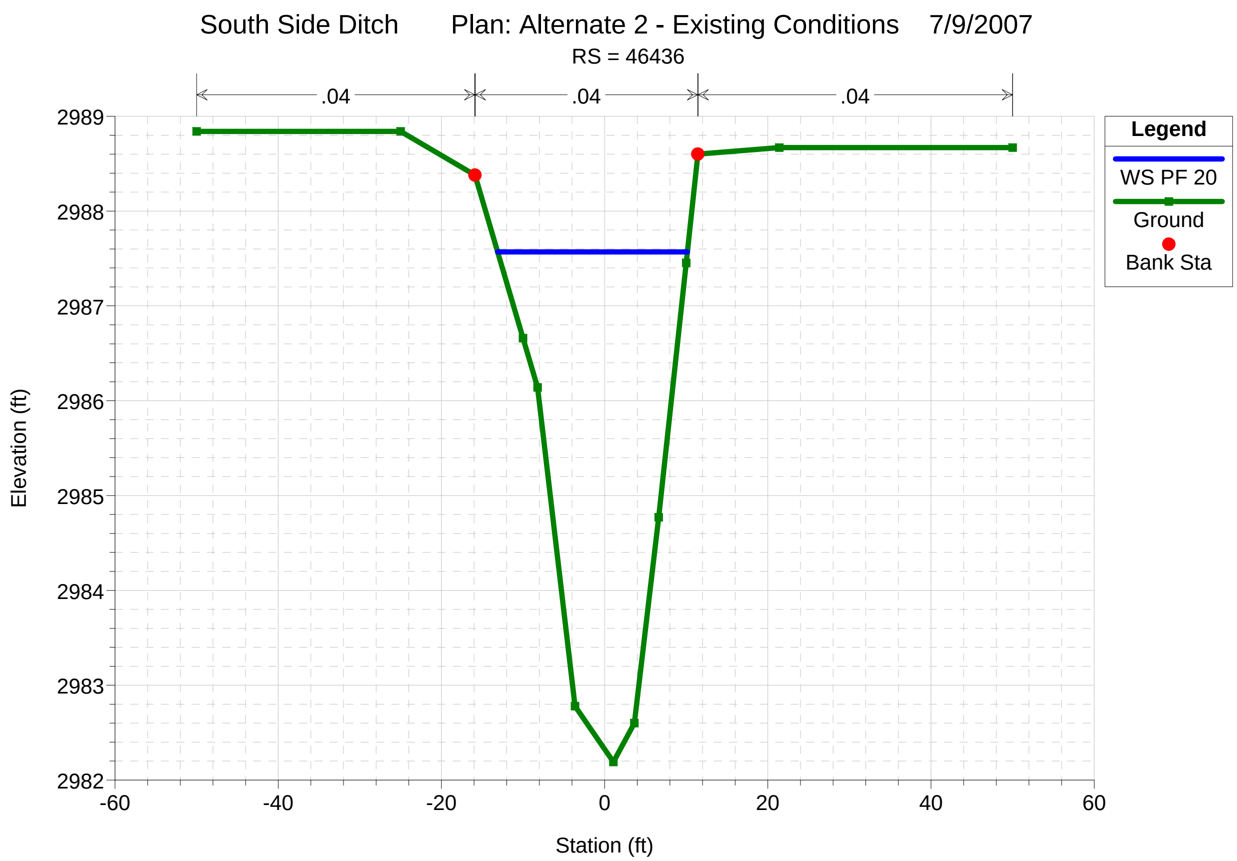


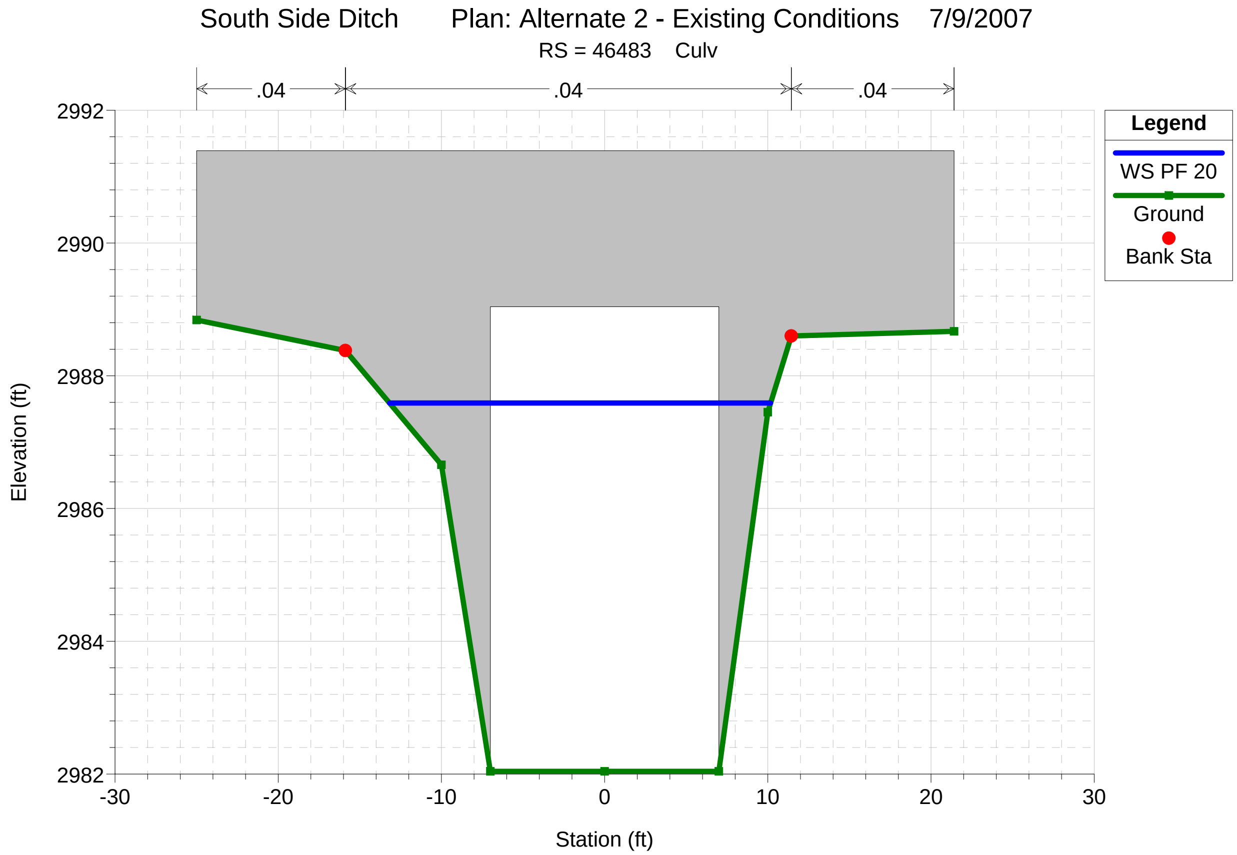
South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 40334 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2983
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
60
Station (ft)

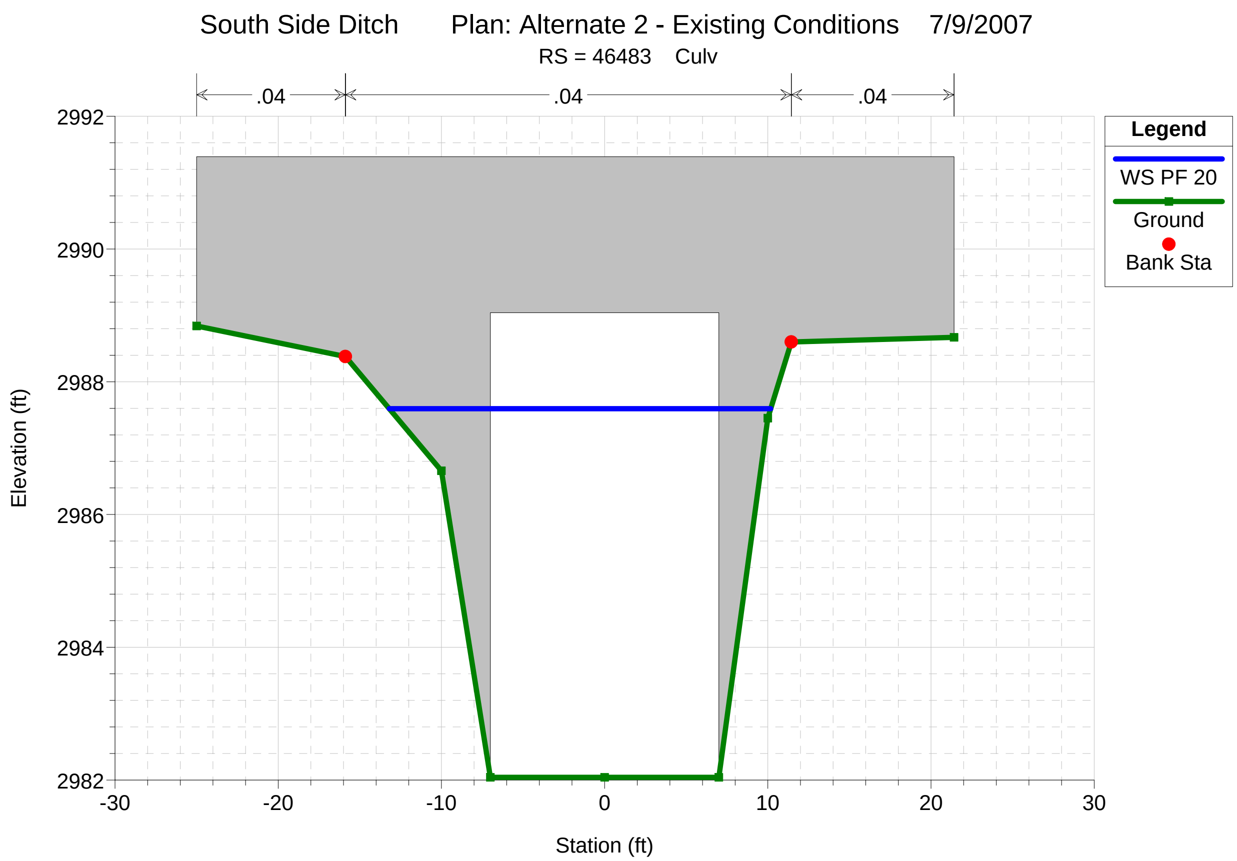

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 40334 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2983
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
60
Station (ft)

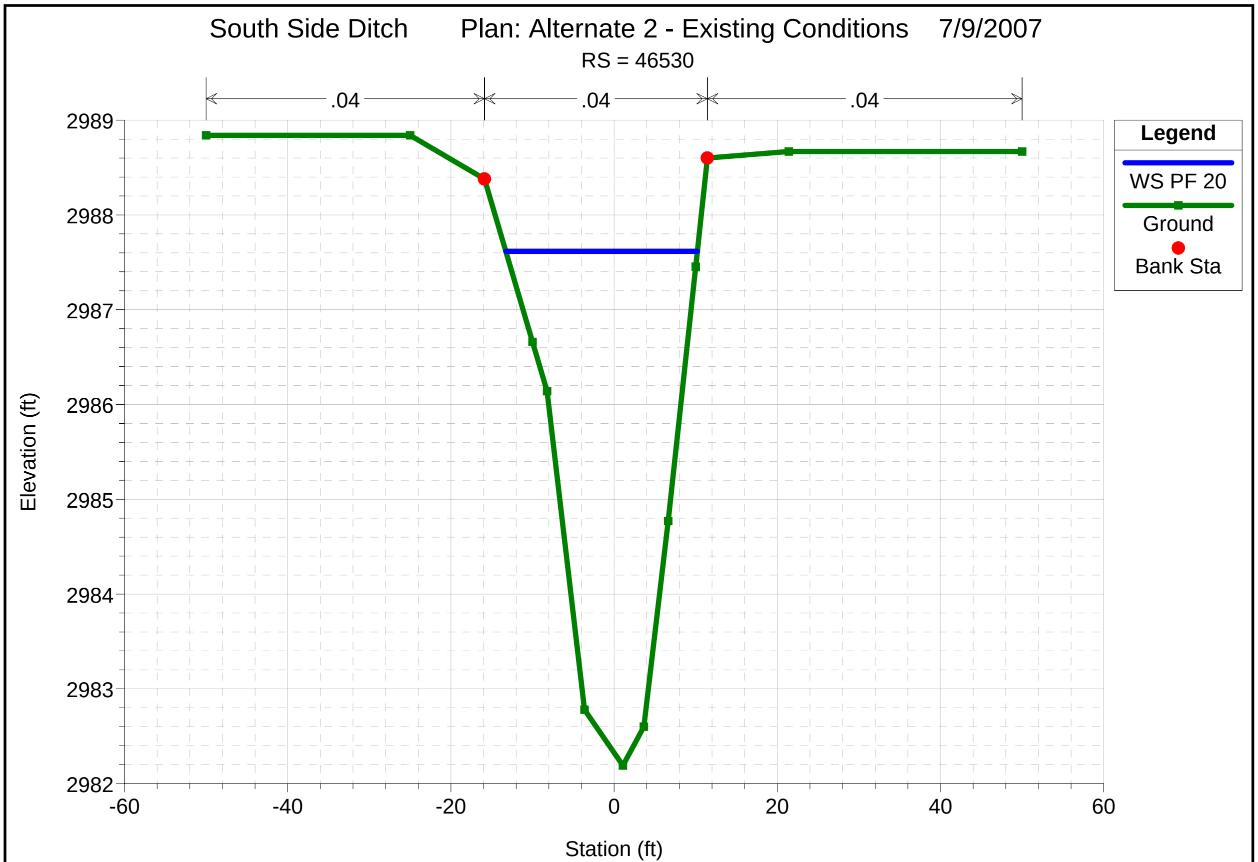

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 40381
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
60
Station (ft)

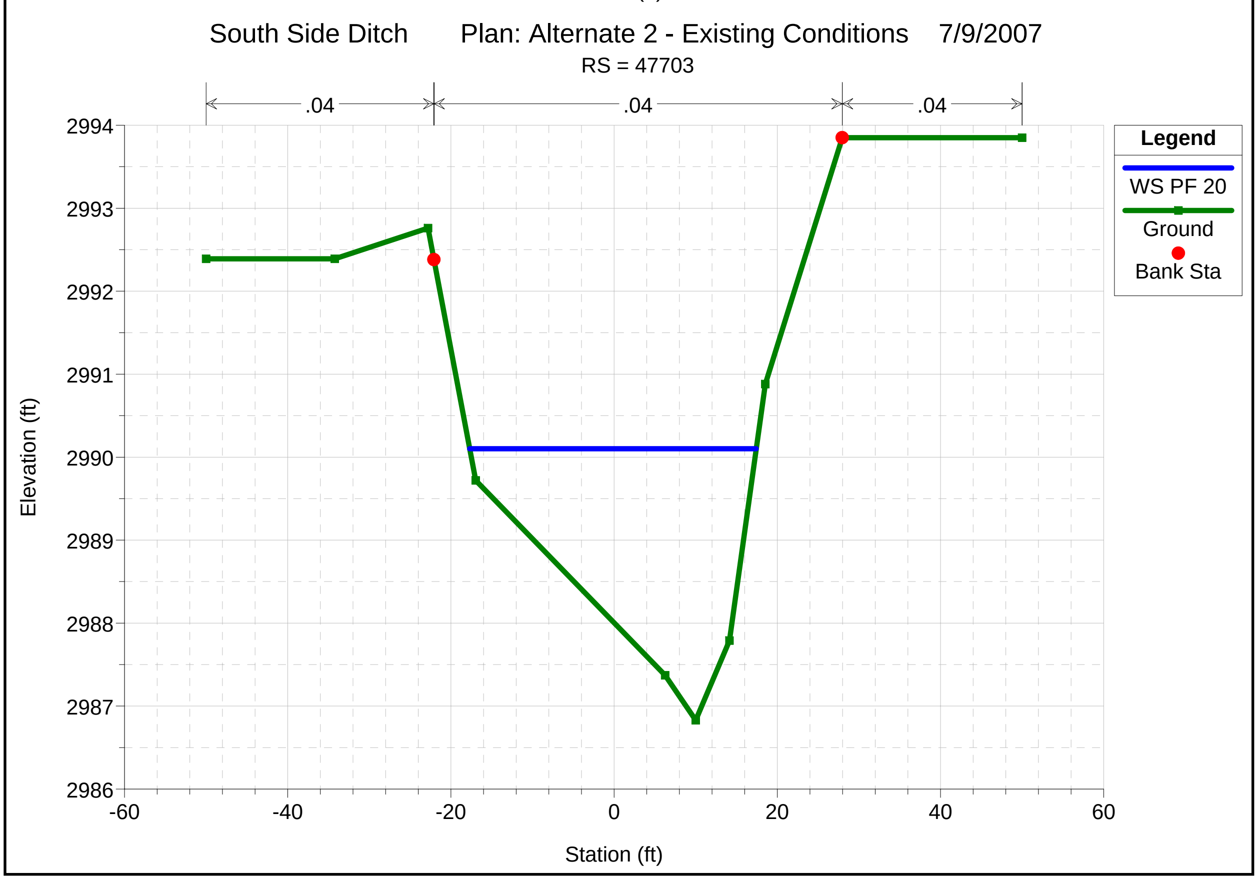

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 41706
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
Station (ft)

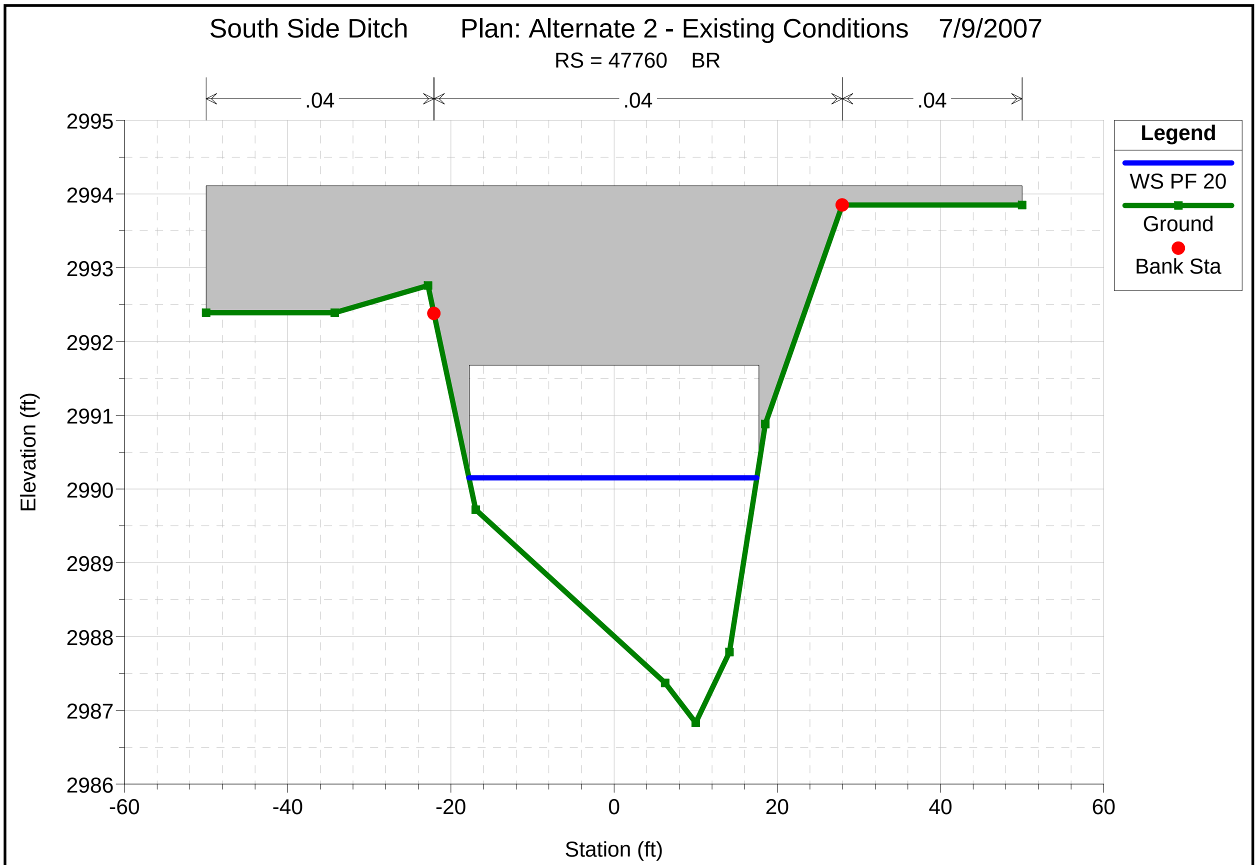

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 46436
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2989
2988
2987
2986
2985
2984
2983
2982
-60
-40
-20
0
20
40
60
Station (ft)

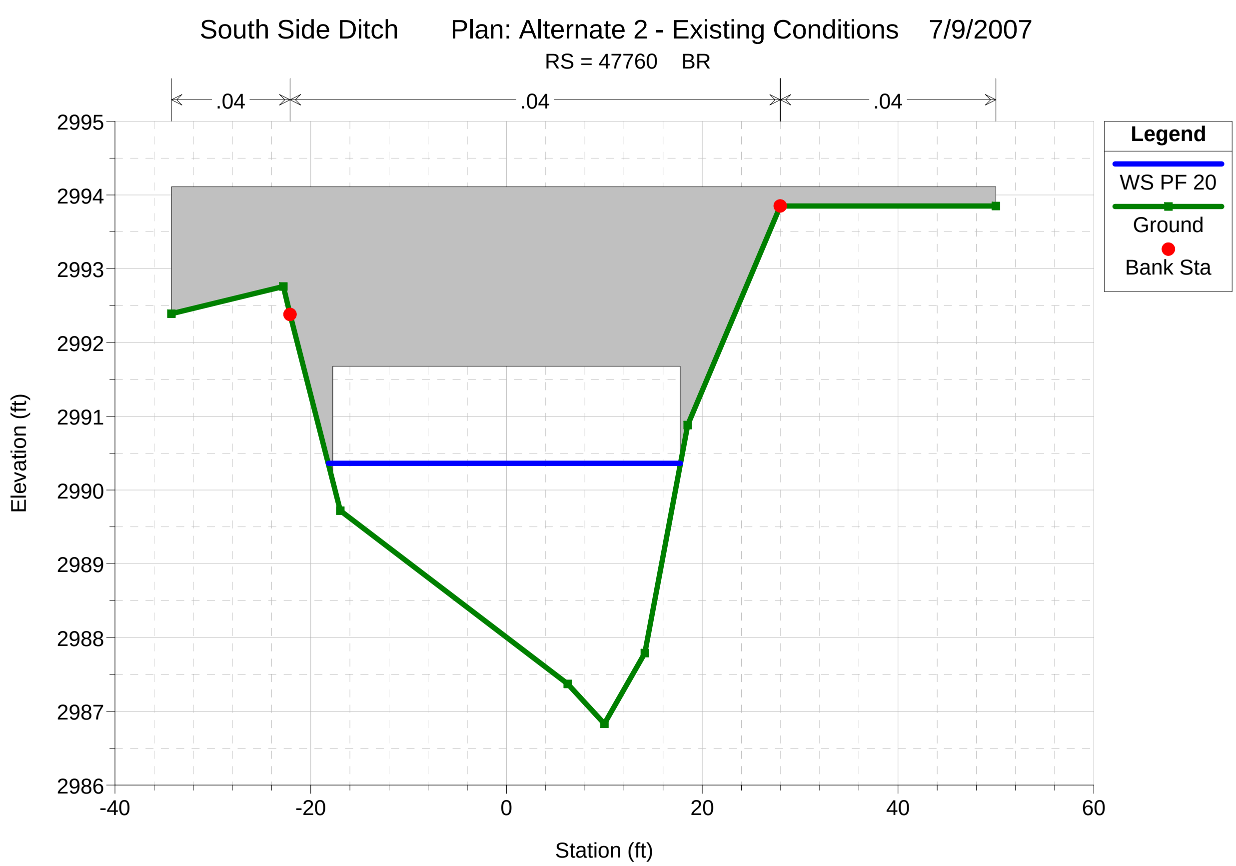

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 46483 Culv
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2992
2990
2988
2986
2984
2982
-30
-20
-10
0
10
20
30
Station (ft)

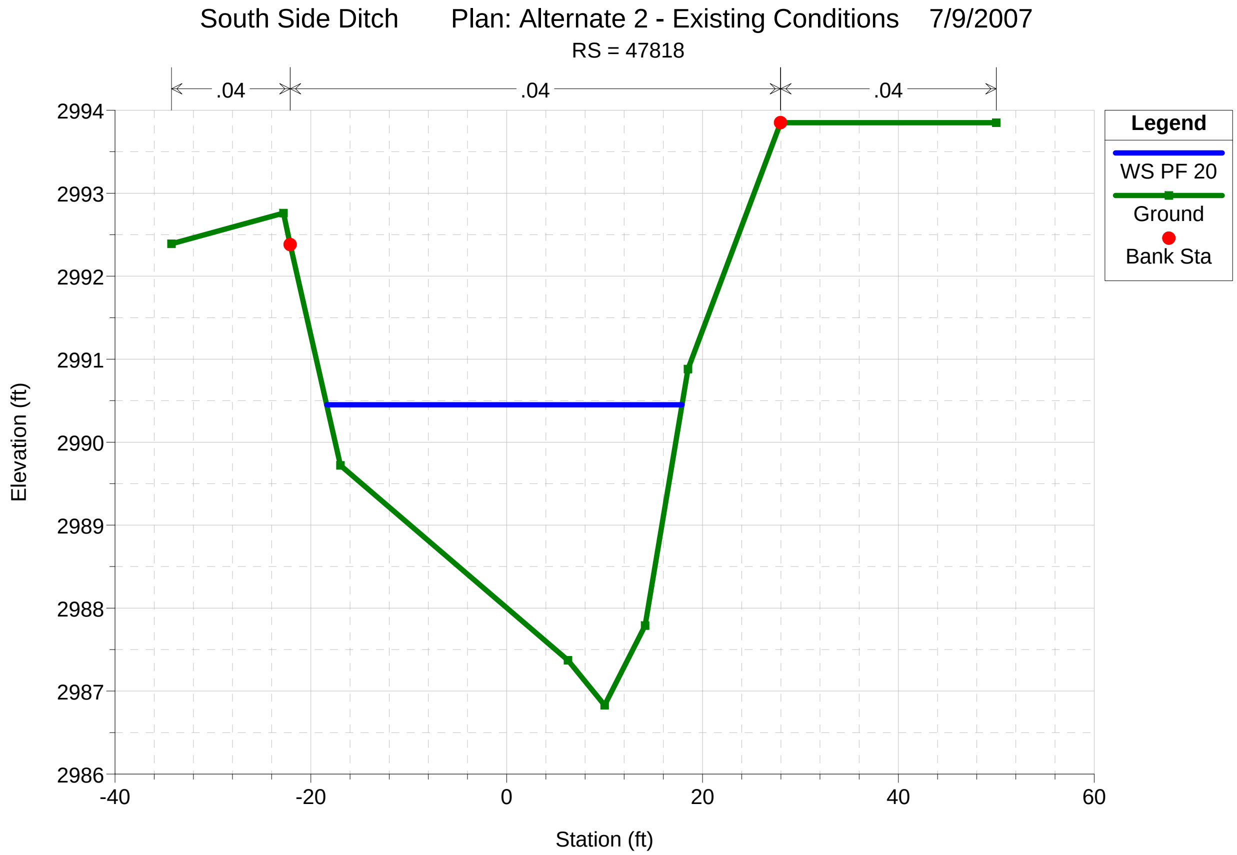

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 46483 Culv
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2992
2990
2988
2986
2984
2982
-30
-20
-10
0
10
20
30
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 46530
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2989
2988
2987
2986
2985
2984
2983
2982
-60
-40
-20
0
20
40
60
Station (ft)

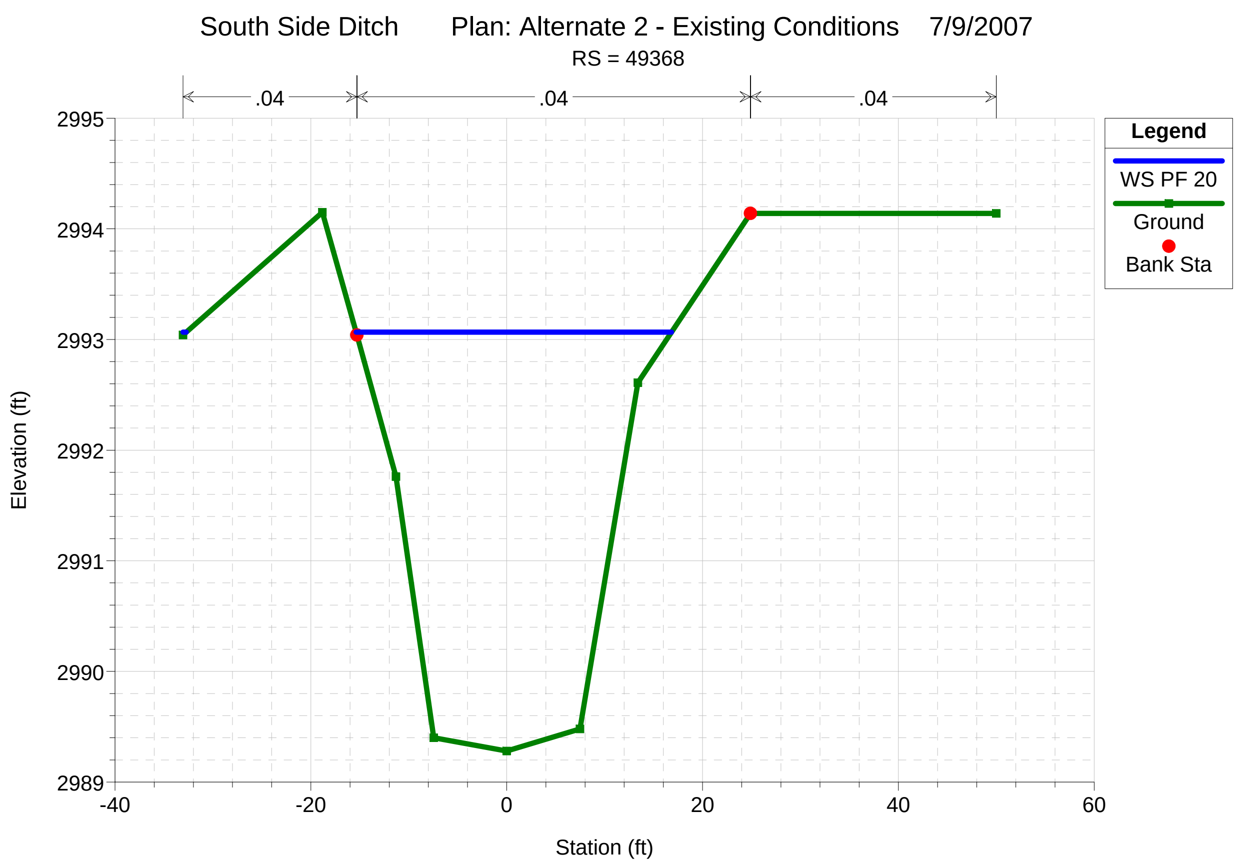

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 47703
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2994
2993
2992
2991
2990
2989
2988
2987
2986
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 47760 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2995
2994
2993
2992
2991
2990
2989
2988
2987
2986
-60
-40
-20
0
20
40
60
Station (ft)

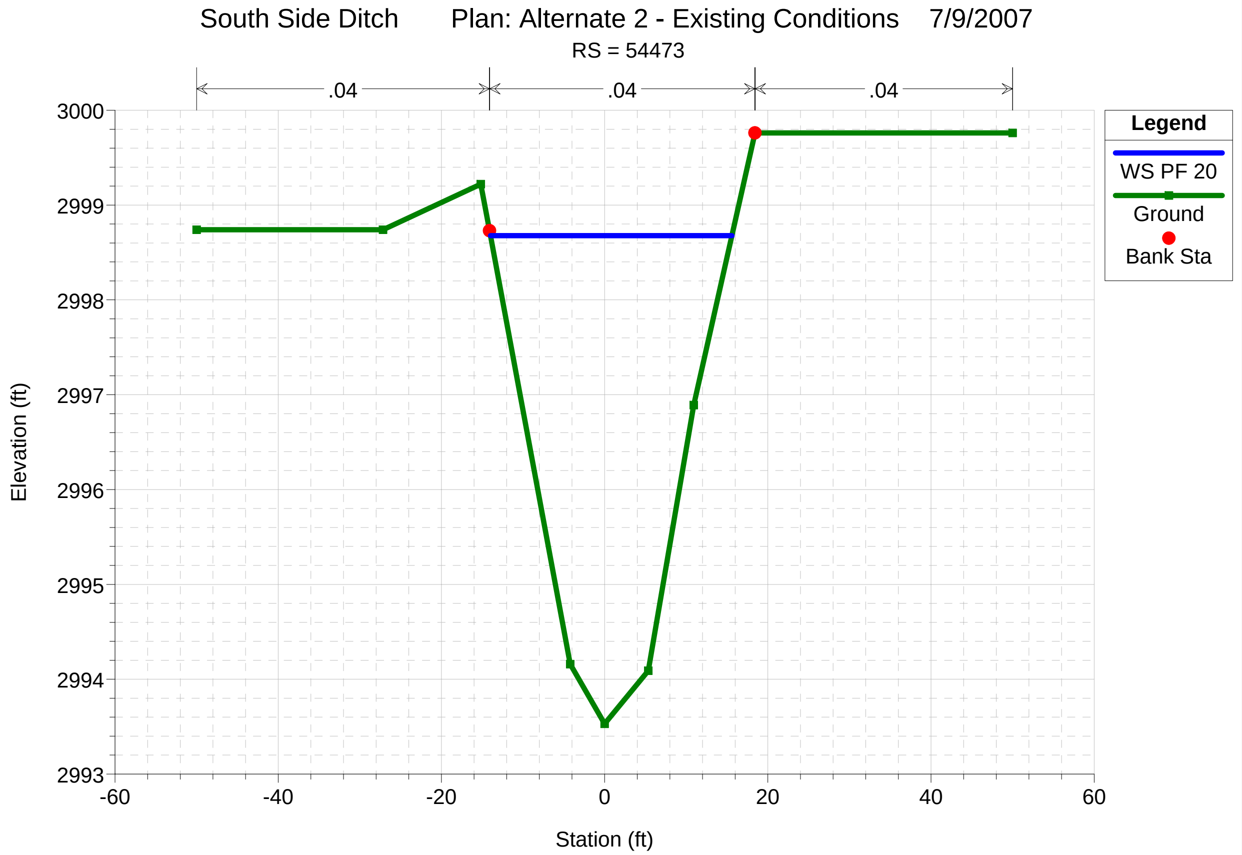

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 47760 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2995
2994
2993
2992
2991
2990
2989
2988
2987
2986
-40
-20
0
20
40
60
Station (ft)

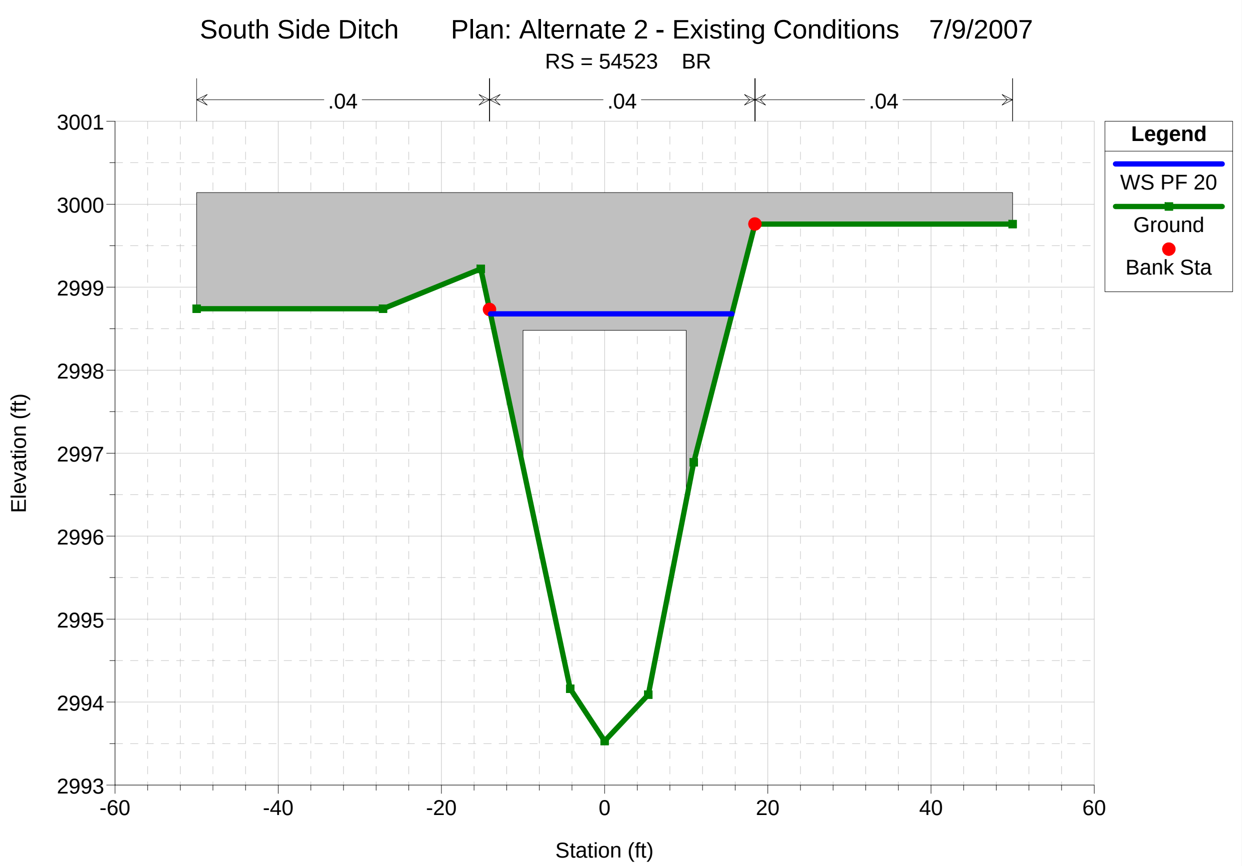


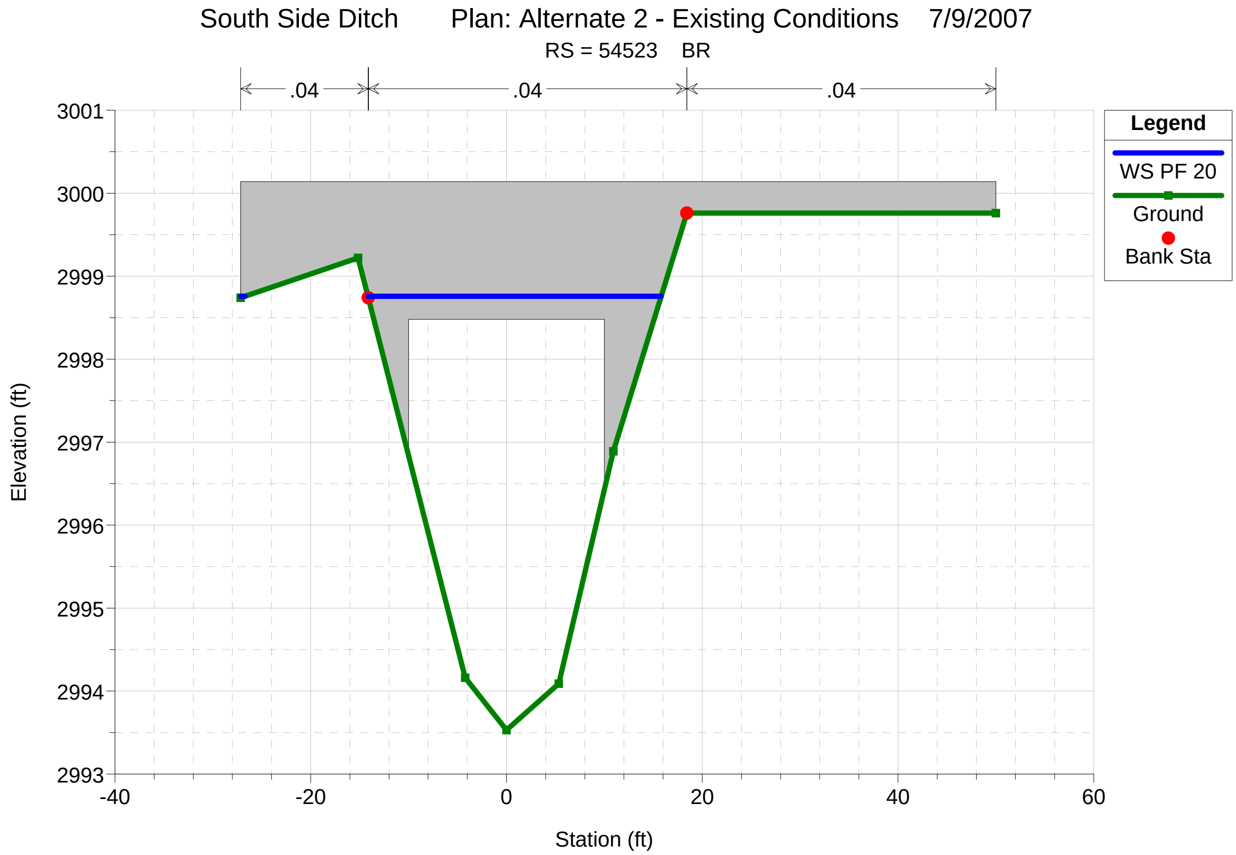
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 47818
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2994
2993
2992
2991
2990
2989
2988
2987
2986
-40
-20
0
20
40
60
Station (ft)

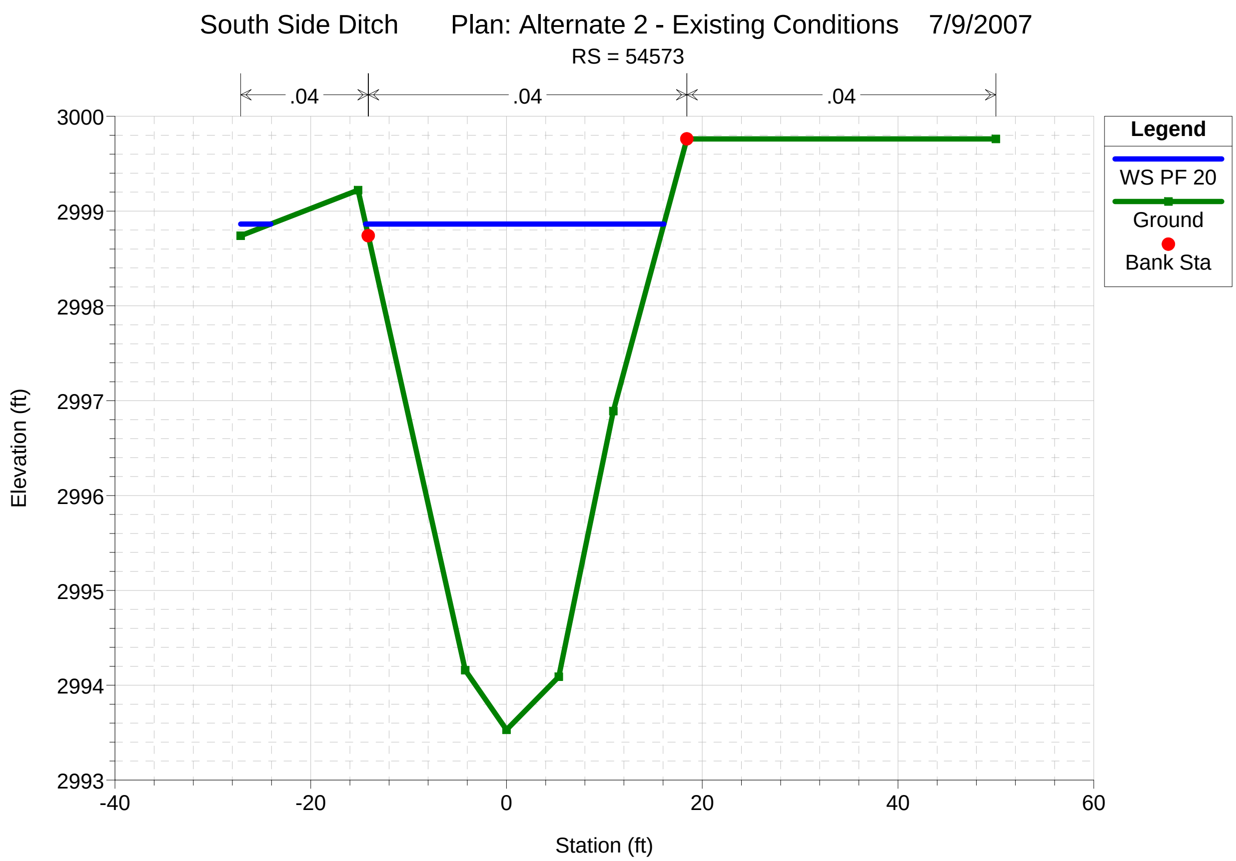


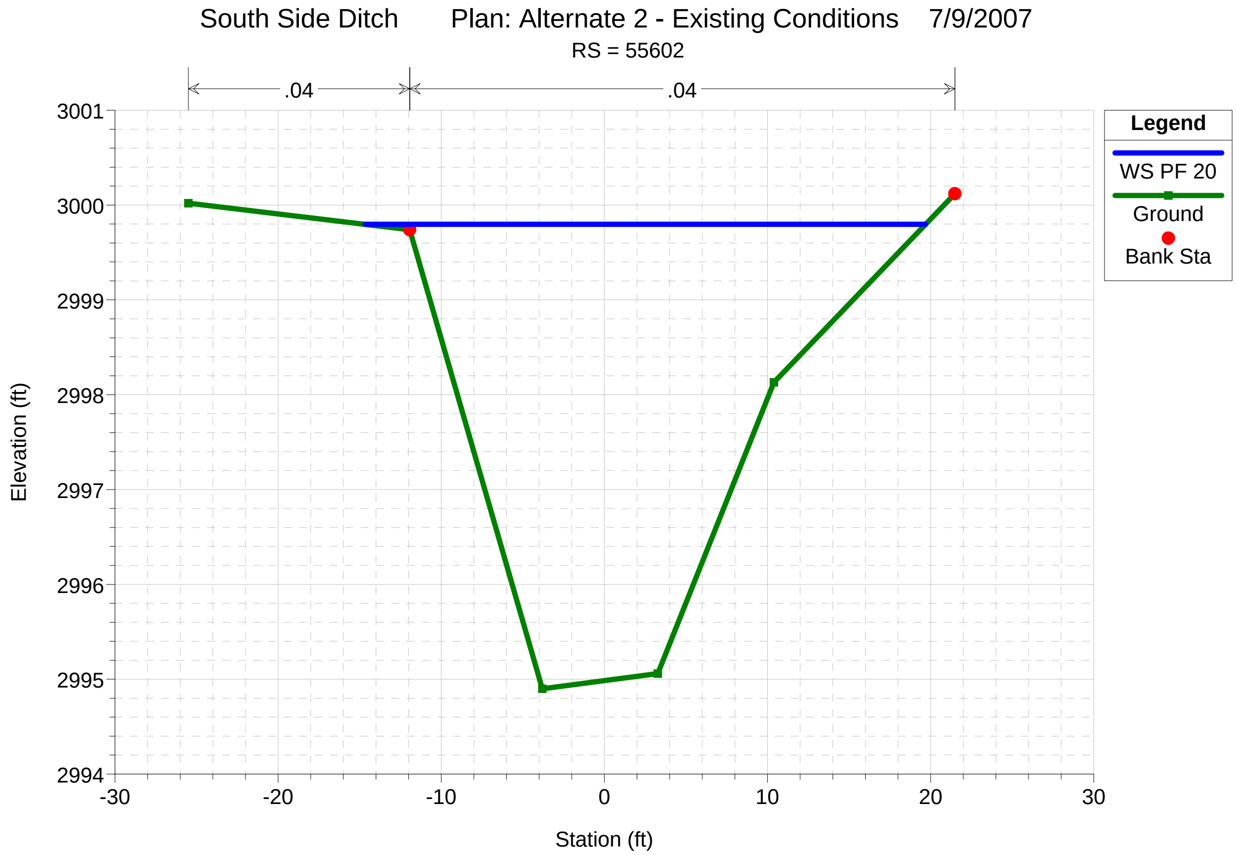
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 49368
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2995
2994
2993
2992
2991
2990
2989
-40
-20
0
20
40
60
Station (ft)

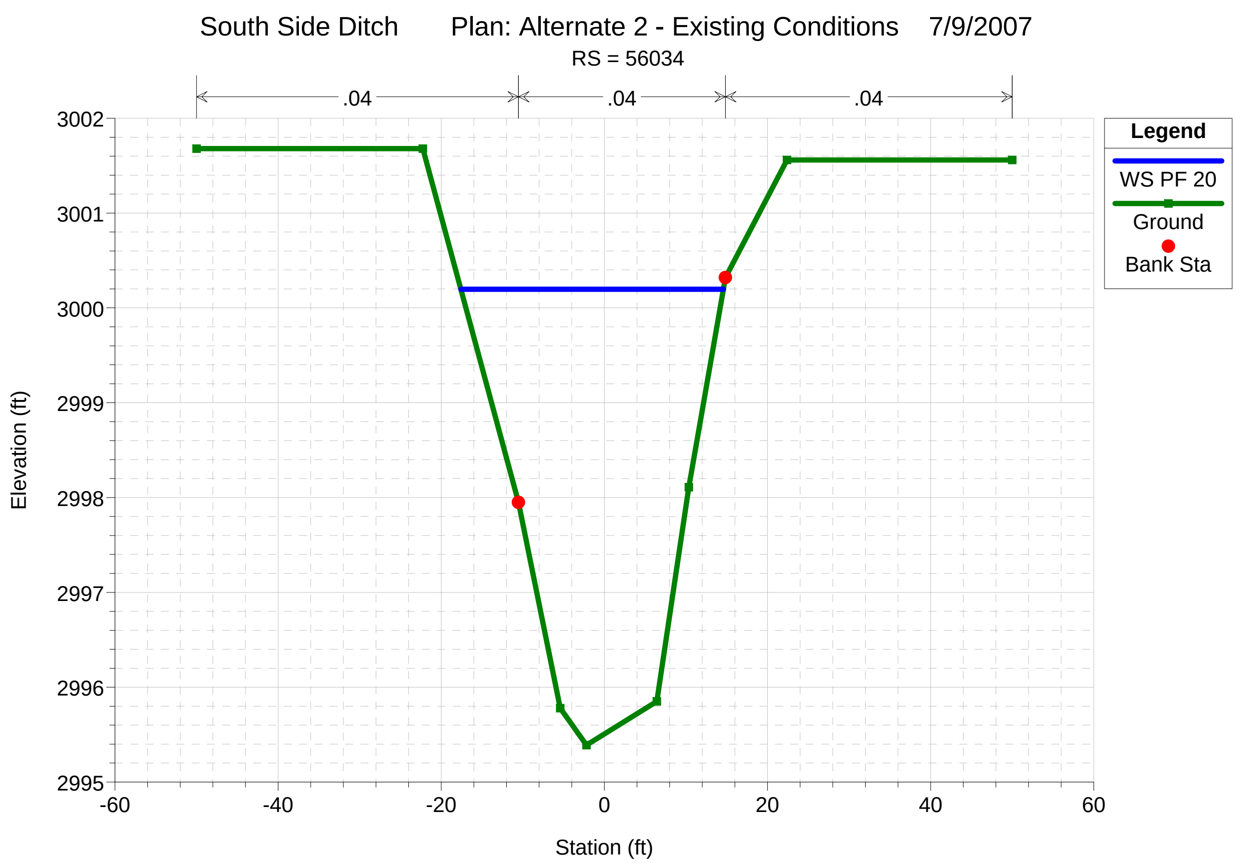

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 54473
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3000
2999
2998
2997
2996
2995
2994
2993
-60
-40
-20
0
20
40
60

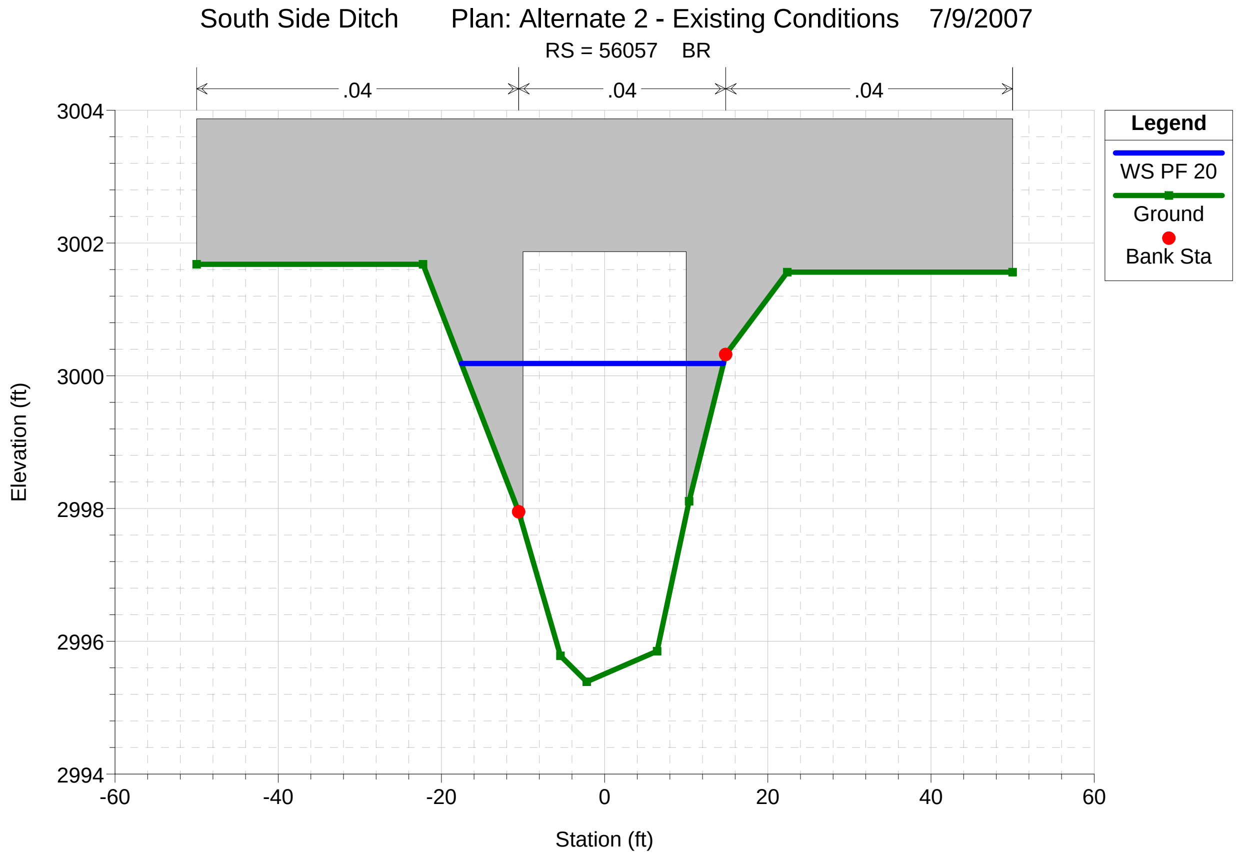

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 54523 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3001
3000
2999
2998
2997
2996
2995
2994
2993
-60
-40
-20
0
20
40
60

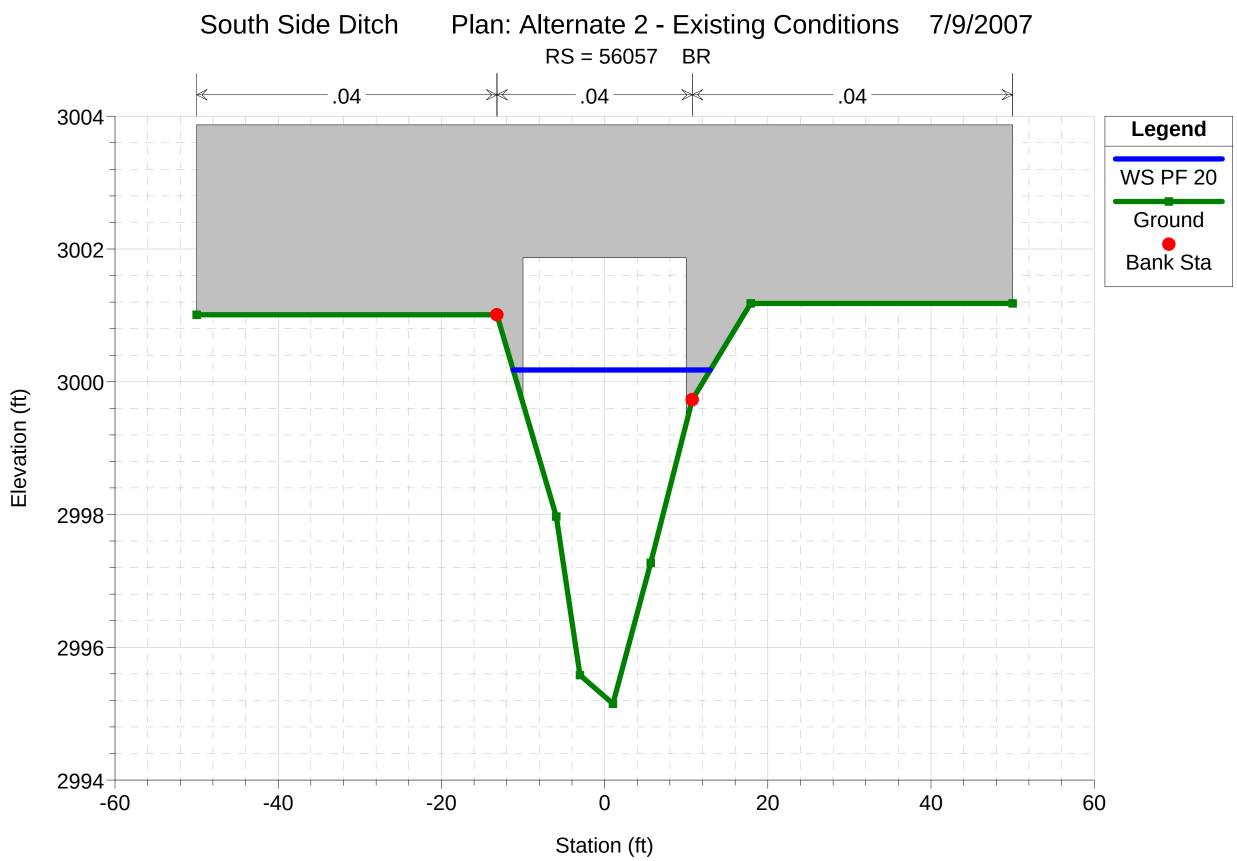

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 54523 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)

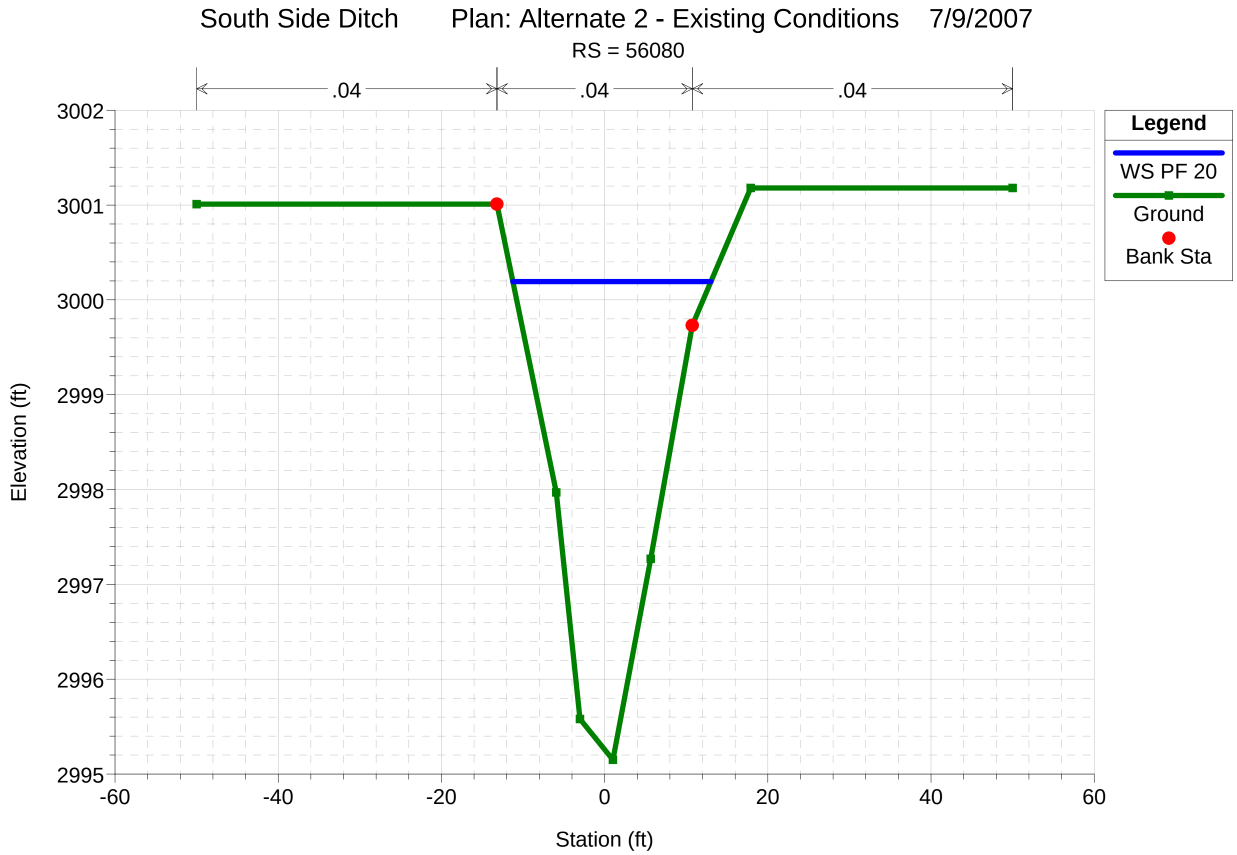

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 54573
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)

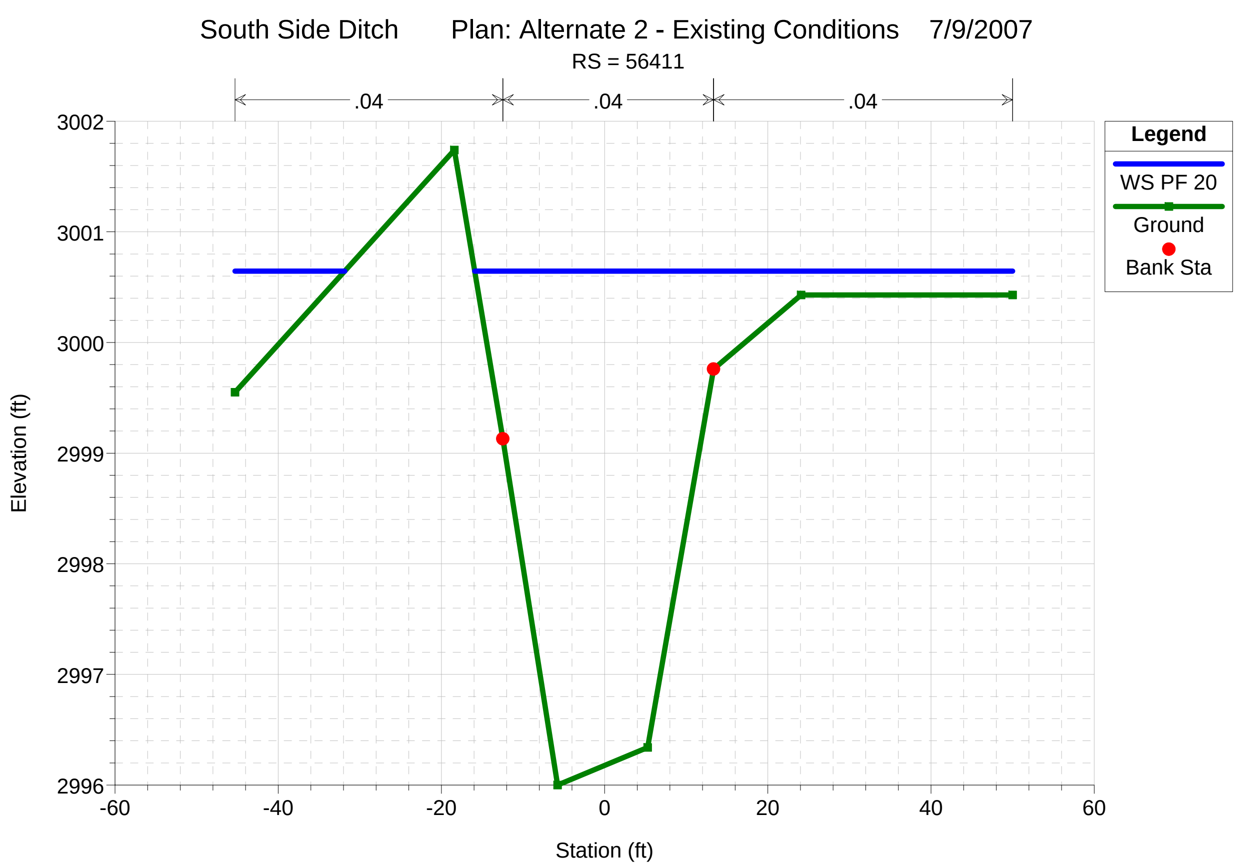

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 55602
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3001
3000
2999
2998
2997
2996
2995
2994
-30
-20
-10
0
10
20
30

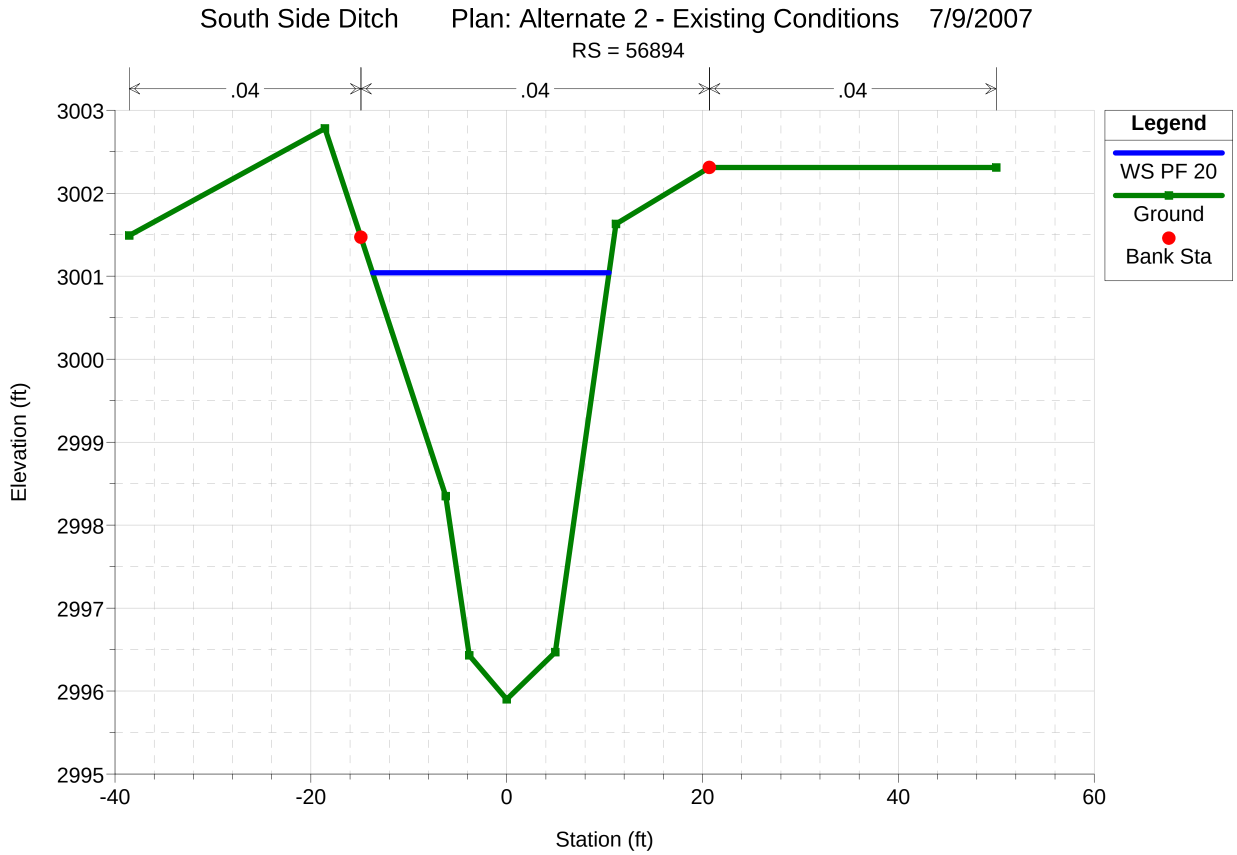

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 56034
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3002
3001
3000
2999
2998
2997
2996
2995
-60
-40
-20
0
20
40
60

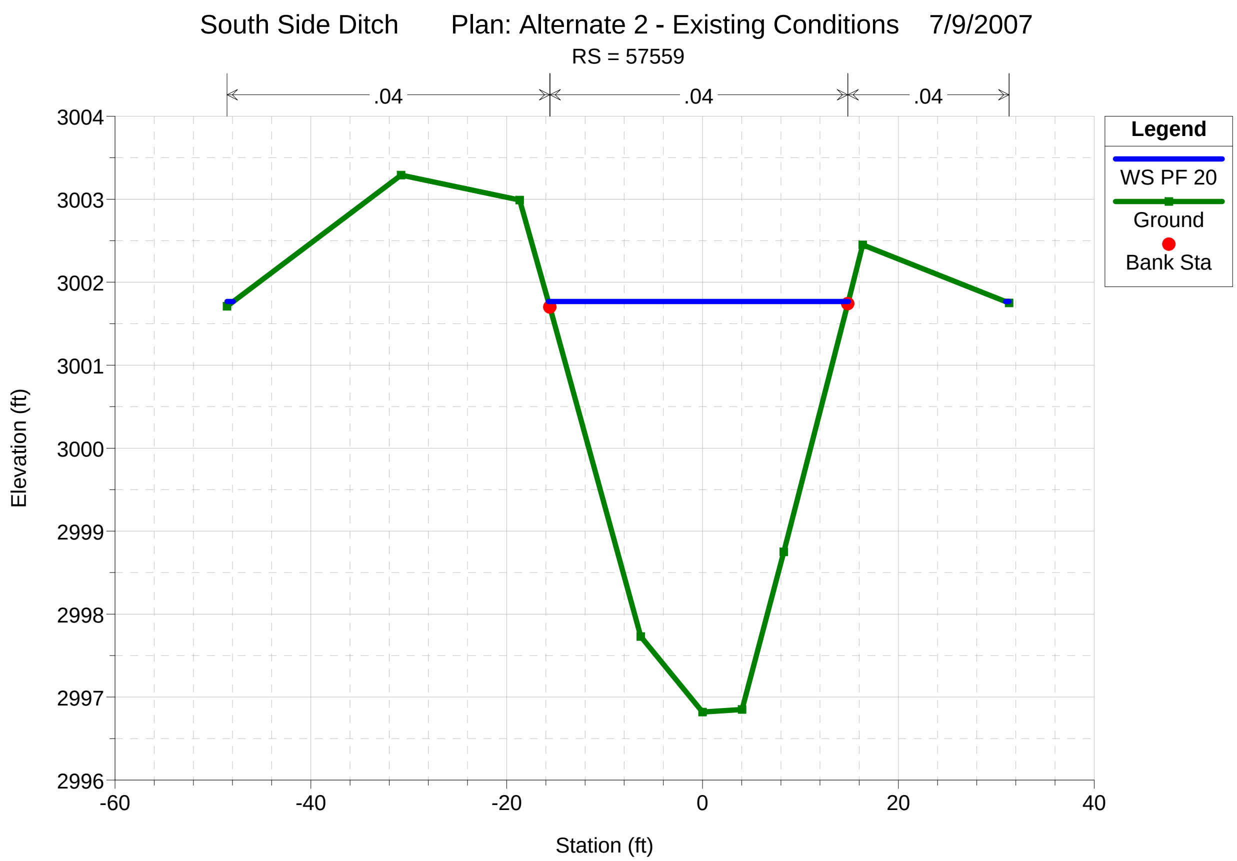

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 56057 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
3004
3002
3000
2998
2996
2994
Elevation (ft)
-60
-40
-20
0
20
40
60
Station (ft)

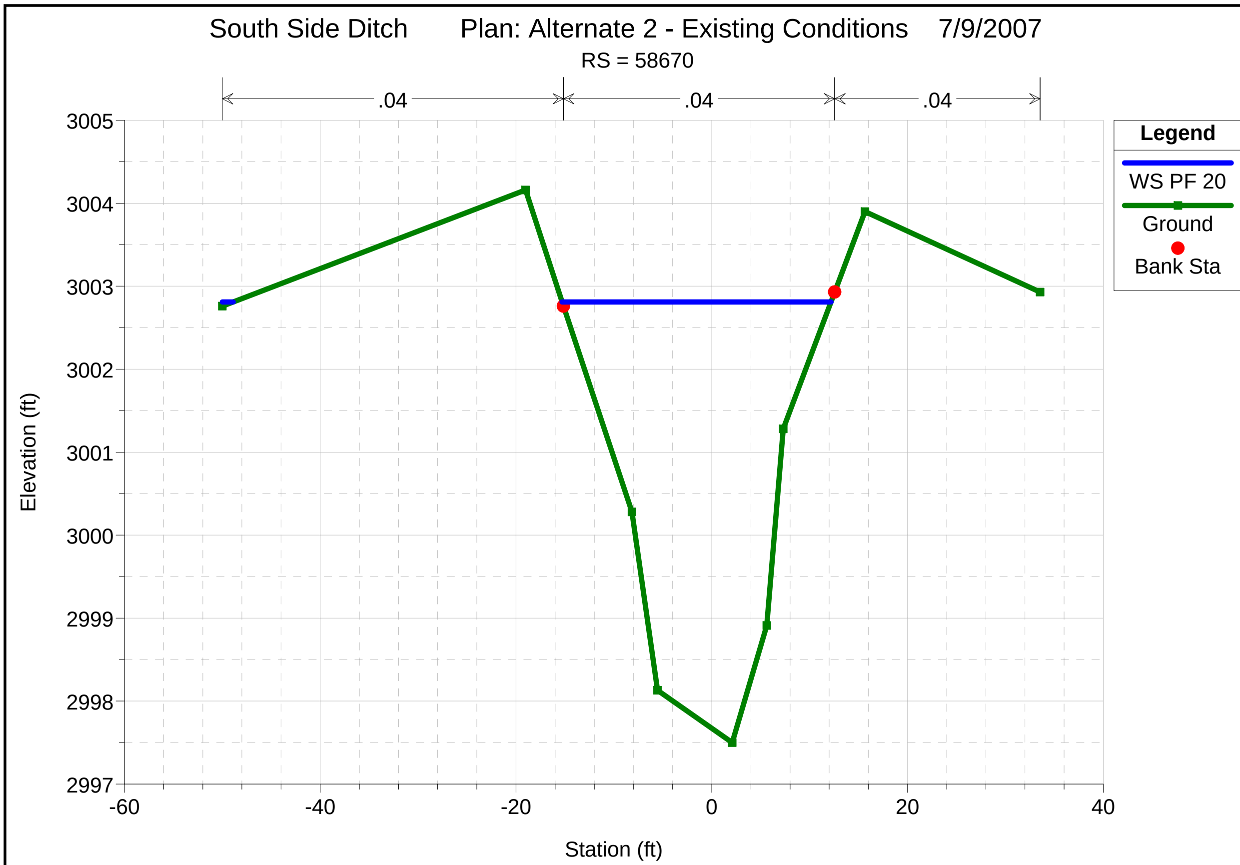

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 56057 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
3004
3002
3000
2998
2996
2994
Elevation (ft)
-60
-40
-20
0
20
40
60
Station (ft)

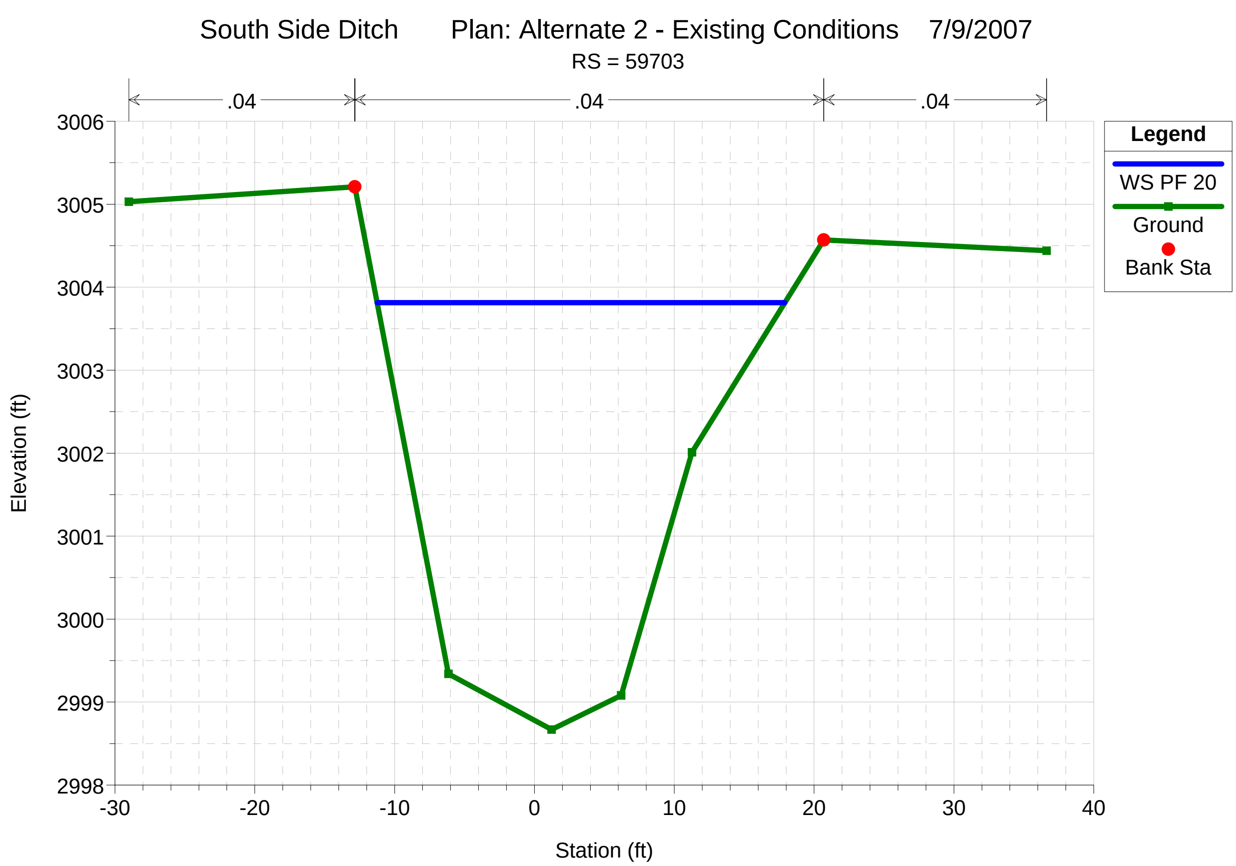

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 56080
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3002
3001
3000
2999
2998
2997
2996
2995
-60
-40
-20
0
20
40
60
Station (ft)

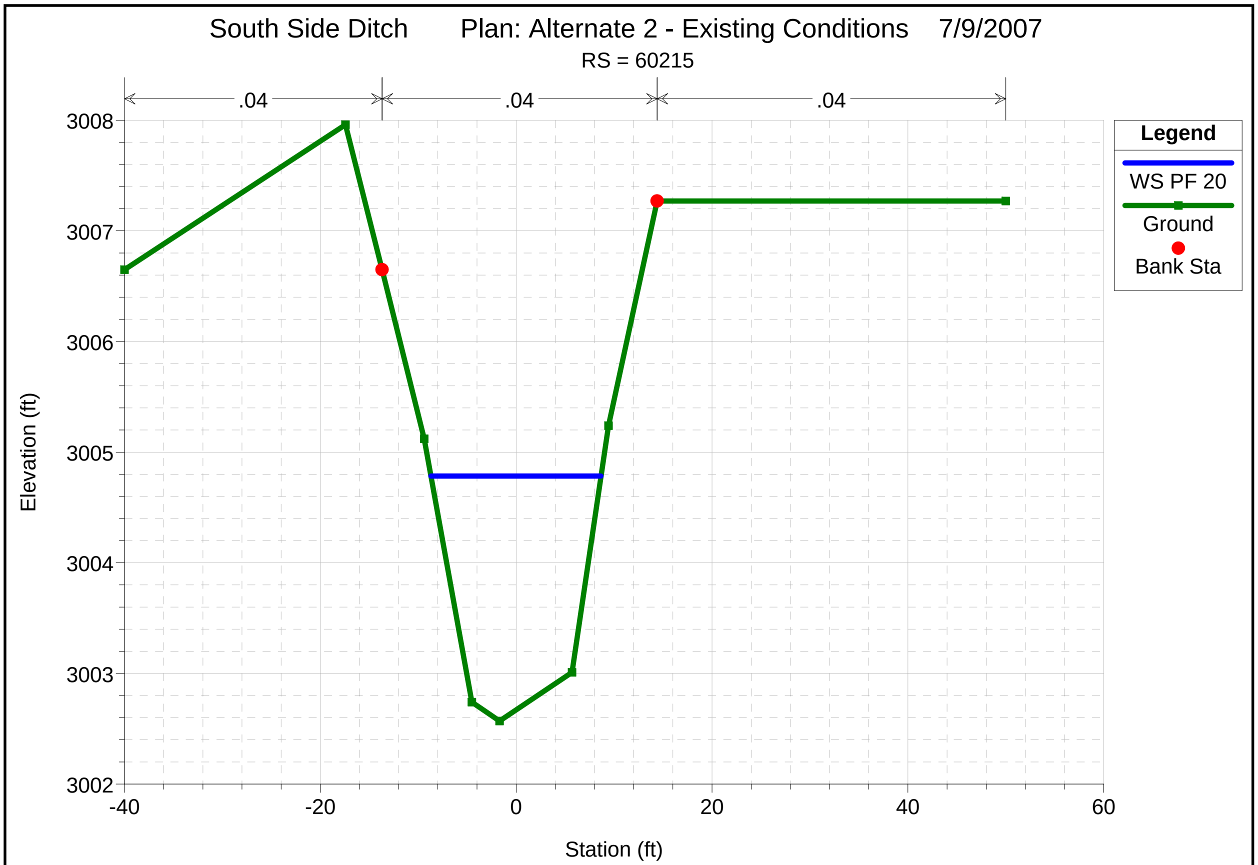

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 56411
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3002
3001
3000
2999
2998
2997
2996
-60
-40
-20
0
20
40
60
Station (ft)

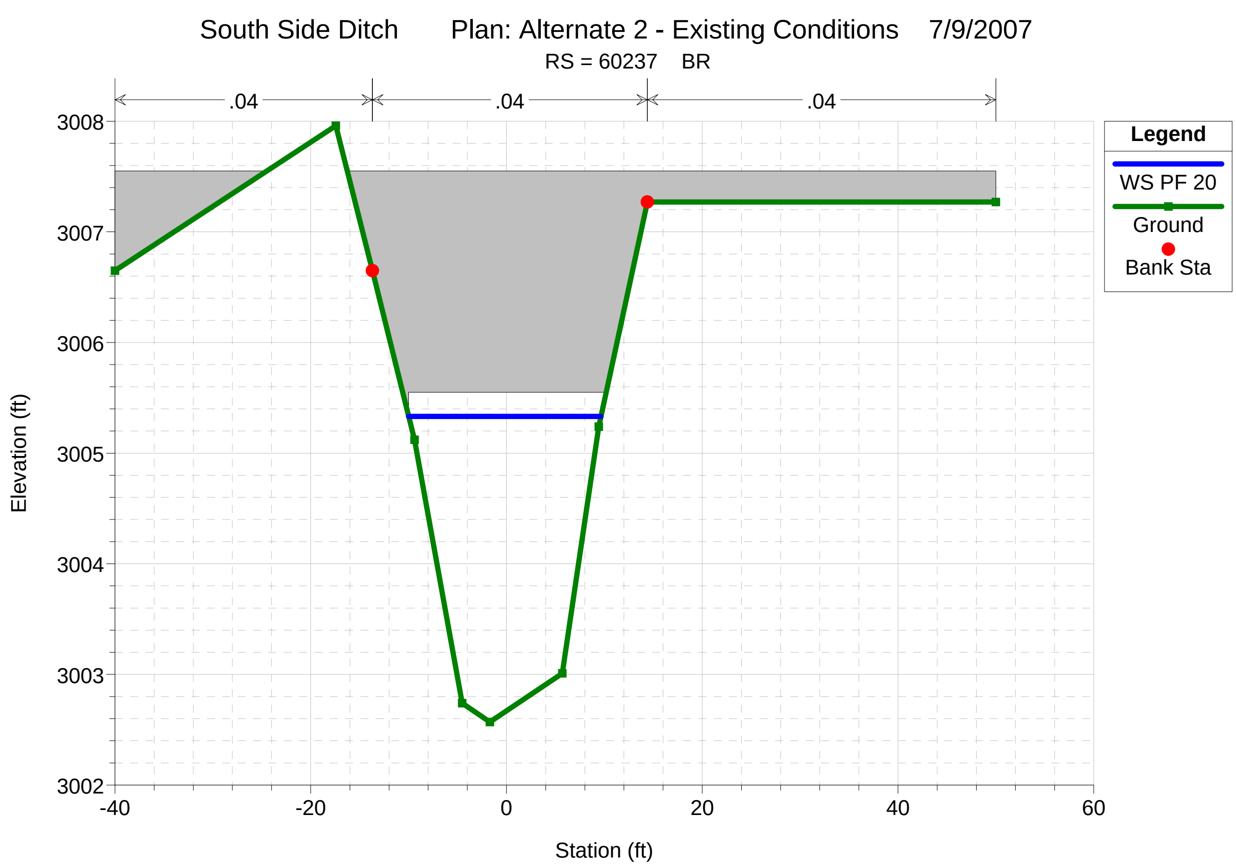

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 56894
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3003
3002
3001
3000
2999
2998
2997
2996
2995
-40
-20
0
20
40
60
Station (ft)

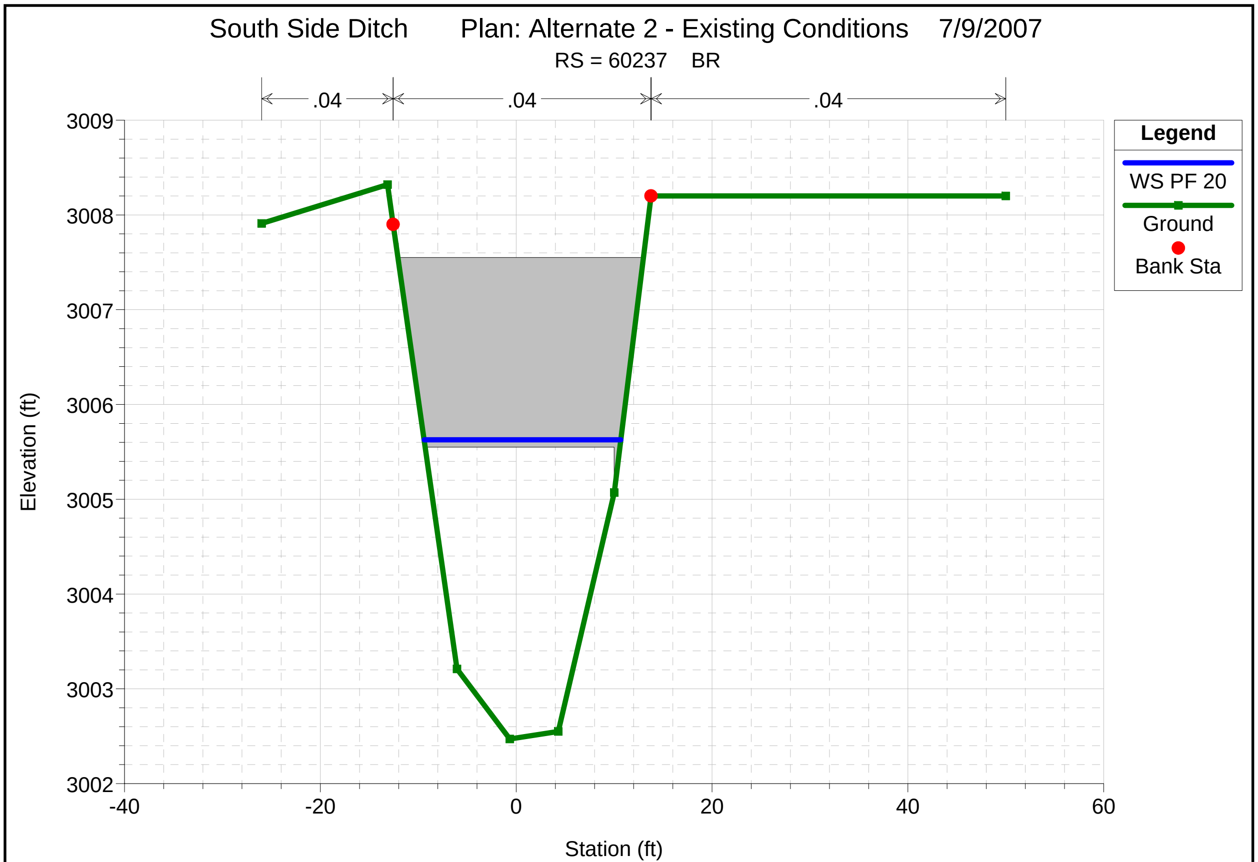

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 57559
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3004
3003
3002
3001
3000
2999
2998
2997
2996
-60
-40
-20
0
20
40
Station (ft)

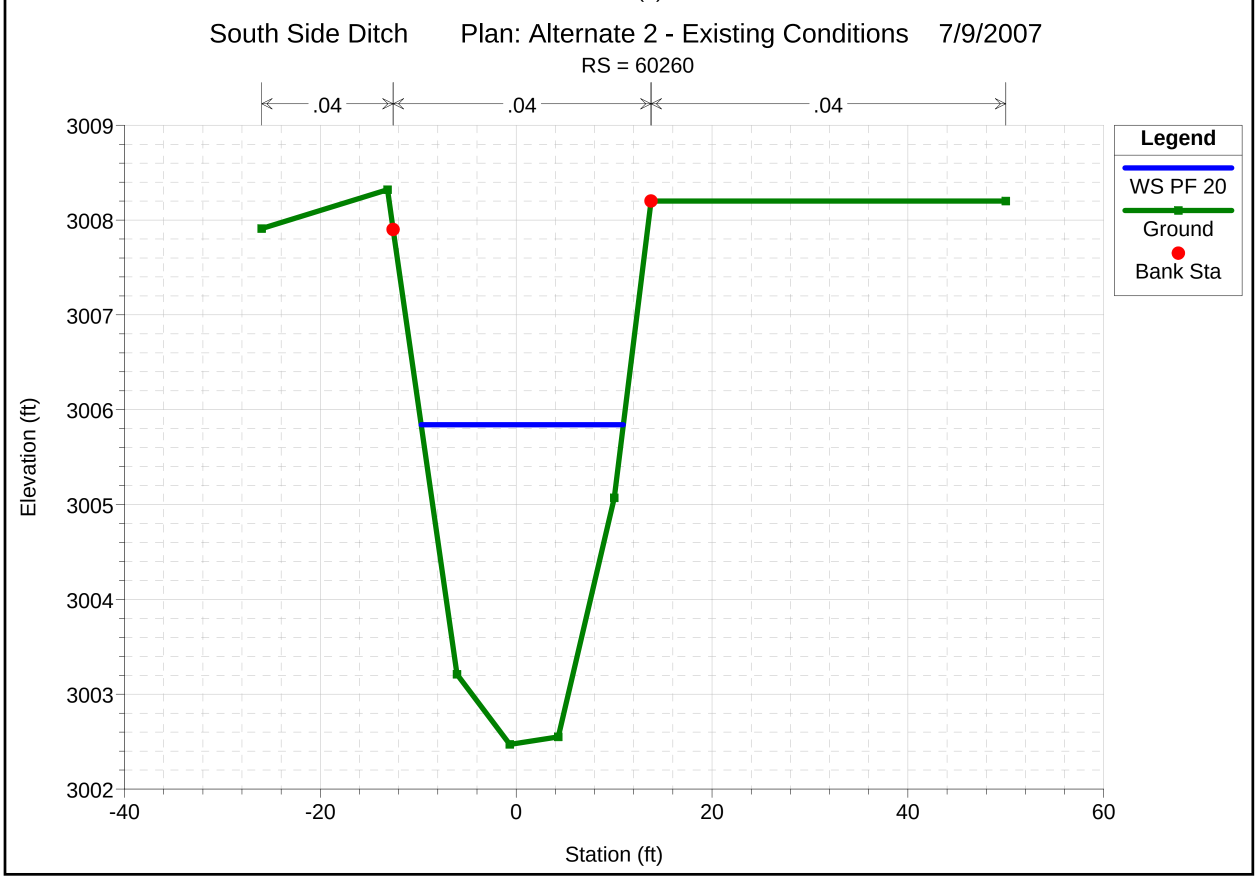

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 58670
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3005
3004
3003
3002
3001
3000
2999
2998
2997
-60
-40
-20
0
20
40
Station (ft)

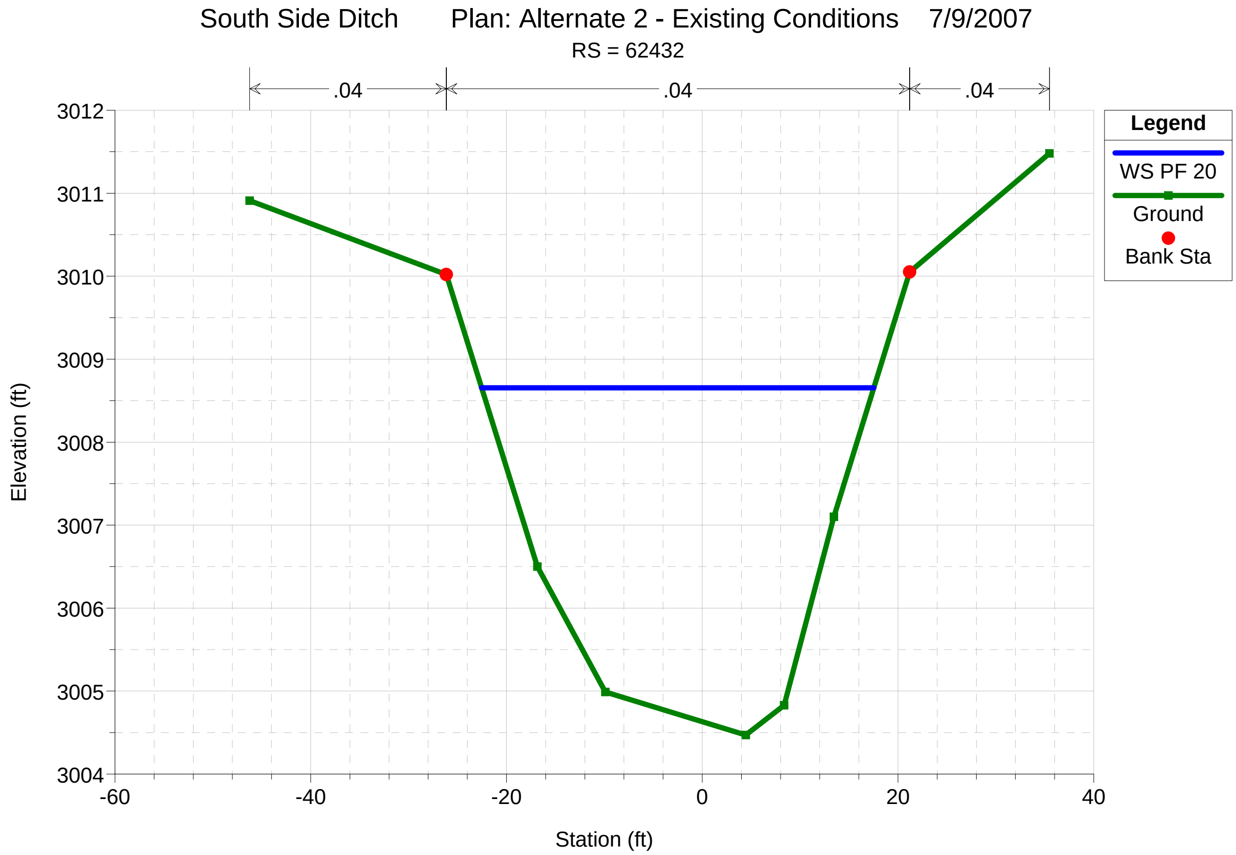

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 59703
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3006
3005
3004
3003
3002
3001
3000
2999
2998
-30
-20
-10
0
10
20
30
40
Station (ft)

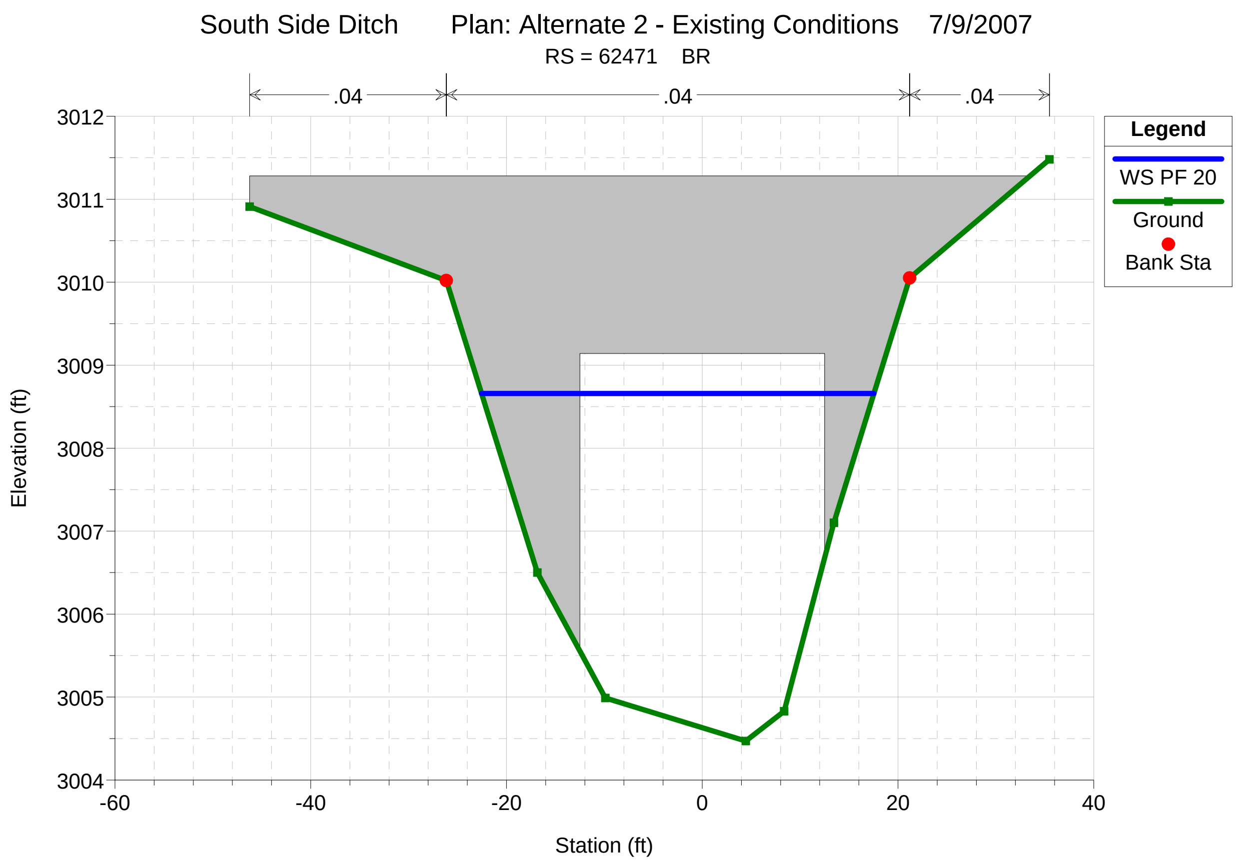

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 60215
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3008
3007
3006
3005
3004
3003
3002
-40
-20
0
20
40
60
Station (ft)

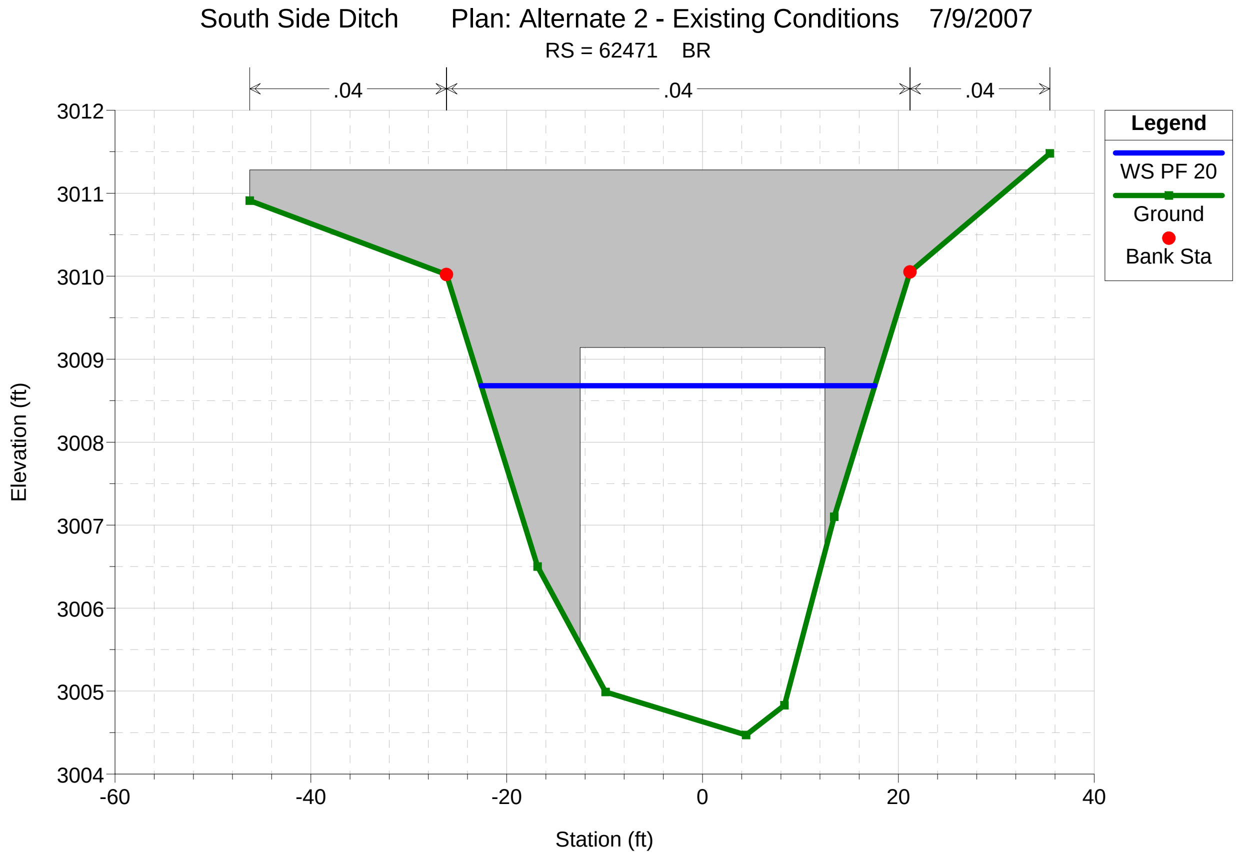

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 60237 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3008
3007
3006
3005
3004
3003
3002
-40
-20
0
20
40
60
Station (ft)

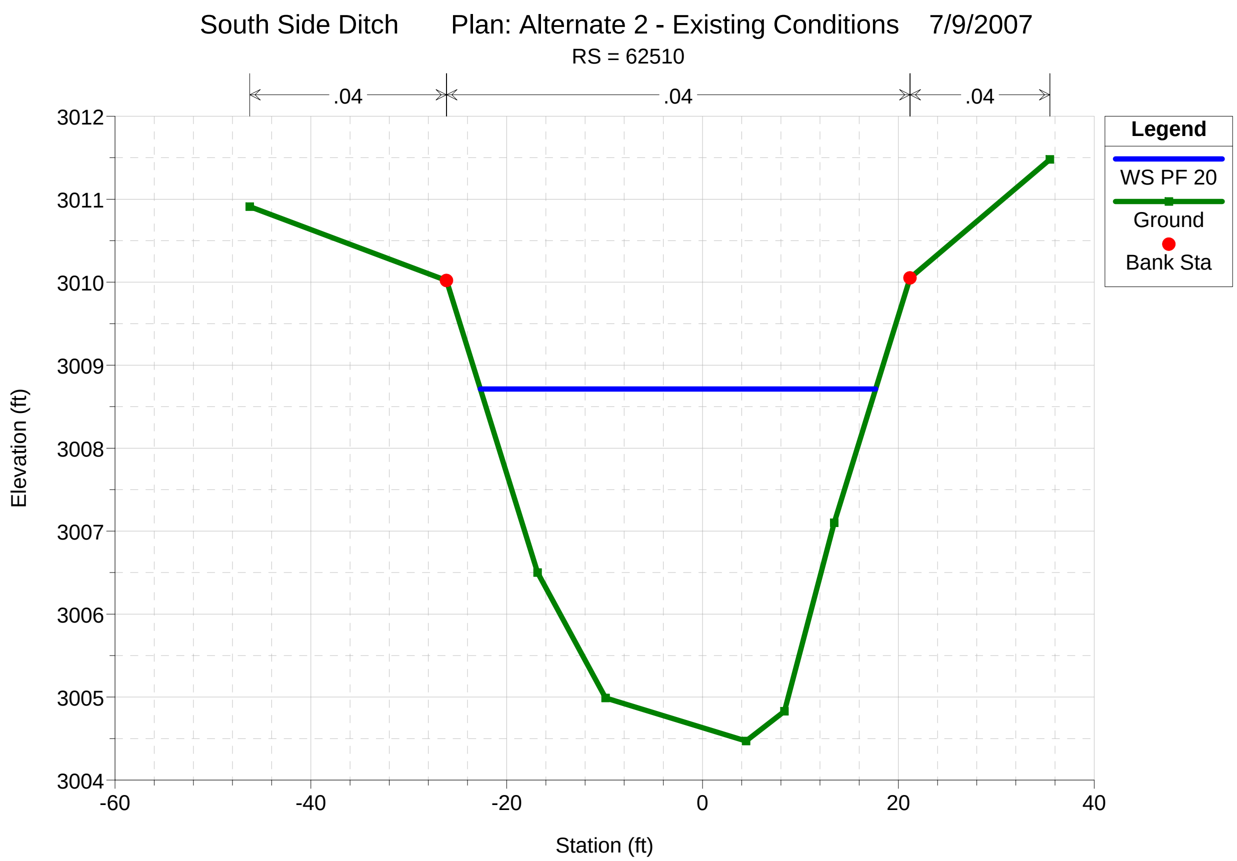

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 60237
BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3009
3008
3007
3006
3005
3004
3003
3002
-40
-20
0
20
40
60
Station (ft)

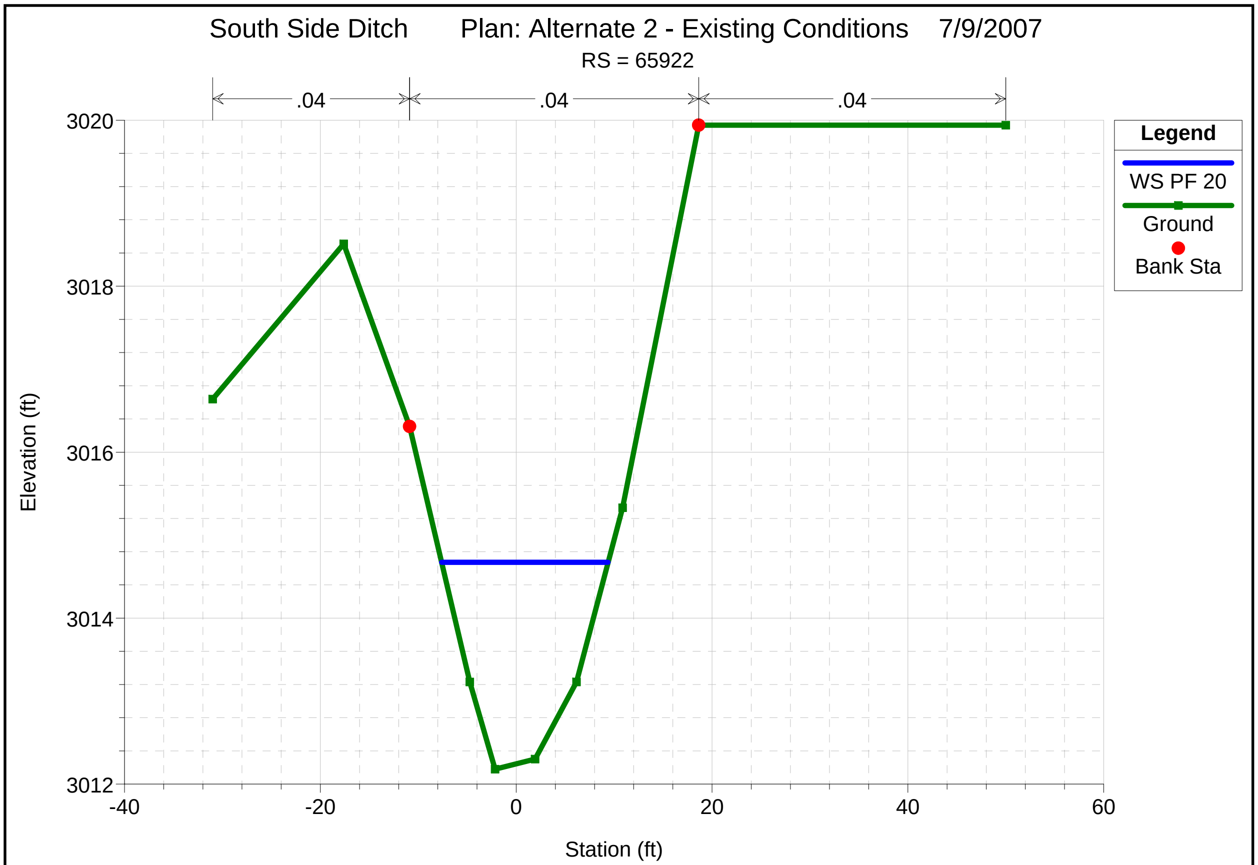

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 60260
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3009
3008
3007
3006
3005
3004
3003
3002
-40
-20
0
20
40
60
Station (ft)

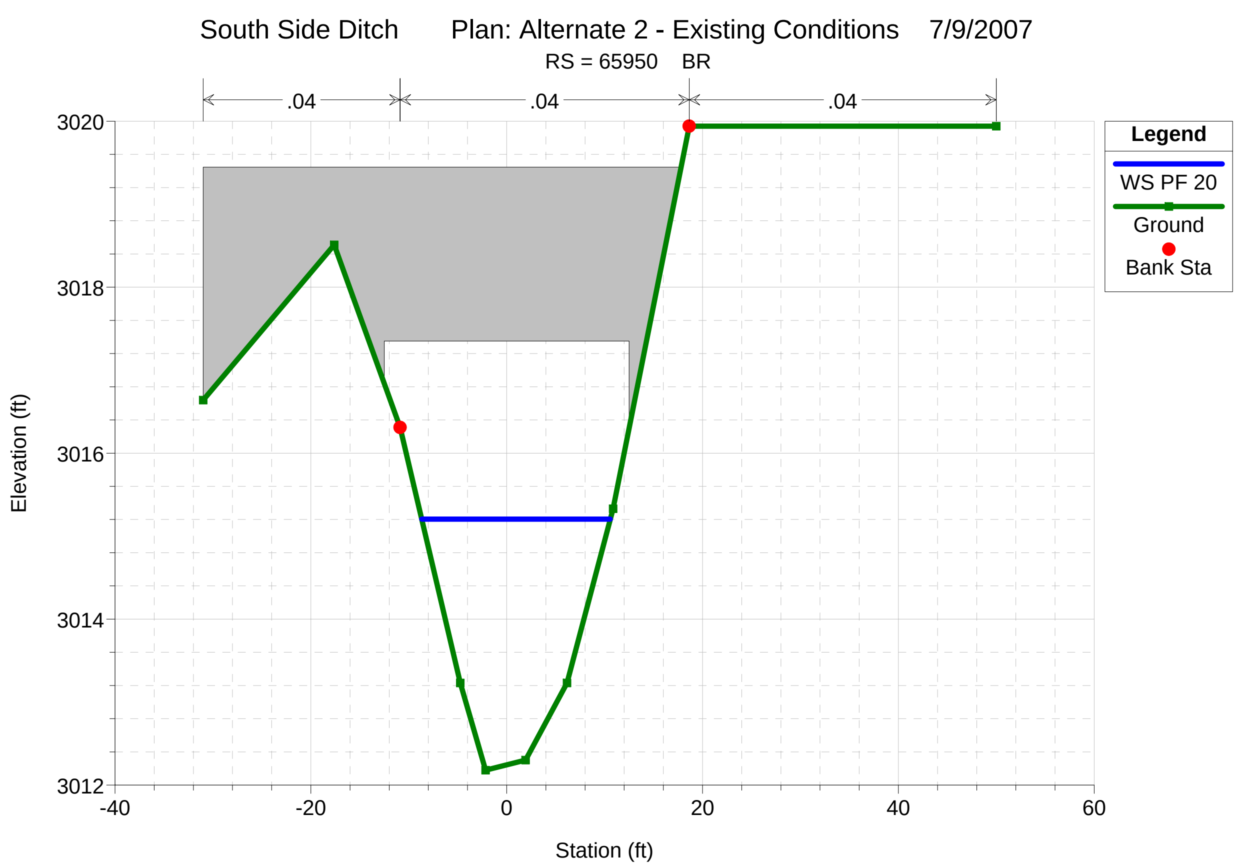

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 62432
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3012
3011
3010
3009
3008
3007
3006
3005
3004
-60
-40
-20
0
20
40
Station (ft)

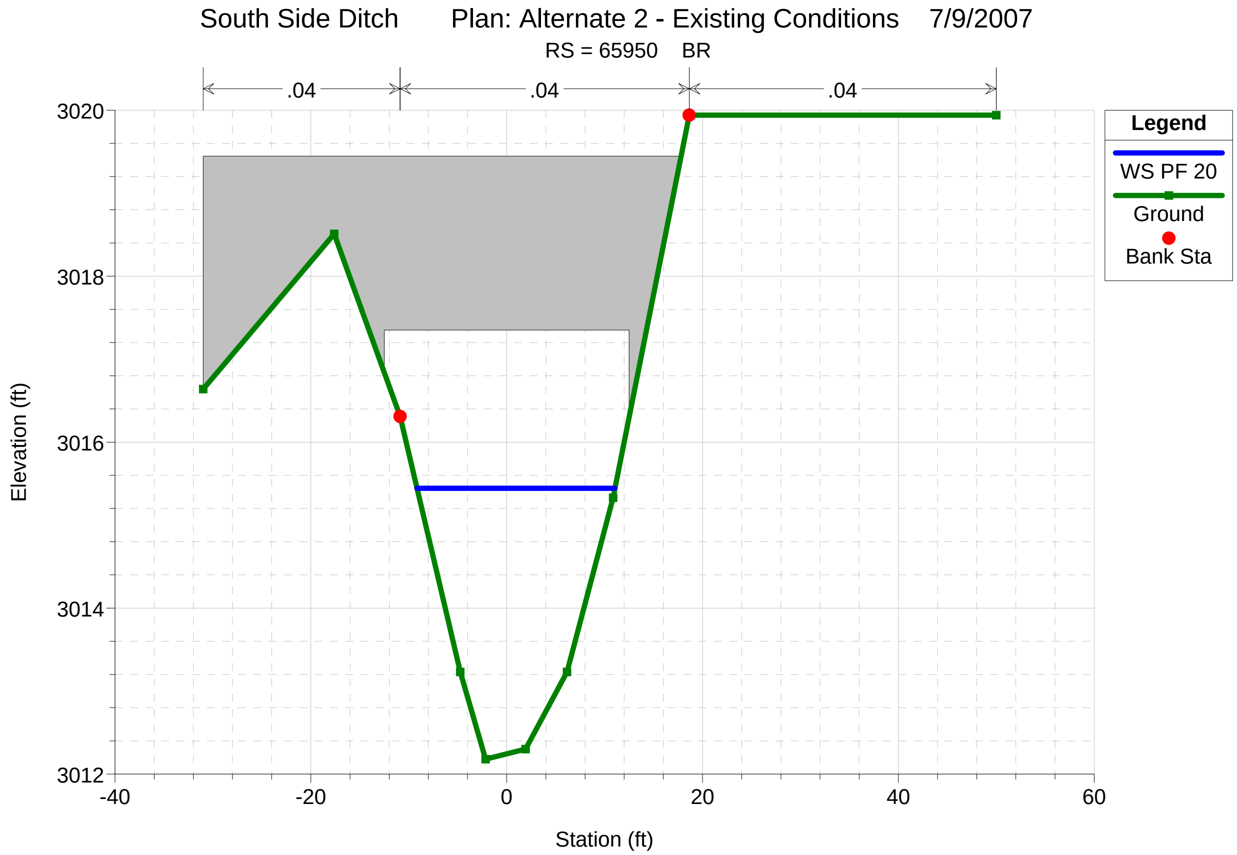

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 62471 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3012
3011
3010
3009
3008
3007
3006
3005
3004
-60
-40
-20
0
20
40
Station (ft)

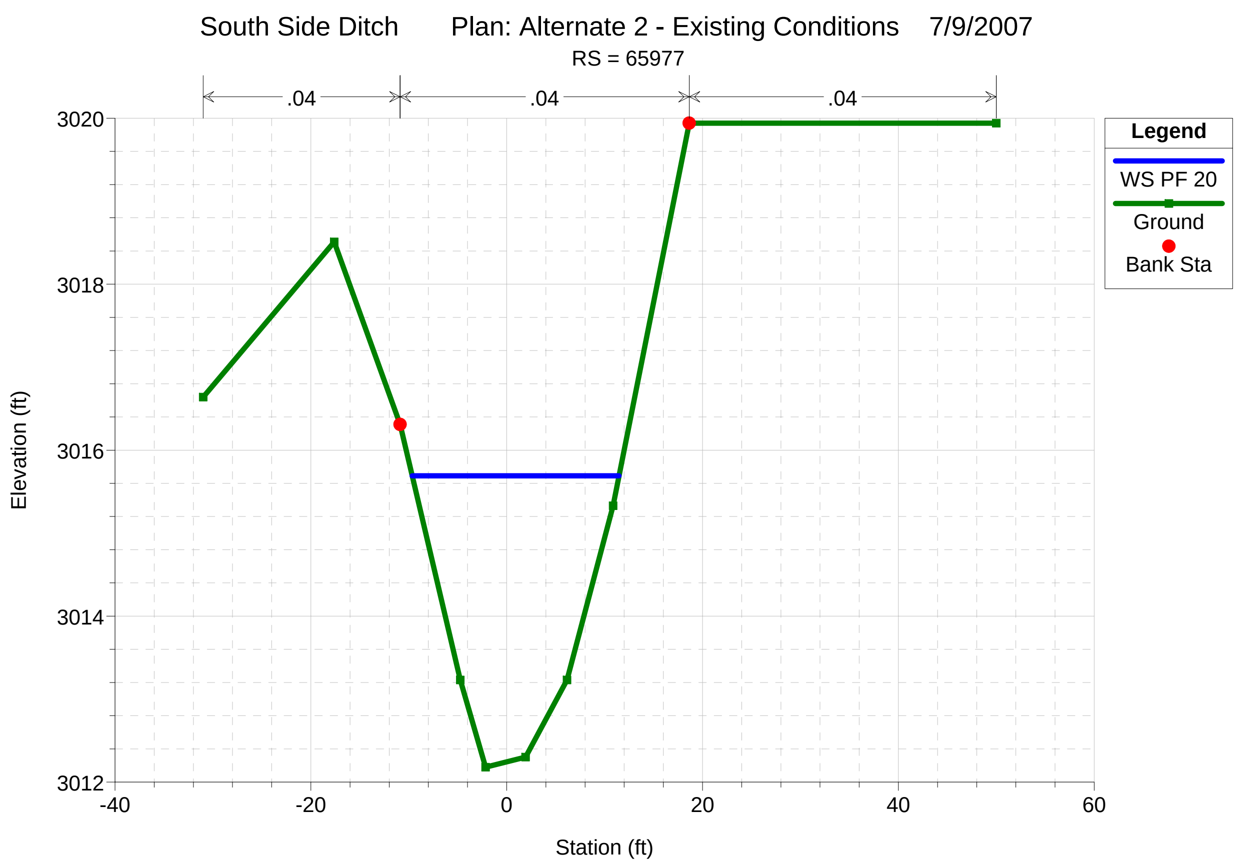

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 62471 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3012
3011
3010
3009
3008
3007
3006
3005
3004
-60
-40
-20
0
20
40
Station (ft)

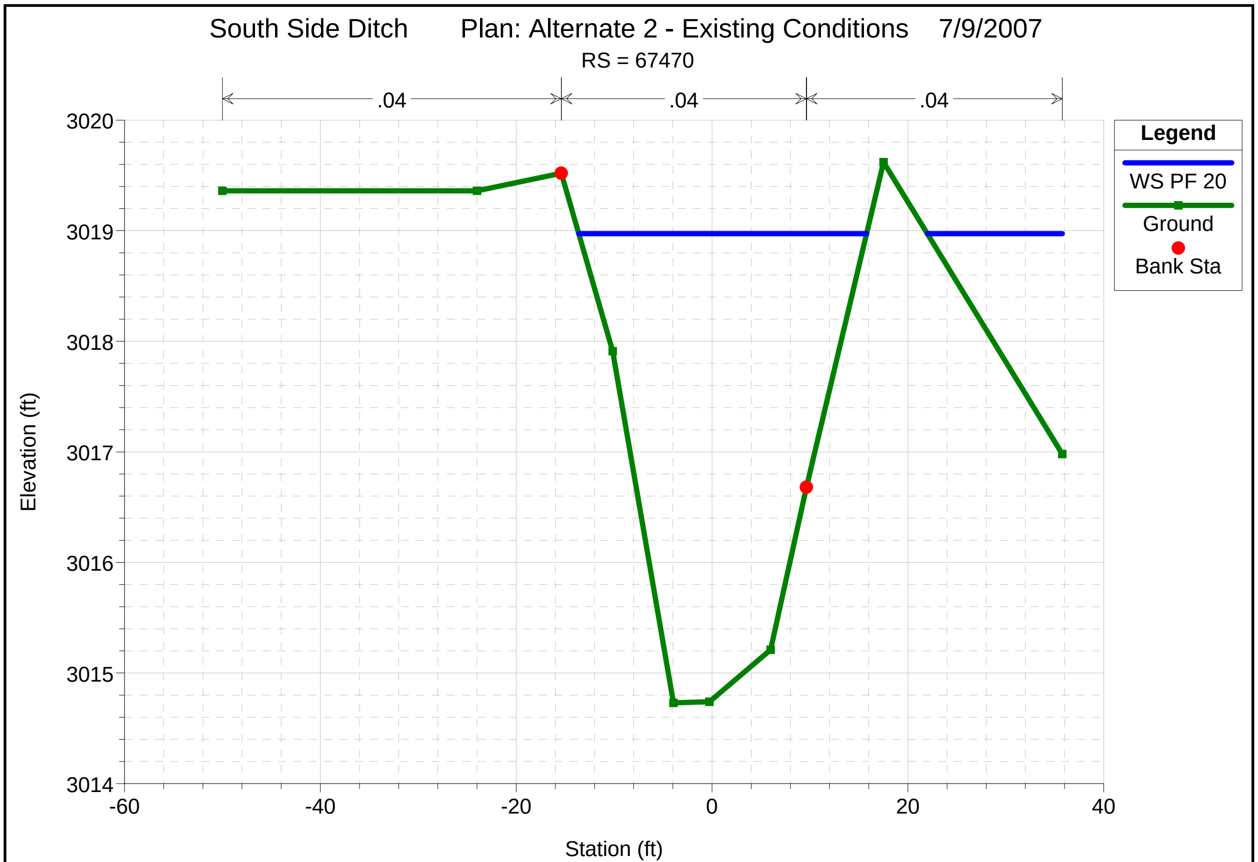

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 62510
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3012
3011
3010
3009
3008
3007
3006
3005
3004
-60
-40
-20
0
20
40
Station (ft)

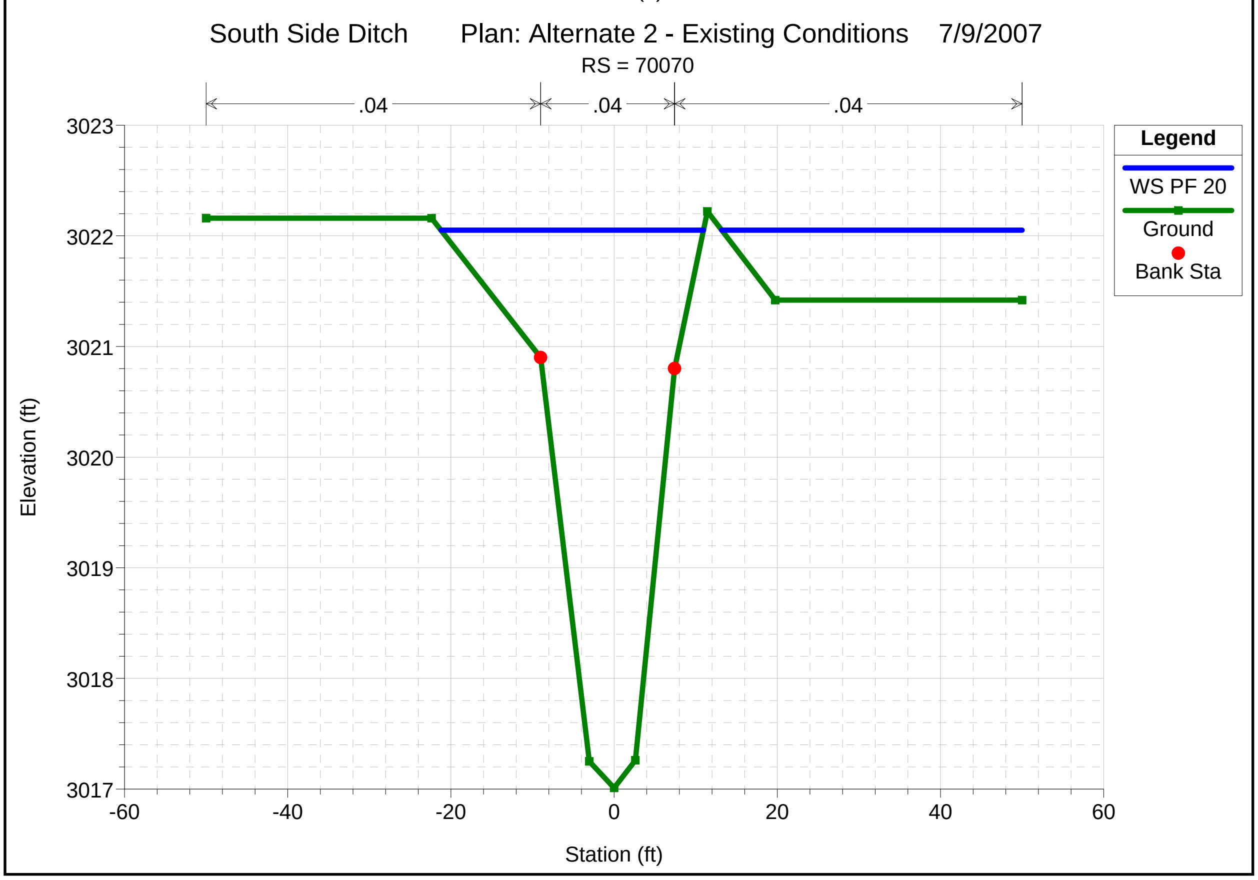

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 65922
.04
.04
.04
3020
3018
3016
3014
3012
-40
-20
0
20
40
60
Elevation (ft)
Station (ft)
Legend
WS PF 20
Ground
Bank Sta

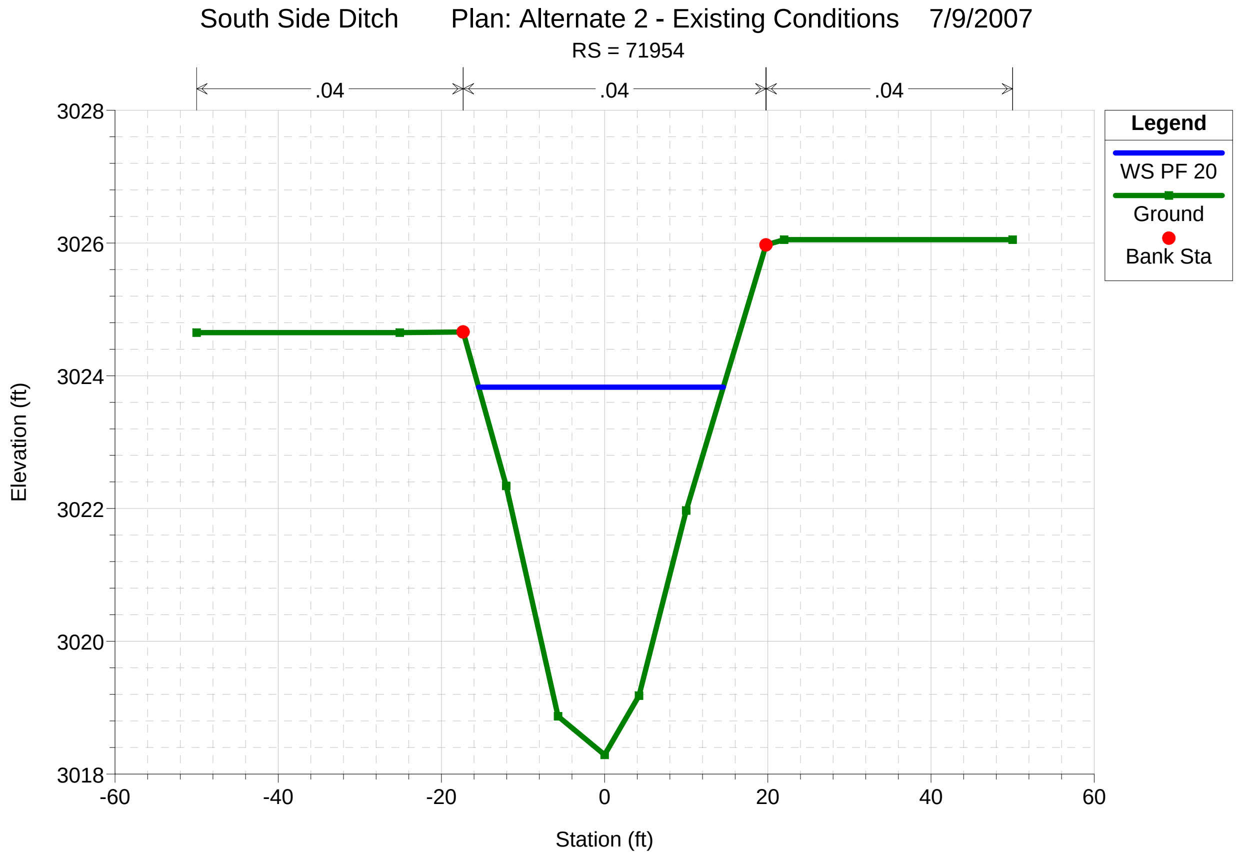

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 65950 BR
.04
.04
.04
3020
3018
3016
3014
3012
-40
-20
0
20
40
60
Elevation (ft)
Station (ft)
Legend
WS PF 20
Ground
Bank Sta

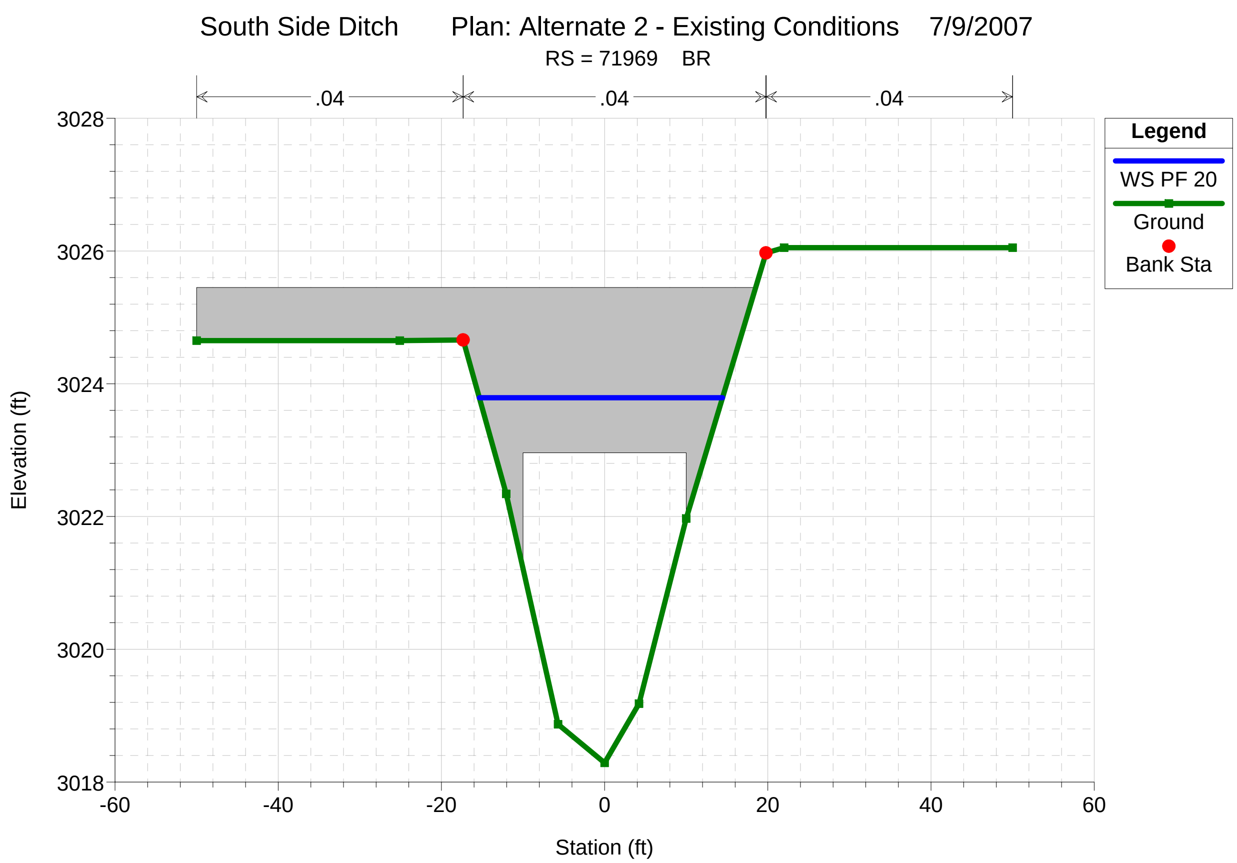

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 65950 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3020
3018
3016
3014
3012
-40
-20
0
20
40
60
Station (ft)

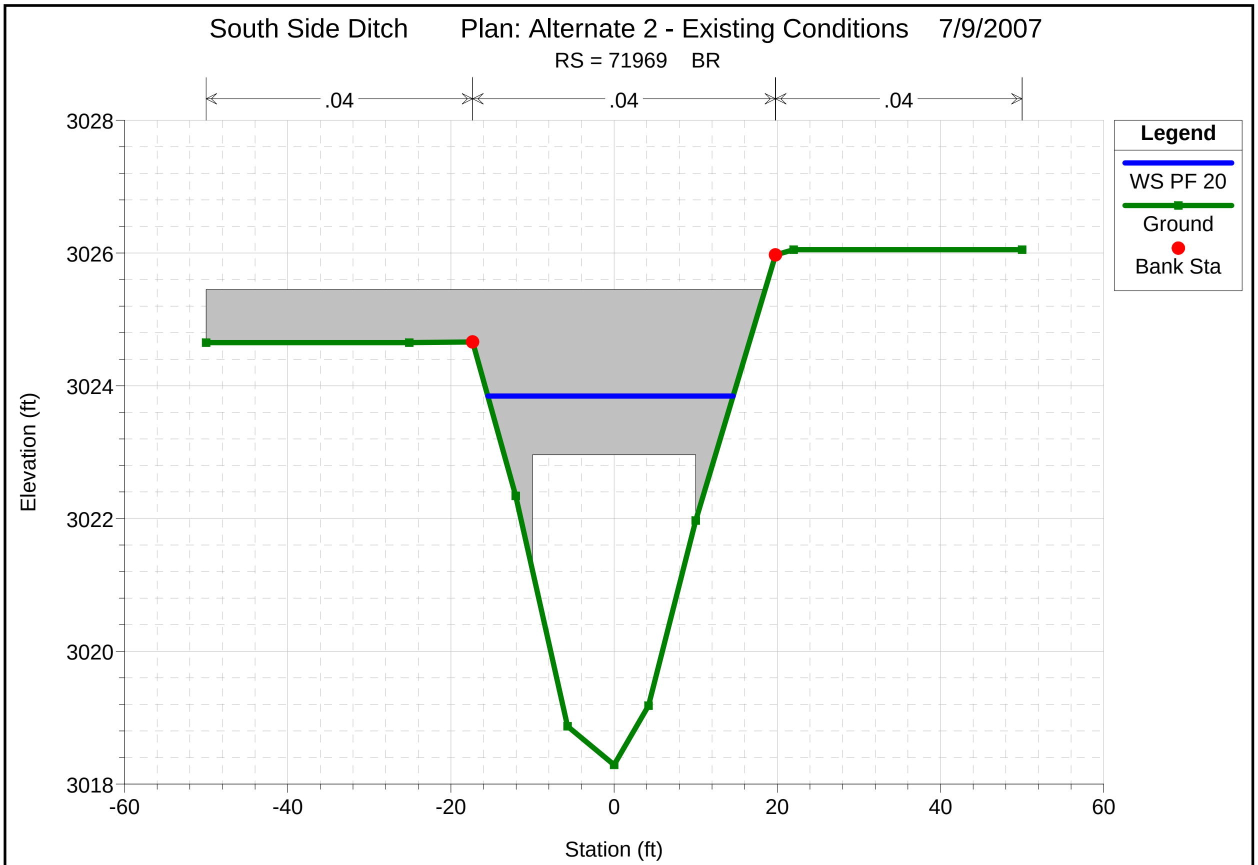

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 65977
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3020
3018
3016
3014
3012
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 67470
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3020
3019
3018
3017
3016
3015
3014
-60
-40
-20
0
20
40
Station (ft)

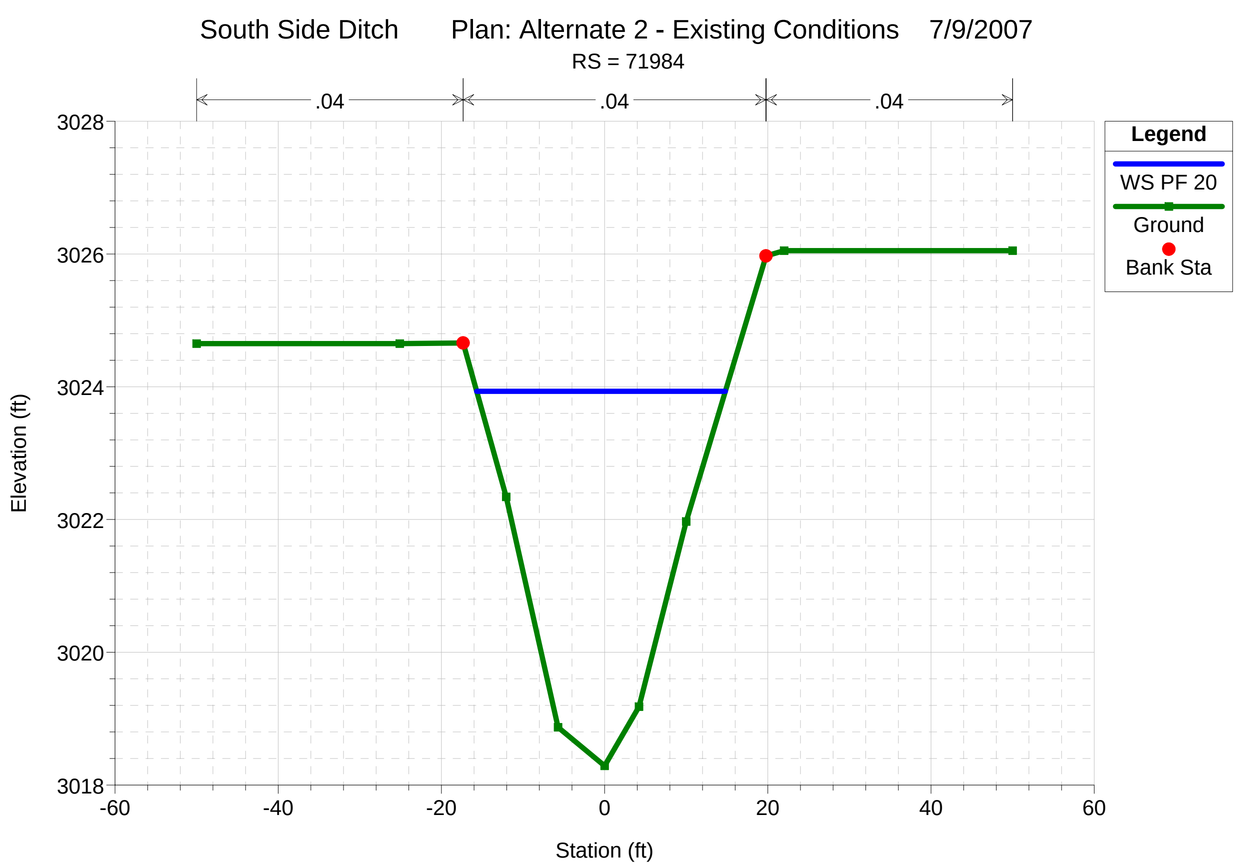

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 70070
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3023
3022
3021
3020
3019
3018
3017
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 71954
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3018
3020
3022
3024
3026
3028
Station (ft)
-60
-40
-20
0
20
40
60

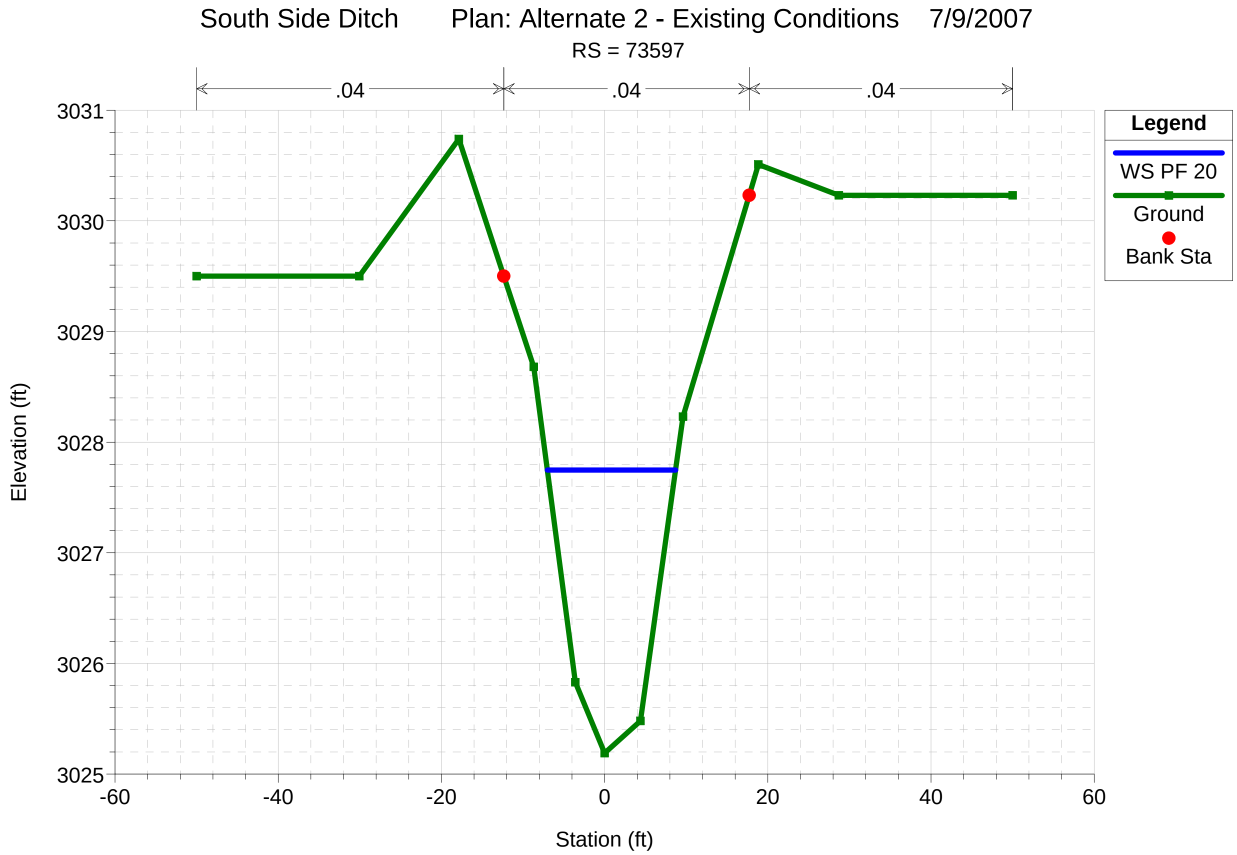

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 71969 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3018
3020
3022
3024
3026
3028
Station (ft)
-60
-40
-20
0
20
40
60



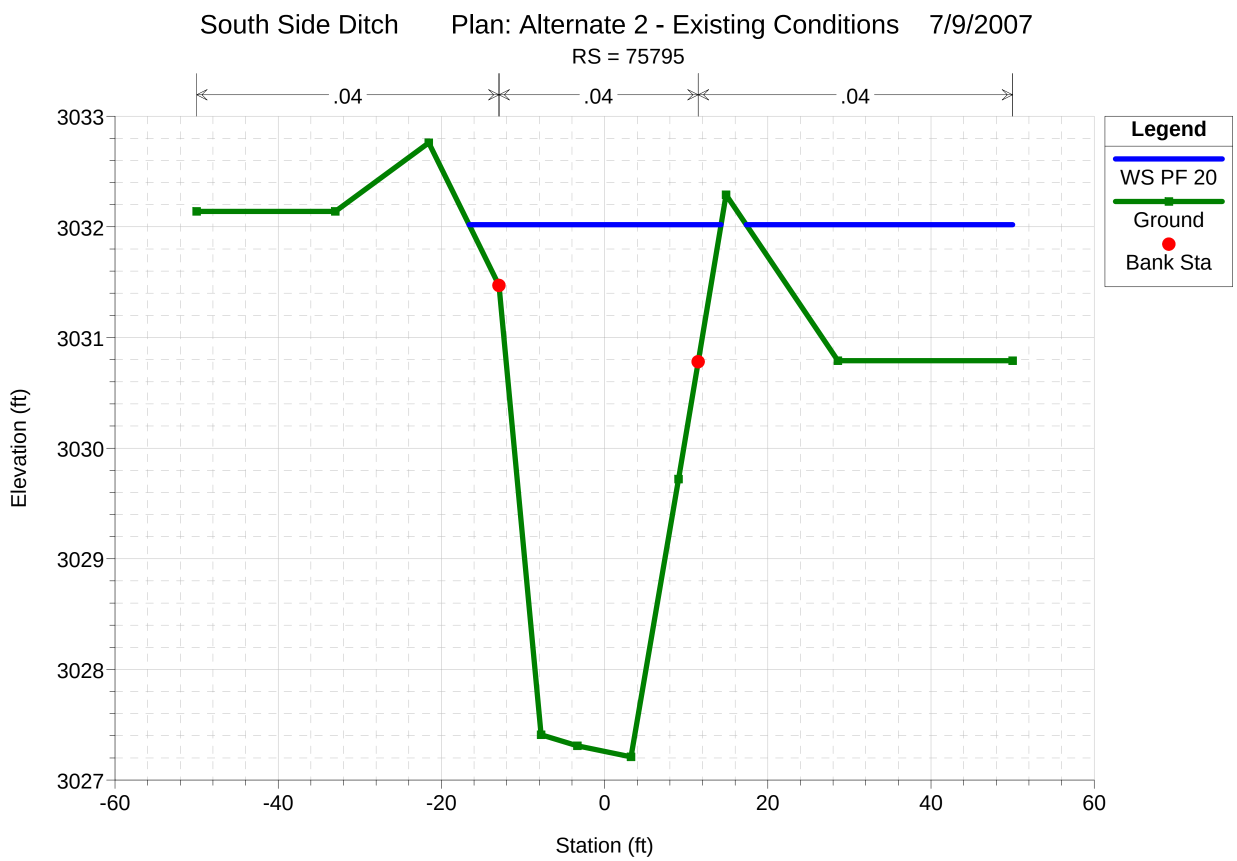
South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 71969 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
3028
3026
3024
3022
3020
3018
Elevation (ft)
-60
-40
-20
0
20
40
60
Station (ft)



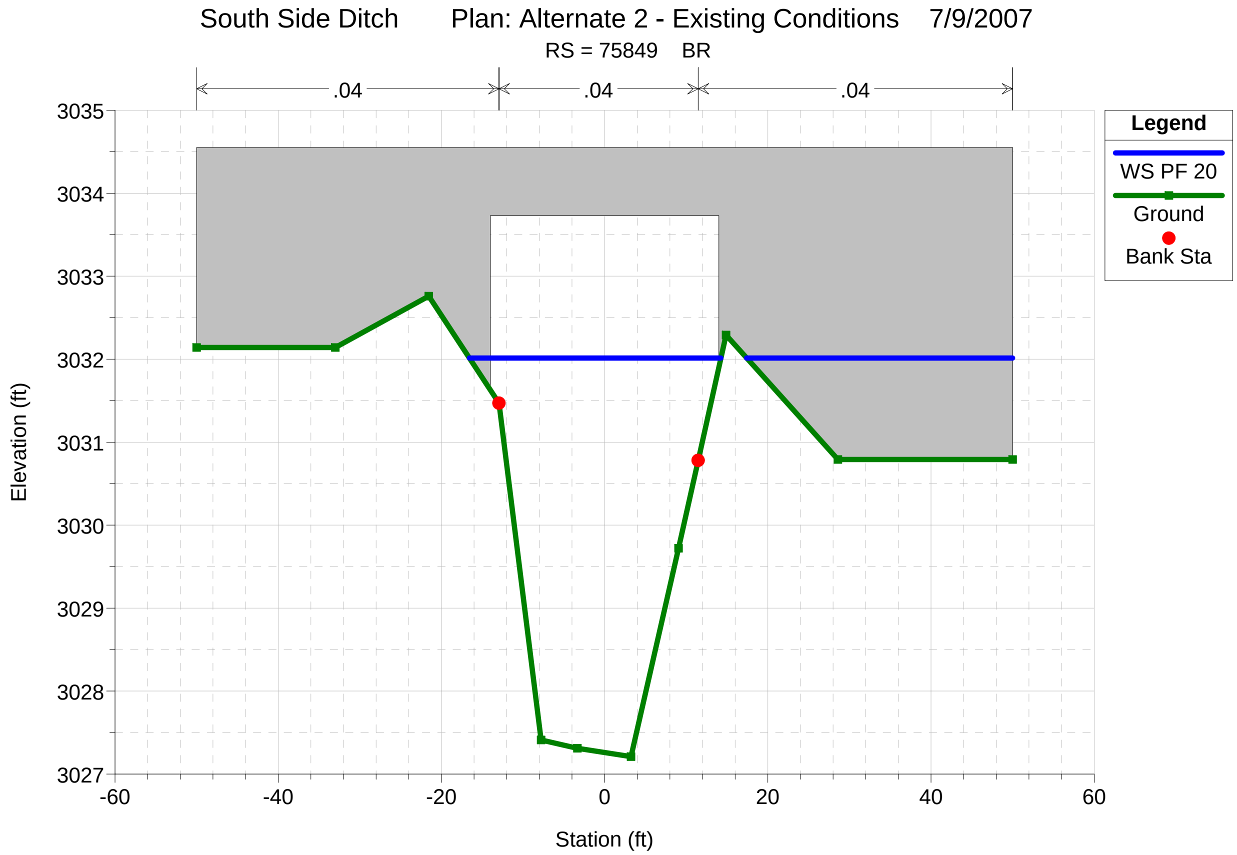
South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 71984
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
3028
3026
3024
3022
3020
3018
Elevation (ft)
-60
-40
-20
0
20
40
60
Station (ft)

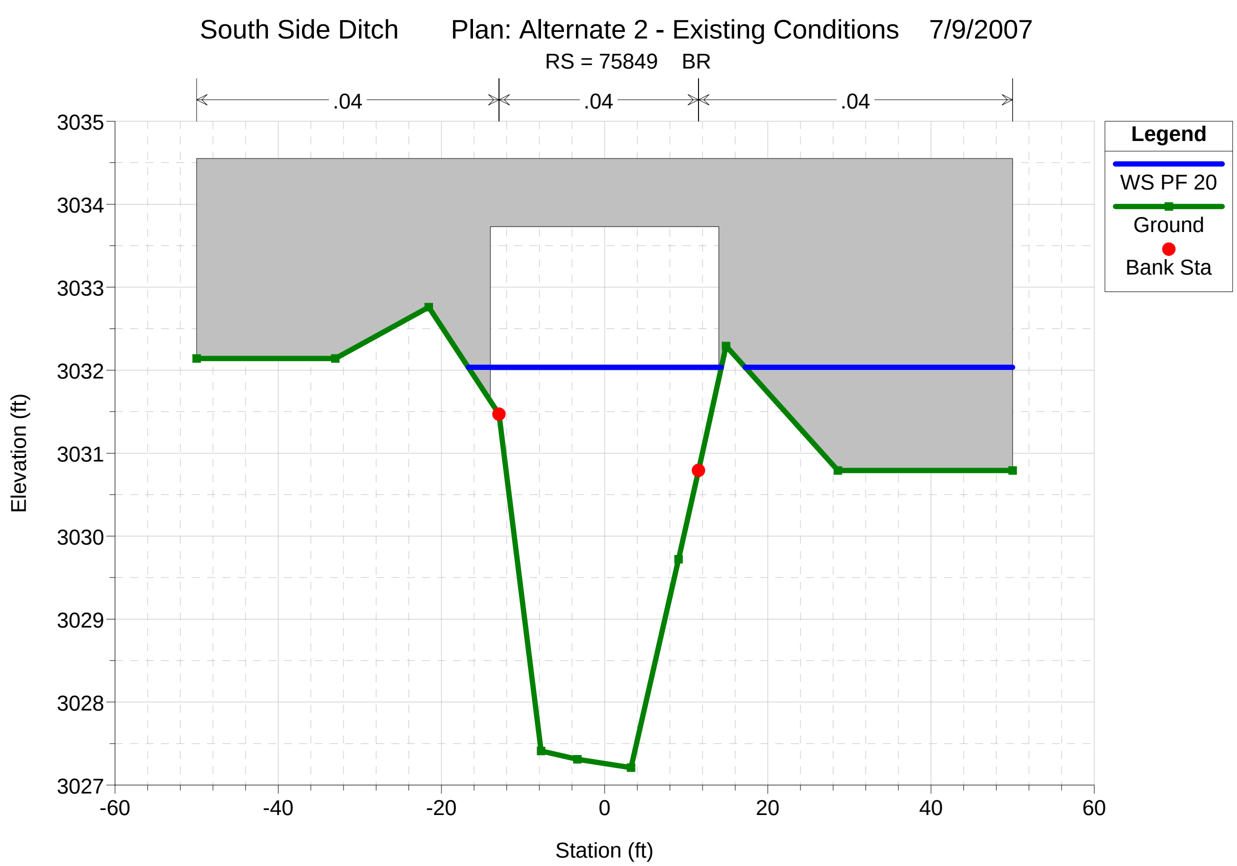


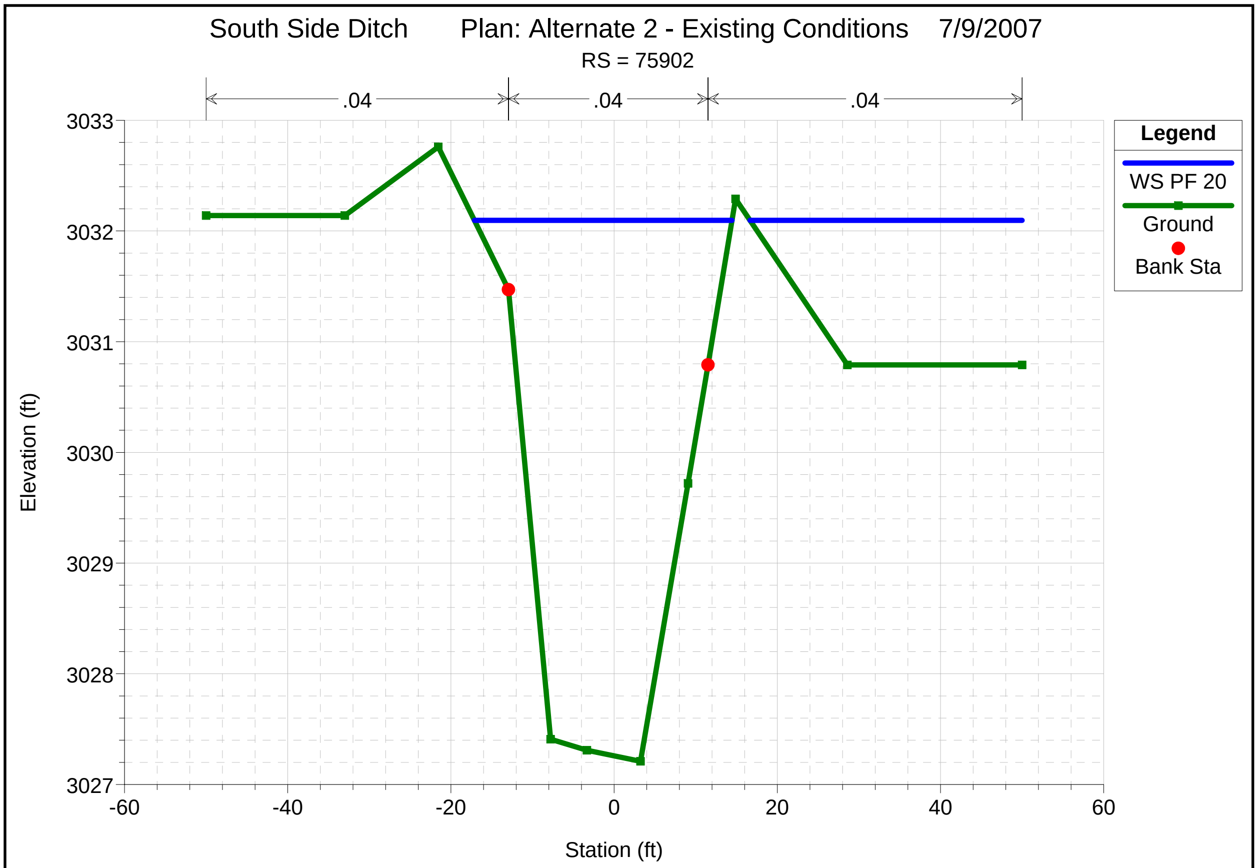
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 73597
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3031
3030
3029
3028
3027
3026
3025
-60
-40
-20
0
20
40
60
Station (ft)



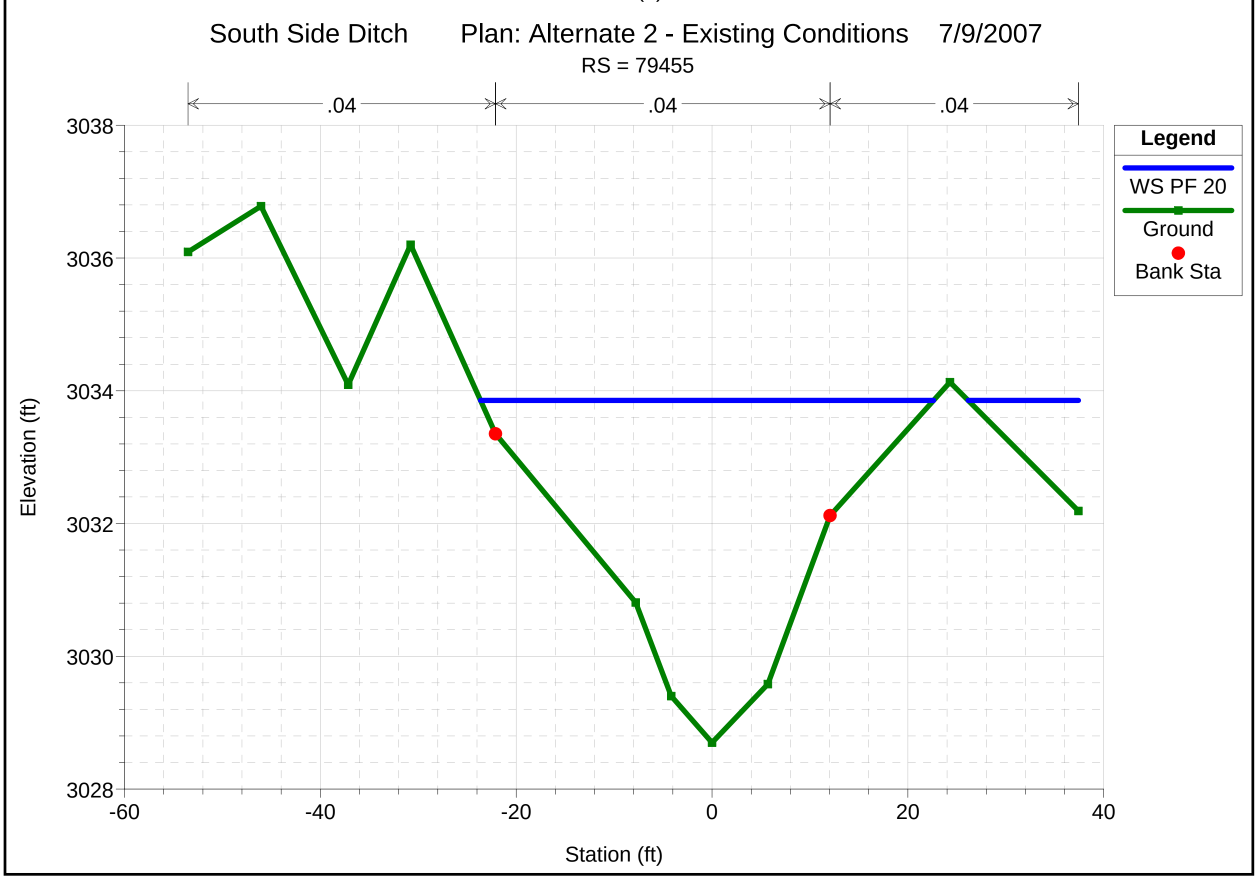
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 75795
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3033
3032
3031
3030
3029
3028
3027
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 75849 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3035
3034
3033
3032
3031
3030
3029
3028
3027
-60
-40
-20
0
20
40
60
Station (ft)

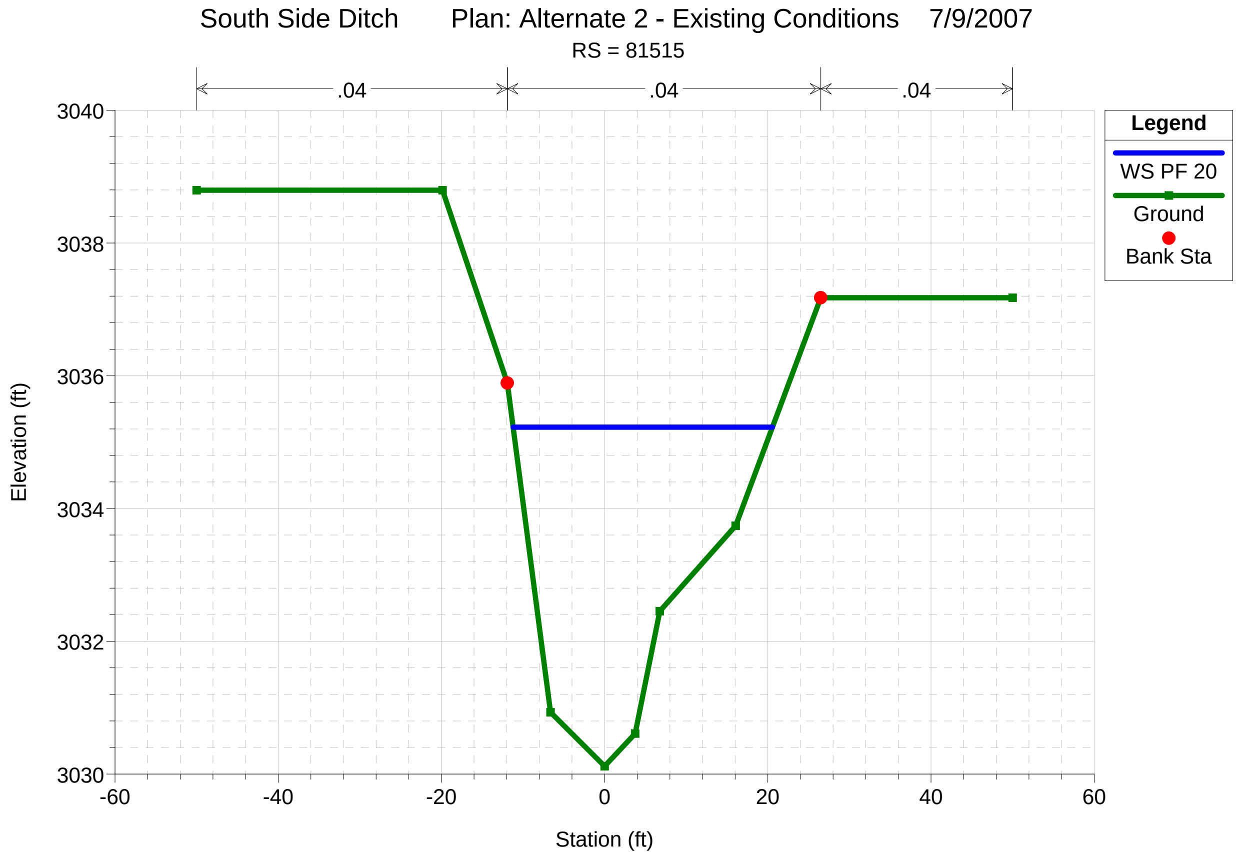

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 75849 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3035
3034
3033
3032
3031
3030
3029
3028
3027
-60
-40
-20
0
20
40
60
Station (ft)

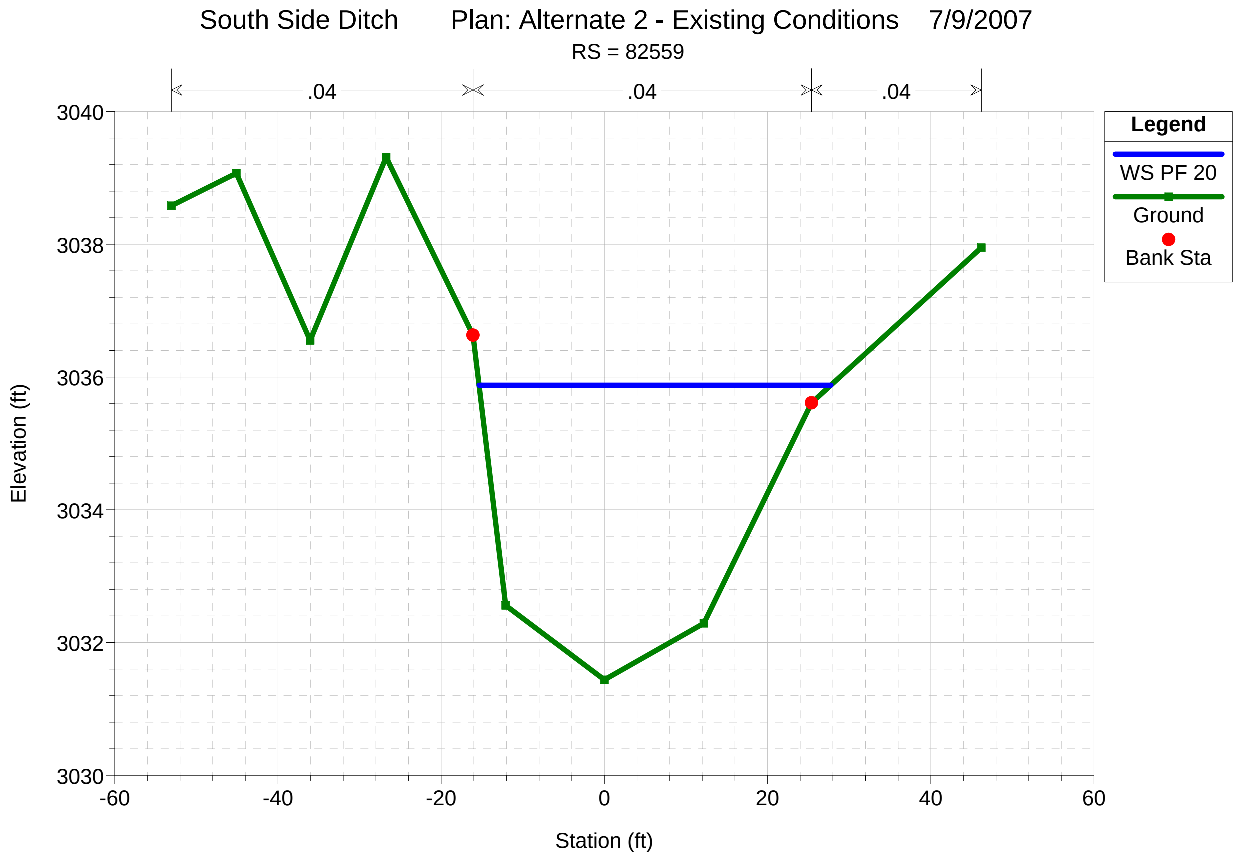


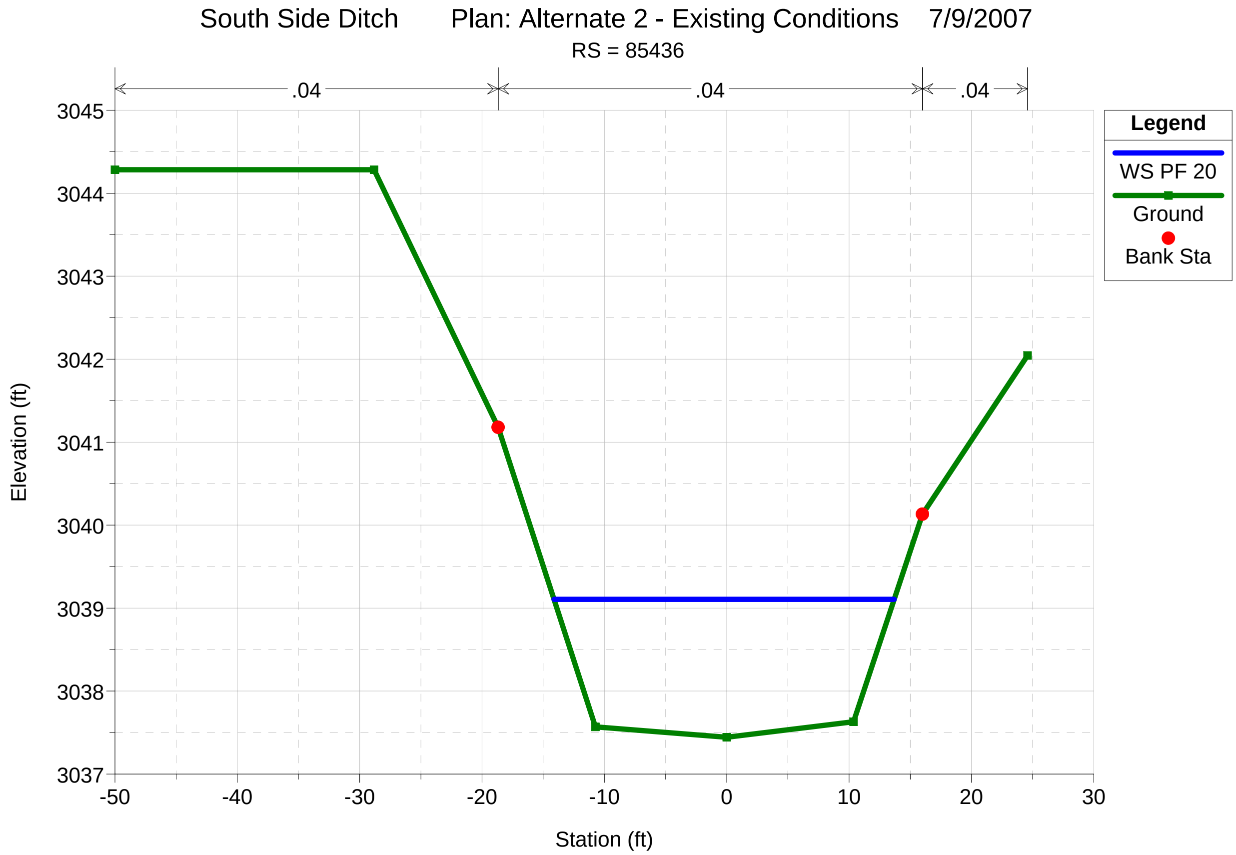
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 75902
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3033
3032
3031
3030
3029
3028
3027
-60
-40
-20
0
20
40
60
Station (ft)



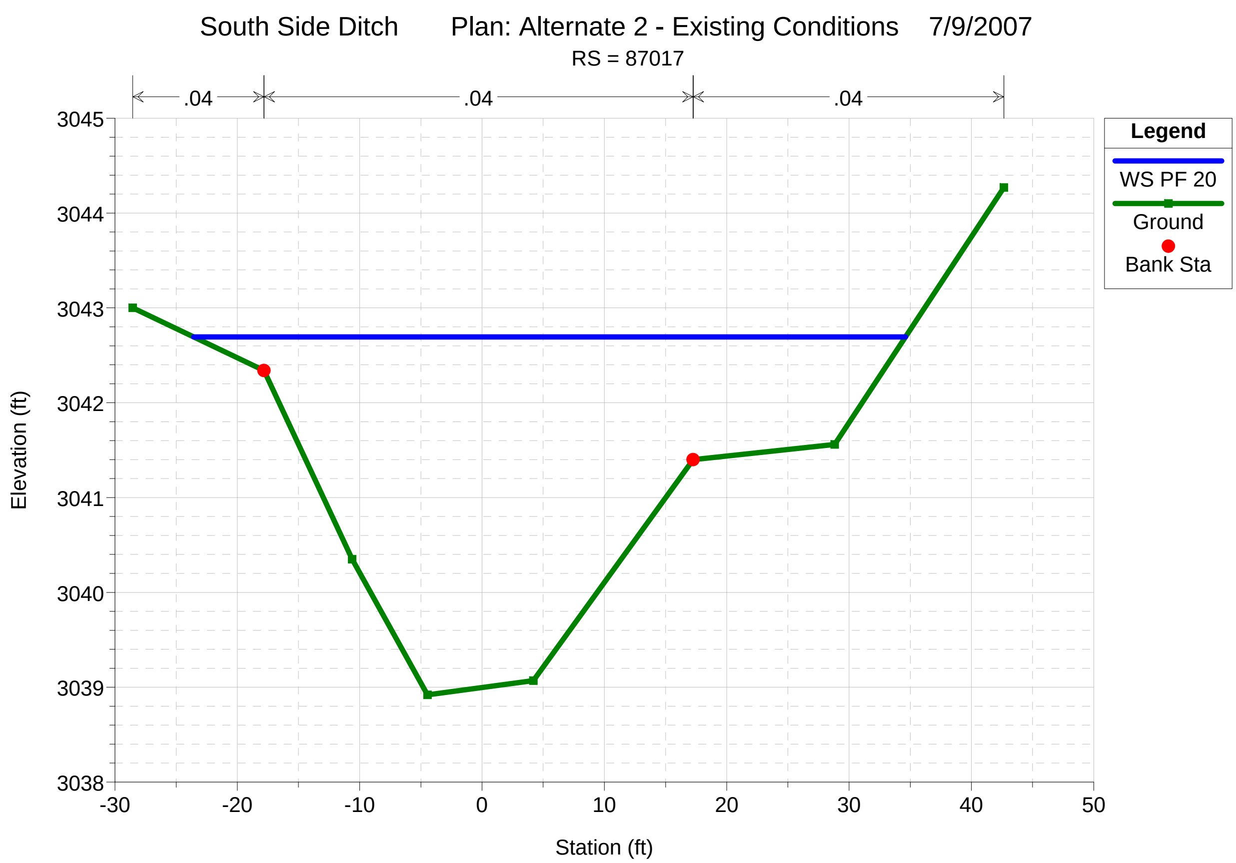
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 79455
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3038
3036
3034
3032
3030
3028
-60
-40
-20
0
20
40
Station (ft)


South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 81515
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3040
3038
3036
3034
3032
3030
-60
-40
-20
0
20
40
60
Station (ft)

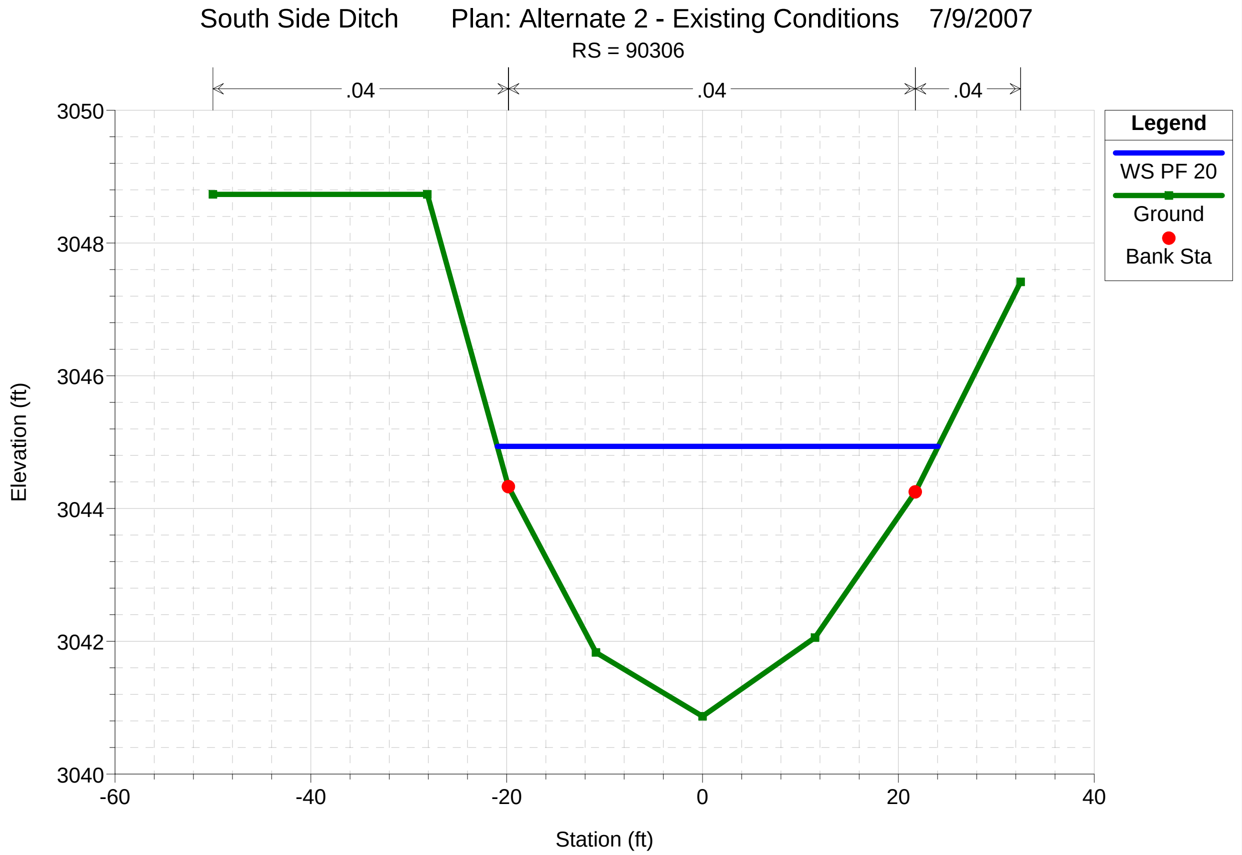

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 82559
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3040
3038
3036
3034
3032
3030
-60
-40
-20
0
20
40
60
Station (ft)

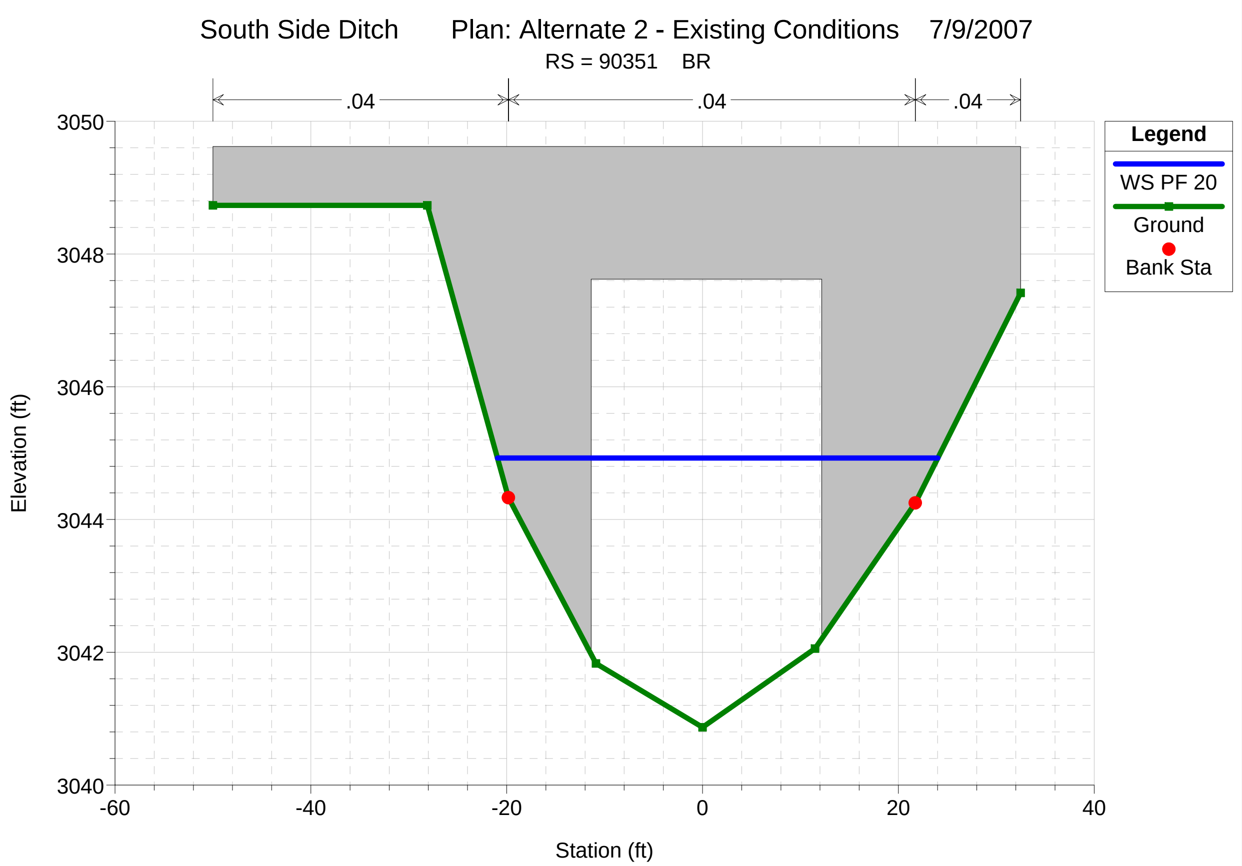


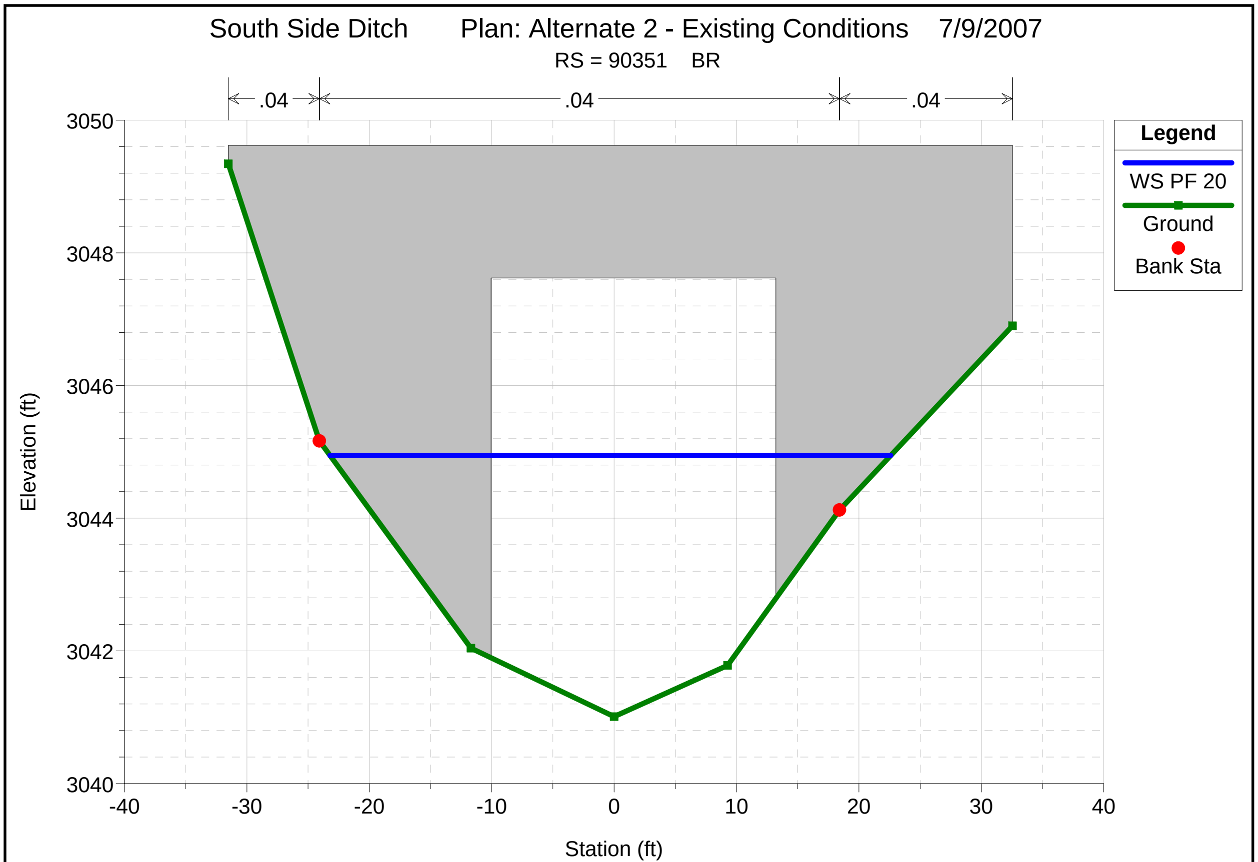
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 85436
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3045
3044
3043
3042
3041
3040
3039
3038
3037
-50
-40
-30
-20
-10
0
10
20
30
Station (ft)

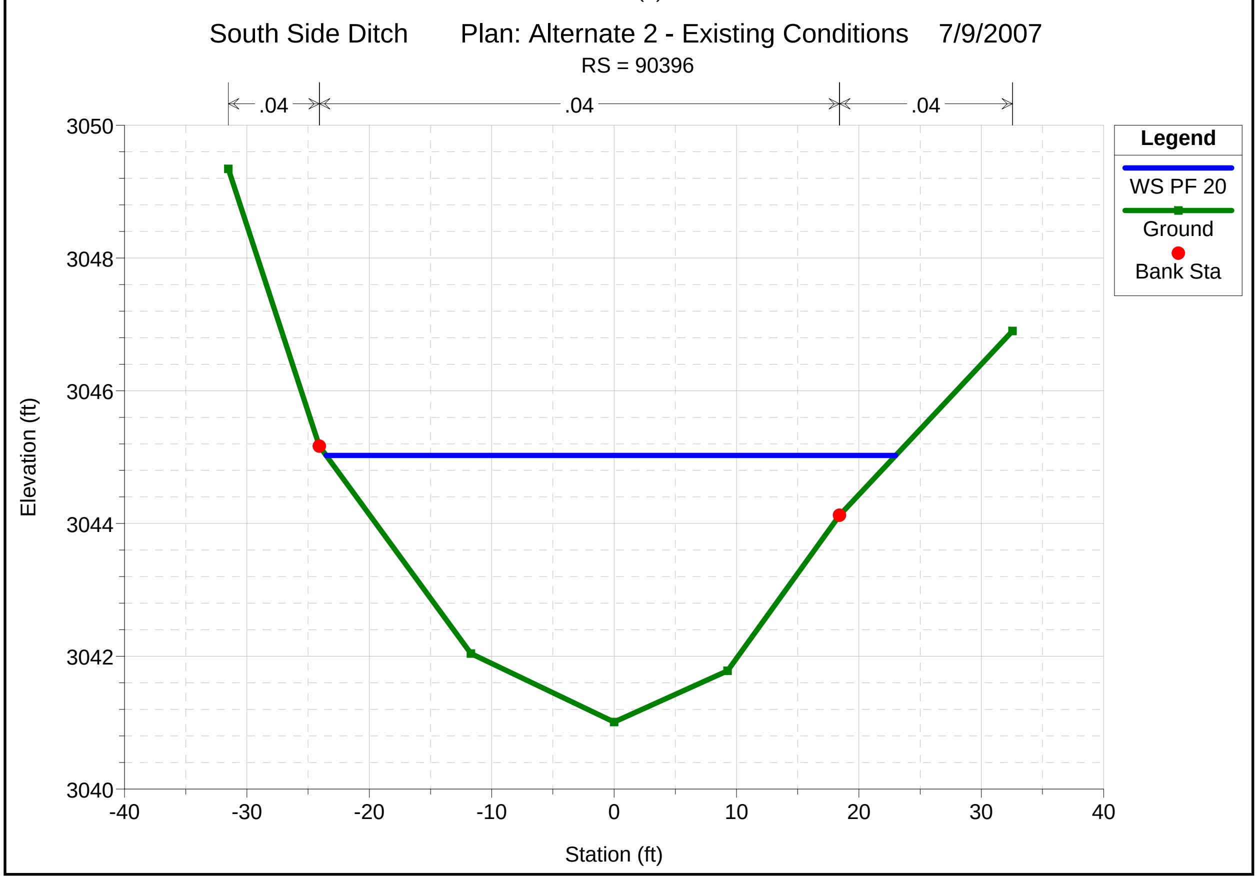


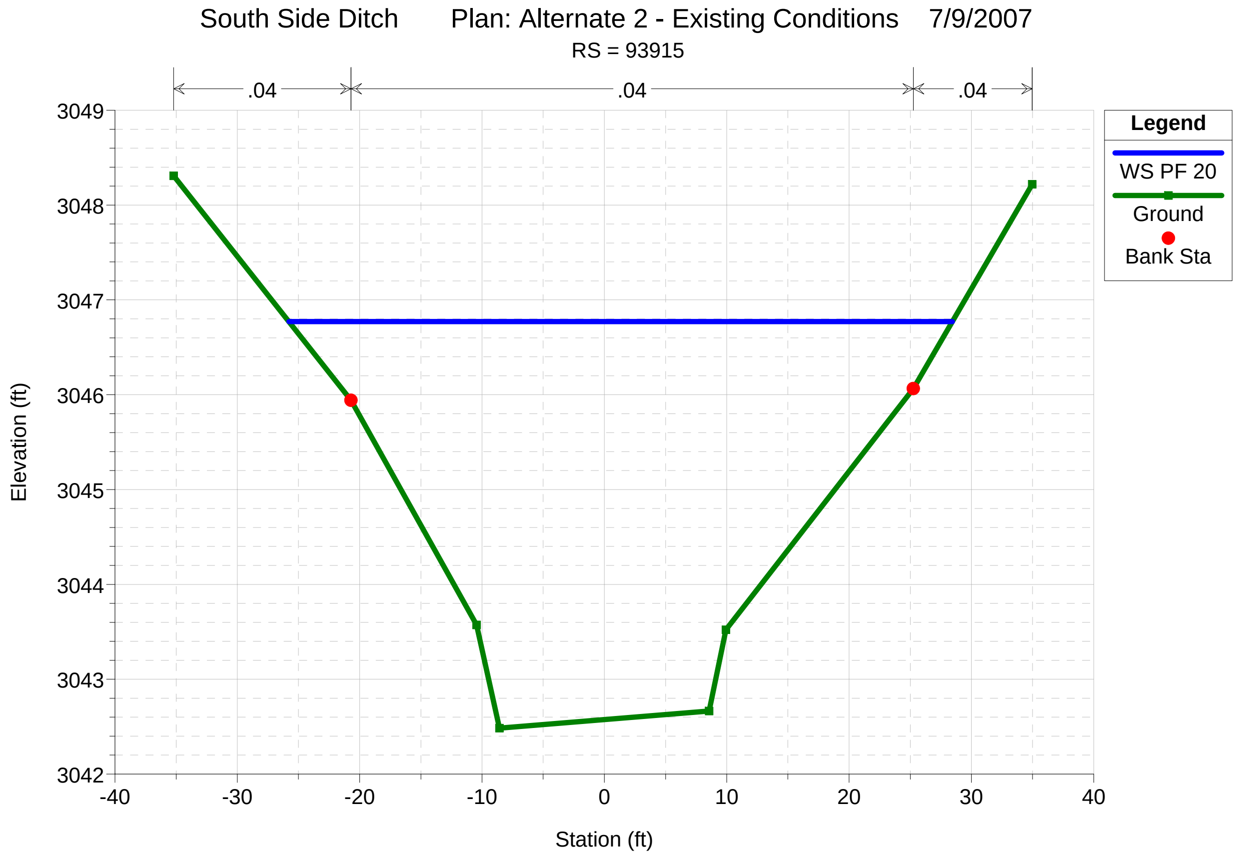
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 87017
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3045
3044
3043
3042
3041
3040
3039
3038
-30
-20
-10
0
10
20
30
40
50
Station (ft)

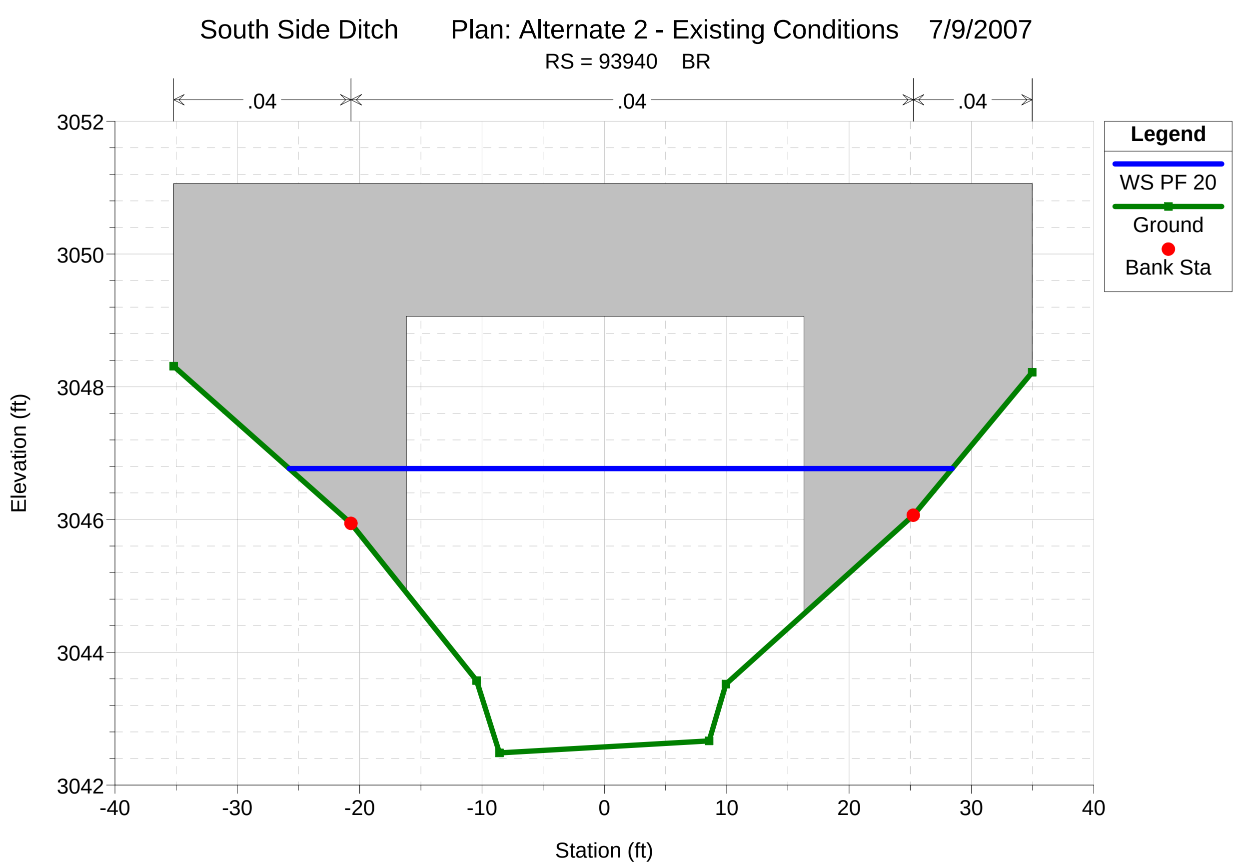

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 90306
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3040
3042
3044
3046
3048
3050
Station (ft)
-60
-40
-20
0
20
40

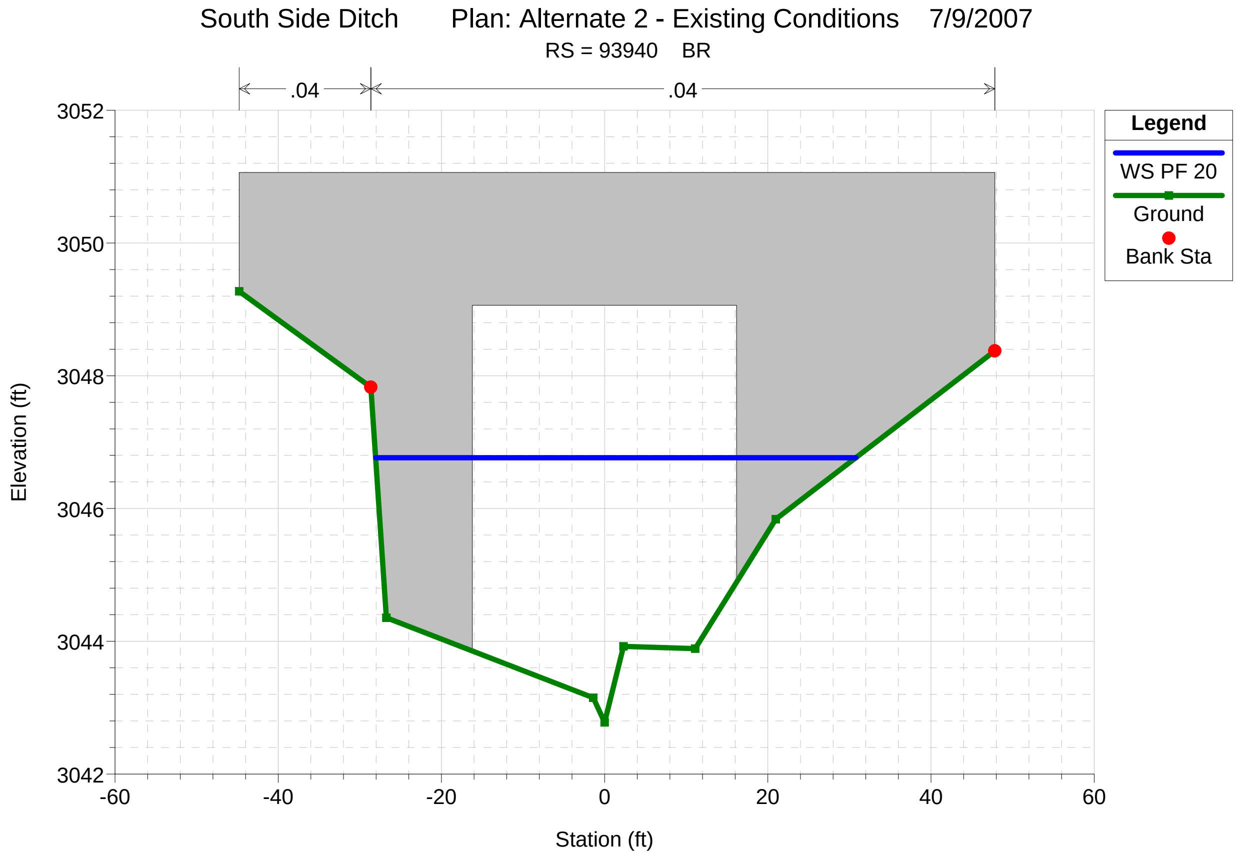

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 90351 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3040
3042
3044
3046
3048
3050
Station (ft)
-60
-40
-20
0
20
40

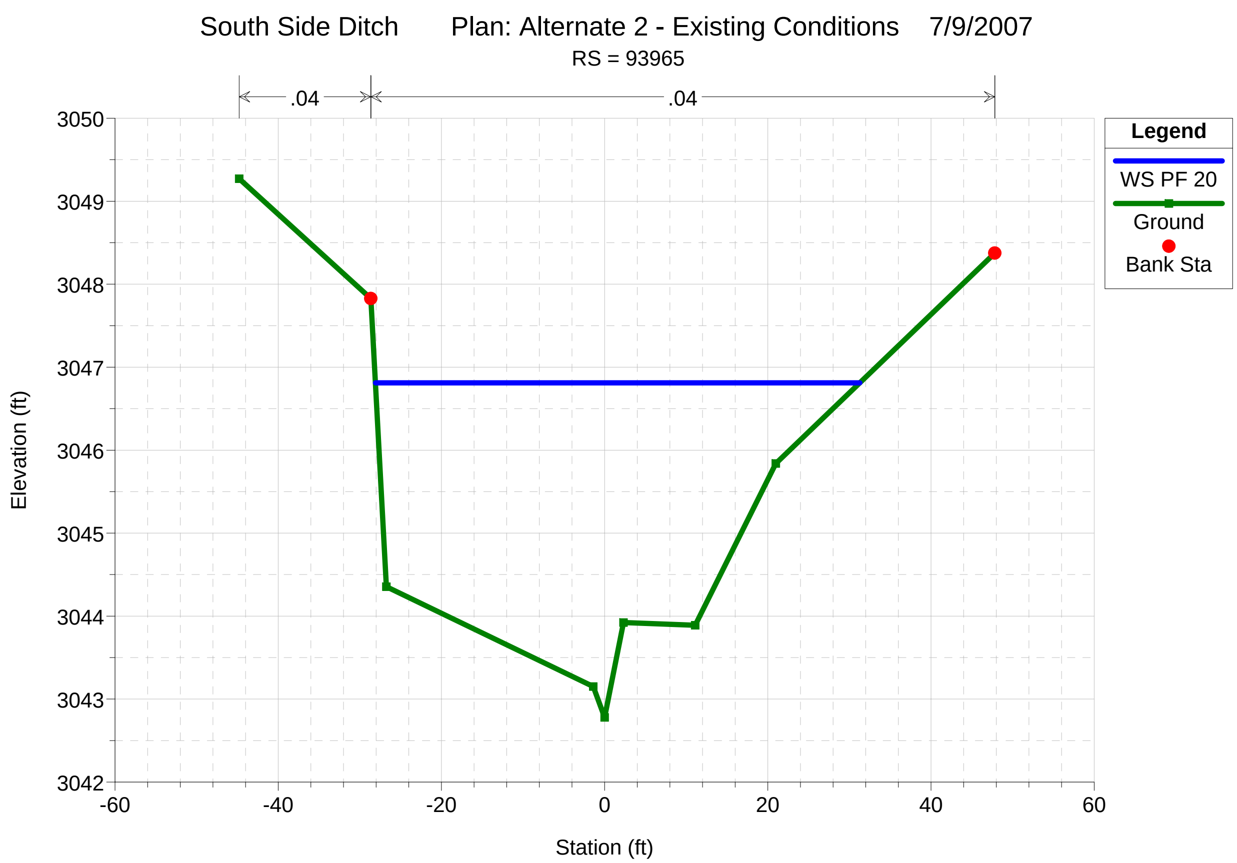

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 90351 BR
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3050
3048
3046
3044
3042
3040
-40
-30
-20
-10
0
10
20
30
40

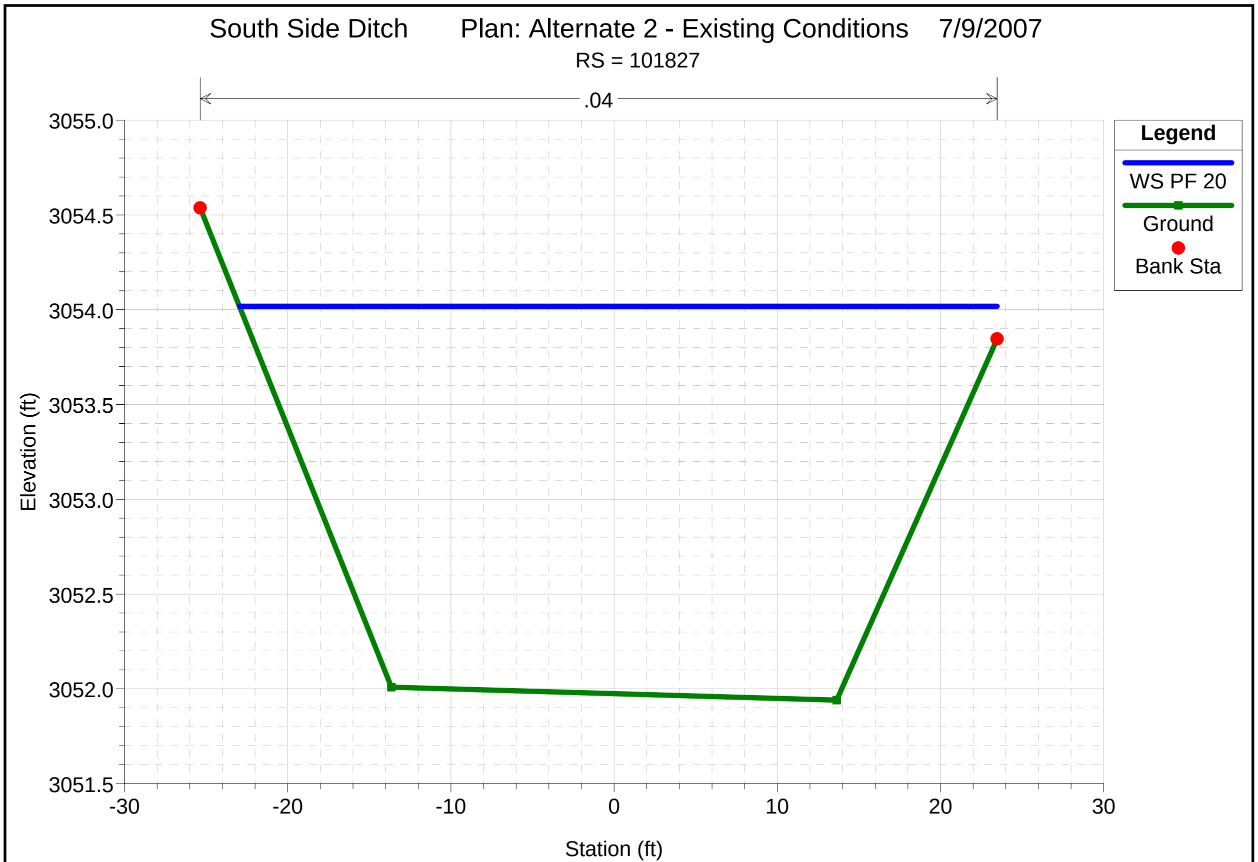

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 90396
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3050
3048
3046
3044
3042
3040
-40
-30
-20
-10
0
10
20
30
40

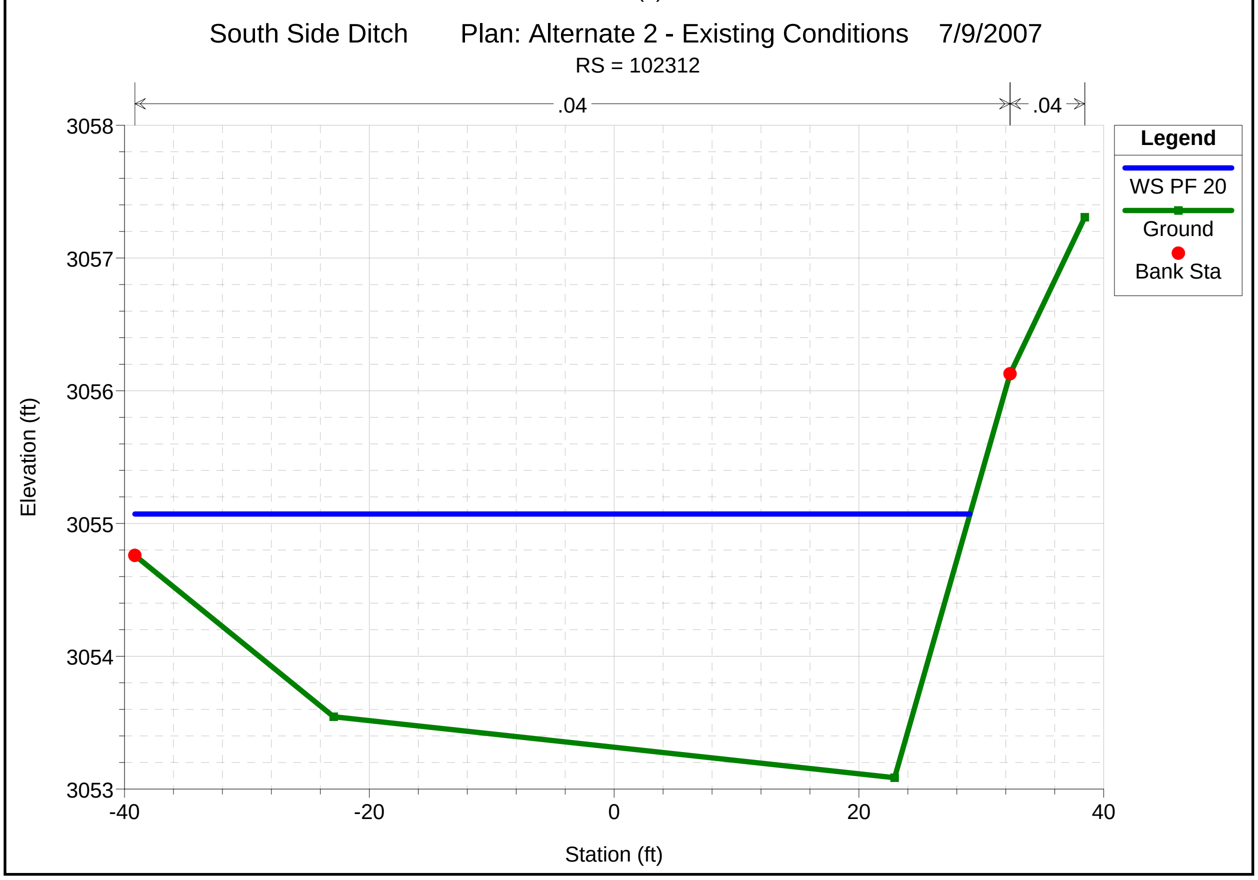

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 93915
.04
.04
.04
Elevation (ft)
Station (ft)
3049
3048
3047
3046
3045
3044
3043
3042
-40
-30
-20
-10
0
10
20
30
40
Legend
WS PF 20
Ground
Bank Sta

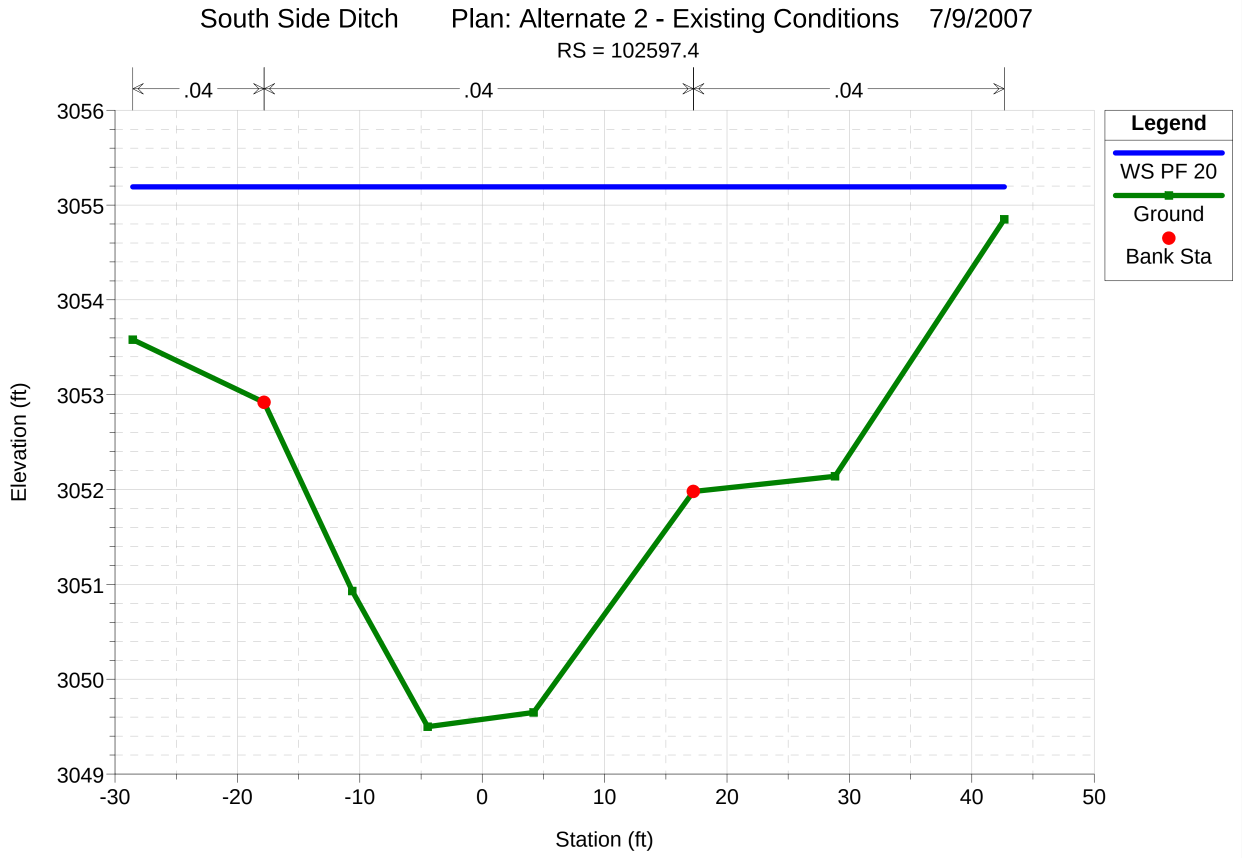

South Side Ditch
Plan: Alternate 2 - Existing Conditions
7/9/2007
RS = 93940 BR
.04
.04
.04
Elevation (ft)
Station (ft)
3052
3050
3048
3046
3044
3042
-40
-30
-20
-10
0
10
20
30
40
Legend
WS PF 20
Ground
Bank Sta


South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 93940 BR
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3052
3050
3048
3046
3044
3042
-60
-40
-20
0
20
40
60
Station (ft)

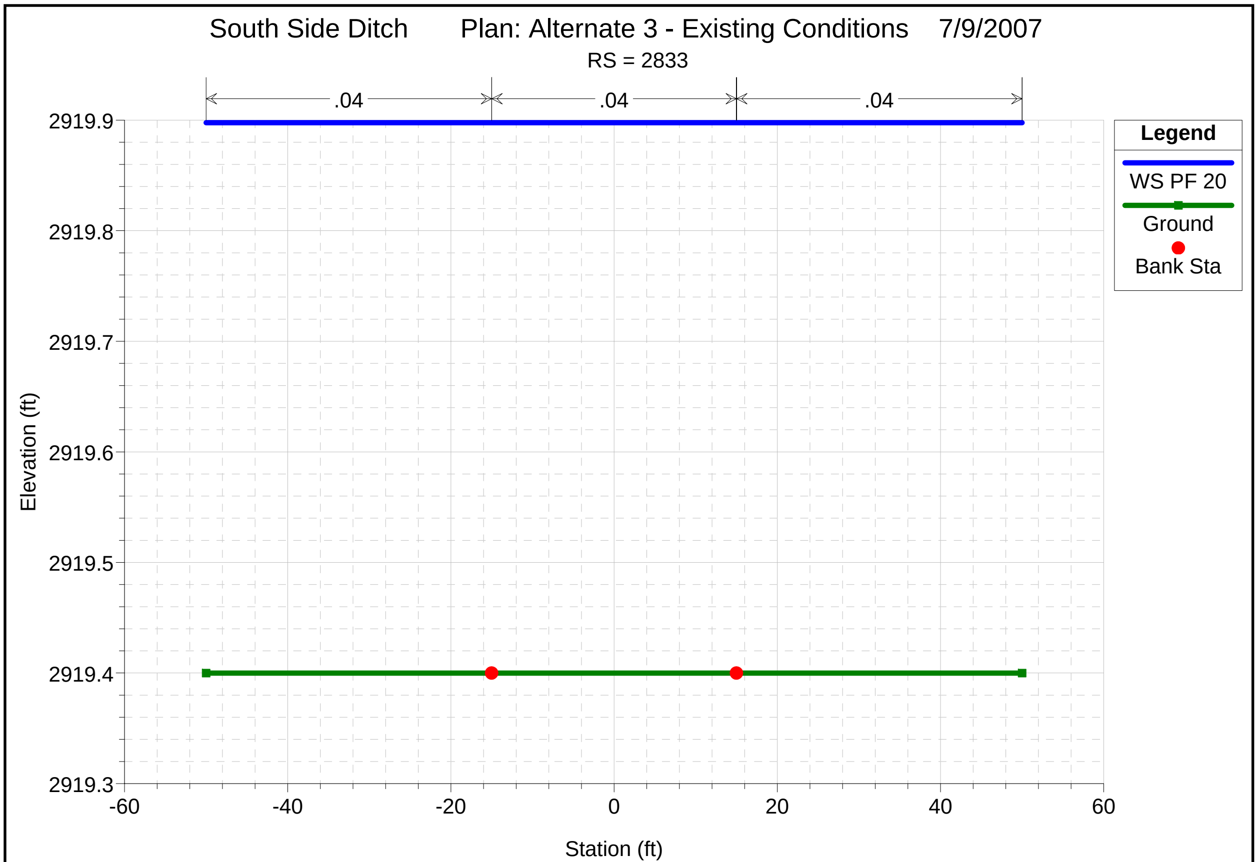

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 93965
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3050
3049
3048
3047
3046
3045
3044
3043
3042
-60
-40
-20
0
20
40
60
Station (ft)

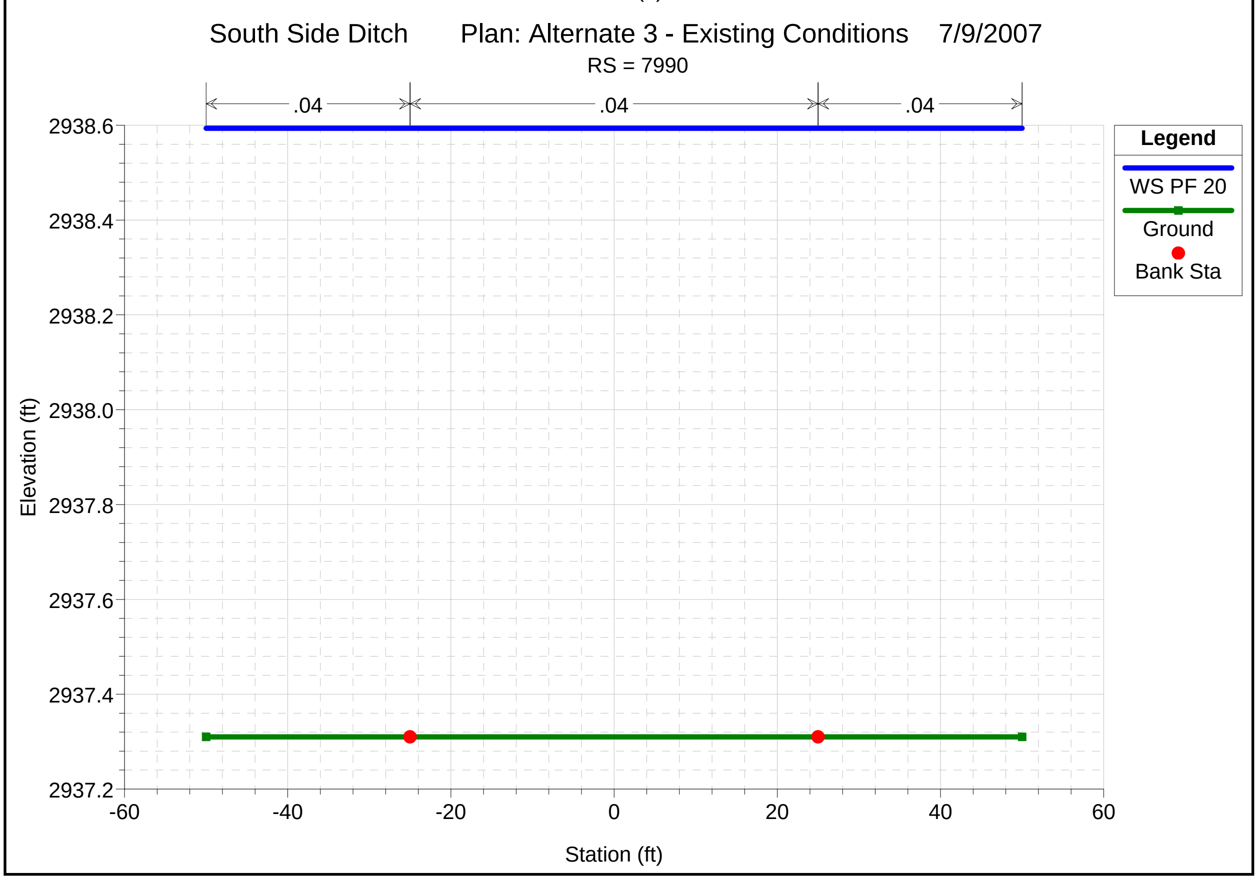

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 101827
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3055.0
3054.5
3054.0
3053.5
3053.0
3052.5
3052.0
3051.5
-30
-20
-10
0
10
20
30
Station (ft)

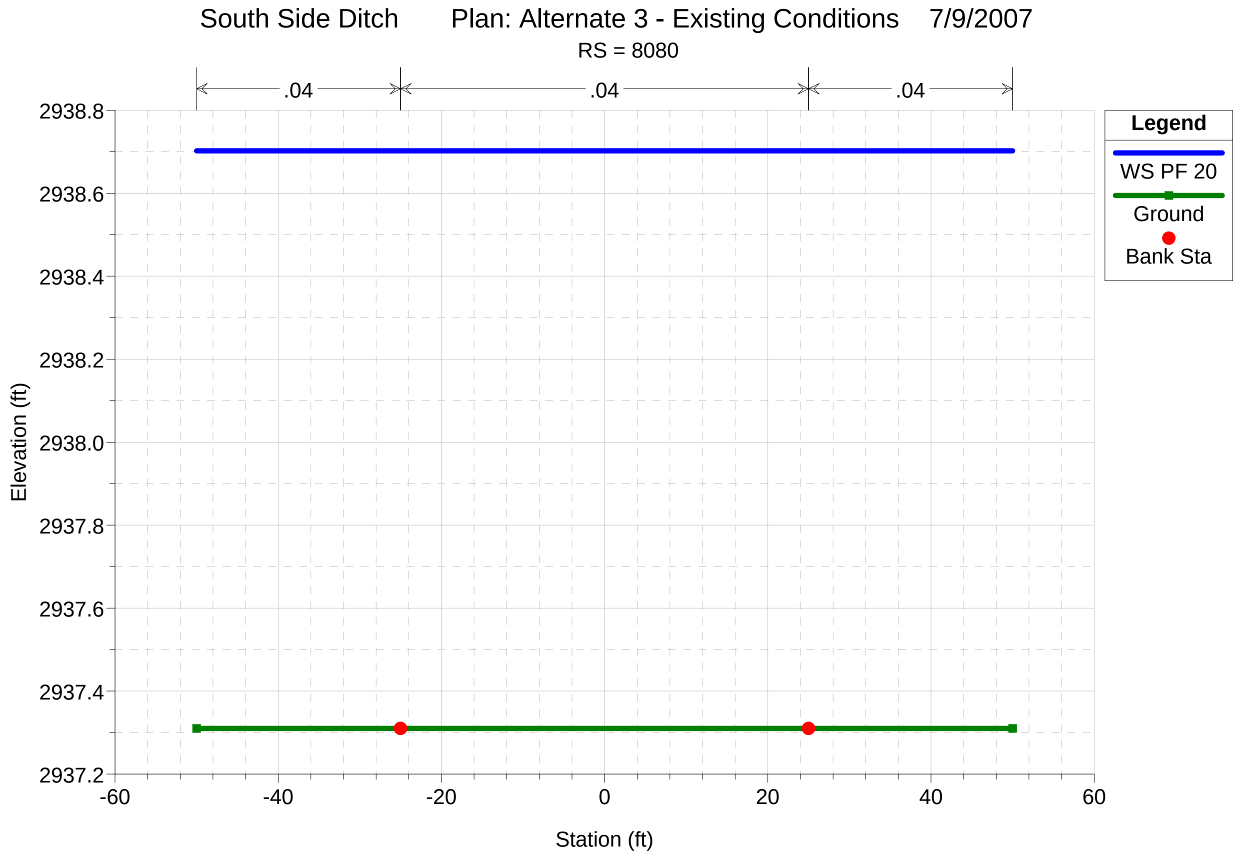

South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 102312
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3058
3057
3056
3055
3054
3053
-40
-20
0
20
40
Station (ft)

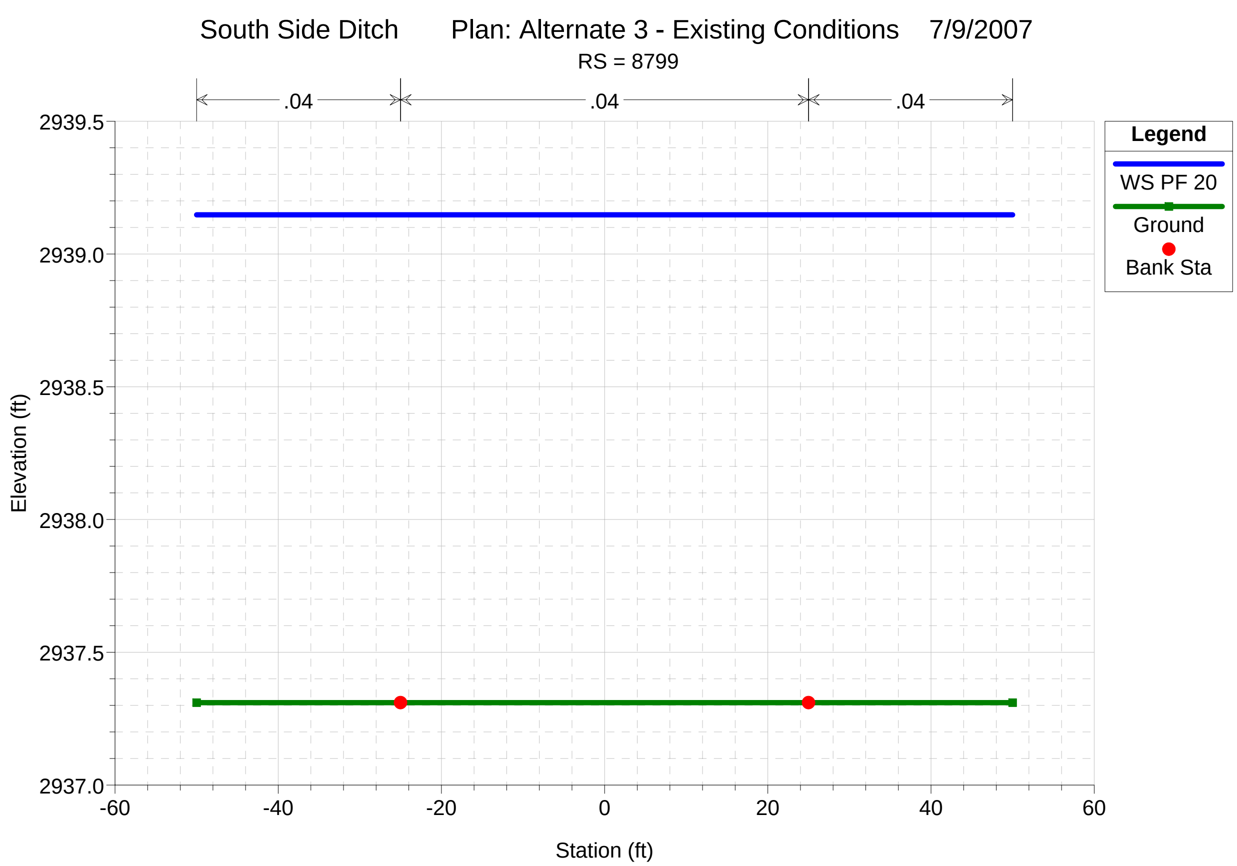


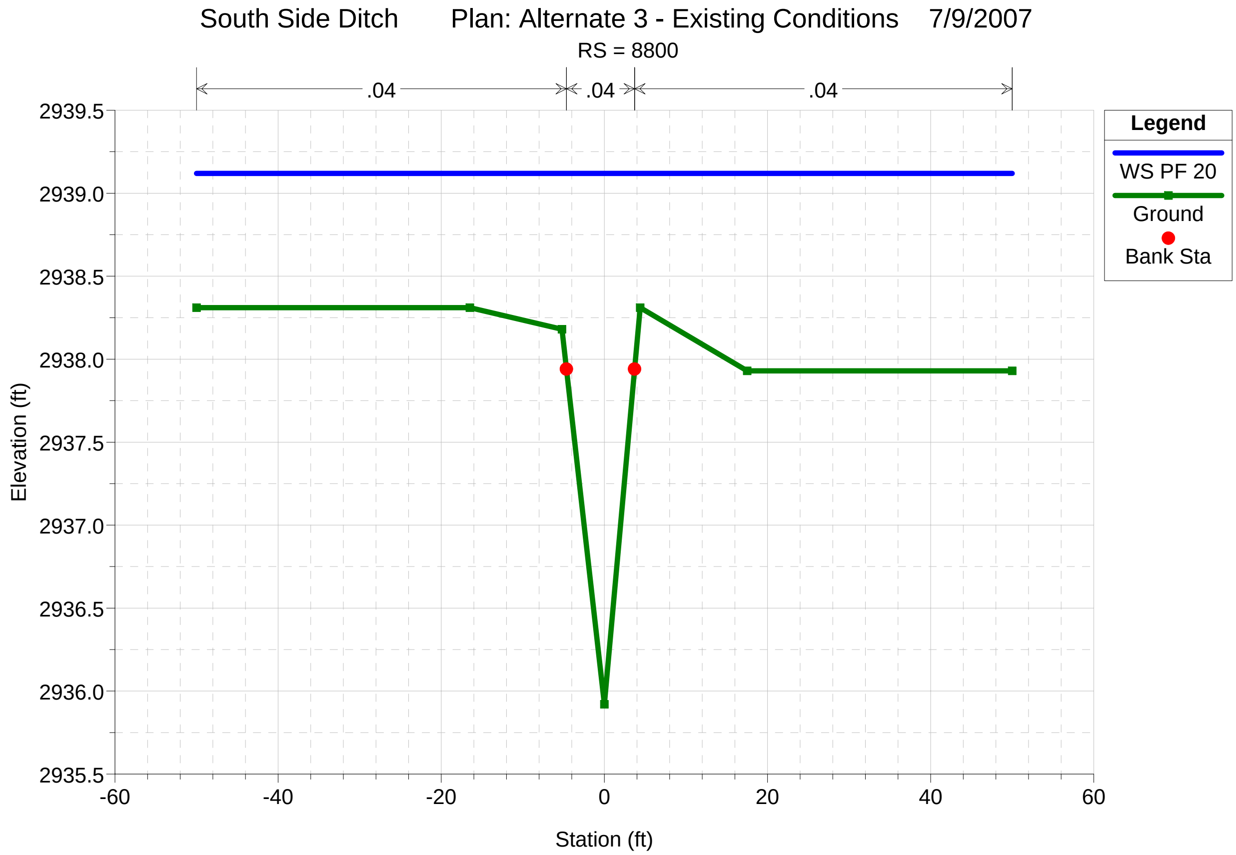
South Side Ditch Plan: Alternate 2 - Existing Conditions 7/9/2007
RS = 102597.4
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3056
3055
3054
3053
3052
3051
3050
3049
-30
-20
-10
0
10
20
30
40
50
Station (ft)

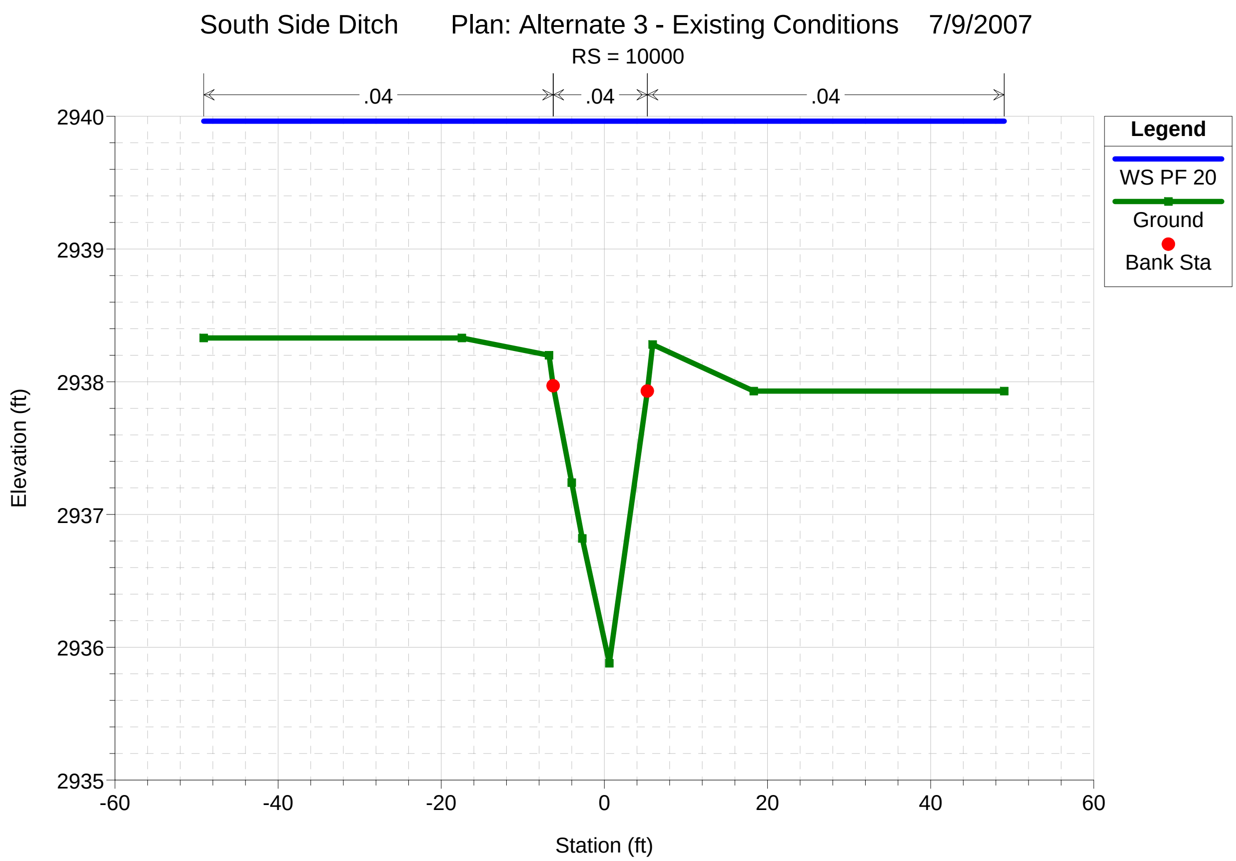

South Side Ditch Plan: Alternate 3 - Existing Conditions 7/9/2007
RS = 2833
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2919.9
2919.8
2919.7
2919.6
2919.5
2919.4
2919.3
-60
-40
-20
0
20
40
60
Station (ft)

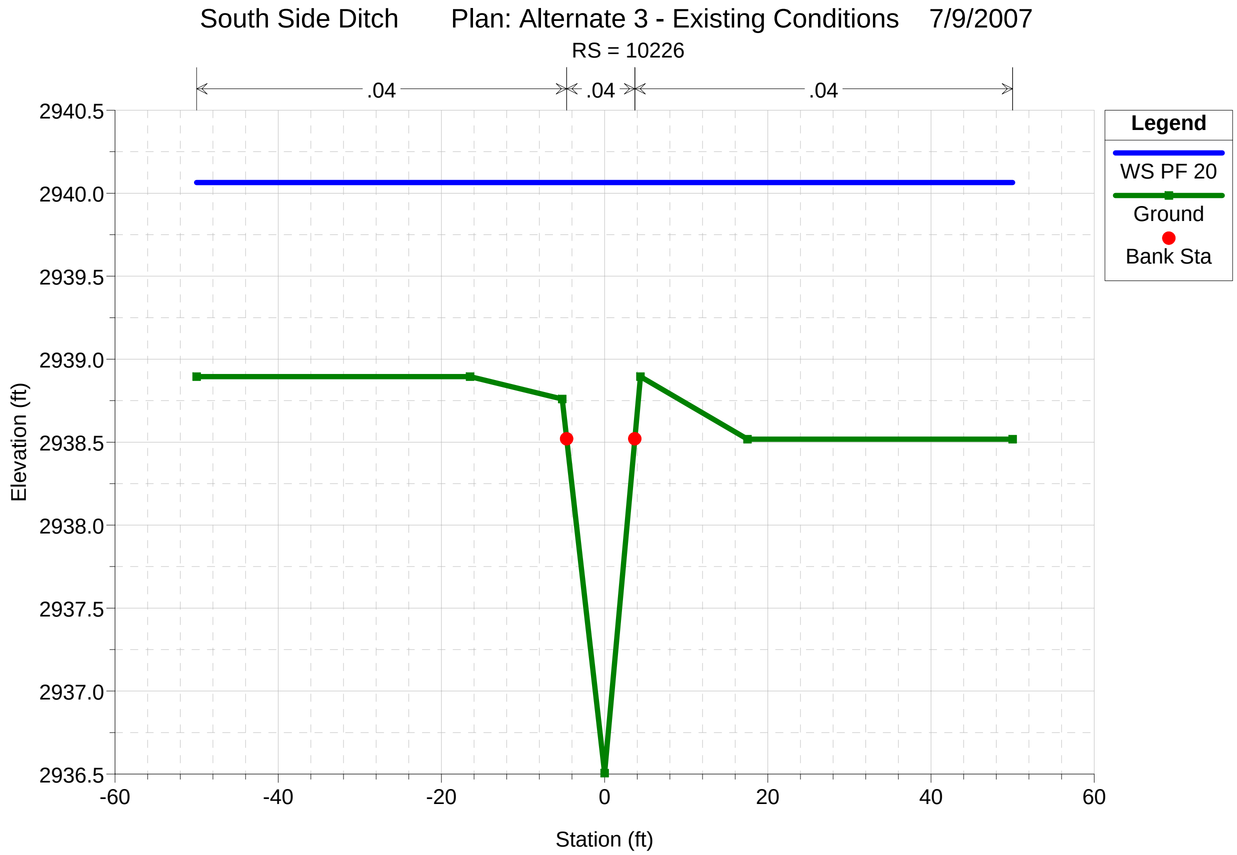

South Side Ditch Plan: Alternate 3 - Existing Conditions 7/9/2007
RS = 7990
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2938.6
2938.4
2938.2
2938.0
2937.8
2937.6
2937.4
2937.2
-60
-40
-20
0
20
40
60
Station (ft)

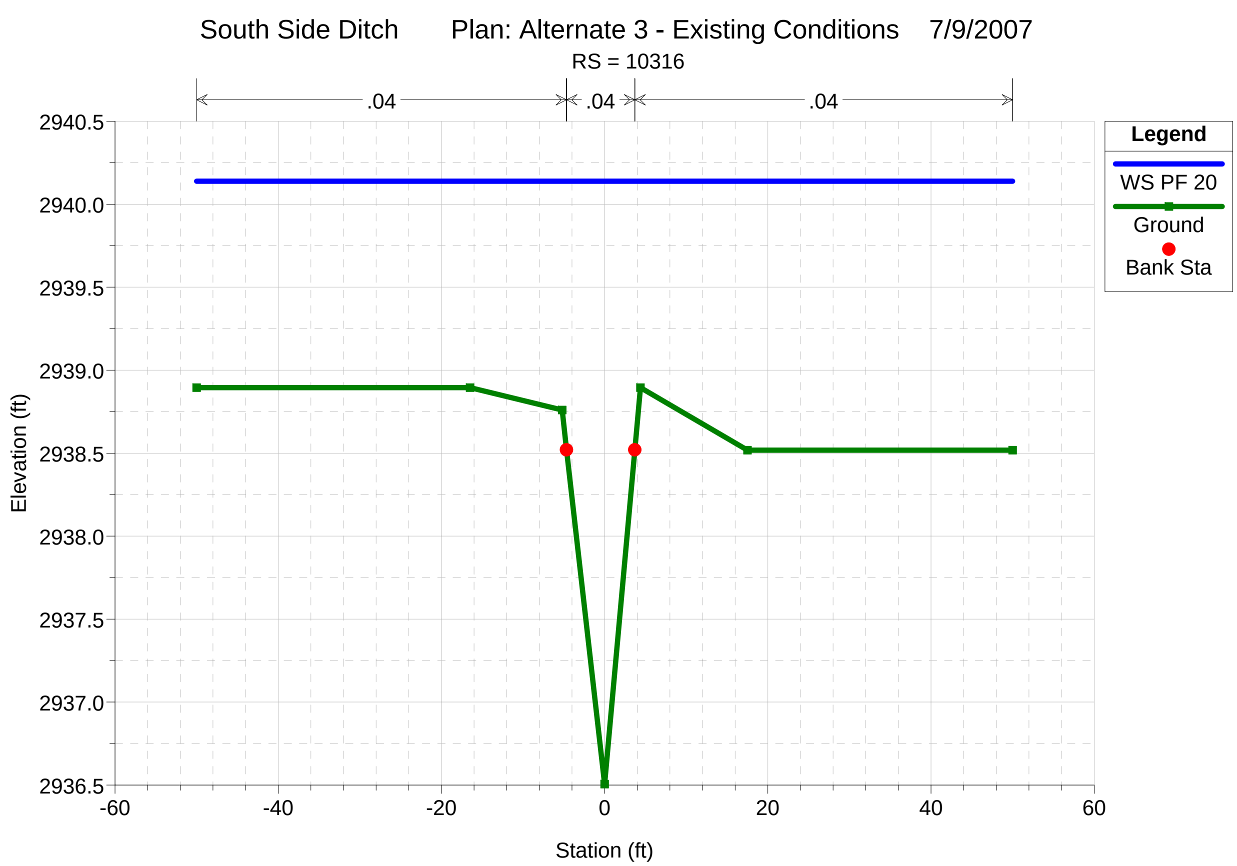

South Side Ditch
Plan: Alternate 3 - Existing Conditions
7/9/2007
RS = 8080
.04
.04
.04
2938.8
2938.6
2938.4
2938.2
2938.0
2937.8
2937.6
2937.4
2937.2
Elevation (ft)
-60
-40
-20
0
20
40
60
Station (ft)
Legend
WS PF 20
Ground
Bank Sta

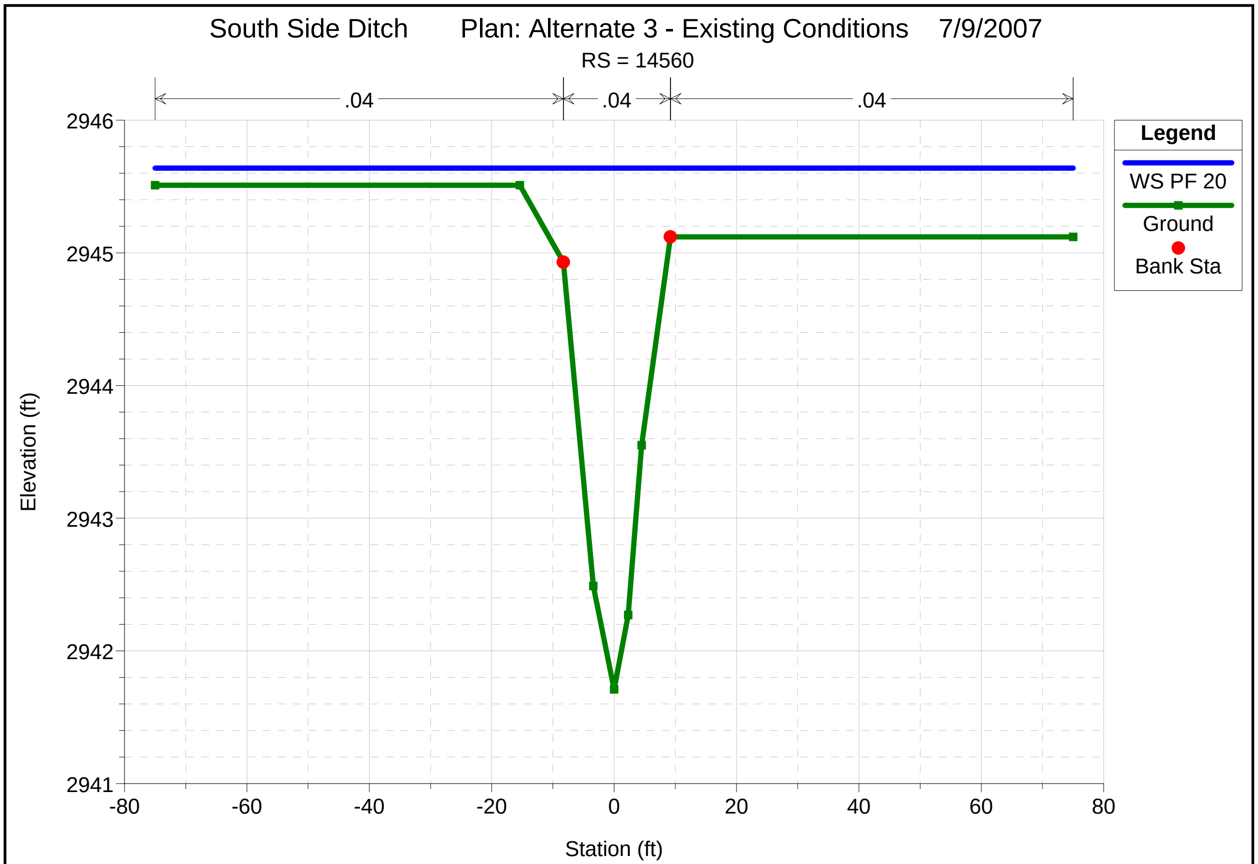

South Side Ditch
Plan: Alternate 3 - Existing Conditions
7/9/2007
RS = 8799
.04
.04
.04
2939.5
2939.0
2938.5
2938.0
2937.5
2937.0
Elevation (ft)
-60
-40
-20
0
20
40
60
Station (ft)
Legend
WS PF 20
Ground
Bank Sta

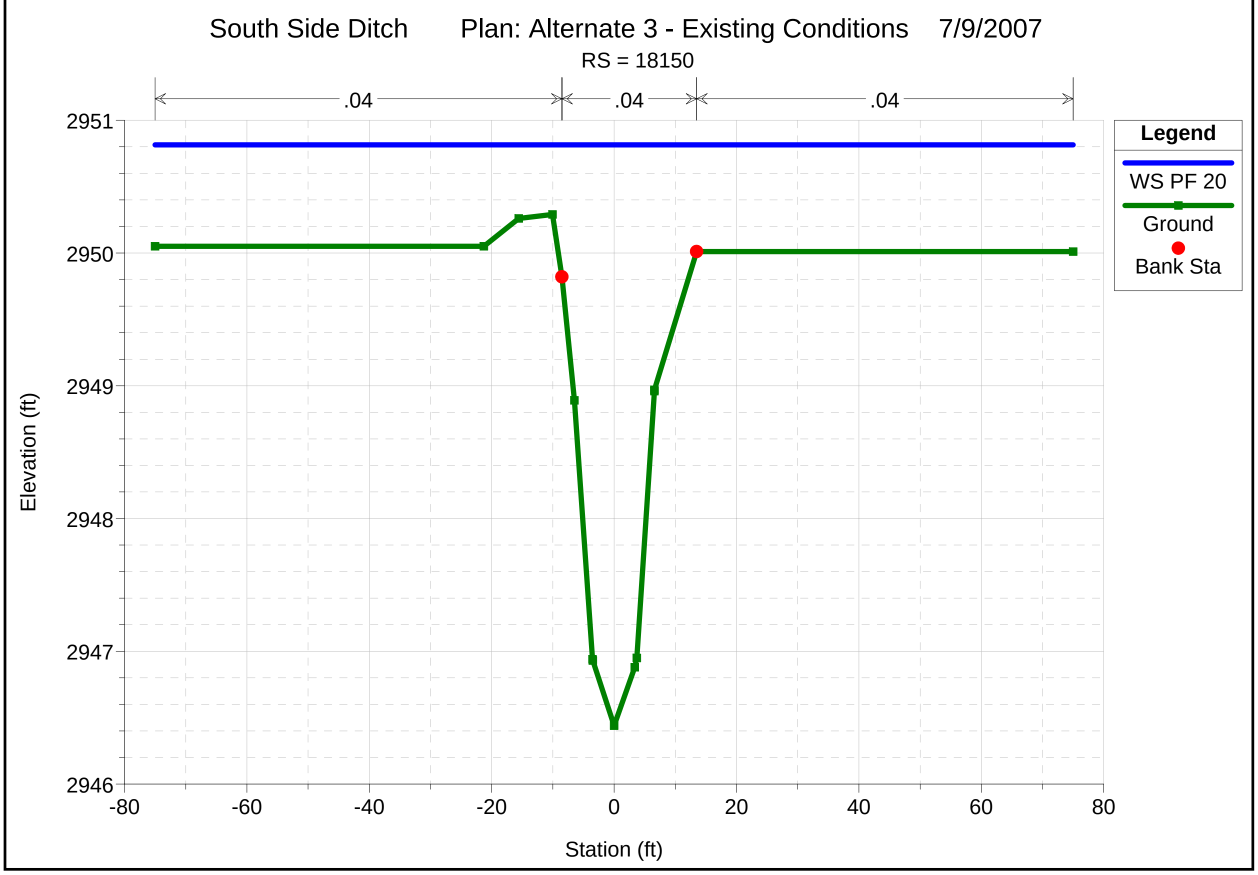

South Side Ditch Plan: Alternate 3 - Existing Conditions 7/9/2007
RS = 8800
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2939.5
2939.0
2938.5
2938.0
2937.5
2937.0
2936.5
2936.0
2935.5
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 3 - Existing Conditions 7/9/2007
RS = 10000
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2940
2939
2938
2937
2936
2935
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 3 - Existing Conditions 7/9/2007
RS = 10226
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2940.5
2940.0
2939.5
2939.0
2938.5
2938.0
2937.5
2937.0
2936.5
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 3 - Existing Conditions 7/9/2007
RS = 10316
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2940.5
2940.0
2939.5
2939.0
2938.5
2938.0
2937.5
2937.0
2936.5
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch
Plan: Alternate 3 - Existing Conditions
7/9/2007
RS = 14560
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2946
2945
2944
2943
2942
2941
-80
-60
-40
-20
0
20
40
60
80
Station (ft)


South Side Ditch
Plan: Alternate 3 - Existing Conditions
7/9/2007
RS = 18150
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2951
2950
2949
2948
2947
2946
-80
-60
-40
-20
0
20
40
60
80
Station (ft)

HEC-RAS Plan: Alt 1 Ex Cond River: South Side Ditch Reach: 1 Profile: PF 20

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	18150	PF 20	200.00	2946.44	2949.27	2949.27	2950.13	0.022107	7.42	26.94	15.89	1.00
1	16194	PF 20	200.00	2937.11	2940.94		2941.08	0.001611	2.98	72.00	34.12	0.30
1	15732	PF 20	200.00	2936.29	2940.68		2940.71	0.000410	1.45	138.05	50.32	0.15
1	15178	PF 20	200.00	2935.49	2940.26	2937.74	2940.37	0.001002	2.63	81.25	31.06	0.24

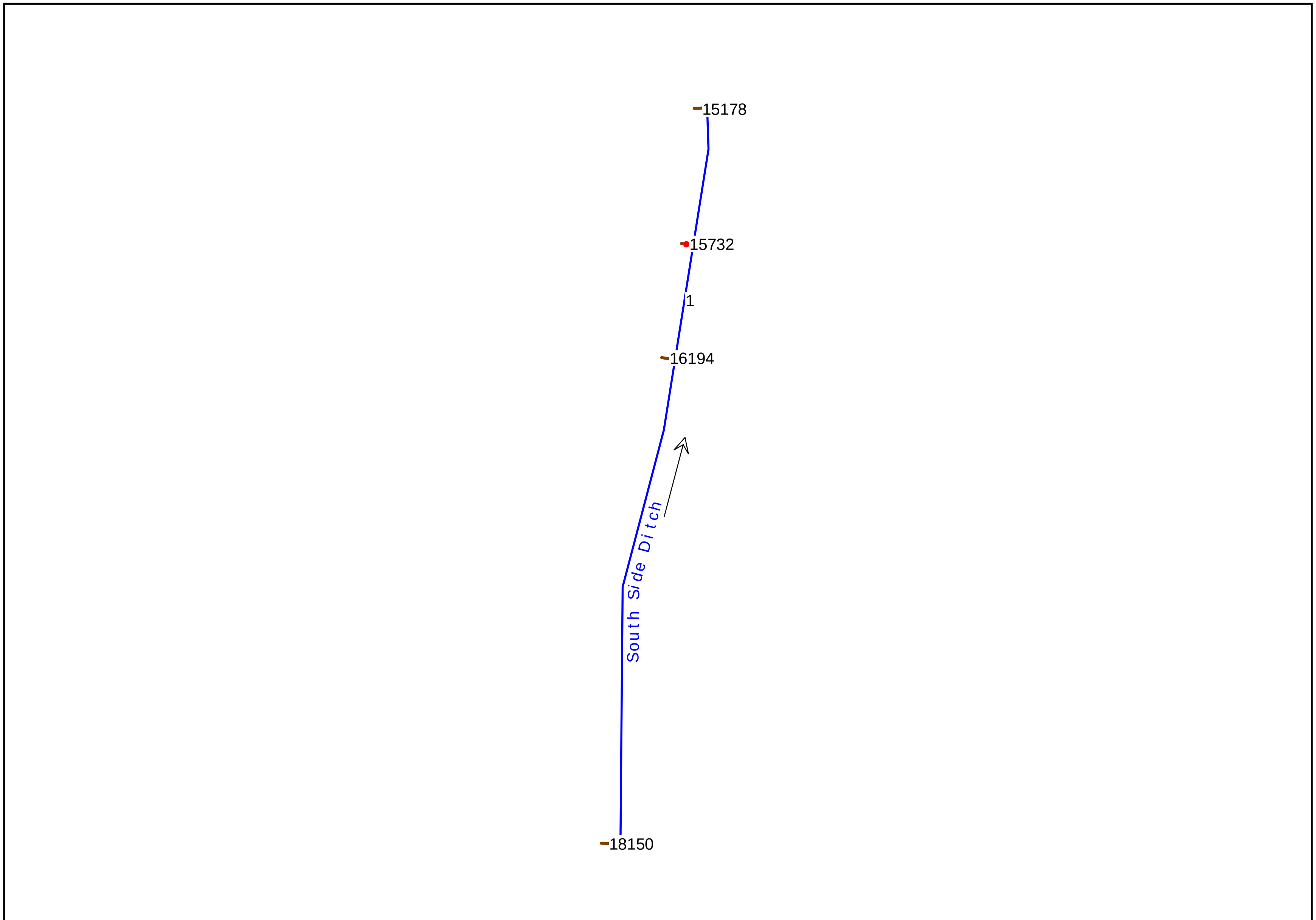
HEC-RAS Plan: Alt 2 Ex Cond River: South Side Ditch Reach: 2 Profile: PF 20

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
2	102597.4	PF 20	200.00	3049.50	3055.19		3055.20	0.000090	0.96	240.53	71.21	0.08
2	102312	PF 20	200.00	3053.09	3055.07		3055.13	0.001677	1.97	101.53	68.23	0.28
2	101827	PF 20	200.00	3051.94	3054.02		3054.13	0.002622	2.63	76.19	46.43	0.36
2	93965	PF 20	200.00	3042.78	3046.81	3044.68	3046.84	0.000467	1.41	142.29	59.35	0.16
2	93940		Bridge									
2	93915	PF 20	200.00	3042.48	3046.77		3046.80	0.000385	1.47	138.13	54.22	0.15
2	90396	PF 20	200.00	3041.01	3045.03	3042.85	3045.08	0.000646	1.79	113.29	46.53	0.19
2	90351		Bridge									
2	90306	PF 20	200.00	3040.87	3044.94		3044.98	0.000594	1.75	114.94	45.04	0.19
2	87017	PF 20	200.00	3038.92	3042.69		3042.75	0.000782	1.96	111.02	58.18	0.21
2	85436	PF 20	200.00	3037.44	3039.11		3039.53	0.013072	5.20	38.50	27.80	0.78
2	82559	PF 20	200.00	3031.44	3035.88		3035.92	0.000423	1.58	126.94	43.11	0.16
2	81515	PF 20	200.00	3030.12	3035.23		3035.30	0.000874	2.14	93.51	31.78	0.22
2	79455	PF 20	200.00	3028.70	3033.86		3033.90	0.000532	1.77	123.97	57.53	0.18
2	75902	PF 20	200.00	3027.21	3032.10	3029.23	3032.14	0.000465	1.83	131.25	64.92	0.17
2	75849		Bridge									
2	75795	PF 20	200.00	3027.21	3032.02		3032.07	0.000510	1.90	126.27	63.52	0.17
2	73597	PF 20	200.00	3025.19	3027.75	3027.75	3028.61	0.021687	7.46	26.82	15.72	1.01
2	71984	PF 20	200.00	3018.29	3023.93	3020.79	3023.99	0.000645	1.99	100.54	30.47	0.19
2	71969		Bridge									
2	71954	PF 20	200.00	3018.29	3023.83		3023.90	0.000700	2.05	97.48	30.00	0.20
2	70070	PF 20	200.00	3017.01	3022.05		3022.16	0.001258	2.87	90.43	68.99	0.26
2	67470	PF 20	200.00	3014.73	3018.97		3019.06	0.001123	2.51	90.73	43.19	0.25
2	65977	PF 20	200.00	3012.18	3015.69	3014.67	3015.97	0.004943	4.26	46.97	21.12	0.50
2	65950		Bridge									
2	65922	PF 20	200.00	3012.18	3014.67	3014.67	3015.49	0.021764	7.28	27.48	17.01	1.01
2	62510	PF 20	200.00	3004.47	3008.71	3006.17	3008.76	0.000528	1.70	117.53	40.37	0.18
2	62471		Bridge									
2	62432	PF 20	200.00	3004.47	3008.66		3008.70	0.000558	1.74	115.21	40.07	0.18
2	60260	PF 20	200.00	3002.47	3005.84	3004.71	3006.10	0.004112	4.04	49.45	20.64	0.46
2	60237		Bridge									
2	60215	PF 20	200.00	3002.57	3004.78	3004.78	3005.60	0.021878	7.23	27.68	17.37	1.01
2	59703	PF 20	200.00	2998.67	3003.81		3003.88	0.000777	2.13	93.98	29.15	0.21
2	58670	PF 20	200.00	2997.50	3002.81		3002.91	0.001182	2.46	81.19	28.59	0.25
2	57559	PF 20	200.00	2996.82	3001.77		3001.84	0.000788	2.12	94.17	31.64	0.21
2	56894	PF 20	200.00	2995.90	3001.04		3001.15	0.001375	2.70	74.09	24.14	0.27
2	56411	PF 20	200.00	2996.00	3000.65		3000.71	0.000623	2.07	112.56	79.37	0.19
2	56080	PF 20	200.00	2995.15	3000.19	2998.21	3000.35	0.002114	3.20	62.93	24.28	0.33
2	56057		Bridge									
2	56034	PF 20	200.00	2995.39	3000.20		3000.27	0.000691	2.17	96.35	32.19	0.20
2	55602	PF 20	200.00	2994.90	2999.80		2999.88	0.001183	2.36	84.80	34.35	0.25
2	54573	PF 20	200.00	2993.53	2998.86	2995.97	2998.93	0.000737	2.08	96.17	33.53	0.21
2	54523		Bridge									
2	54473	PF 20	200.00	2993.53	2998.68		2998.75	0.000874	2.21	90.42	29.58	0.22
2	49368	PF 20	200.00	2989.28	2993.07		2993.16	0.001415	2.49	80.36	32.55	0.28
2	47818	PF 20	200.00	2986.83	2990.45	2989.14	2990.56	0.002023	2.66	75.31	36.29	0.32
2	47760		Bridge									
2	47703	PF 20	200.00	2986.83	2990.10		2990.26	0.003521	3.18	62.83	35.12	0.42
2	46530	PF 20	200.00	2982.19	2987.62	2984.98	2987.74	0.001438	2.75	72.62	23.48	0.28
2	46483		Culvert									
2	46436	PF 20	200.00	2982.19	2987.57		2987.69	0.001494	2.80	71.51	23.26	0.28
2	41706	PF 20	200.00	2976.73	2981.89		2981.97	0.000996	2.36	104.92	77.24	0.24
2	40381	PF 20	200.00	2976.06	2980.92	2978.51	2980.96	0.000590	1.82	132.33	66.36	0.18
2	40334		Bridge									
2	40287	PF 20	200.00	2976.06	2980.74		2980.79	0.000757	2.01	120.71	65.82	0.21
2	37625	PF 20	200.00	2972.72	2977.48	2975.70	2977.64	0.002092	3.38	67.68	34.36	0.34
2	37560		Culvert									
2	37495	PF 20	200.00	2972.72	2977.47		2977.63	0.002122	3.40	67.29	34.24	0.34
2	33933	PF 20	200.00	2968.62	2973.28	2971.08	2973.34	0.000767	2.10	114.60	78.61	0.21
2	33908		Bridge									
2	33883	PF 20	200.00	2968.62	2973.11		2973.19	0.000991	2.30	101.80	74.94	0.24
2	30756	PF 20	200.00	2964.37	2968.91		2969.04	0.001863	2.96	77.40	63.19	0.32
2	25326	PF 20	200.00	2957.56	2962.16	2959.93	2962.23	0.000899	2.33	108.73	76.31	0.23
2	25310		Bridge									
2	25294	PF 20	200.00	2957.56	2961.94		2962.04	0.001285	2.66	92.11	74.99	0.27
2	24773	PF 20	200.00	2956.22	2961.20		2961.32	0.001463	2.97	82.26	80.79	0.28
2	22063	PF 20	200.00	2952.23	2956.87	2955.15	2957.02	0.001730	3.38	79.49	61.13	0.31
2	21998		Culvert									
2	21933	PF 20	200.00	2952.23	2956.89		2956.99	0.001772	2.67	91.42	86.41	0.31
2	20590	PF 20	200.00	2949.66	2953.49	2952.21	2953.65	0.003706	3.42	79.76	143.68	0.43
2	18150.*	PF 20	200.00	2946.44	2951.02		2951.04	0.000490	1.59	187.76	150.00	0.17
2	14560	PF 20	200.00	2941.71	2944.76	2944.76	2945.62	0.022274	7.43	26.91	16.10	1.01
2	10316	PF 20	200.00	2936.51	2941.66	2939.23	2941.67	0.000077	0.78	303.88	100.00	0.07
2	10271		Culvert									
2	10226	PF 20	200.00	2936.51	2939.63		2939.70	0.002624	2.92	100.83	100.00	0.35
2	10000.*	PF 20	200.00	2935.88	2938.87	2938.62	2938.98	0.003971	3.53	85.33	98.14	0.44
2	6132	PF 20	200.00	2925.17	2927.63	2926.59	2927.71	0.002224	2.32	86.39	56.59	0.33
2	4513	PF 20	200.00	2918.00	2918.63	2918.63	2918.95	0.027663	4.56	44.38	70.00	1.01

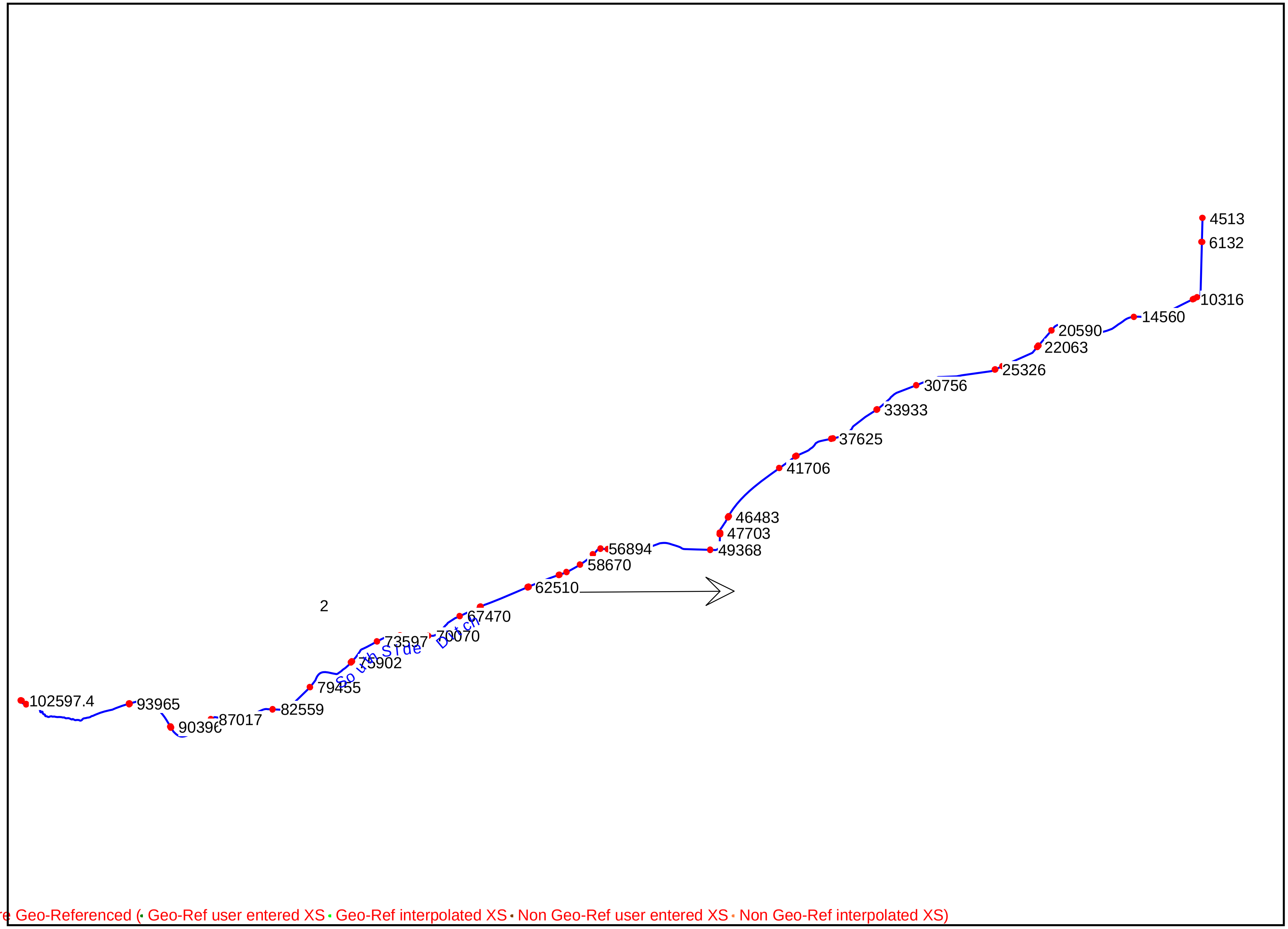
HEC-RAS Plan: Alt 3 Ex Cond River: South Side Ditch Reach: 3 Profile: PF 20

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	18150	PF 20	200.00	2946.44	2950.81		2950.85	0.000802	1.93	157.25	150.00	0.21
3	14560	PF 20	200.00	2941.71	2945.64		2945.79	0.003095	3.53	86.80	150.00	0.40
3	10316	PF 20	200.00	2936.51	2940.14		2940.17	0.000725	1.77	151.68	100.00	0.19
3	10226	PF 20	200.00	2936.51	2940.06		2940.10	0.000852	1.89	144.21	100.00	0.21
3	10000	PF 20	200.00	2935.88	2939.96		2939.98	0.000321	1.35	192.82	98.14	0.14
3	8800	PF 20	200.00	2935.92	2939.12		2939.18	0.002103	2.68	108.30	100.00	0.32
3	8799	PF 20	200.00	2937.31	2939.15		2939.17	0.000400	1.11	183.76	100.00	0.14
3	8080	PF 20	200.00	2937.31	2938.70		2938.73	0.000997	1.46	139.21	100.00	0.22
3	7990	PF 20	200.00	2937.31	2938.59	2937.81	2938.63	0.001303	1.58	128.37	100.00	0.25
3	2833	PF 20	200.00	2919.40	2919.90	2919.90	2920.15	0.030041	4.04	49.78	100.00	1.01

Proposed Conditions



None of the XS's are Geo-Referenced (Geo-Ref user entered XS · Geo-Ref interpolated XS · Non Geo-Ref user entered XS · Non Geo-Ref interpolated XS)



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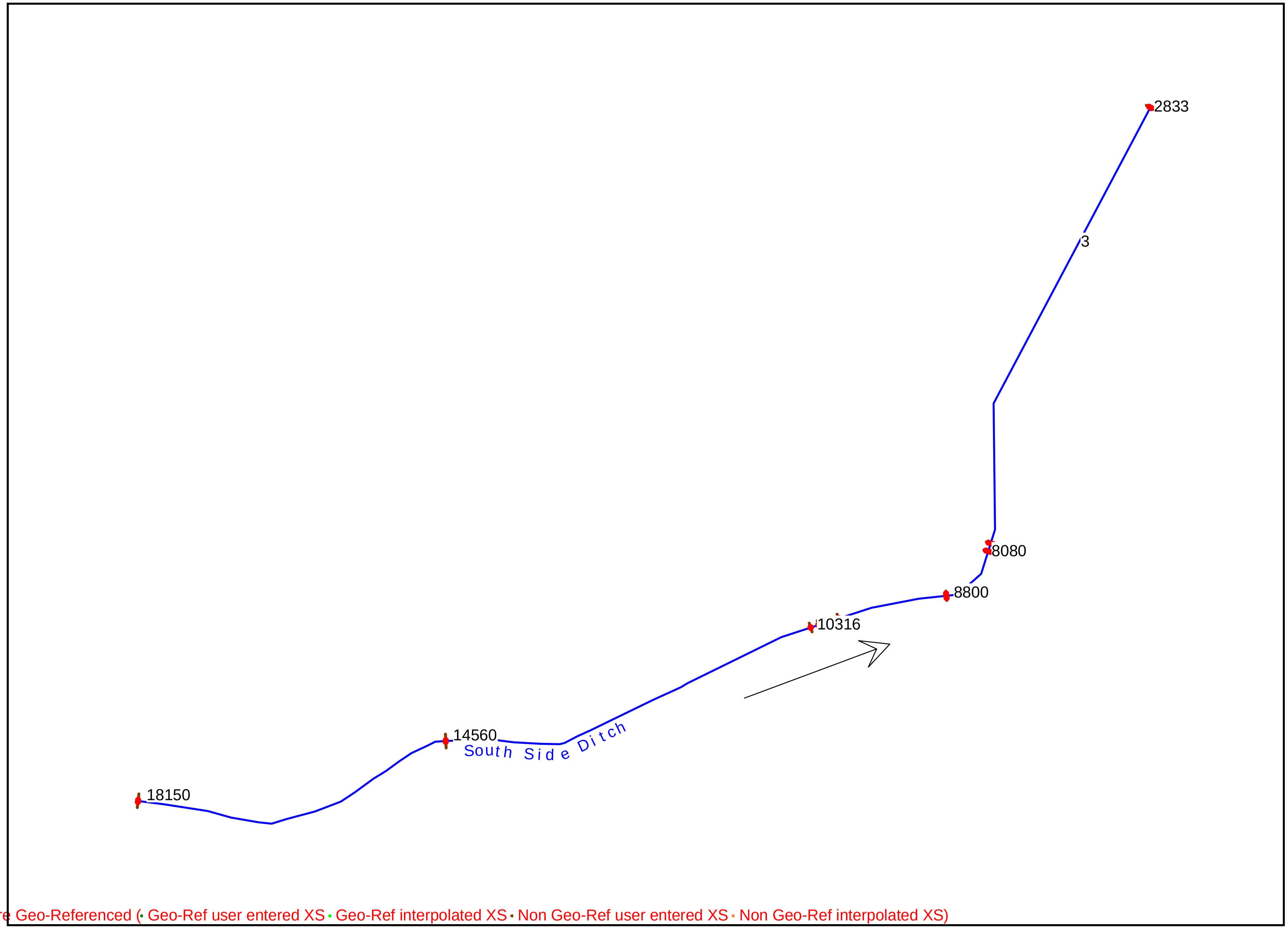

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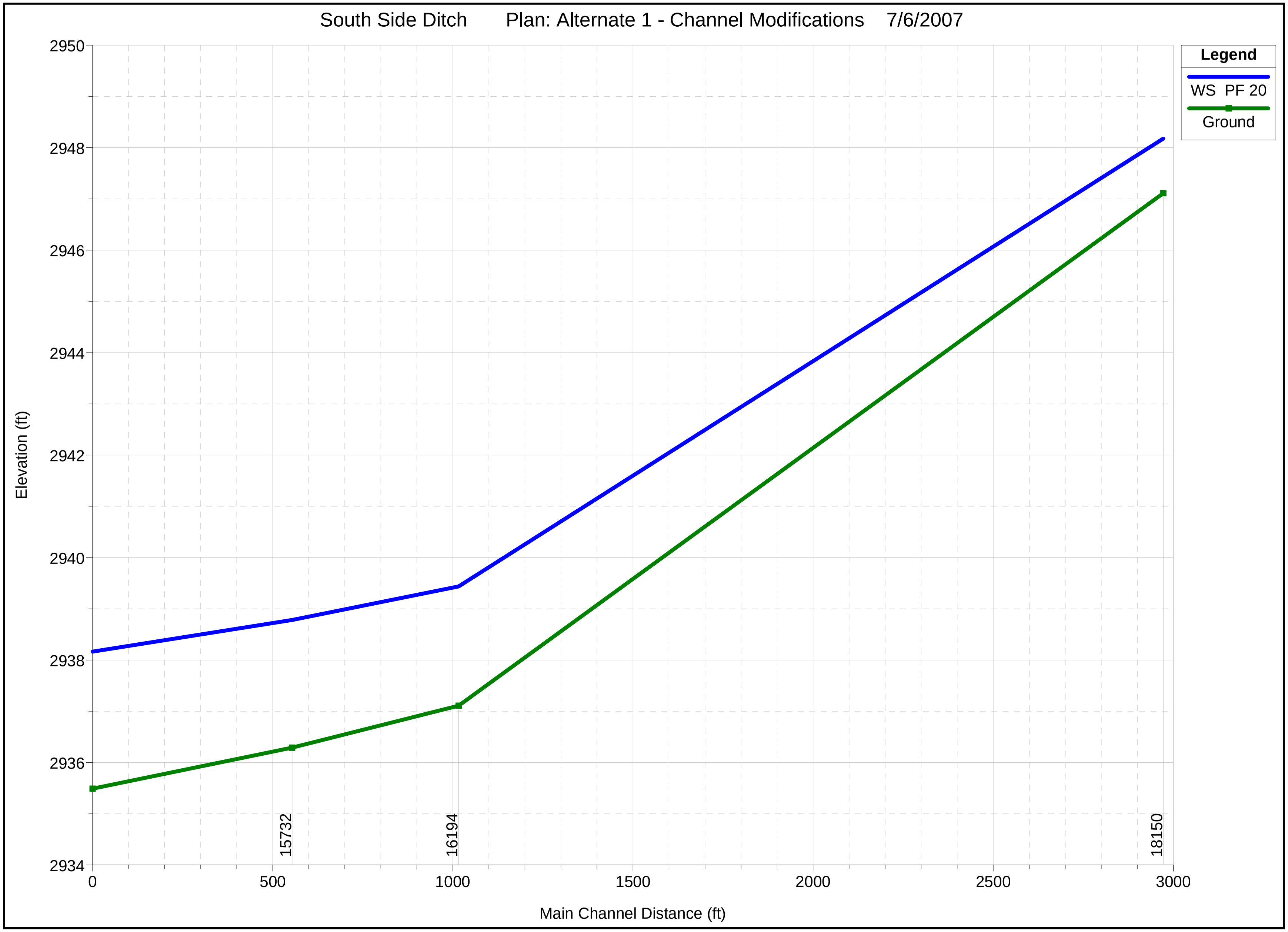
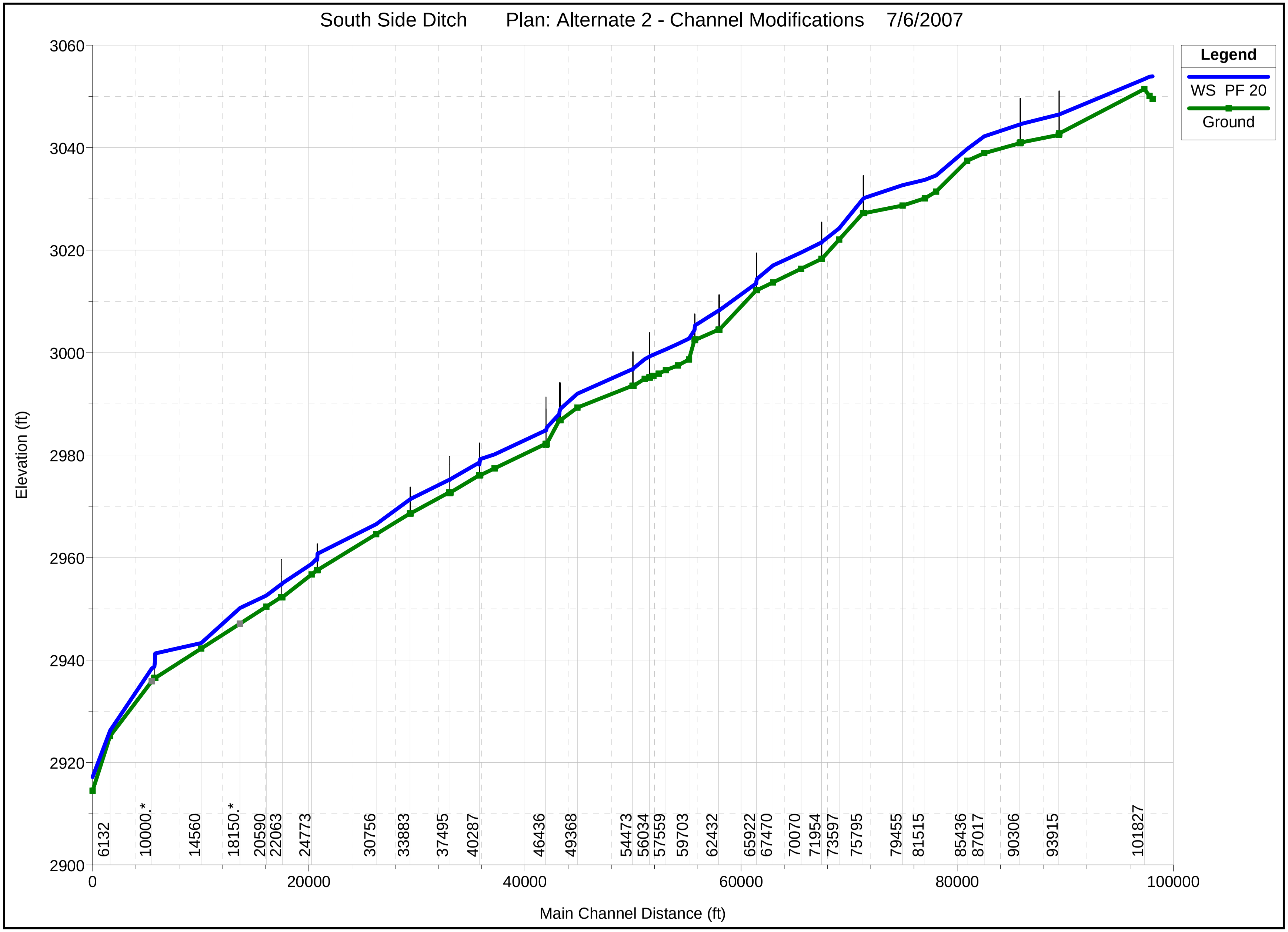
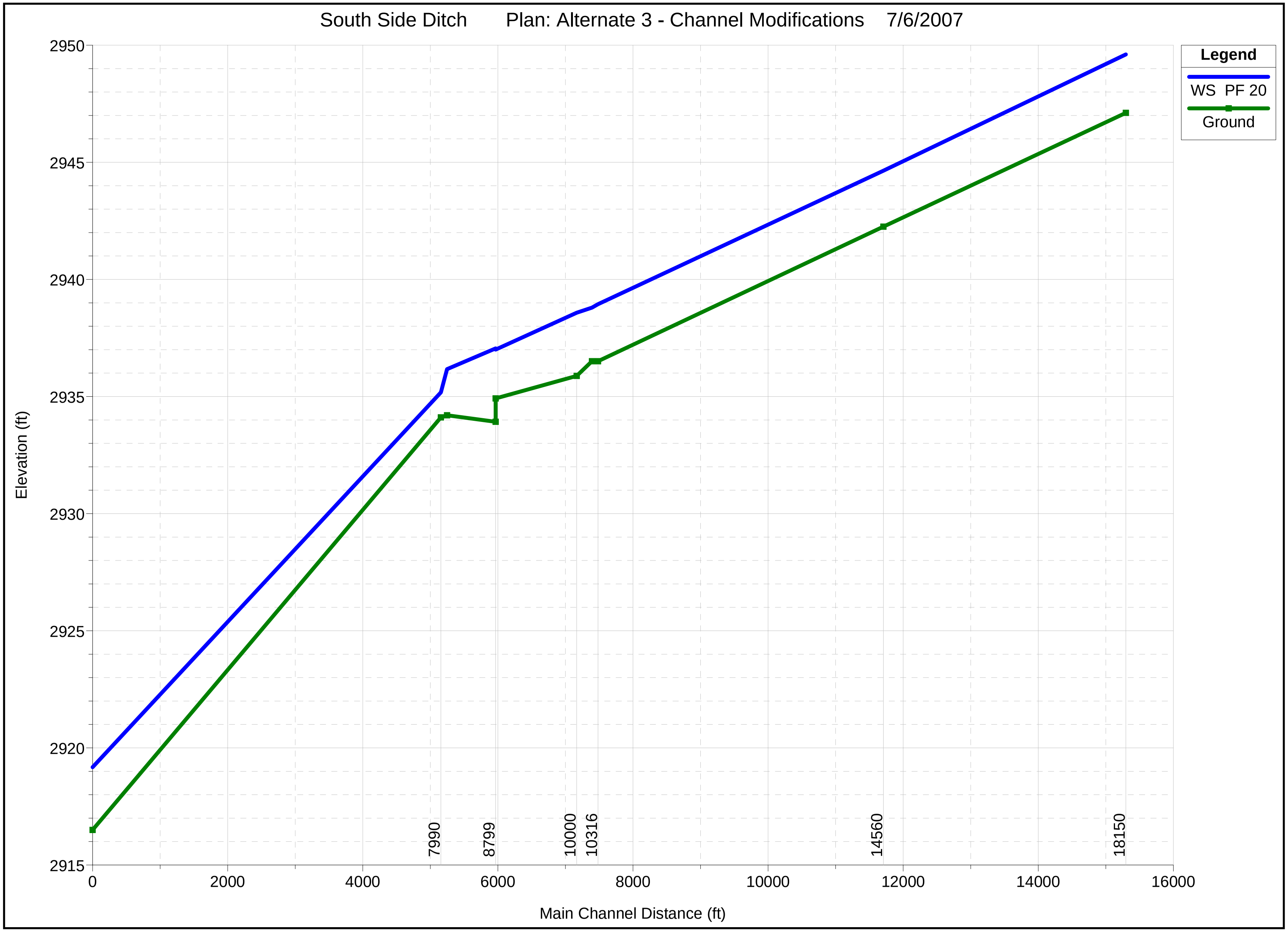
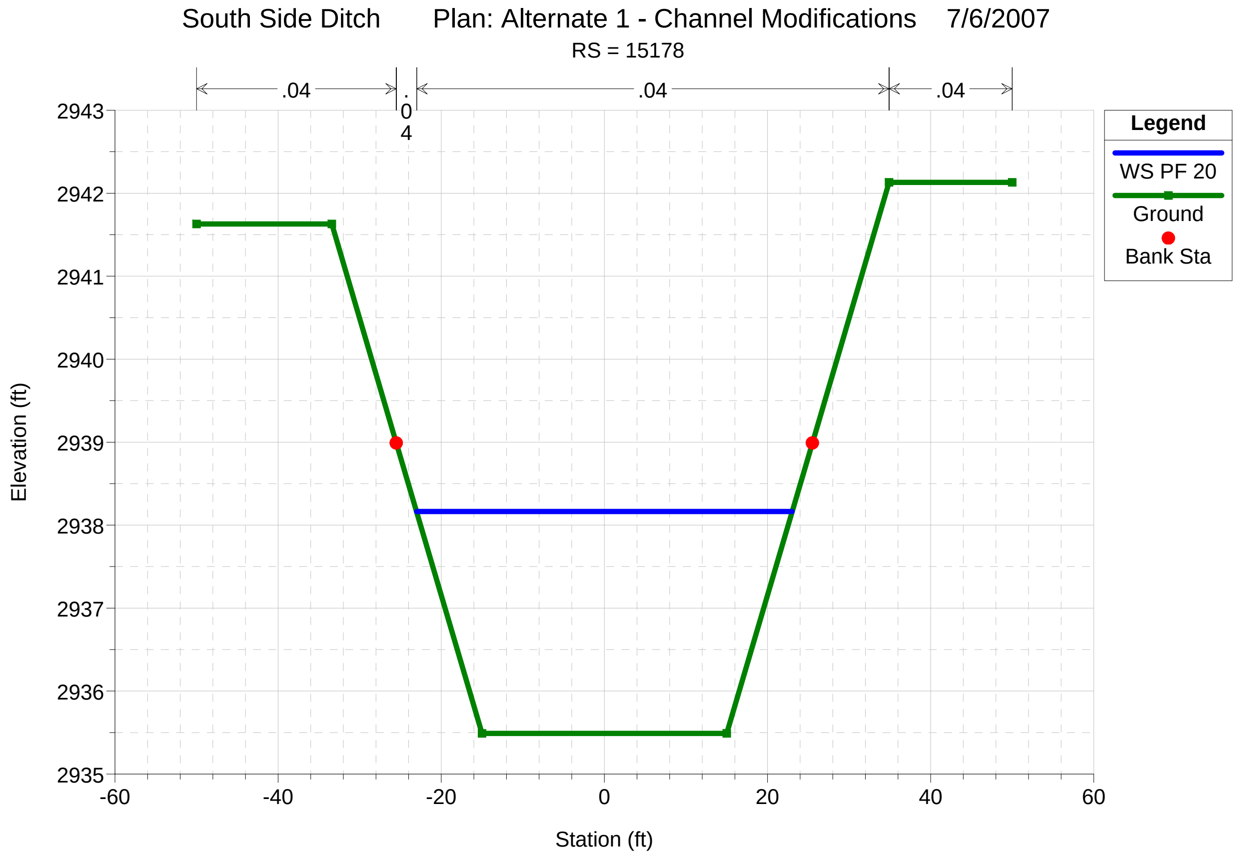

South Side Ditch Plan: Alternate 1 - Channel Modifications 7/6/2007
Legend
WS PF 20
Ground
Elevation (ft)
2950
2948
2946
2944
2942
2940
2938
2936
2934
Main Channel Distance (ft)
0
500
1000
1500
2000
2500
3000
15732
16194
18150

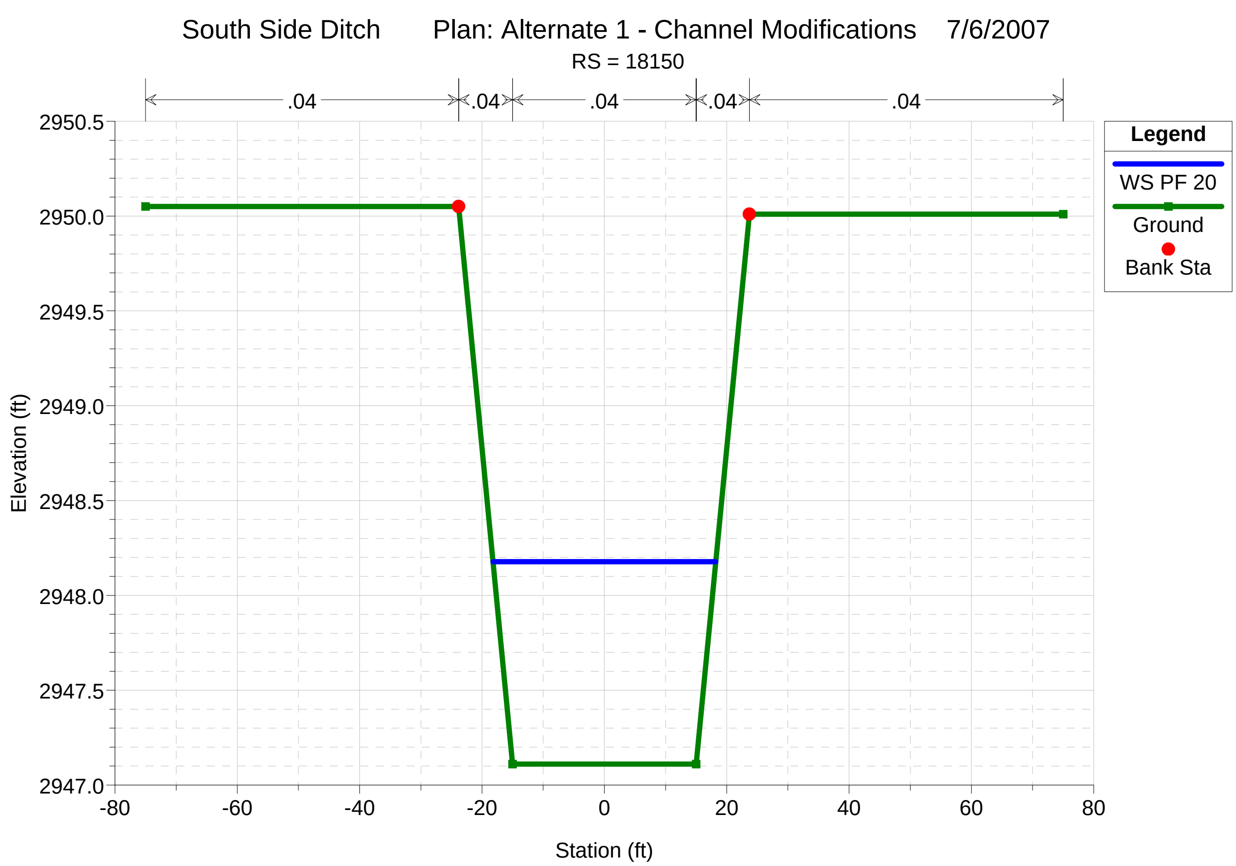


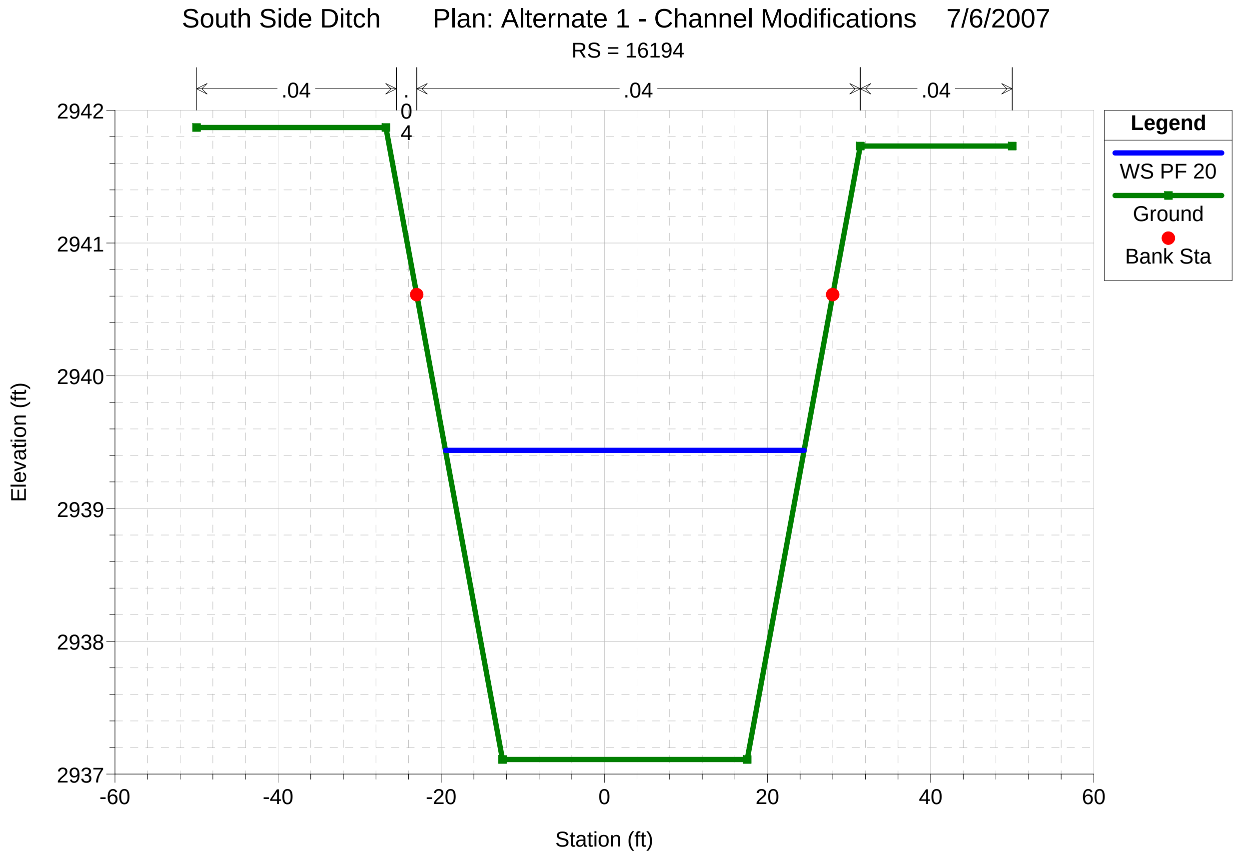
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
Legend
WS PF 20
Ground
Elevation (ft)
Main Channel Distance (ft)
3060
3040
3020
3000
2980
2960
2940
2920
2900
0
20000
40000
60000
80000
100000
6132
10000.*
14560
18150.*
20590
22063
24773
30756
33883
37495
40287
46436
49368
54473
56034
57559
59703
62432
65922
67470
70070
71954
73597
75795
79455
81515
85436
87017
90306
93915
101827

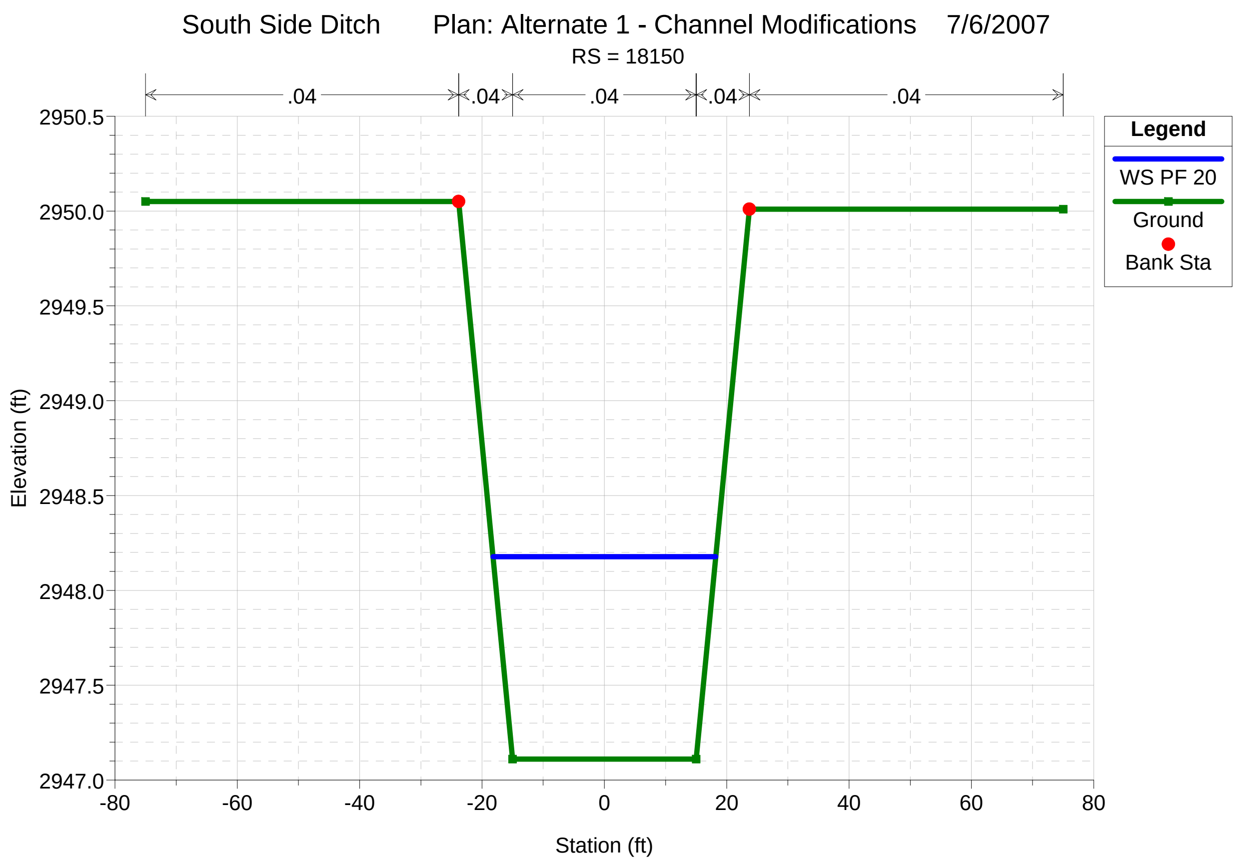


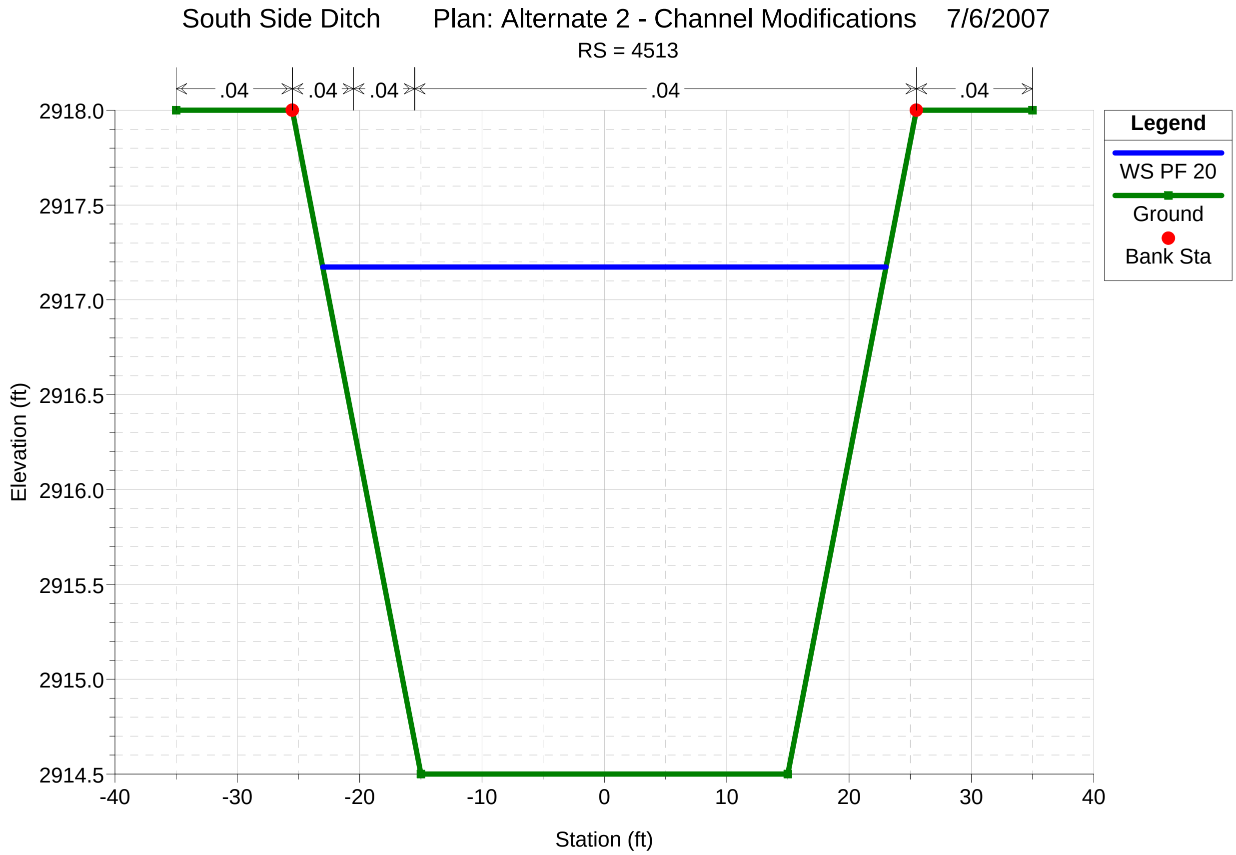
South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
Legend
WS PF 20
Ground
Elevation (ft)
2950
2945
2940
2935
2930
2925
2920
2915
Main Channel Distance (ft)
0
2000
4000
6000
8000
10000
12000
14000
16000
7990
8799
10000
10316
14560
18150

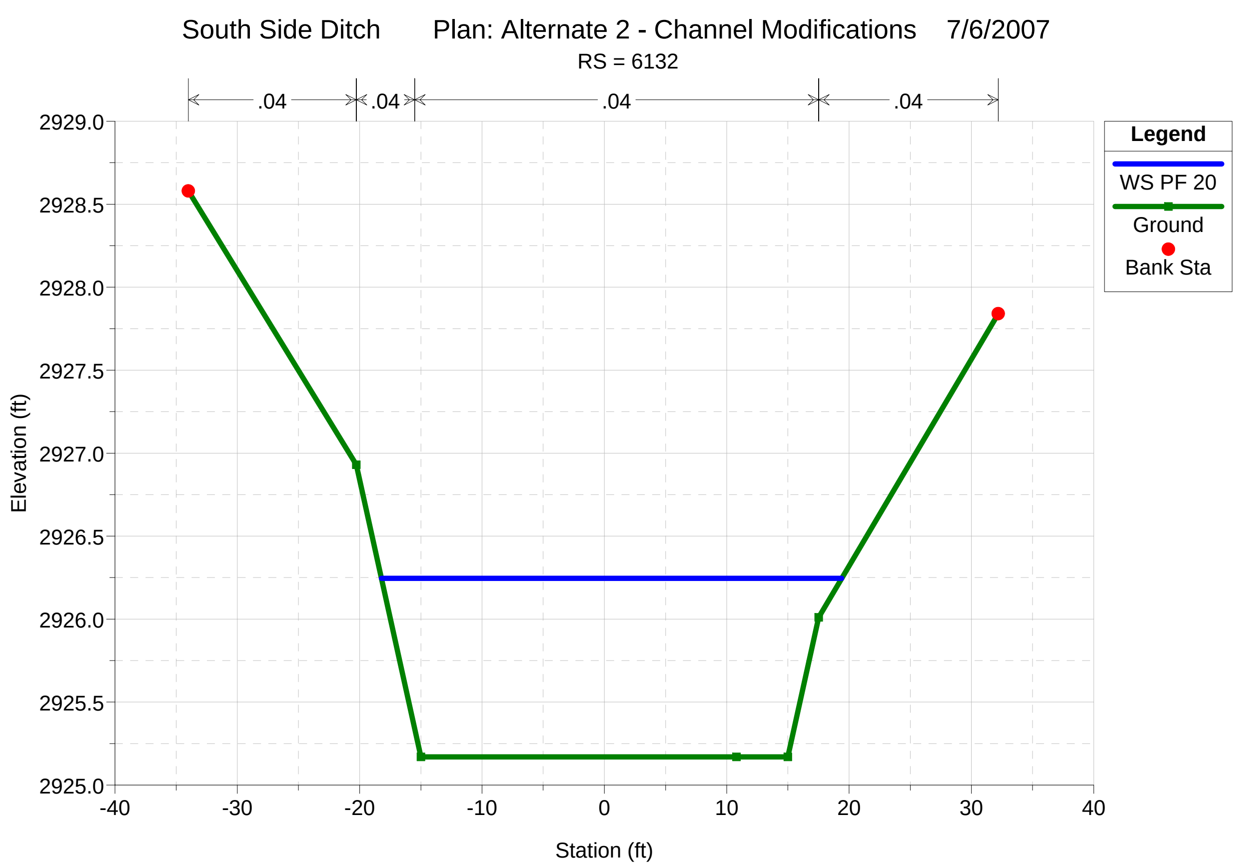

South Side Ditch Plan: Alternate 1 - Channel Modifications 7/6/2007
RS = 15178
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2943
2942
2941
2940
2939
2938
2937
2936
2935
-60
-40
-20
0
20
40
60
Station (ft)

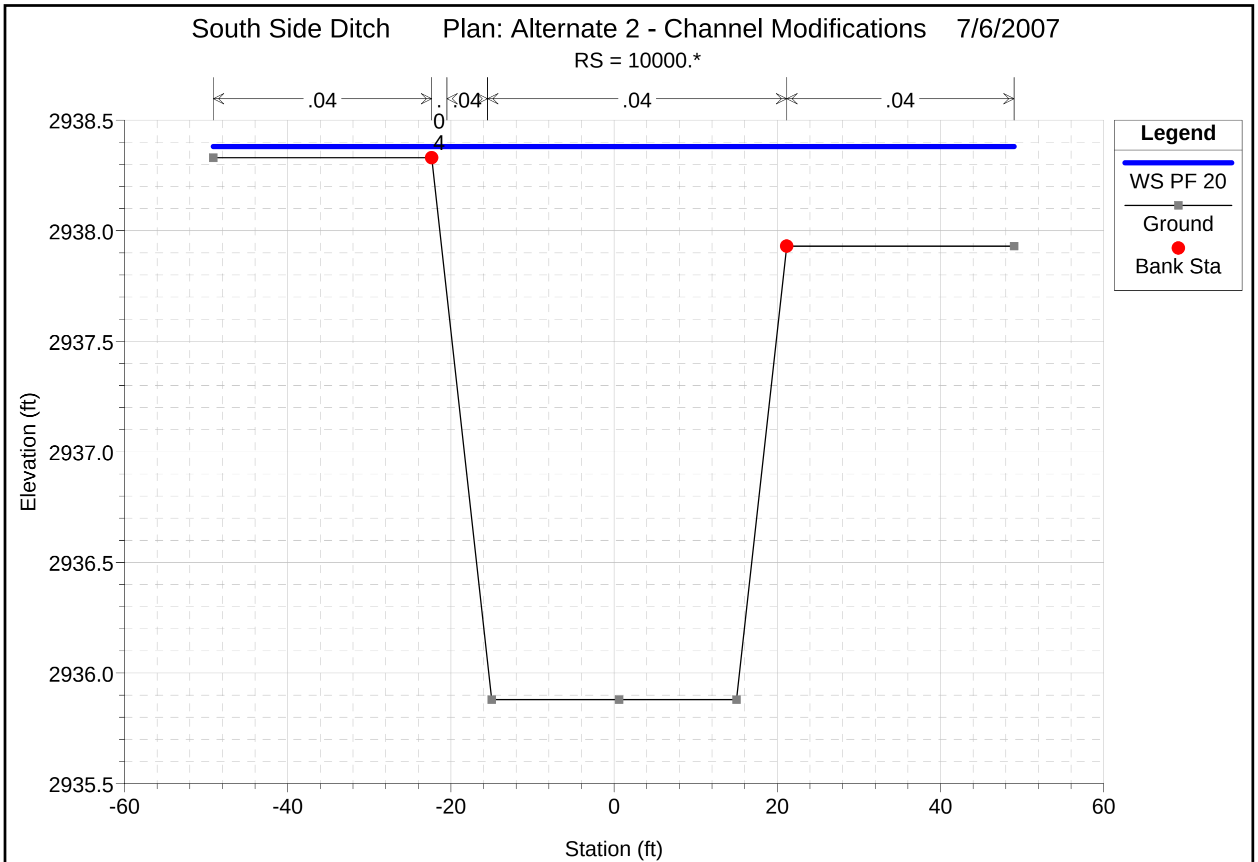

South Side Ditch Plan: Alternate 1 - Channel Modifications 7/6/2007
RS = 18150
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2950.5
2950.0
2949.5
2949.0
2948.5
2948.0
2947.5
2947.0
-80
-60
-40
-20
0
20
40
60
80
Station (ft)

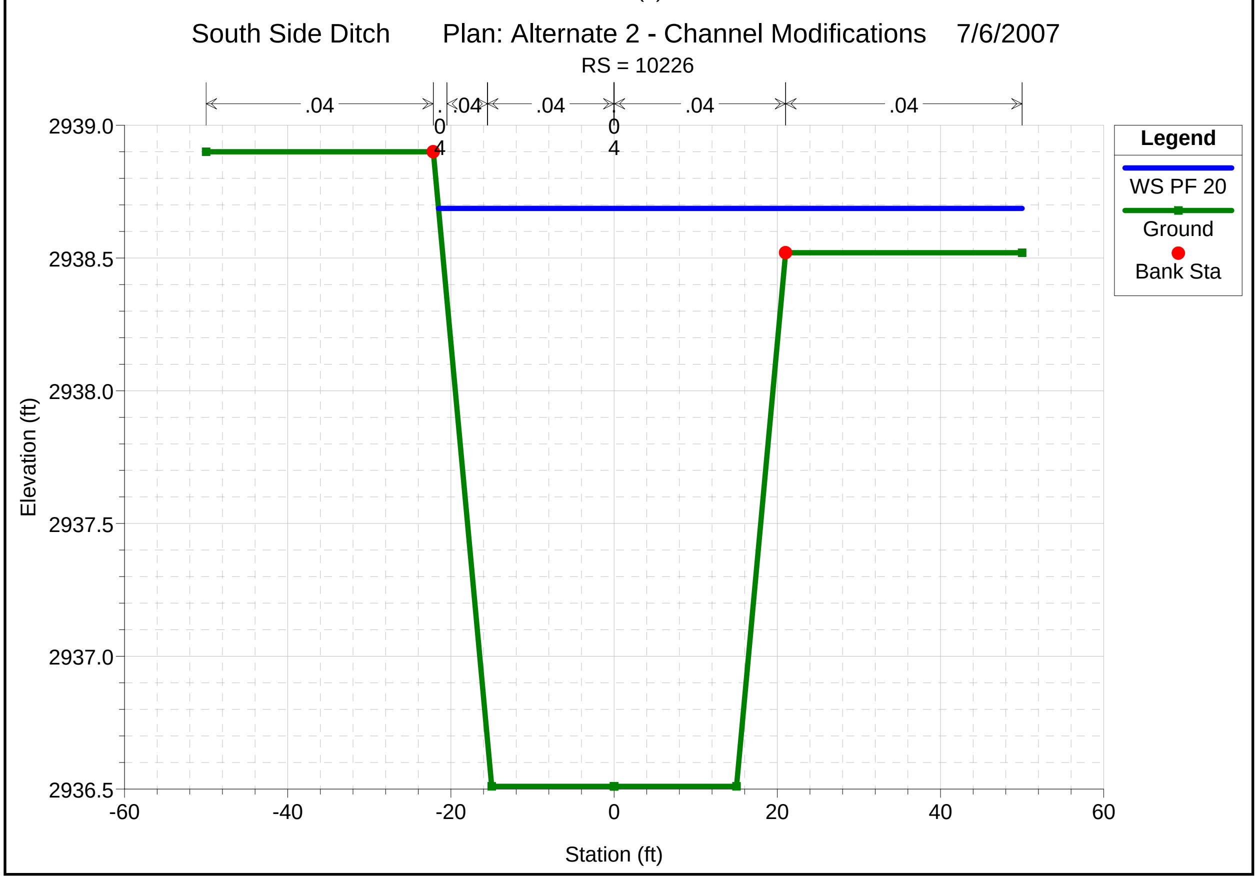

South Side Ditch Plan: Alternate 1 - Channel Modifications 7/6/2007
RS = 16194
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2942
2941
2940
2939
2938
2937
-60
-40
-20
0
20
40
60
Station (ft)

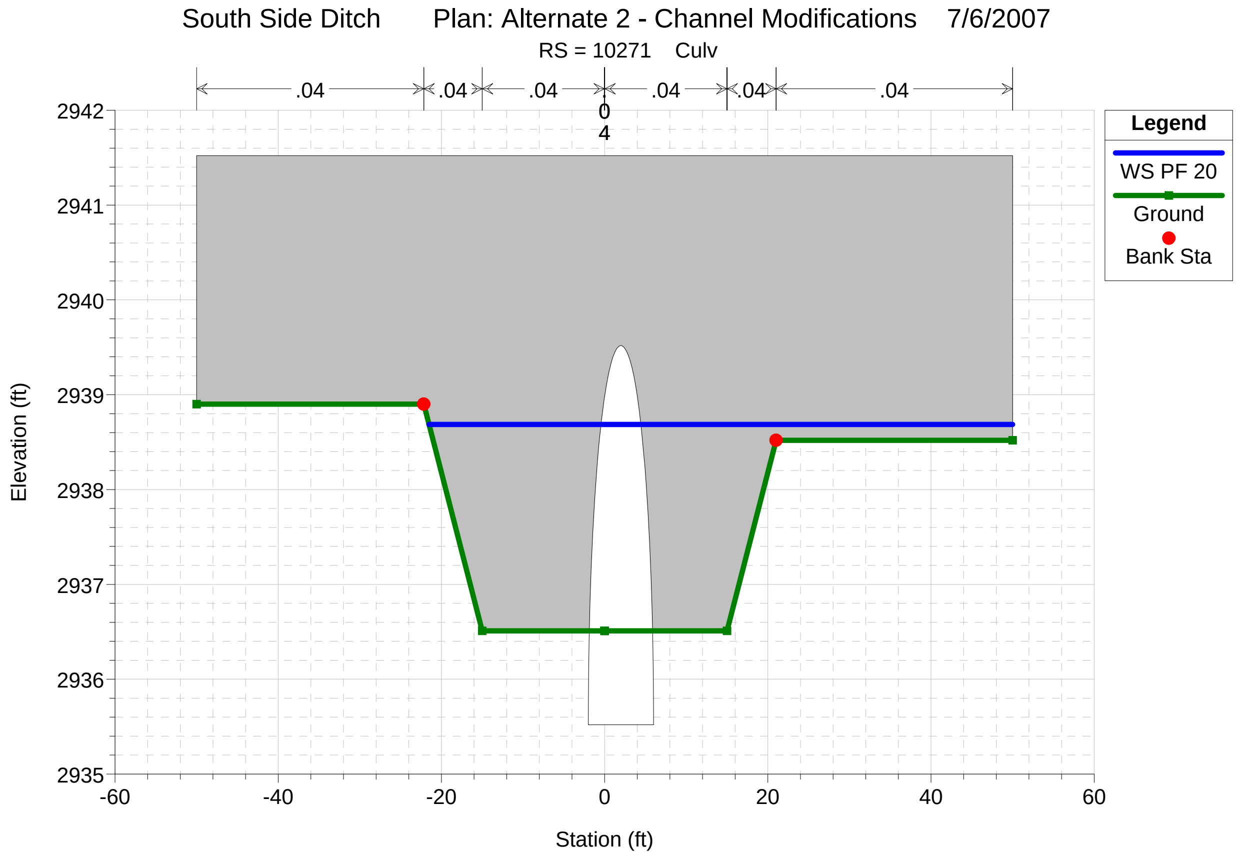

South Side Ditch Plan: Alternate 1 - Channel Modifications 7/6/2007
RS = 18150
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2950.5
2950.0
2949.5
2949.0
2948.5
2948.0
2947.5
2947.0
-80
-60
-40
-20
0
20
40
60
80
Station (ft)

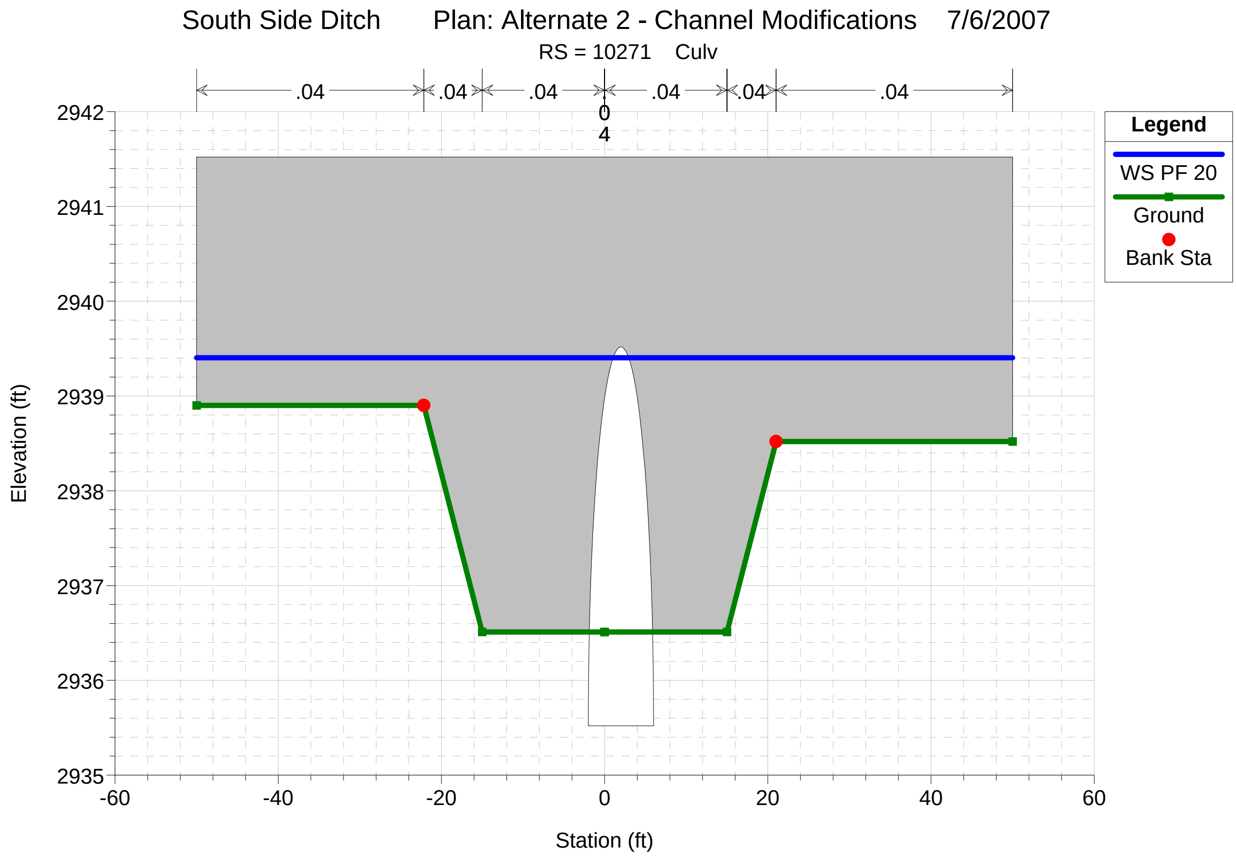

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 4513
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2918.0
2917.5
2917.0
2916.5
2916.0
2915.5
2915.0
2914.5
-40
-30
-20
-10
0
10
20
30
40
Station (ft)

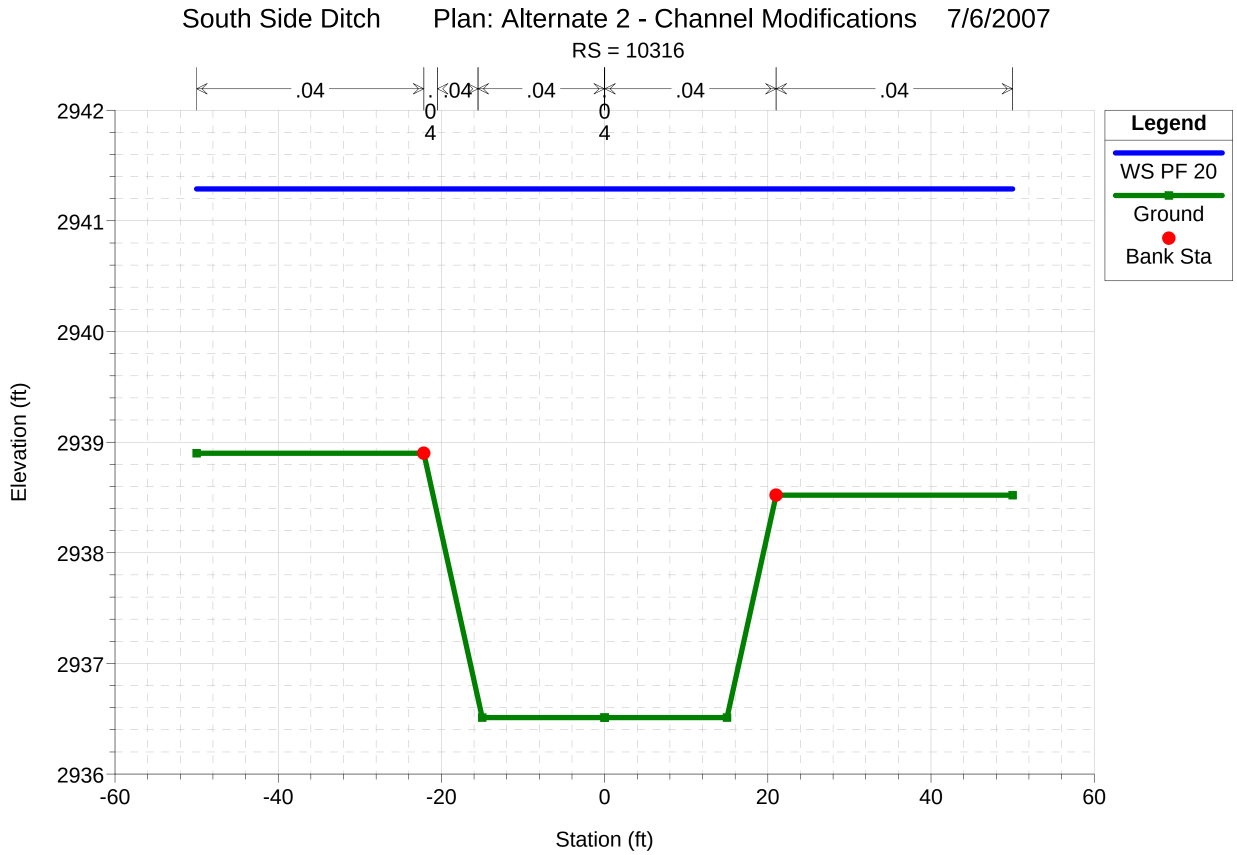

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 6132
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2929.0
2928.5
2928.0
2927.5
2927.0
2926.5
2926.0
2925.5
2925.0
-40
-30
-20
-10
0
10
20
30
40
Station (ft)

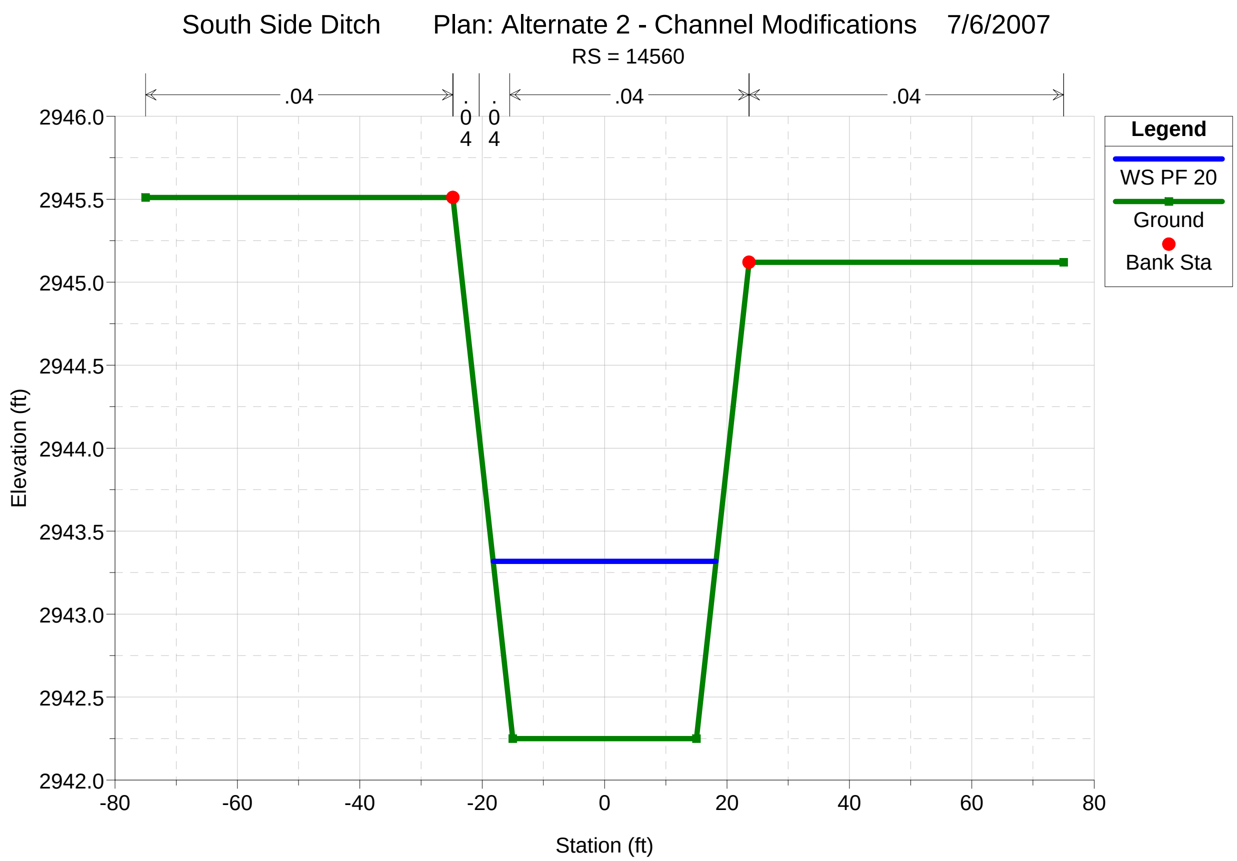

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 10000.*
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)

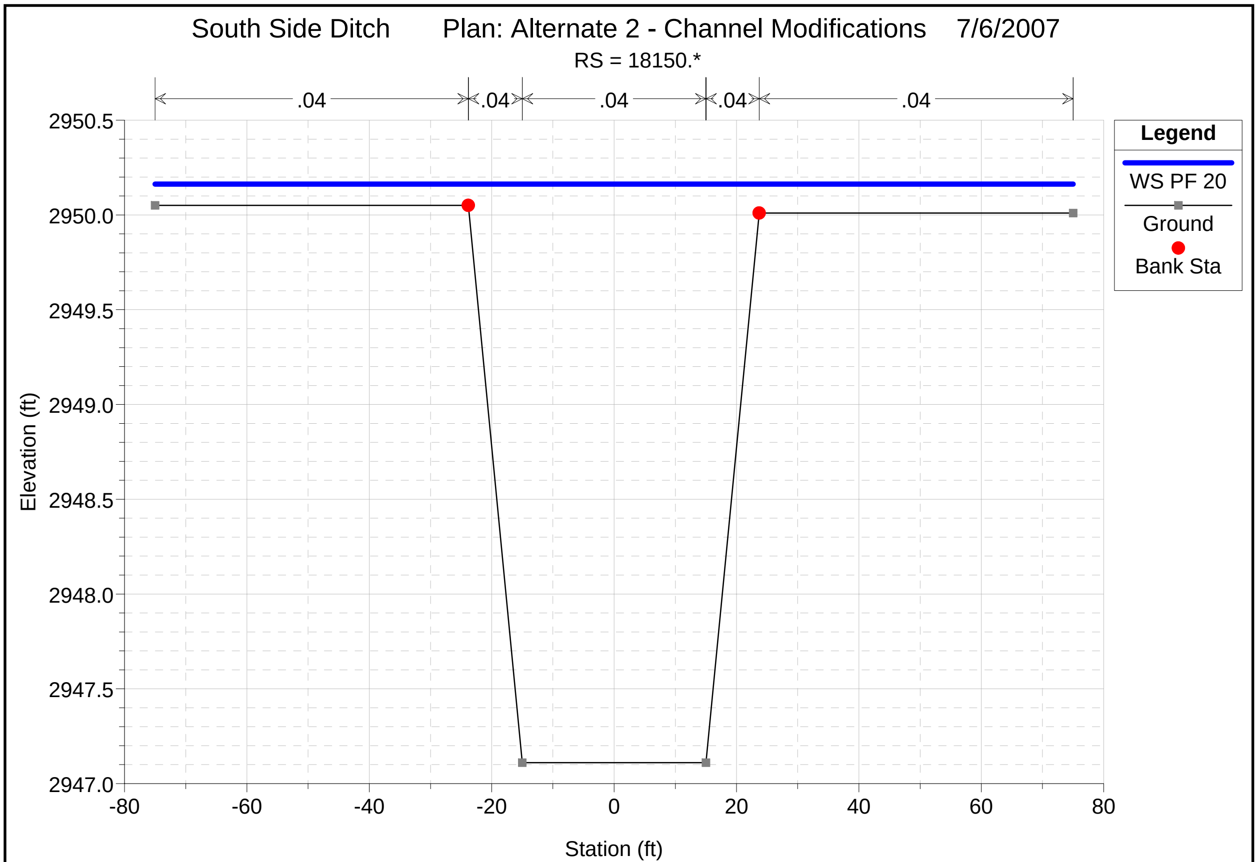

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 10226
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)

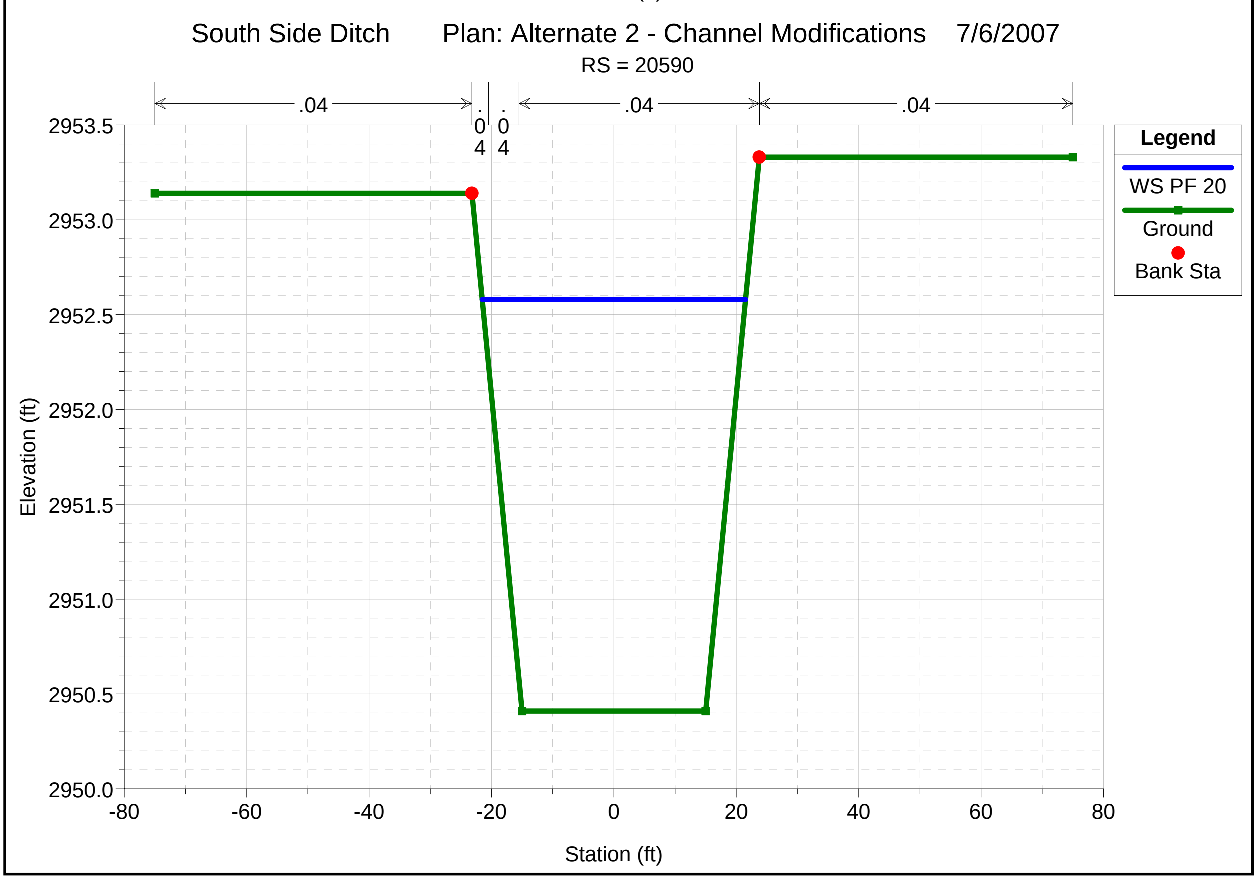

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 10271 Culv
.04
.04
.04
.04
.04
.04
0
4
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2942
2941
2940
2939
2938
2937
2936
2935
-60
-40
-20
0
20
40
60
Station (ft)

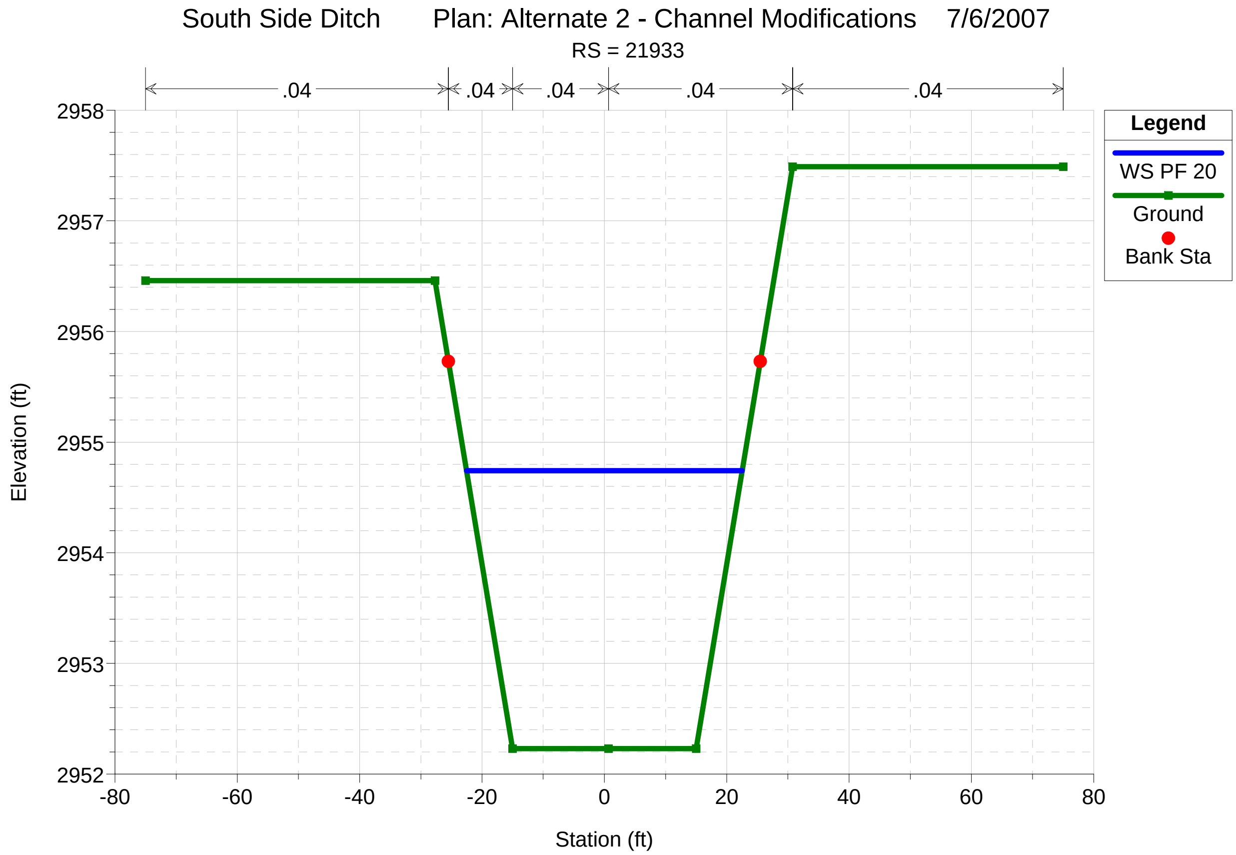

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 10271 Culv
.04
.04
.04
.04
.04
.04
0
4
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2942
2941
2940
2939
2938
2937
2936
2935
-60
-40
-20
0
20
40
60
Station (ft)

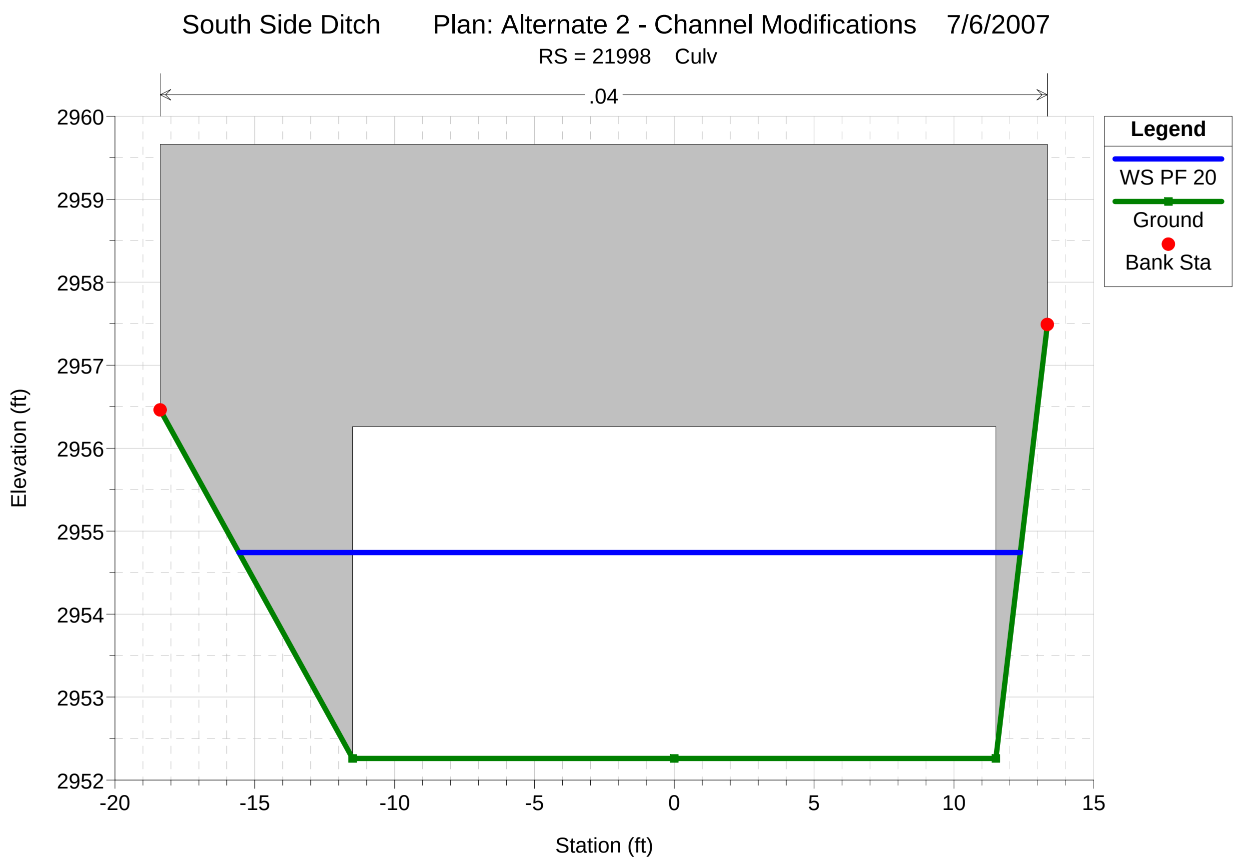

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 10316
.04
.04
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2942
2941
2940
2939
2938
2937
2936
-60
-40
-20
0
20
40
60
Station (ft)

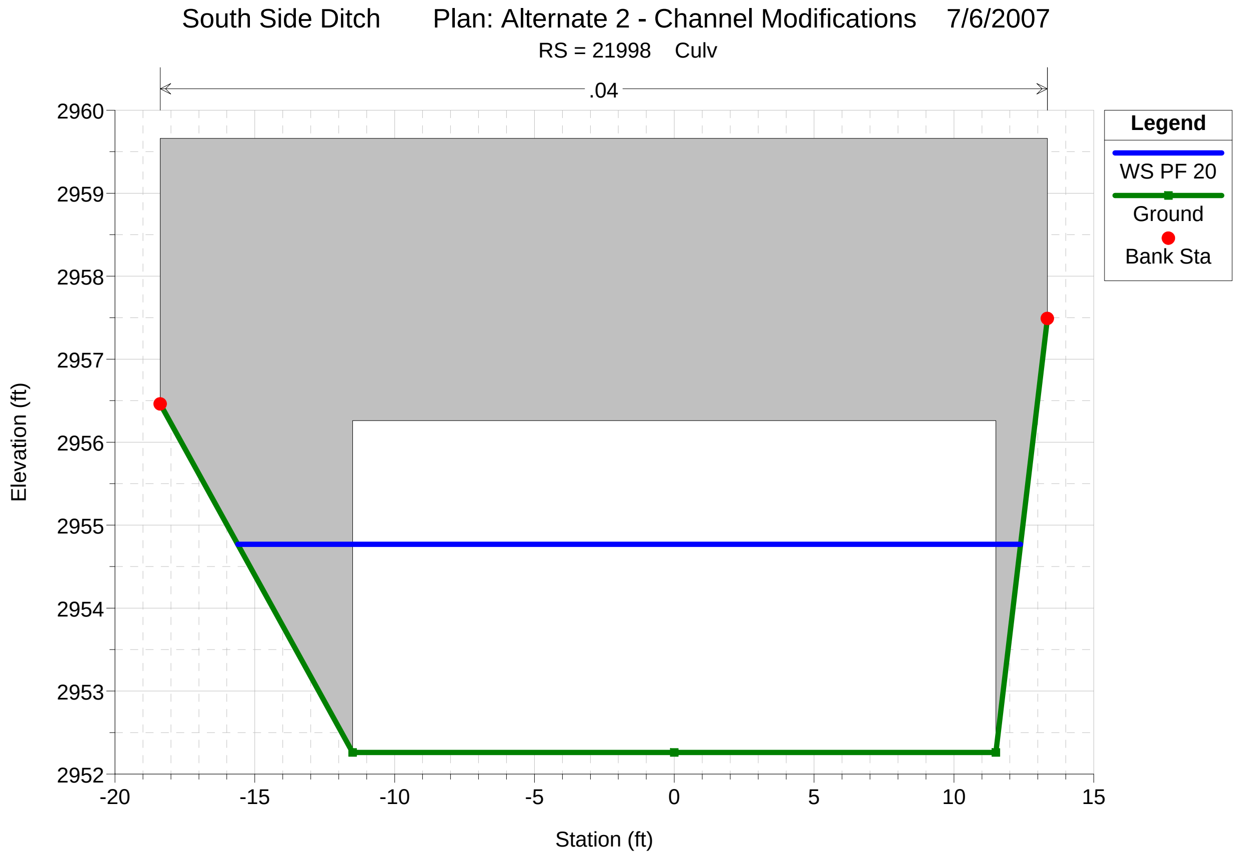

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 14560
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2946.0
2945.5
2945.0
2944.5
2944.0
2943.5
2943.0
2942.5
2942.0
-80
-60
-40
-20
0
20
40
60
80
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 18150.*
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2950.5
2950.0
2949.5
2949.0
2948.5
2948.0
2947.5
2947.0
-80
-60
-40
-20
0
20
40
60
80
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 20590
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2953.5
2953.0
2952.5
2952.0
2951.5
2951.0
2950.5
2950.0
-80
-60
-40
-20
0
20
40
60
80
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 21933
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2958
2957
2956
2955
2954
2953
2952
-80
-60
-40
-20
0
20
40
60
80
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 21998 Culv
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2960
2959
2958
2957
2956
2955
2954
2953
2952
-20
-15
-10
-5
0
5
10
15
Station (ft)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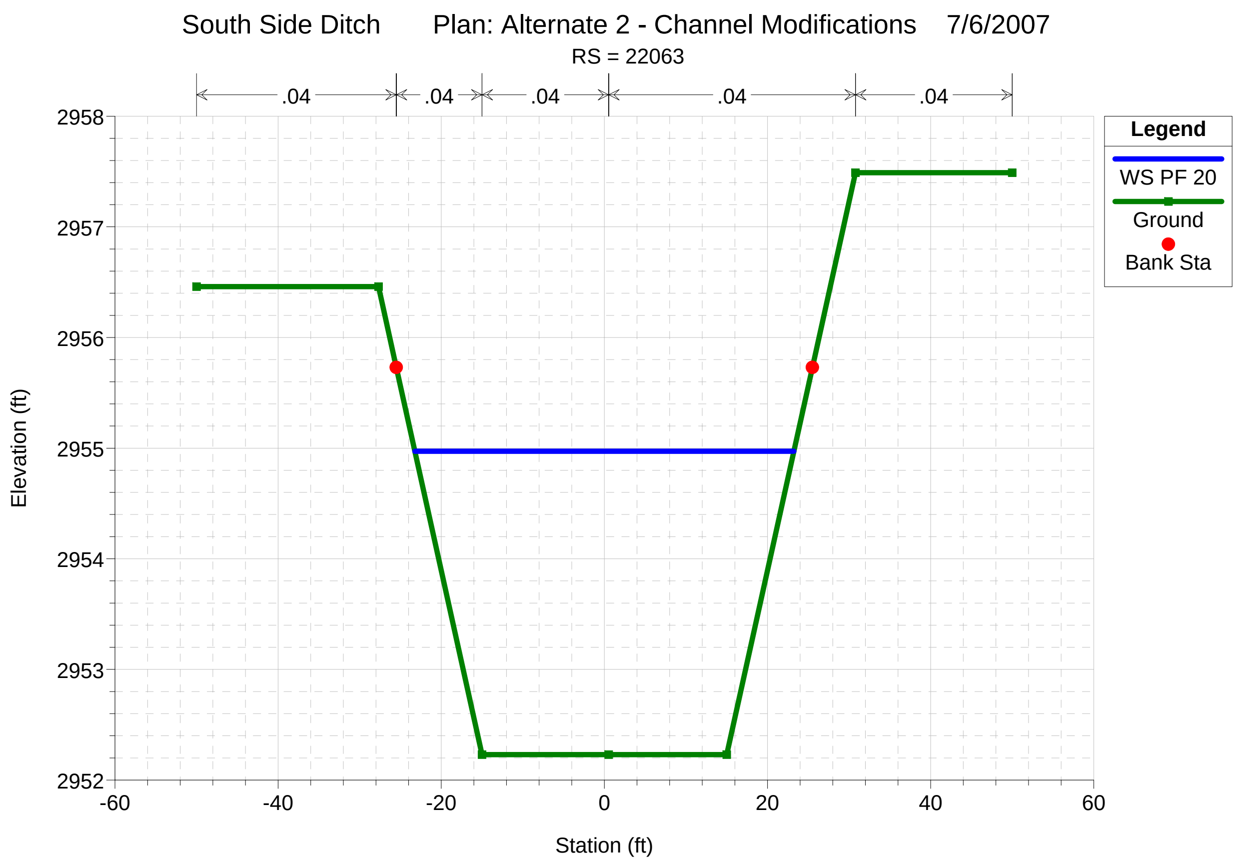
RS = 21998 Culv
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
2960
2959
2958
2957
2956
2955
2954
2953
2952
-20
-15
-10
-5
0
5
10
15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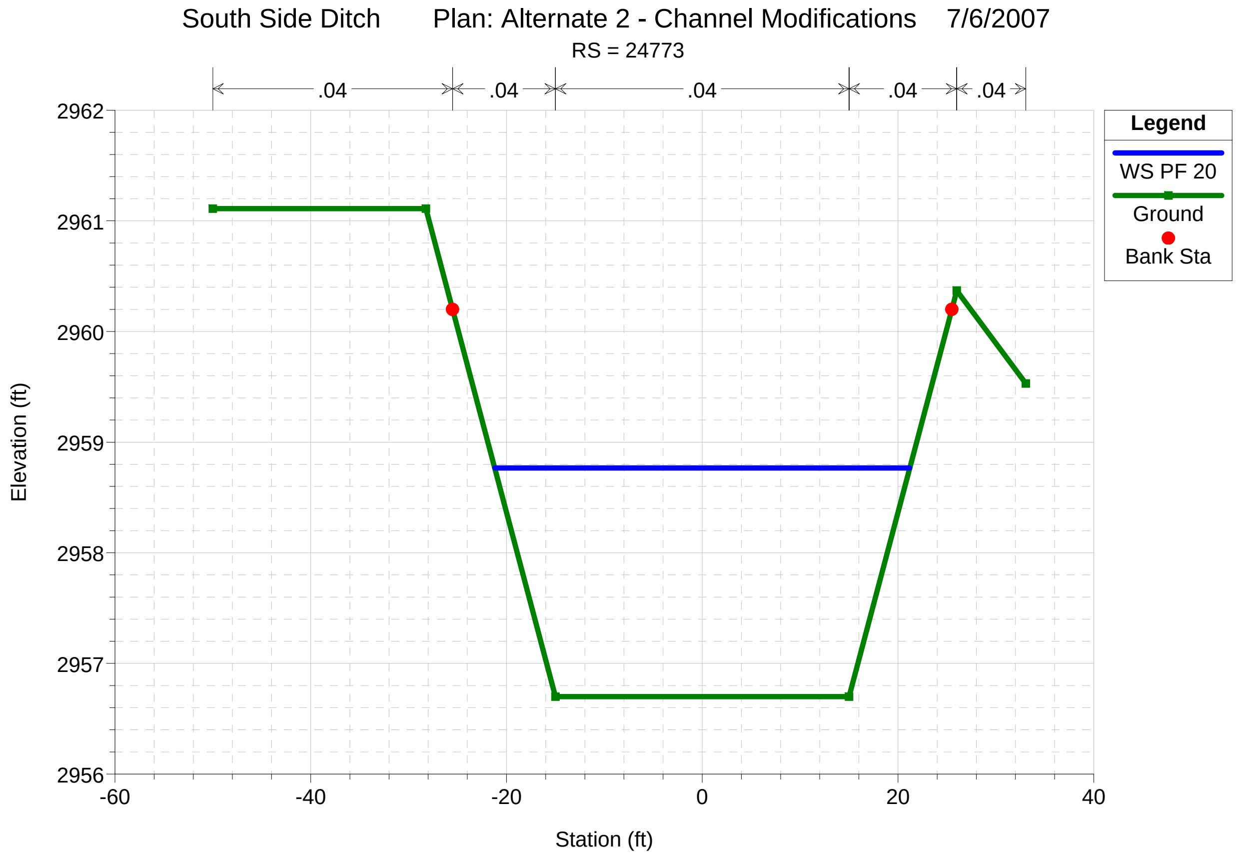
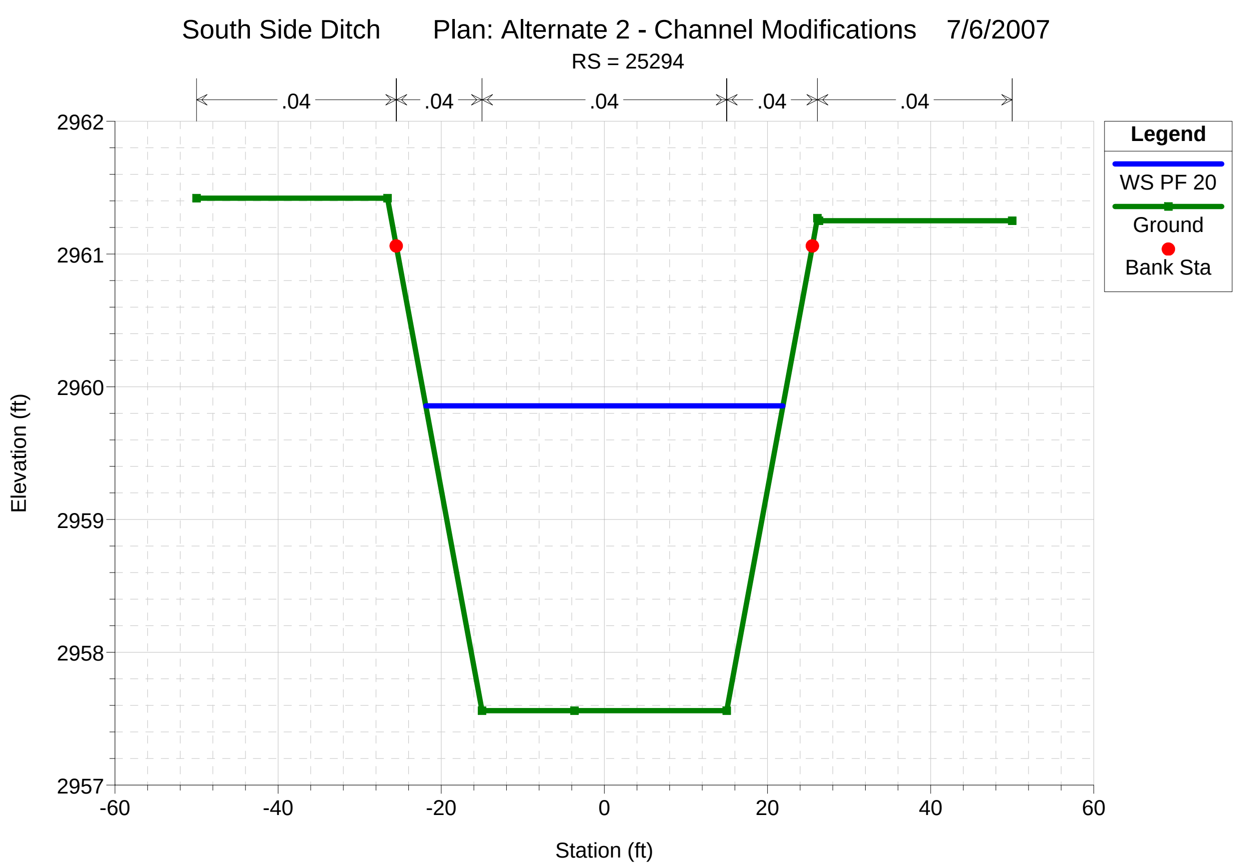
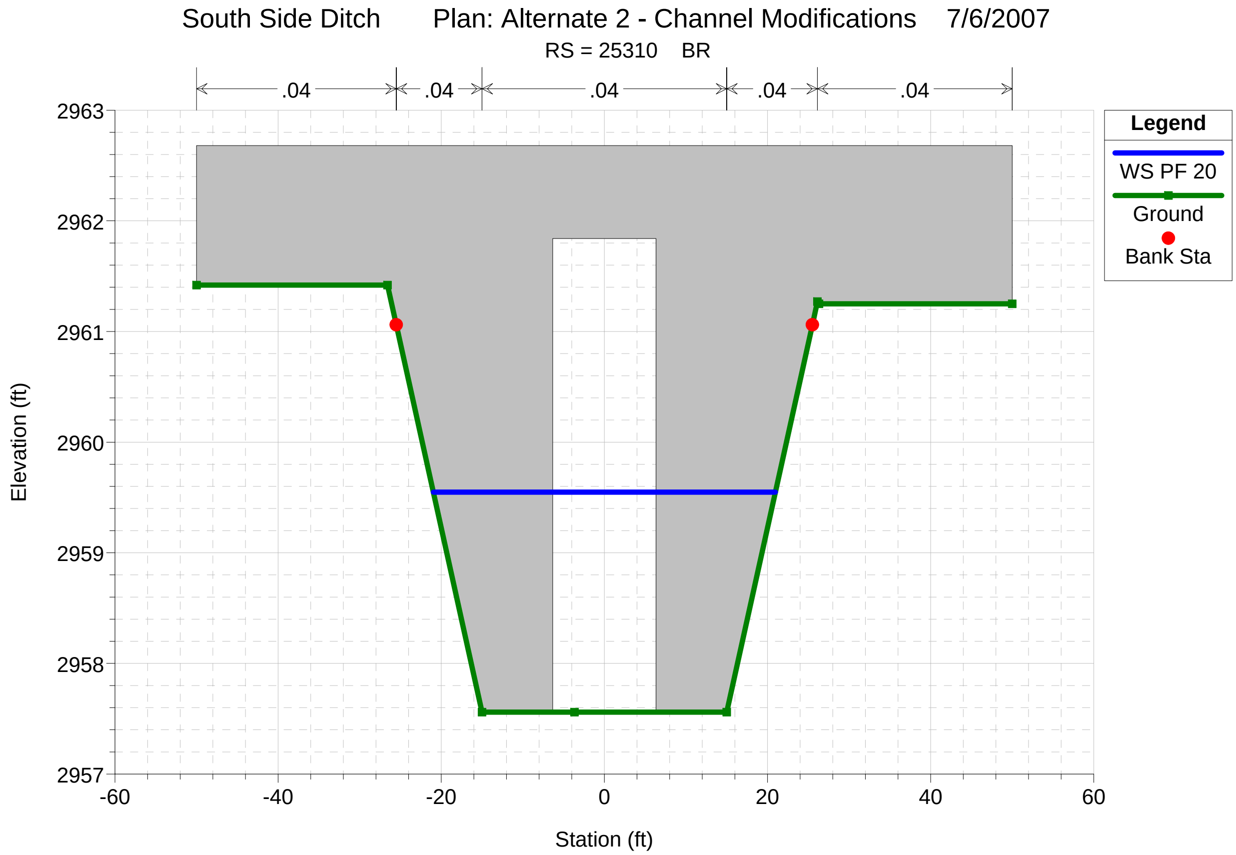
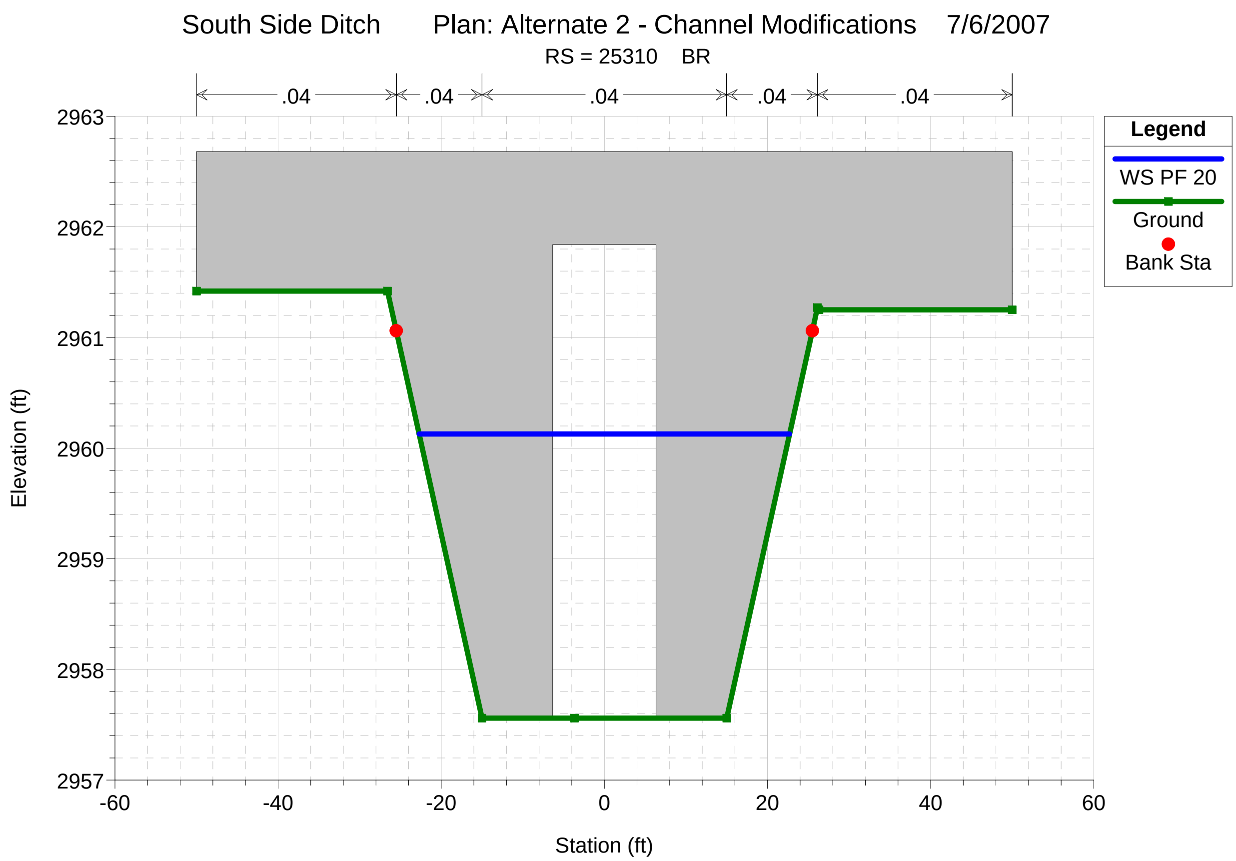
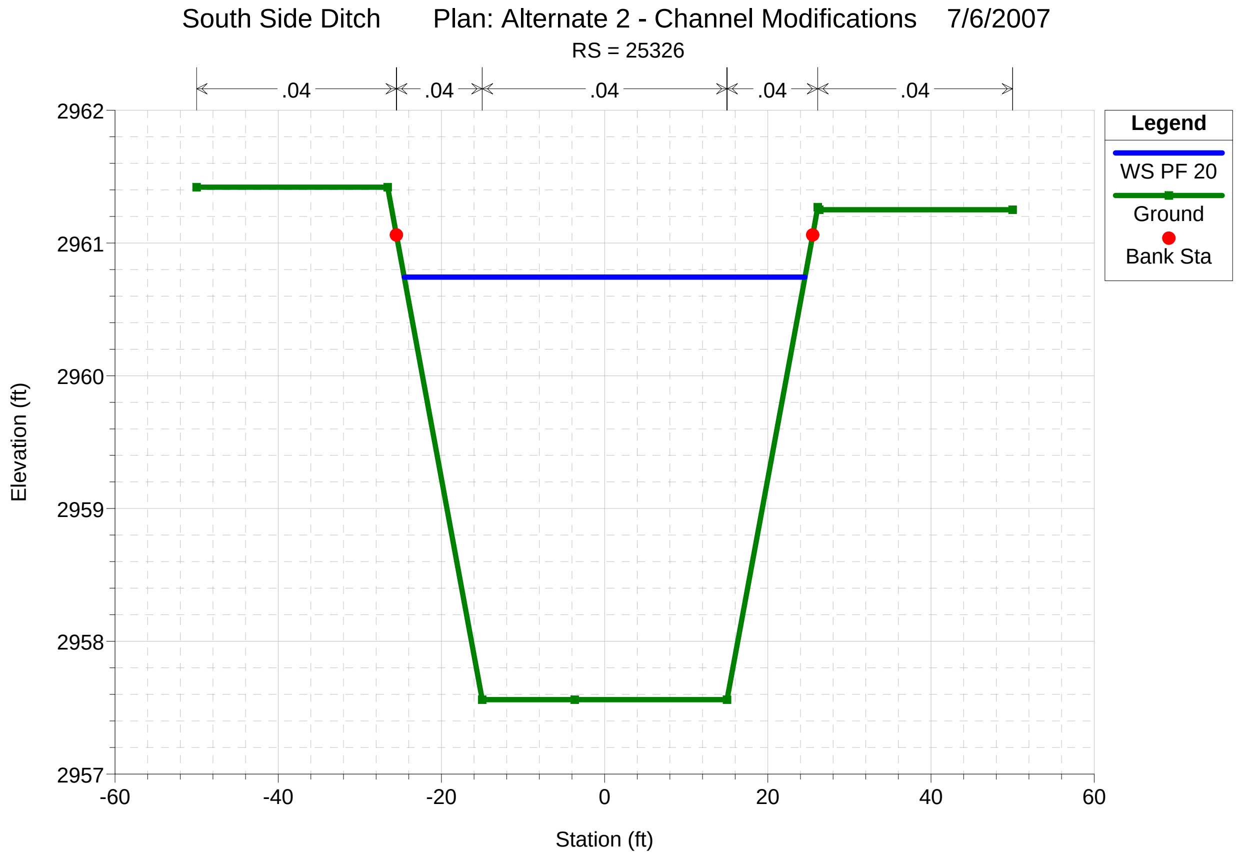
RS = 22063
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
2958
2957
2956
2955
2954
2953
2952
-60
-40
-20
0
20
40
60

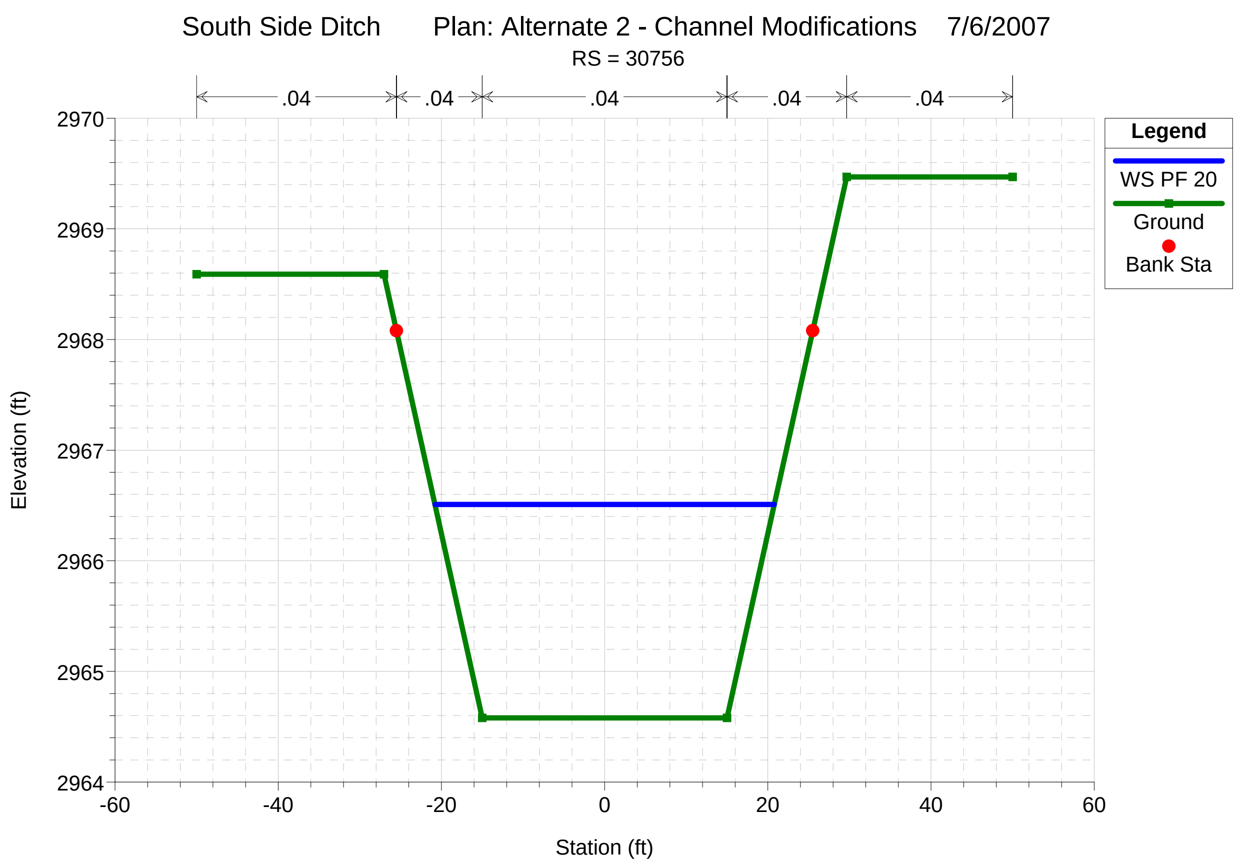

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 24773
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2962
2961
2960
2959
2958
2957
2956
-60
-40
-20
0
20
40
Station (ft)

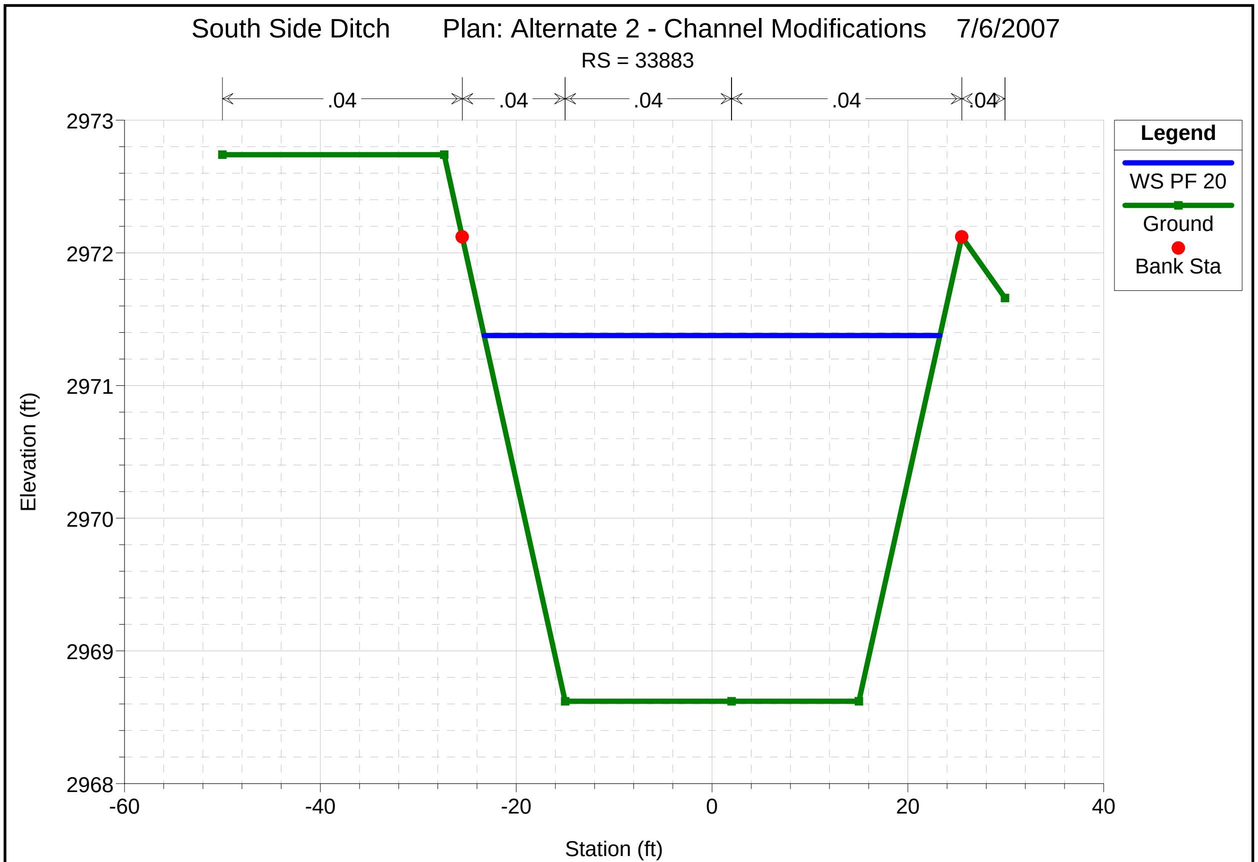

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 25294
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2962
2961
2960
2959
2958
2957
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 25310 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2963
2962
2961
2960
2959
2958
2957
-60
-40
-20
0
20
40
60
Station (ft)

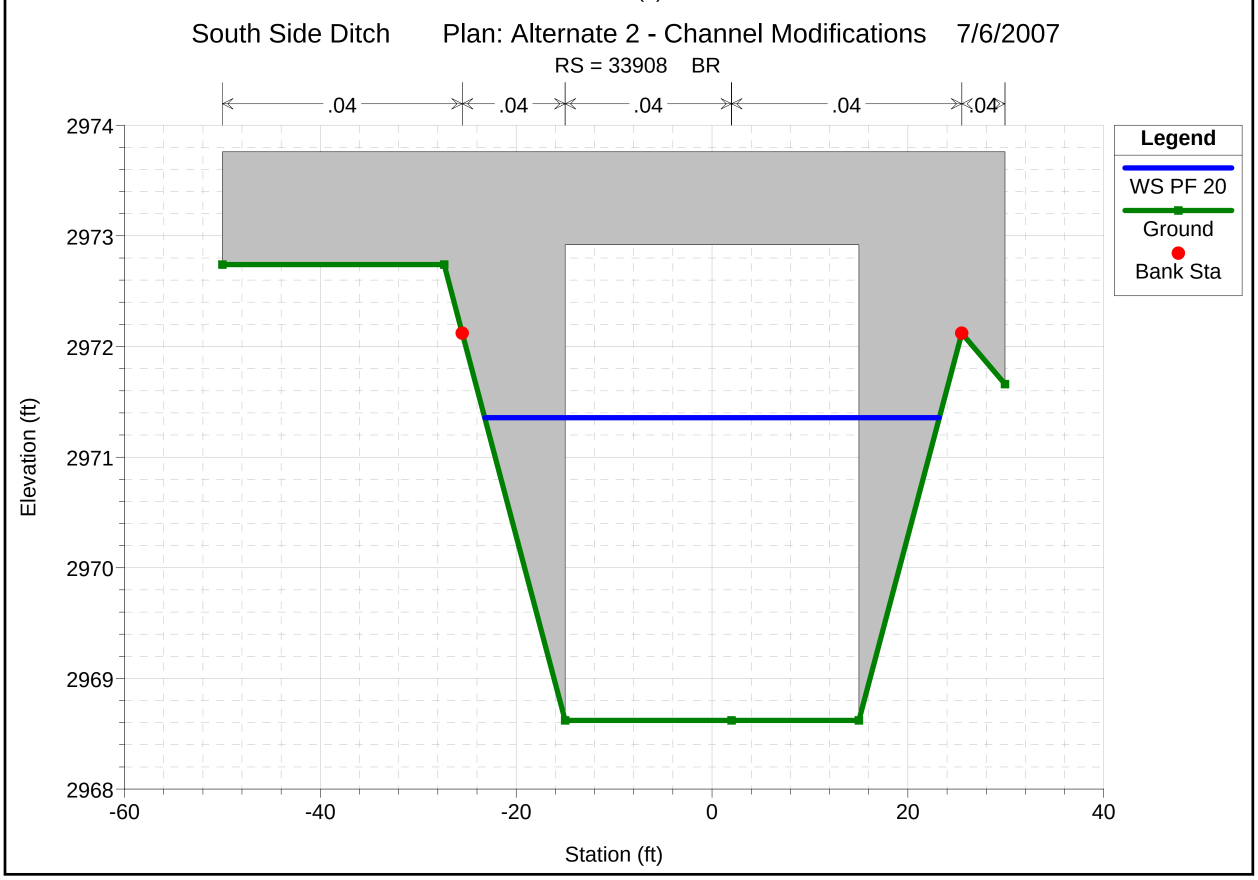

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 25310 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2963
2962
2961
2960
2959
2958
2957
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 25326
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2962
2961
2960
2959
2958
2957
-60
-40
-20
0
20
40
60
Station (ft)

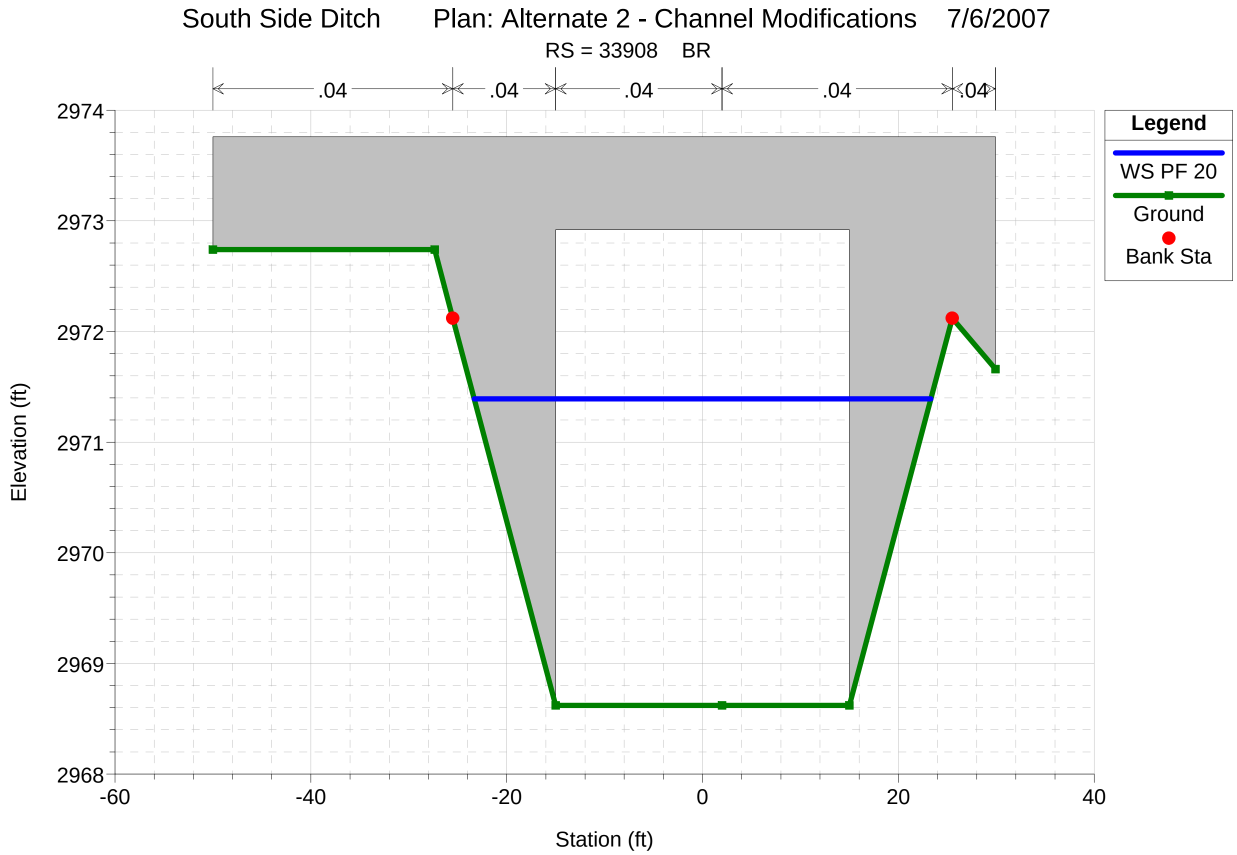

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 30756
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2970
2969
2968
2967
2966
2965
2964
-60
-40
-20
0
20
40
60
Station (ft)



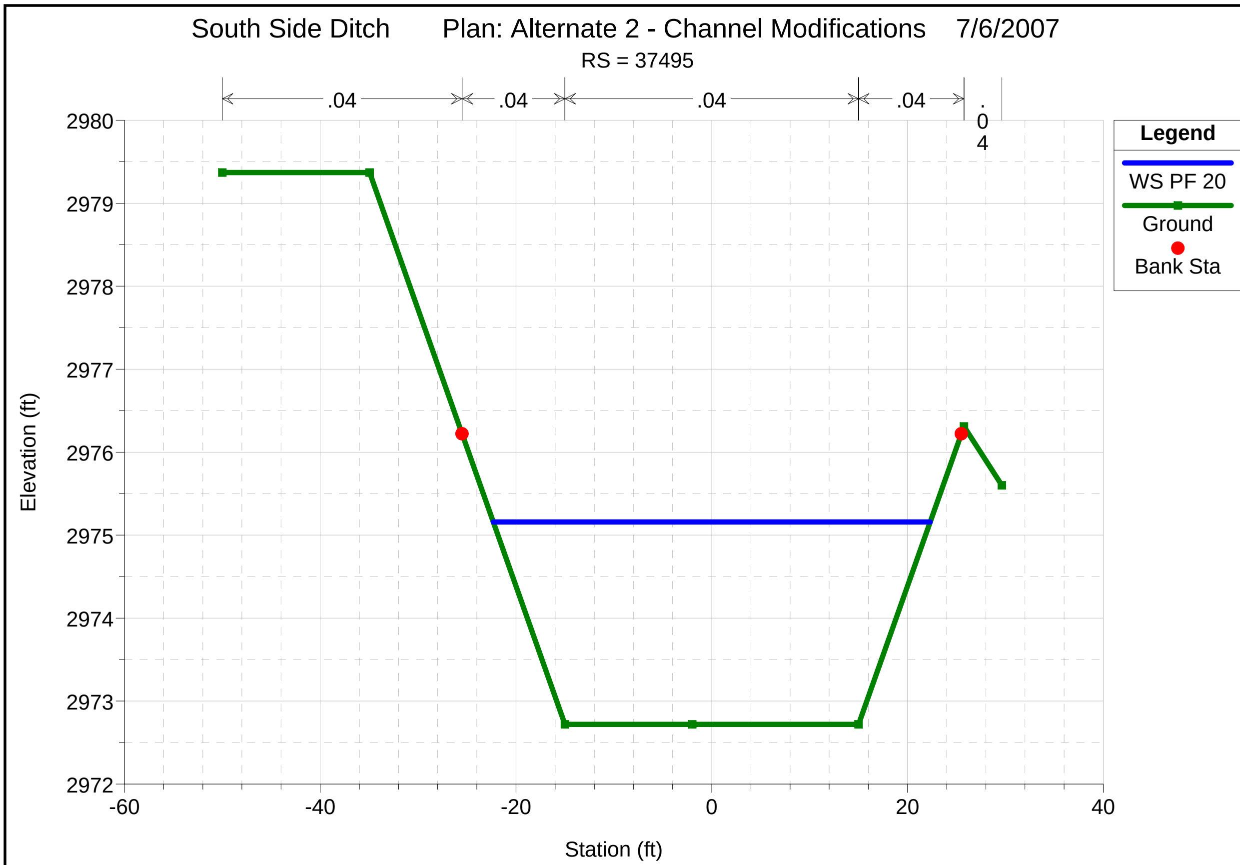
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 33883
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2973
2972
2971
2970
2969
2968
-60
-40
-20
0
20
40
Station (ft)

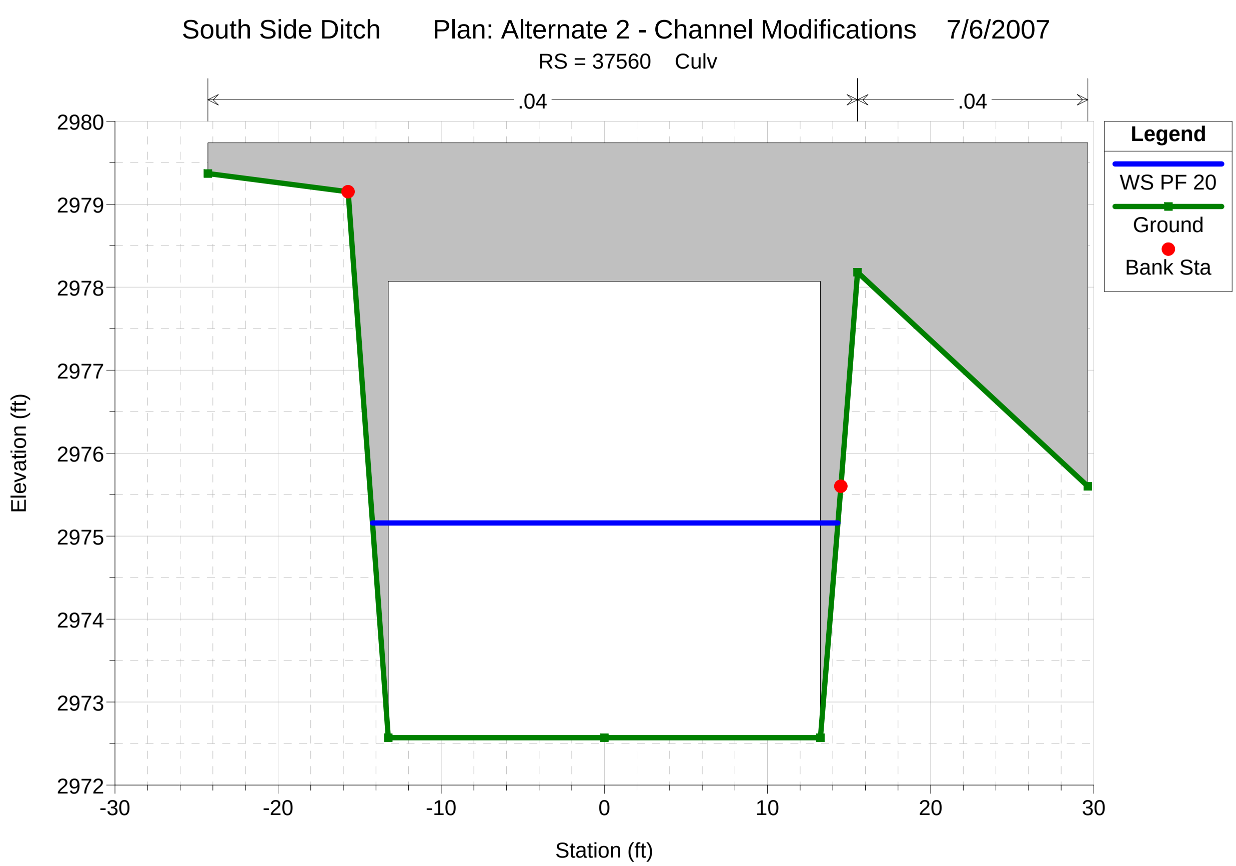


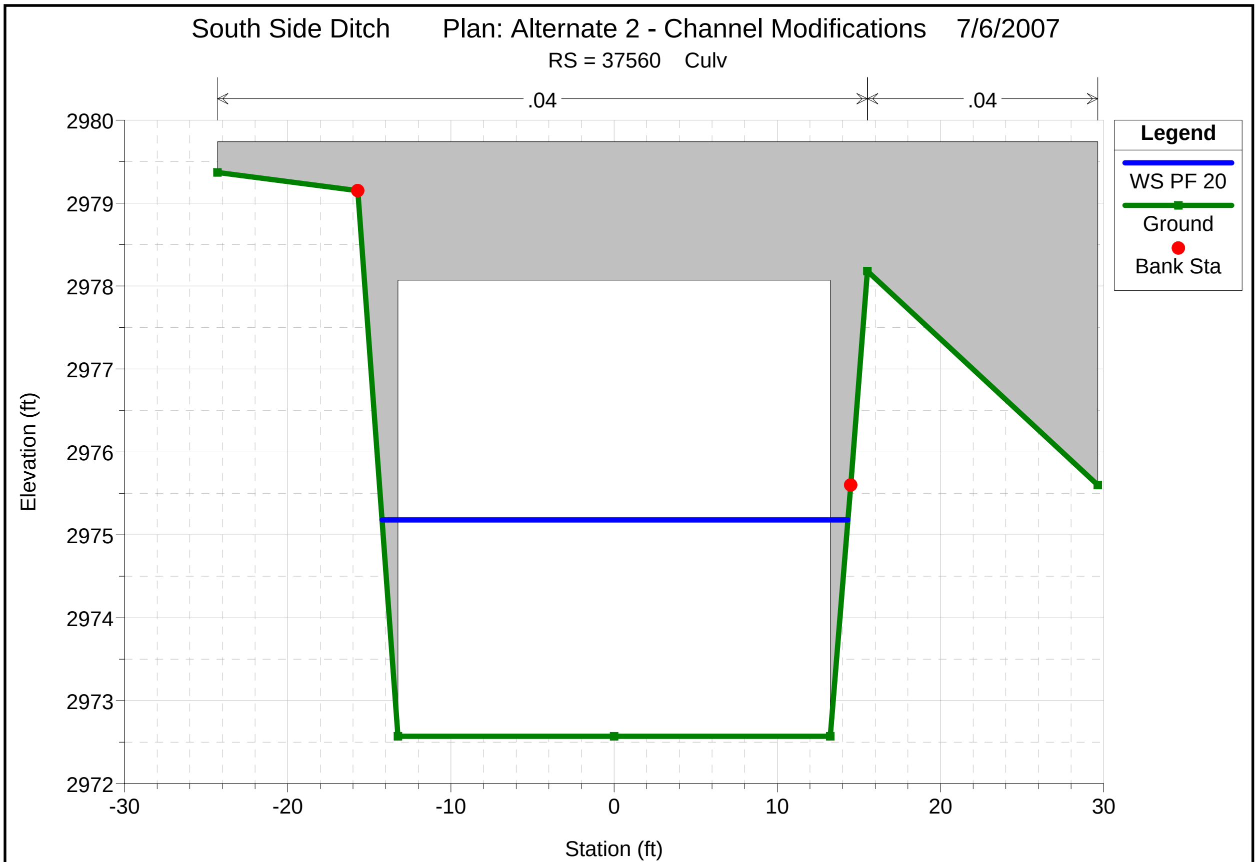
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 33908 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2974
2973
2972
2971
2970
2969
2968
-60
-40
-20
0
20
40
Station (ft)

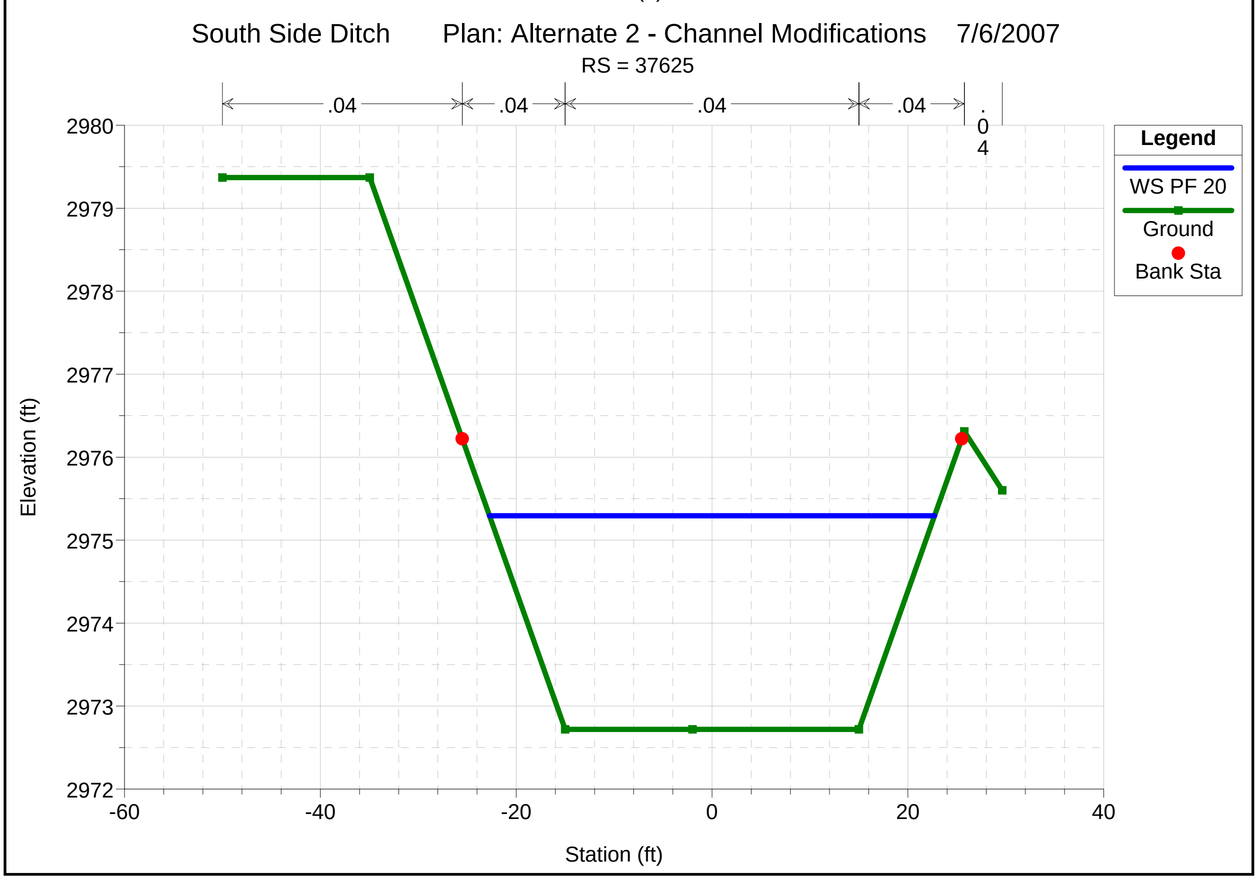

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 33908 BR
.04
.04
.04
.04
.04
2974
2973
2972
2971
2970
2969
2968
Elevation (ft)
-60
-40
-20
0
20
40
Station (ft)
Legend
WS PF 20
Ground
Bank Sta

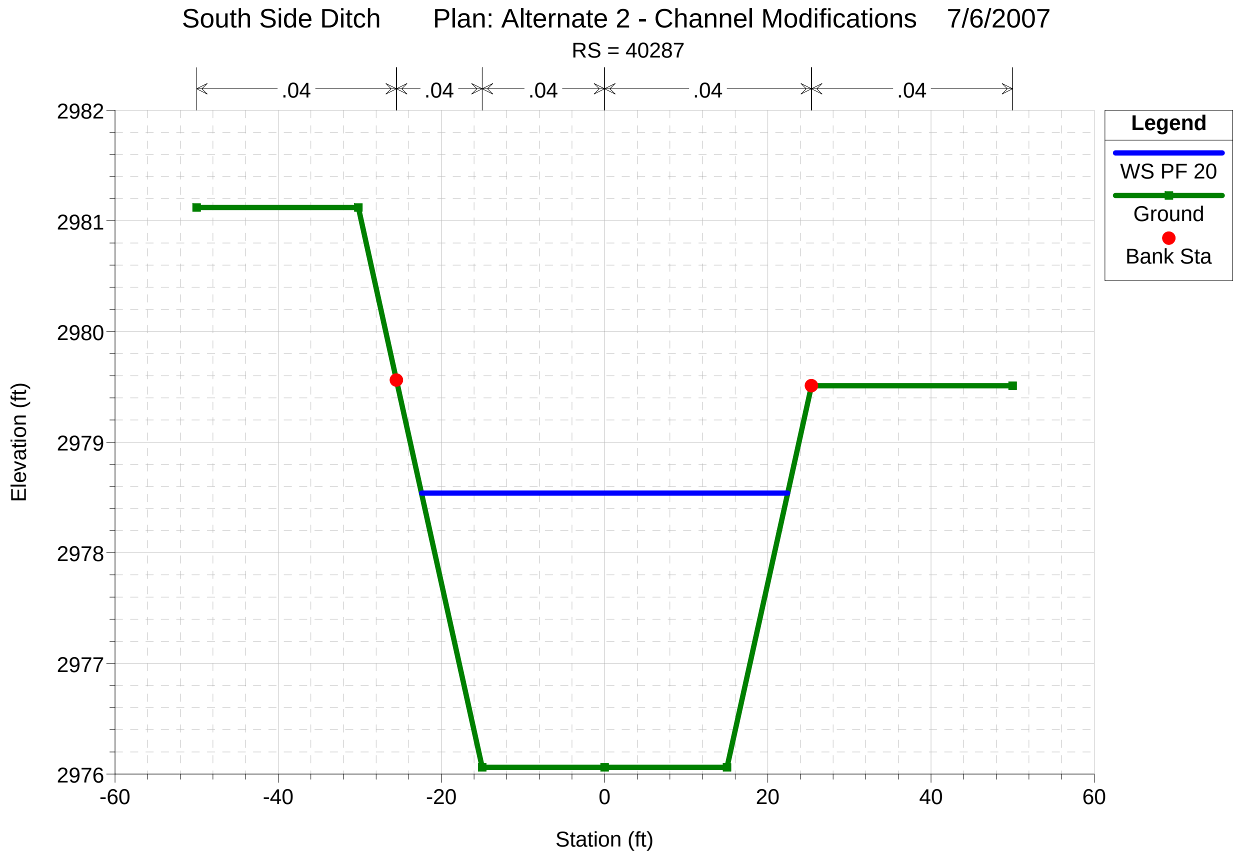

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 33933
.04
.04
.04
.04
.04
2973
2972
2971
2970
2969
2968
Elevation (ft)
-60
-40
-20
0
20
40
Station (ft)
Legend
WS PF 20
Ground
Bank Sta

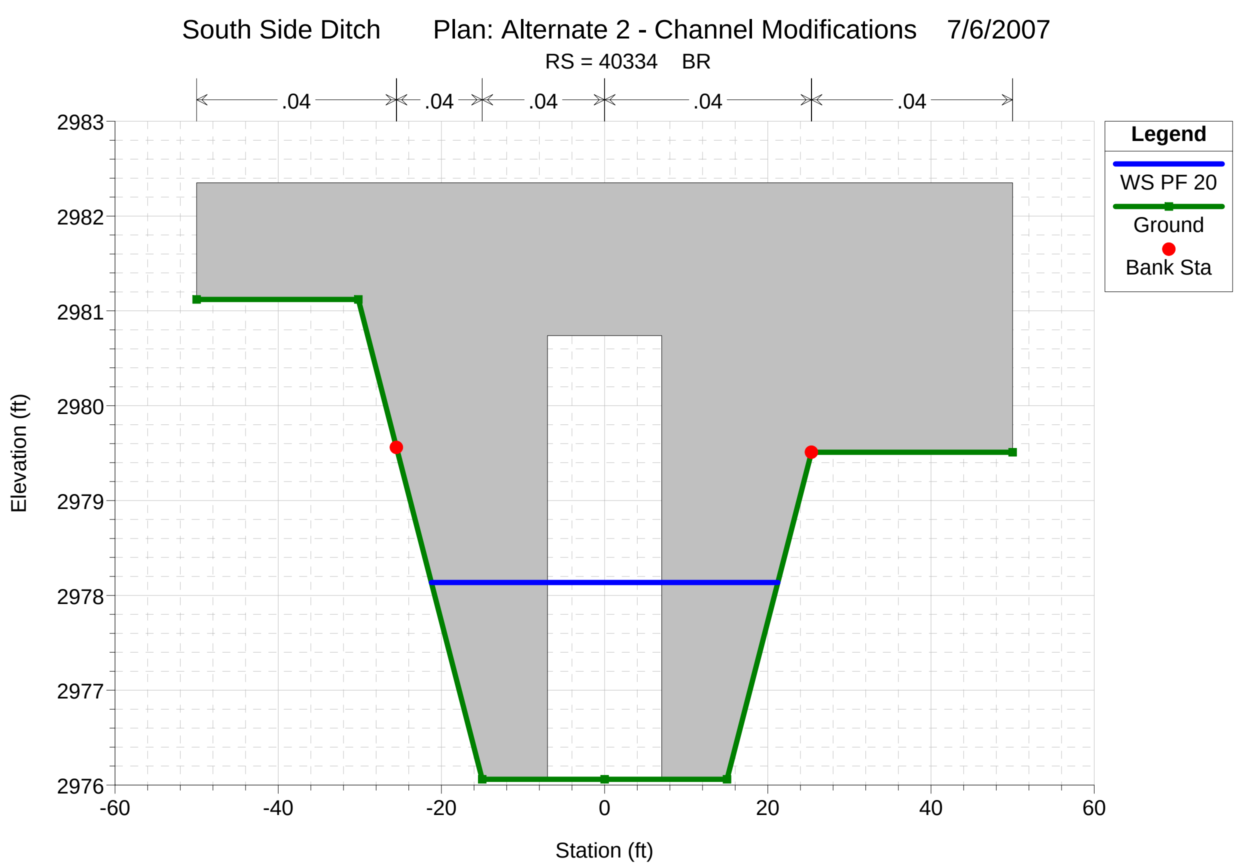

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 37495
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
2980
2979
2978
2977
2976
2975
2974
2973
2972
-60
-40
-20
0
20
40

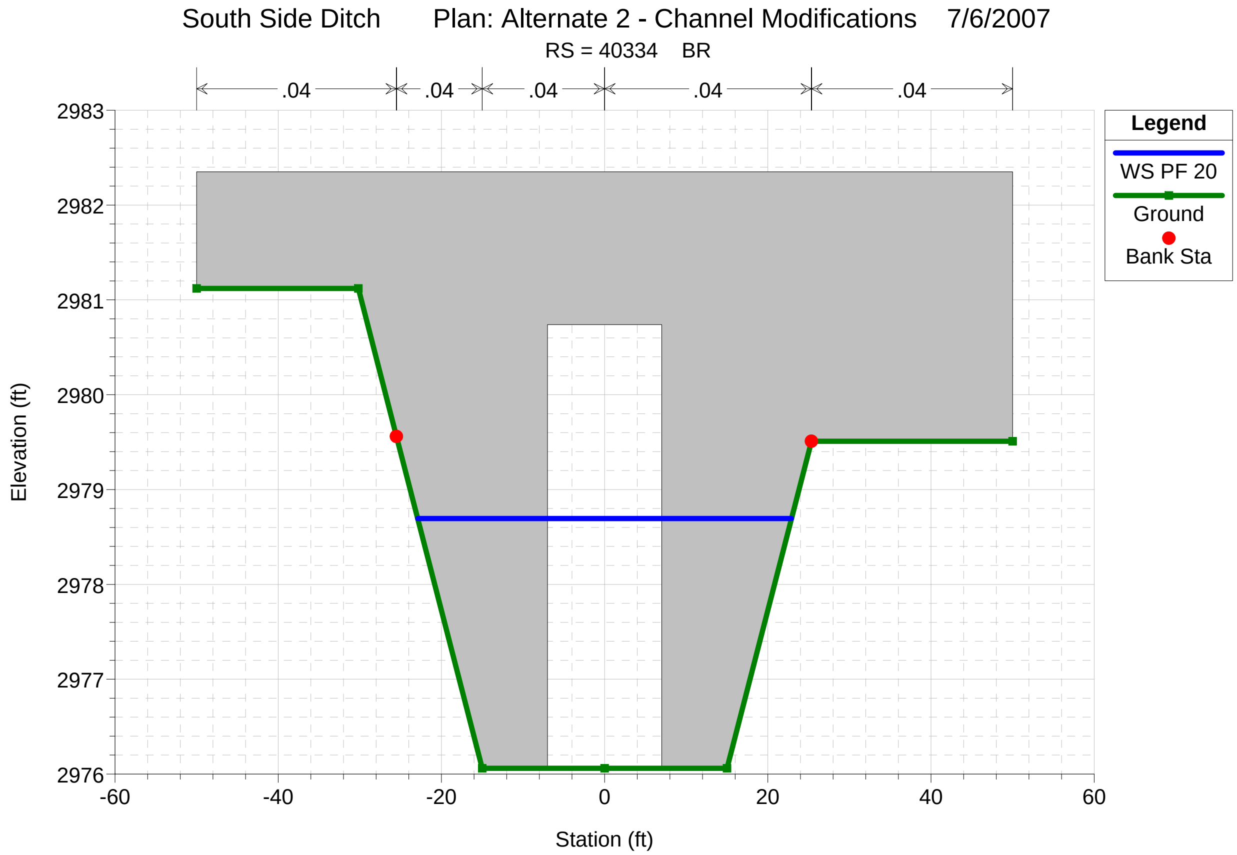

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 37560 Culv
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
2980
2979
2978
2977
2976
2975
2974
2973
2972
-30
-20
-10
0
10
20
30


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 37560 Culv
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2980
2979
2978
2977
2976
2975
2974
2973
2972
-30
-20
-10
0
10
20
30
Station (ft)

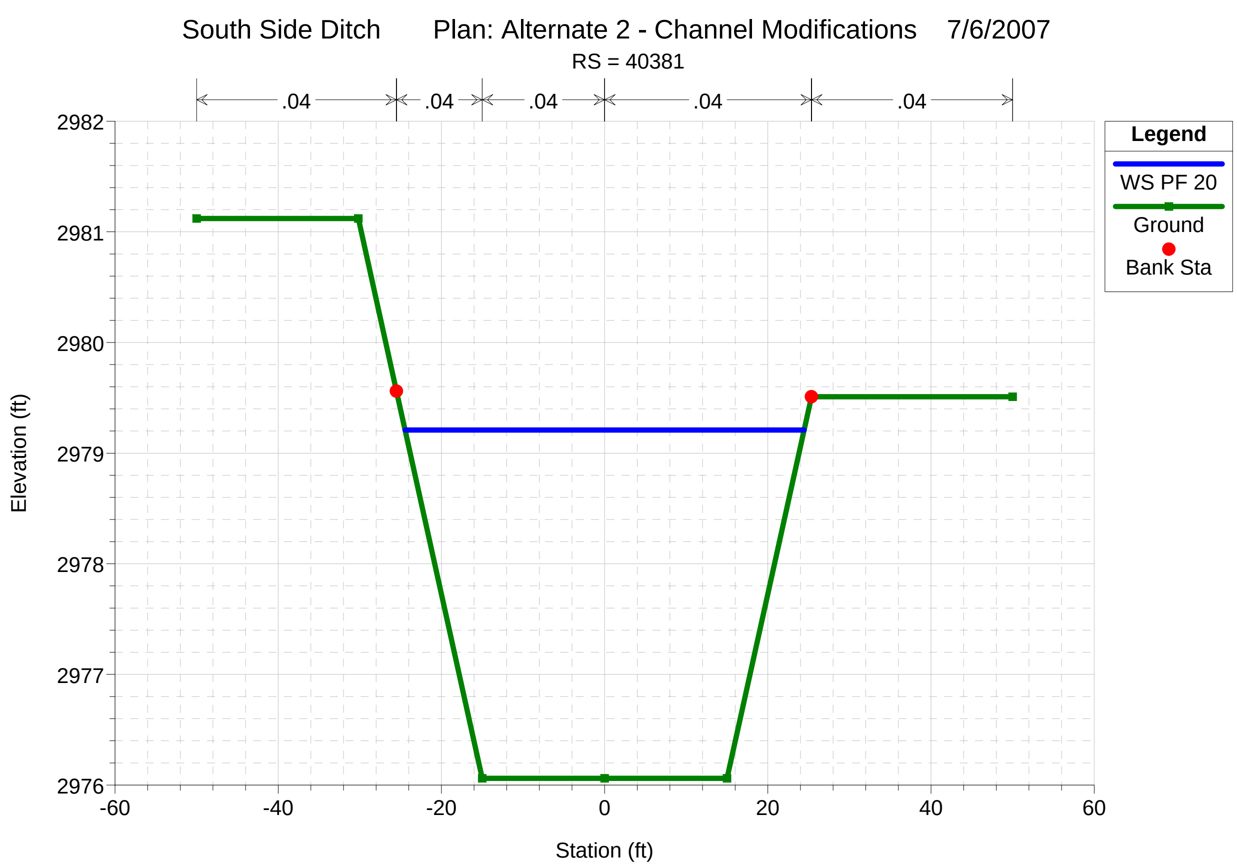

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 37625
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2980
2979
2978
2977
2976
2975
2974
2973
2972
-60
-40
-20
0
20
40
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 40287
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
60
Station (ft)

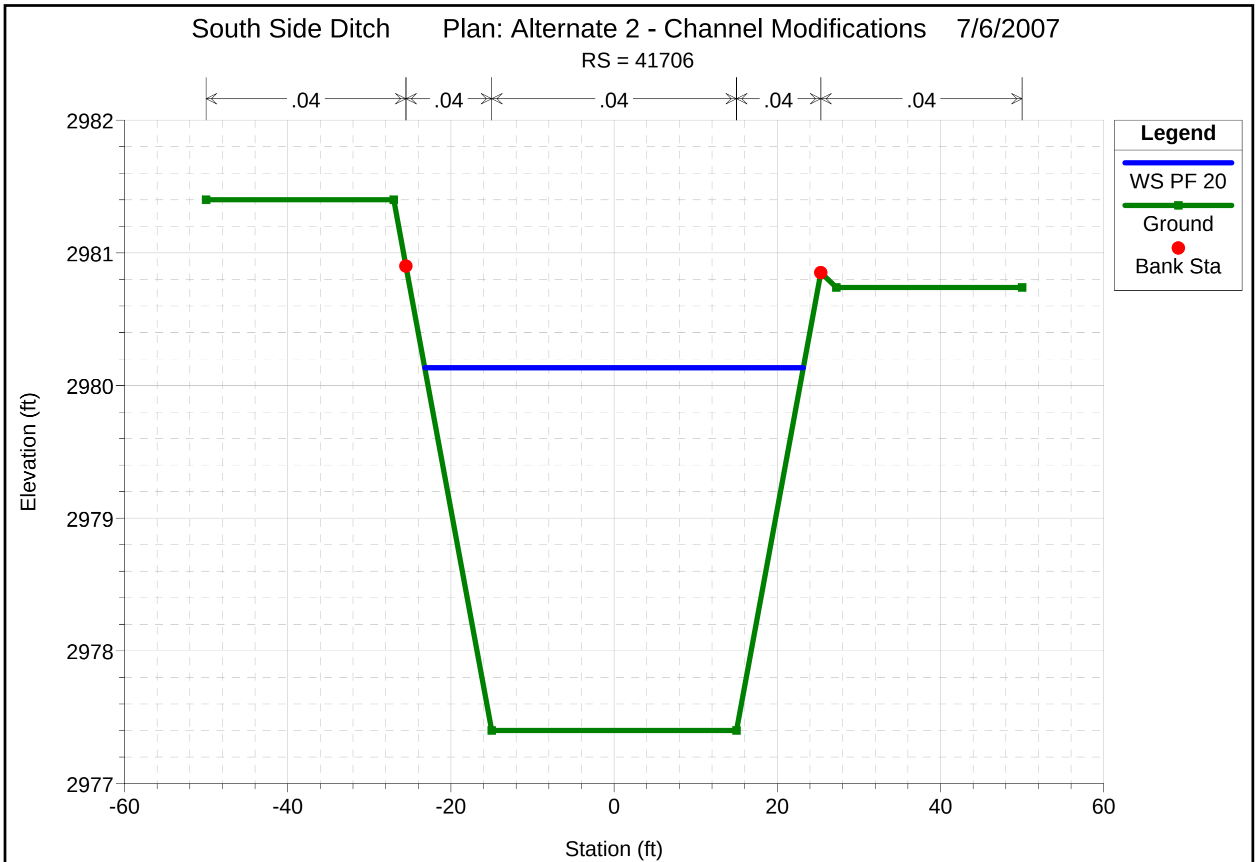

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 40334 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2983
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
60
Station (ft)

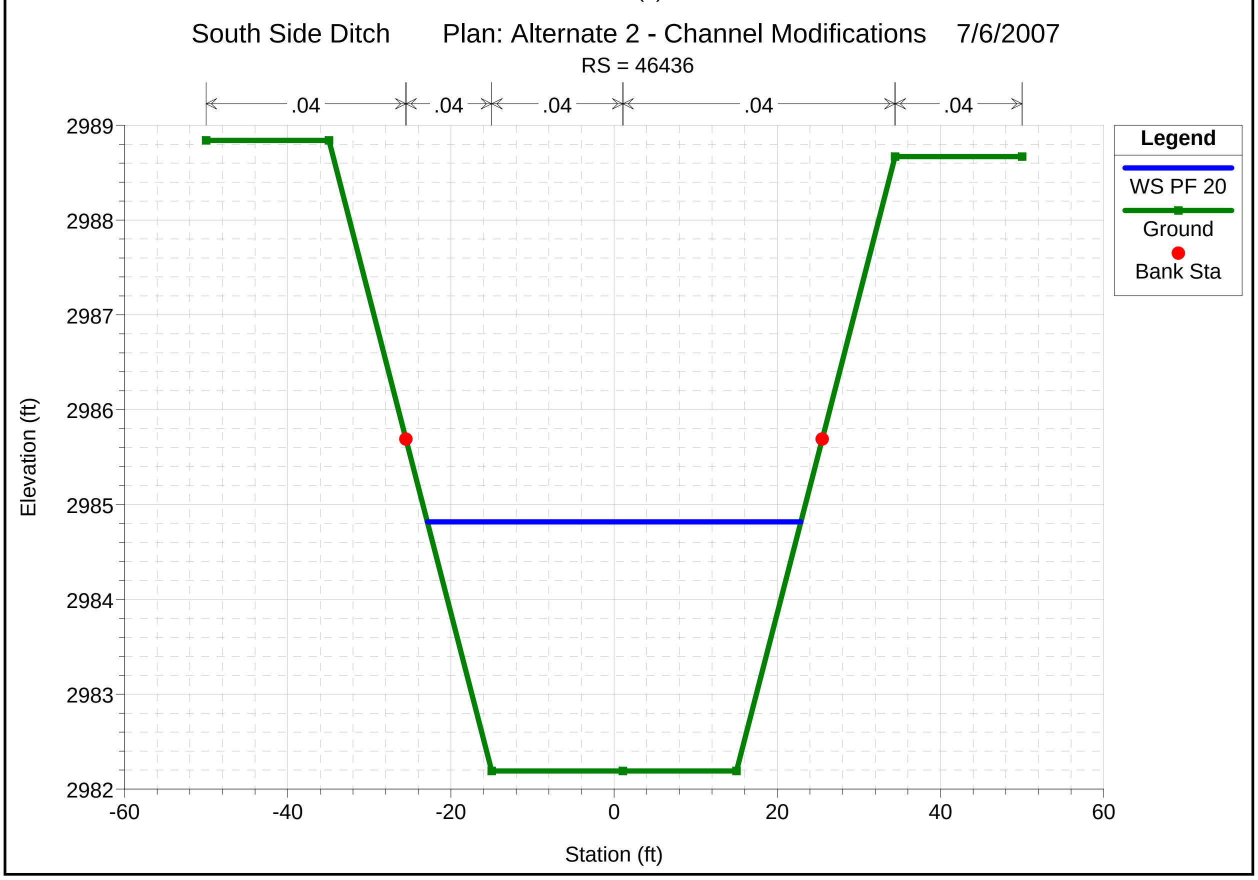


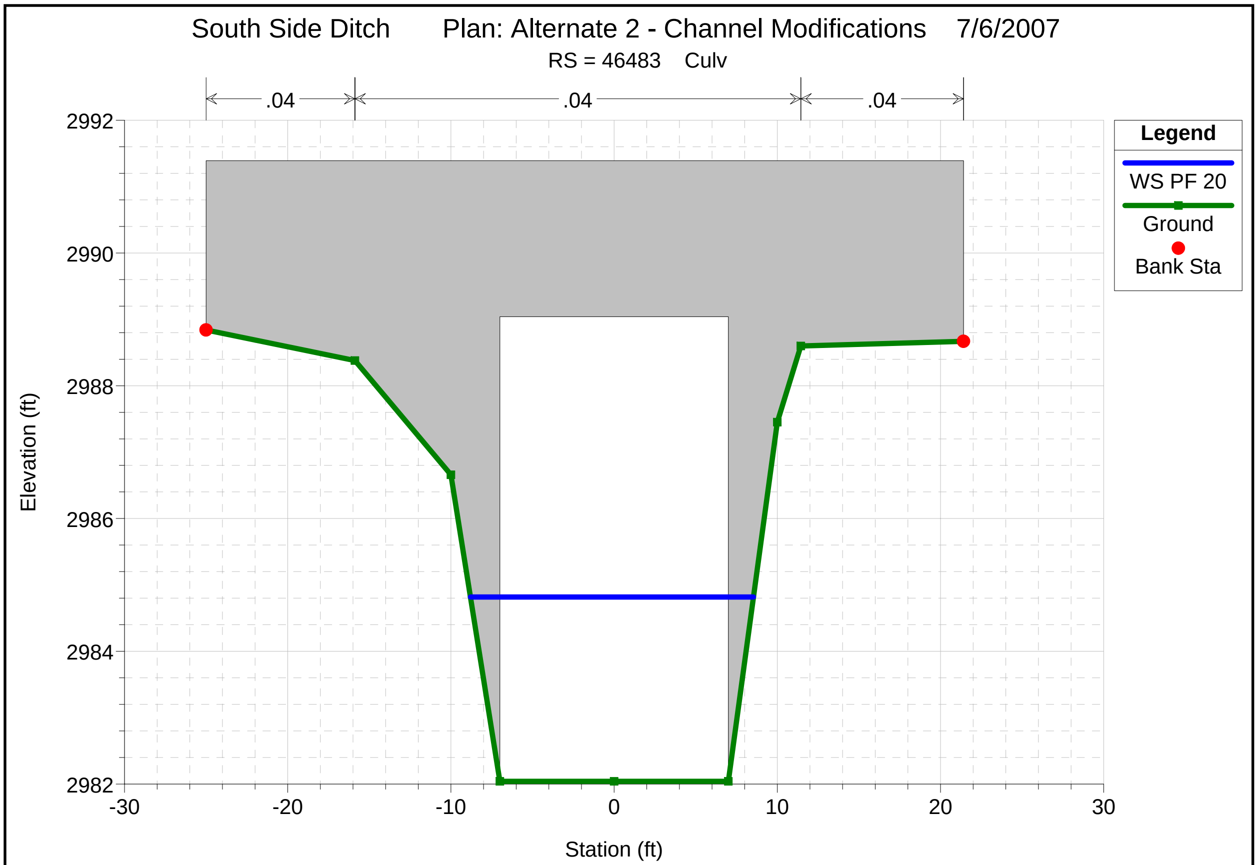
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 40334 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2983
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
60
Station (ft)

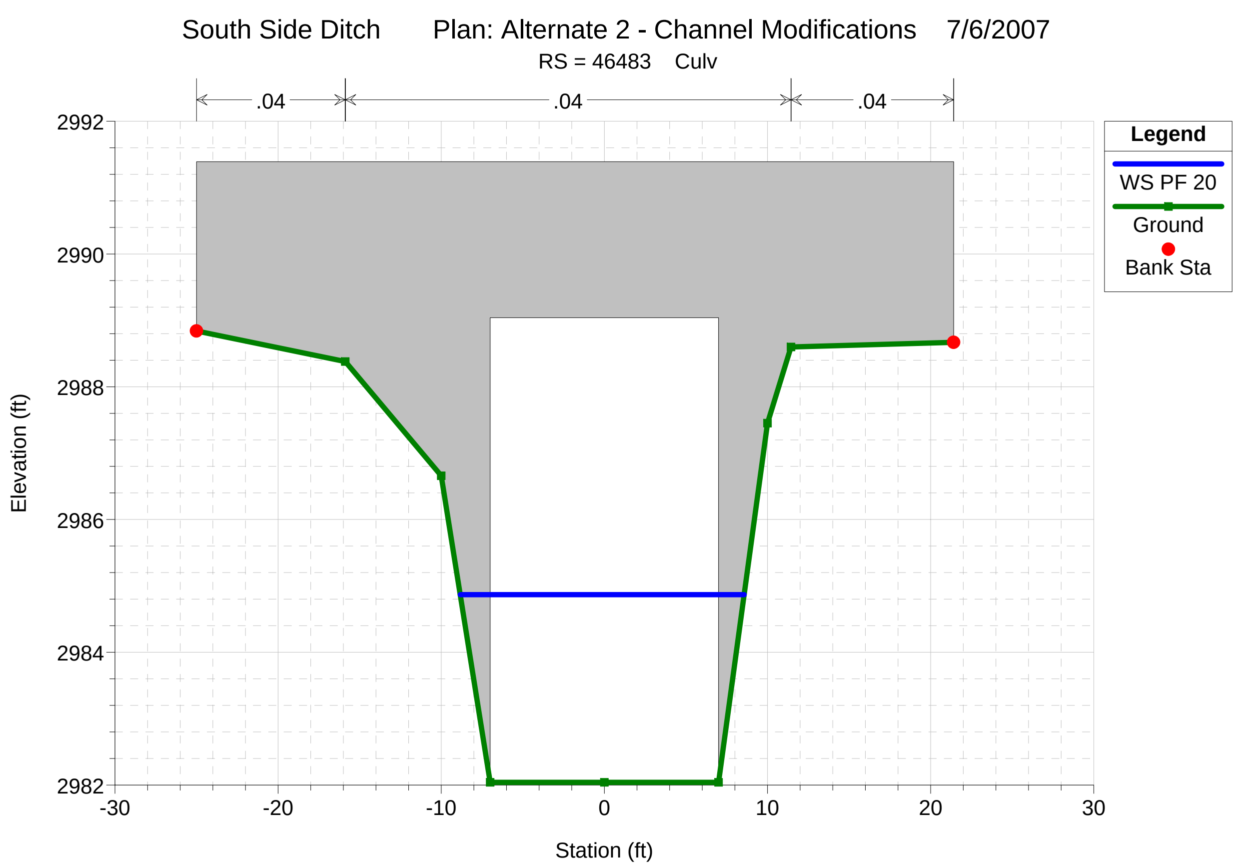


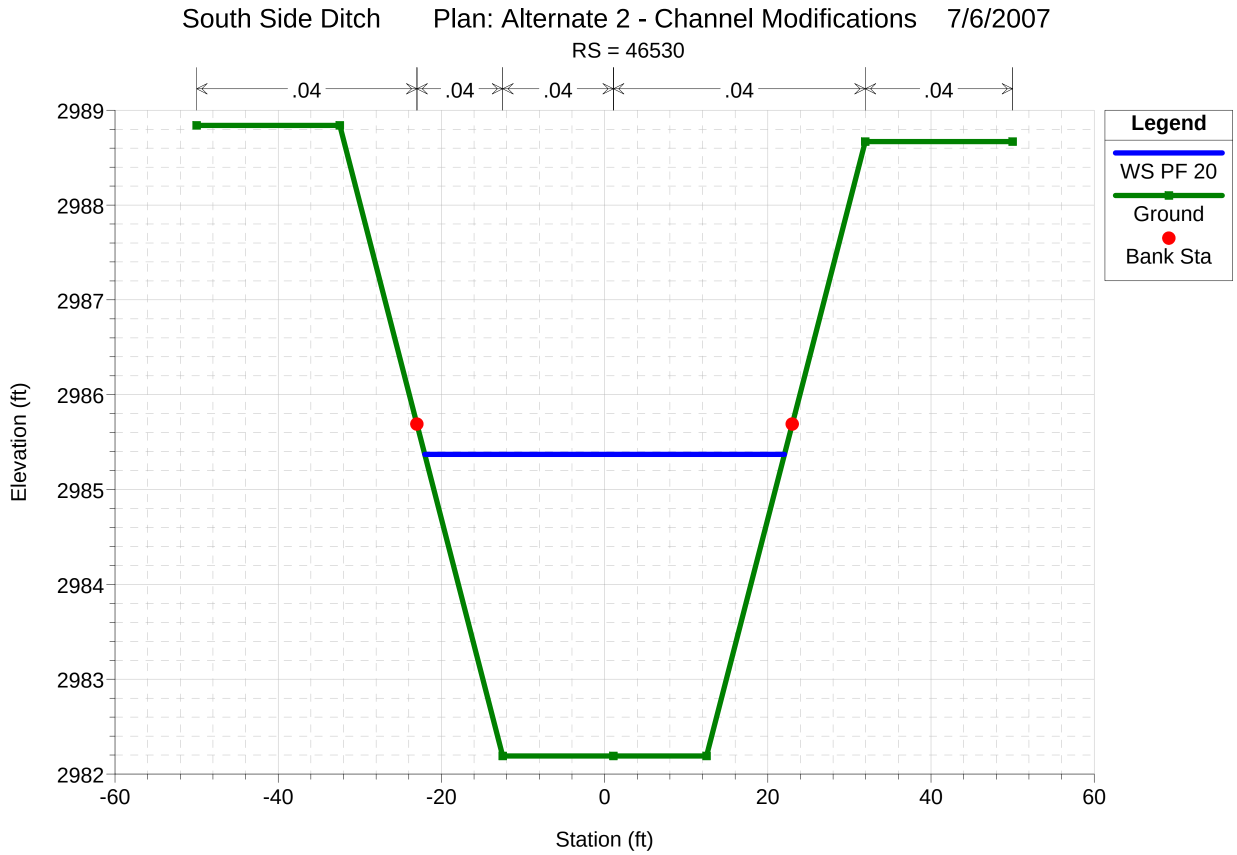
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 40381
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2982
2981
2980
2979
2978
2977
2976
-60
-40
-20
0
20
40
60
Station (ft)

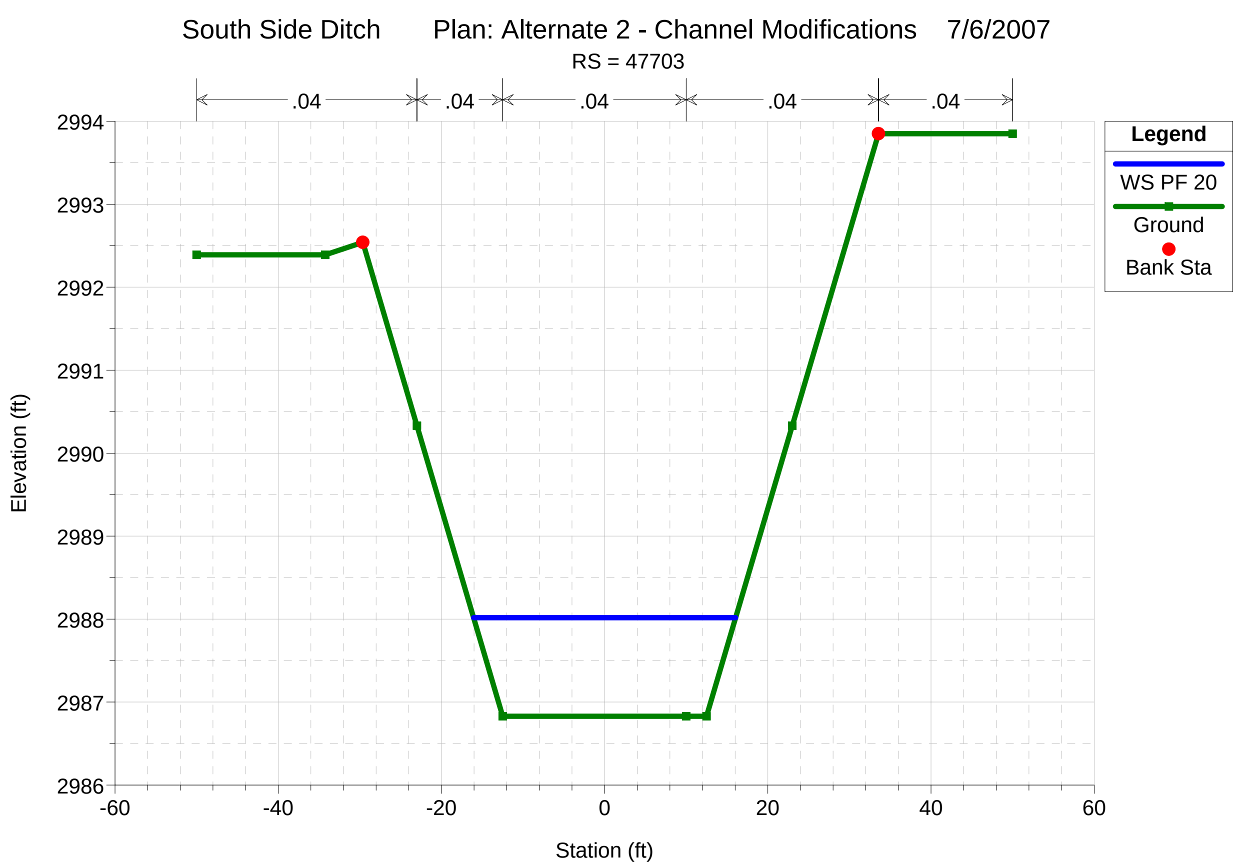

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 41706
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2982
2981
2980
2979
2978
2977
-60
-40
-20
0
20
40
60
Station (ft)

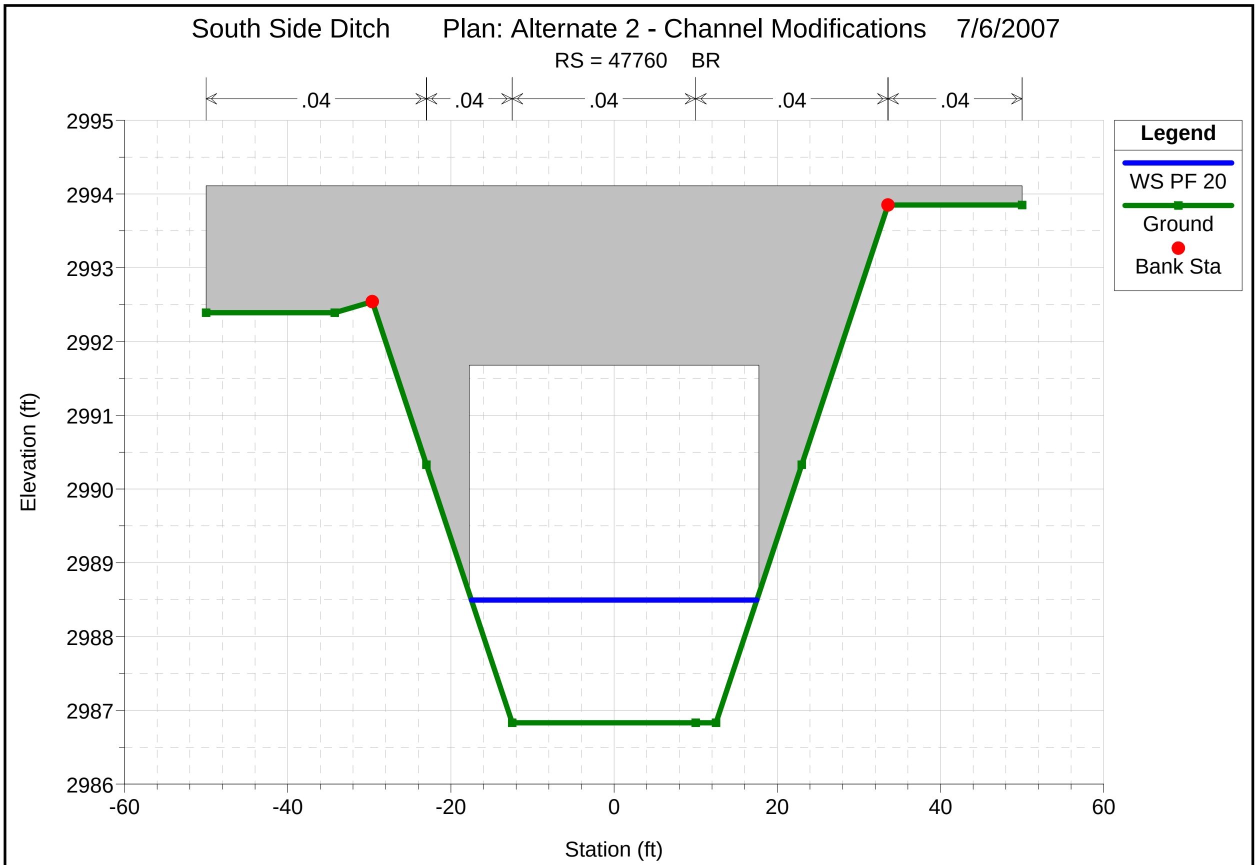

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 46436
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2989
2988
2987
2986
2985
2984
2983
2982
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 46483 Culv
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2992
2990
2988
2986
2984
2982
-30
-20
-10
0
10
20
30
Station (ft)

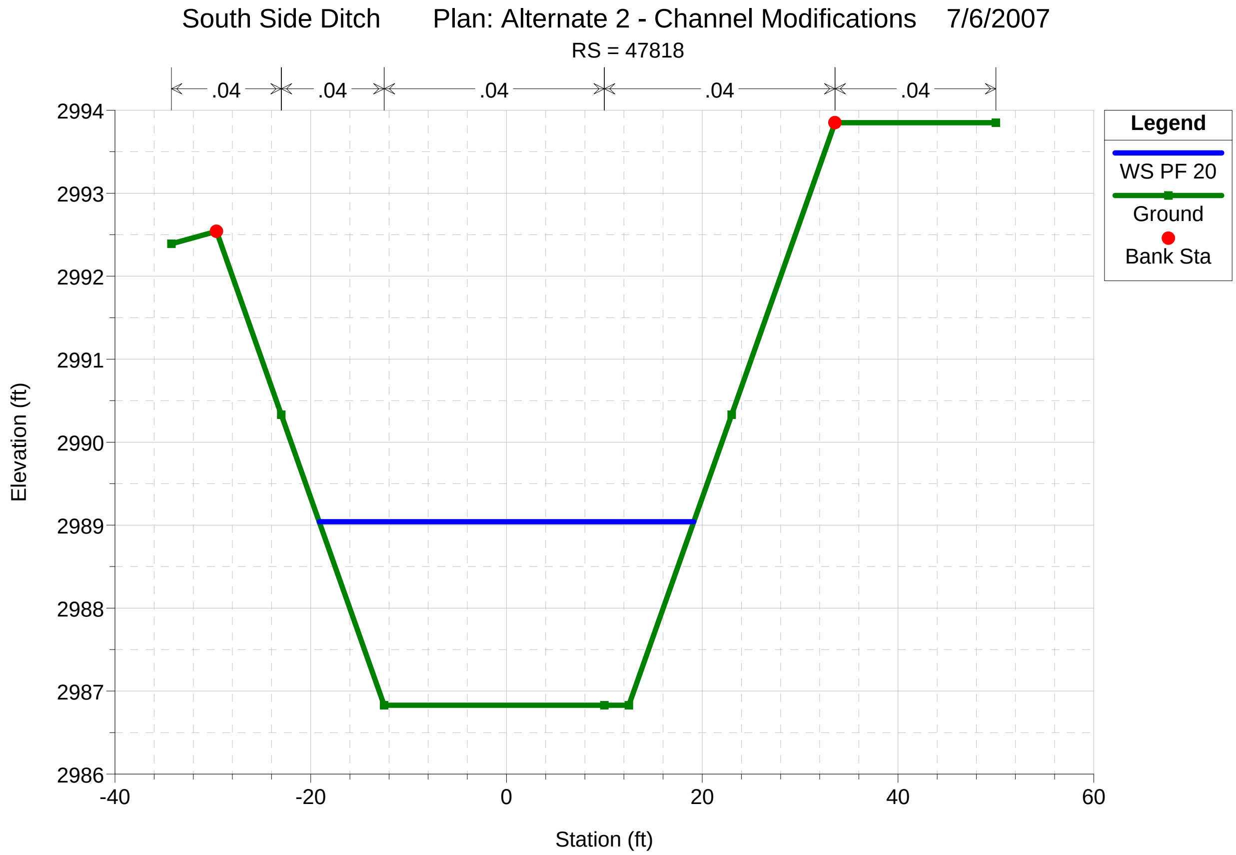

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 46483 Culv
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2992
2990
2988
2986
2984
2982
-30
-20
-10
0
10
20
30
Station (ft)

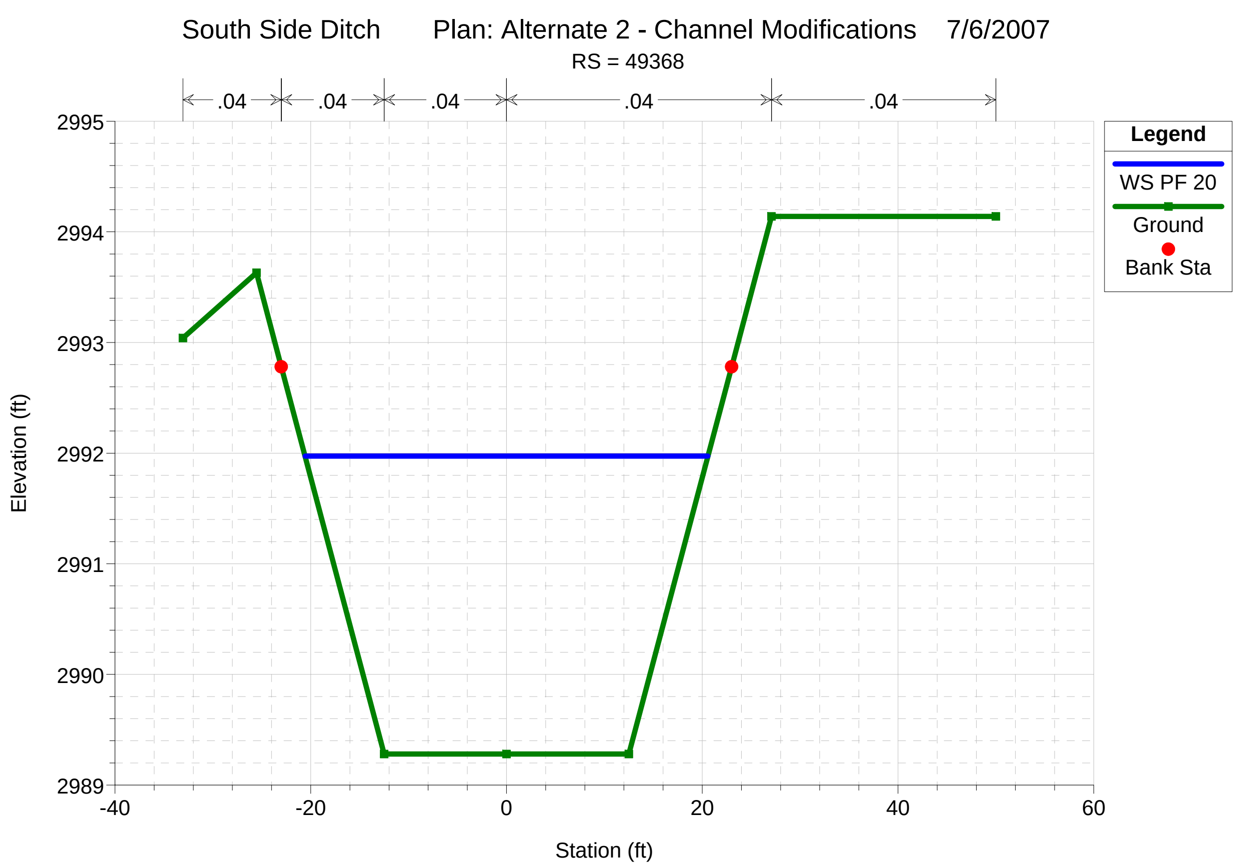

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 46530
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2989
2988
2987
2986
2985
2984
2983
2982
-60
-40
-20
0
20
40
60
Station (ft)

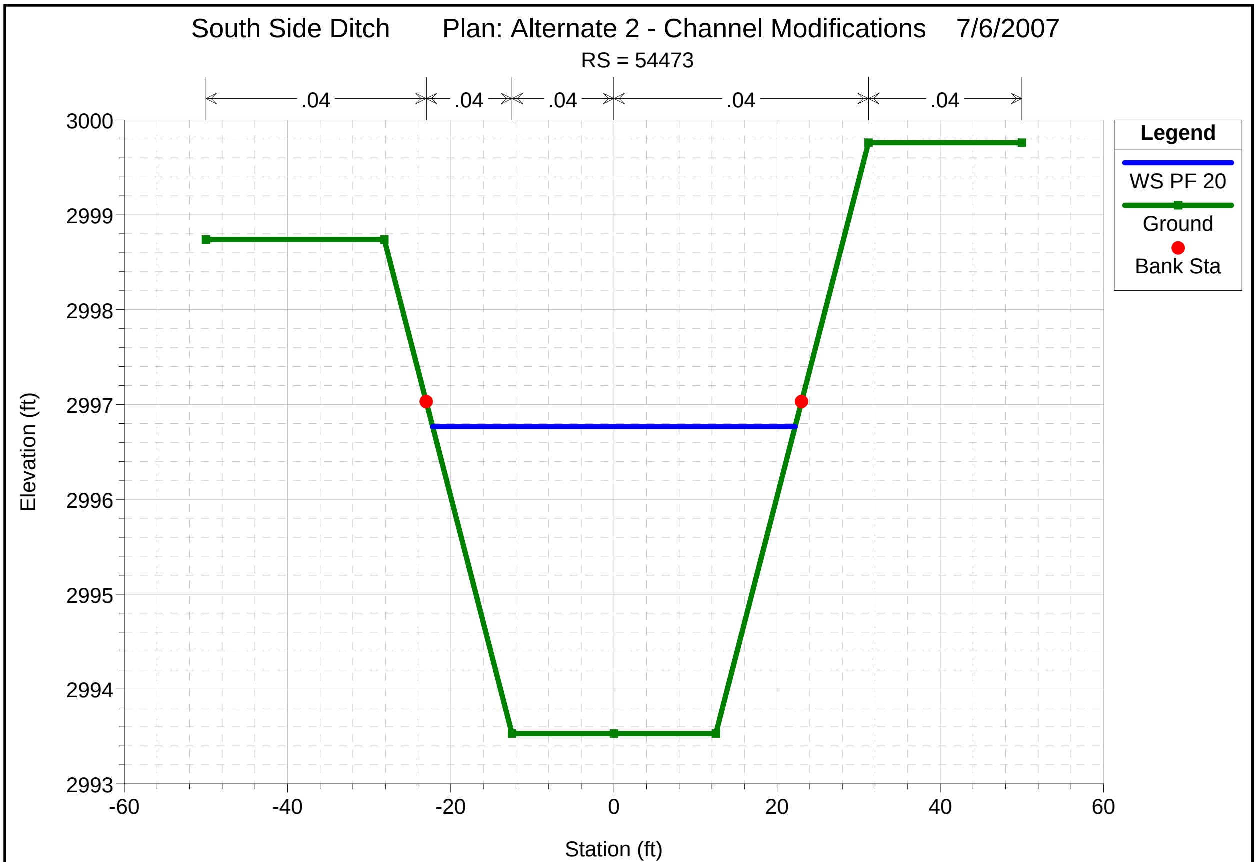

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 47703
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2994
2993
2992
2991
2990
2989
2988
2987
2986
-60
-40
-20
0
20
40
60
Station (ft)

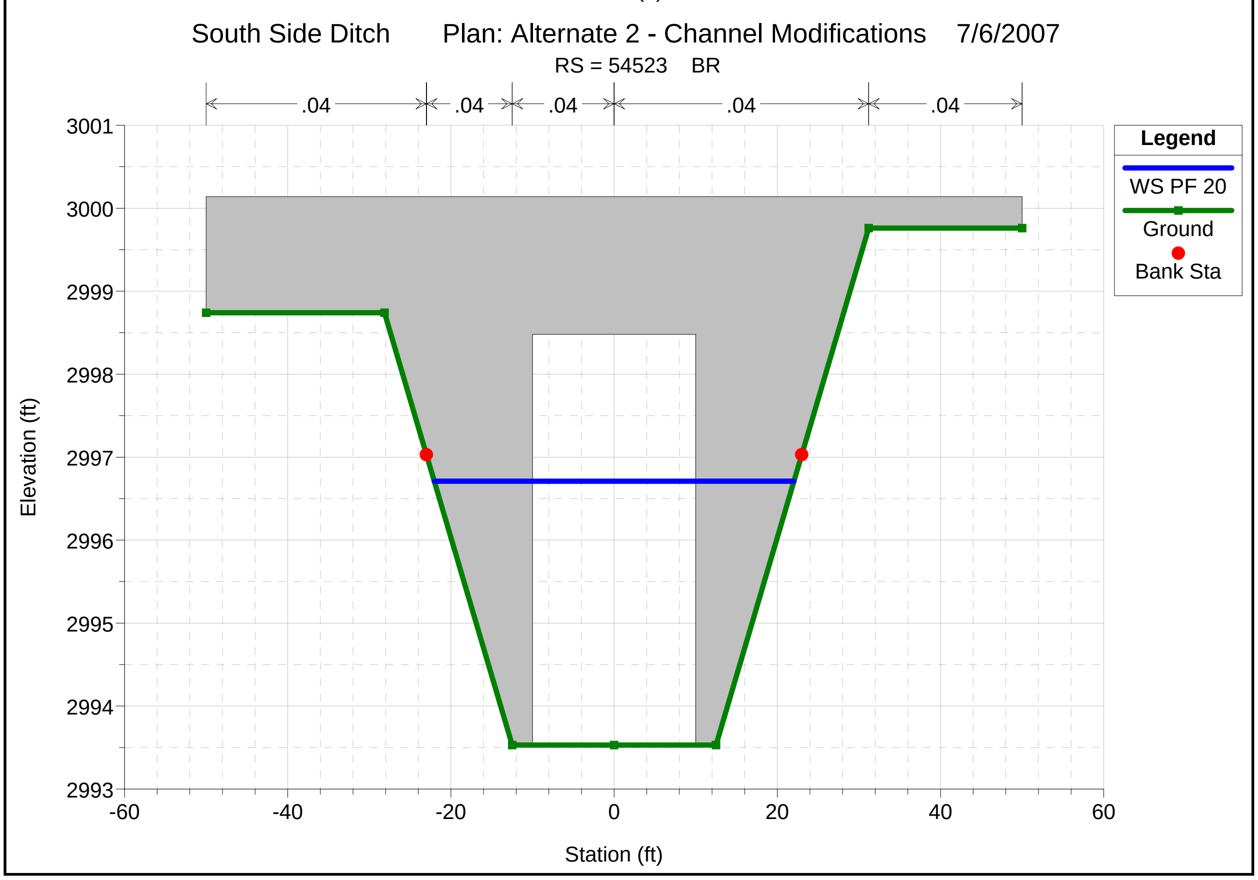

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 47760 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2995
2994
2993
2992
2991
2990
2989
2988
2987
2986
-60
-40
-20
0
20
40
60
Station (ft)

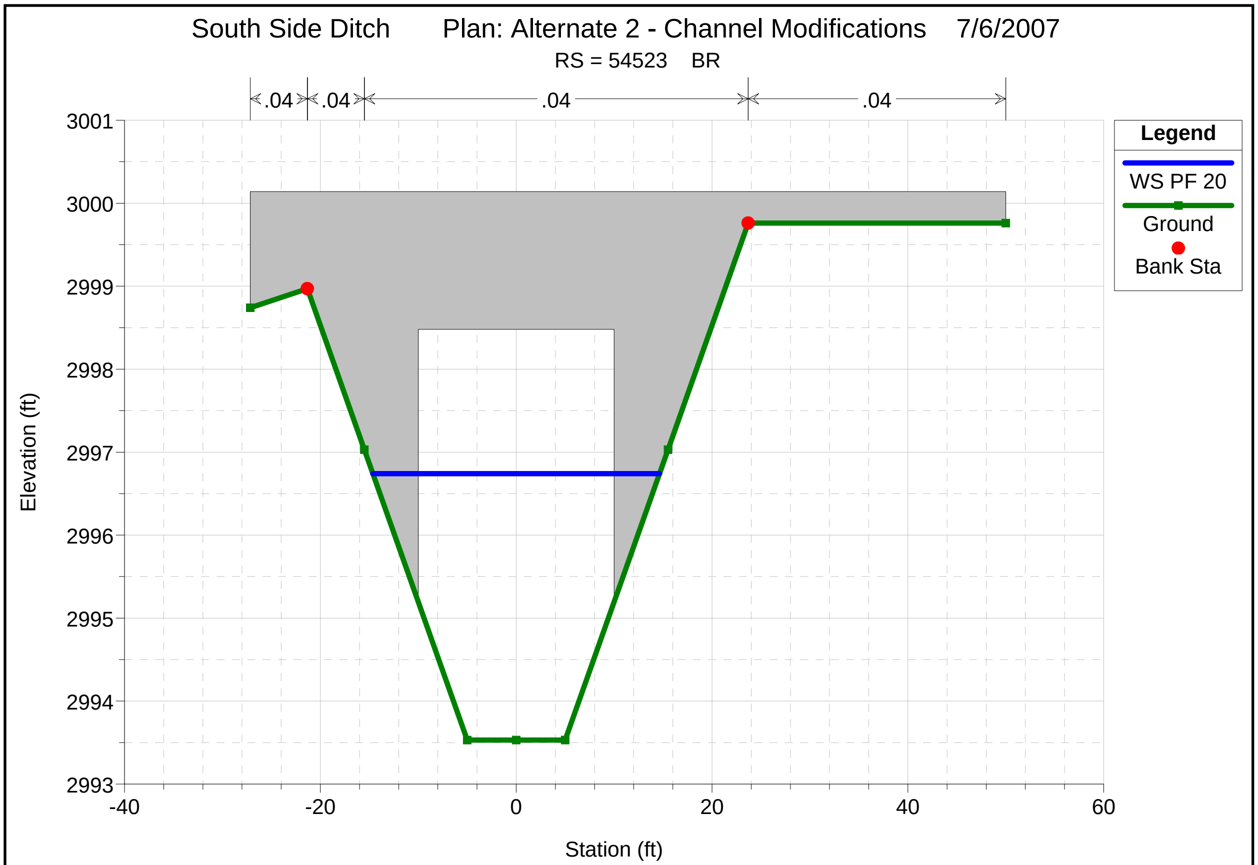

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 47760 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2995
2994
2993
2992
2991
2990
2989
2988
2987
2986
-40
-20
0
20
40
60
Station (ft)

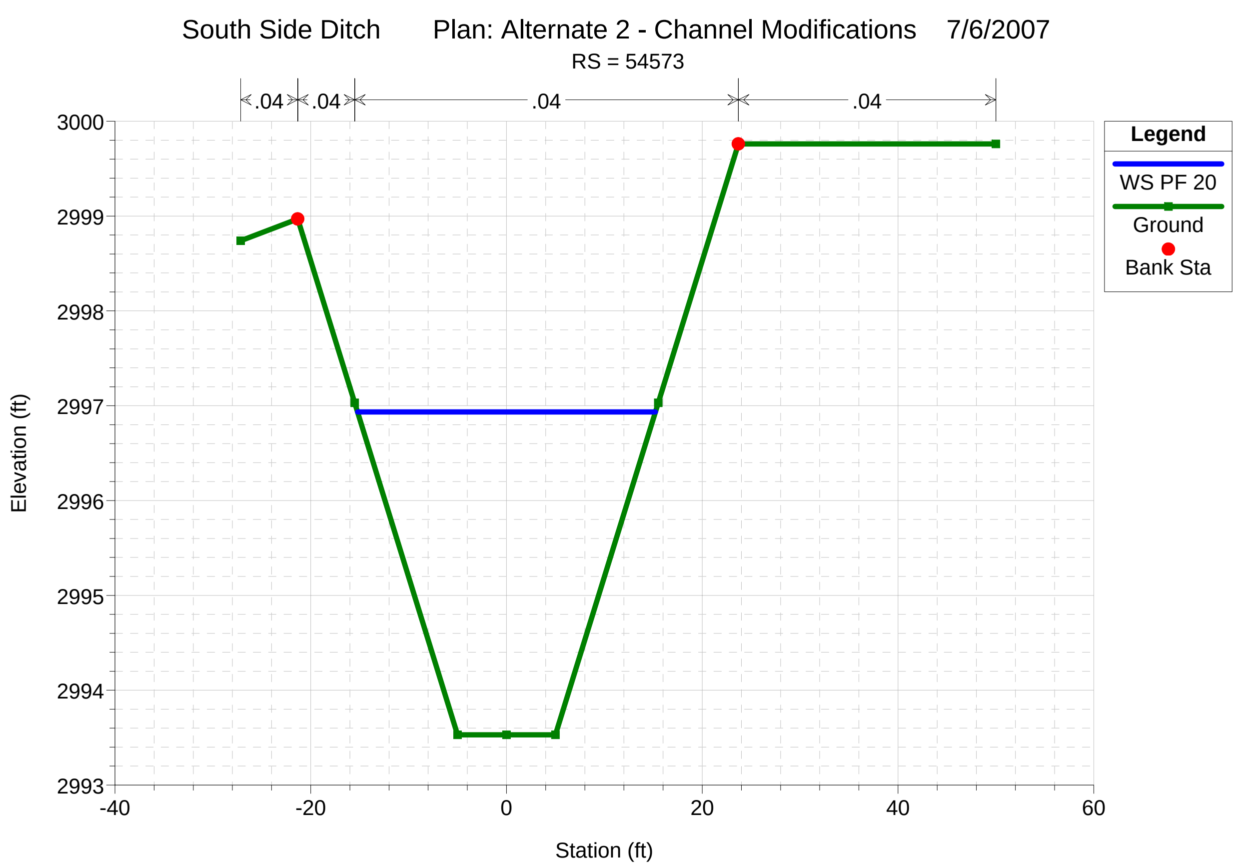

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 47818
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2994
2993
2992
2991
2990
2989
2988
2987
2986
-40
-20
0
20
40
60
Station (ft)

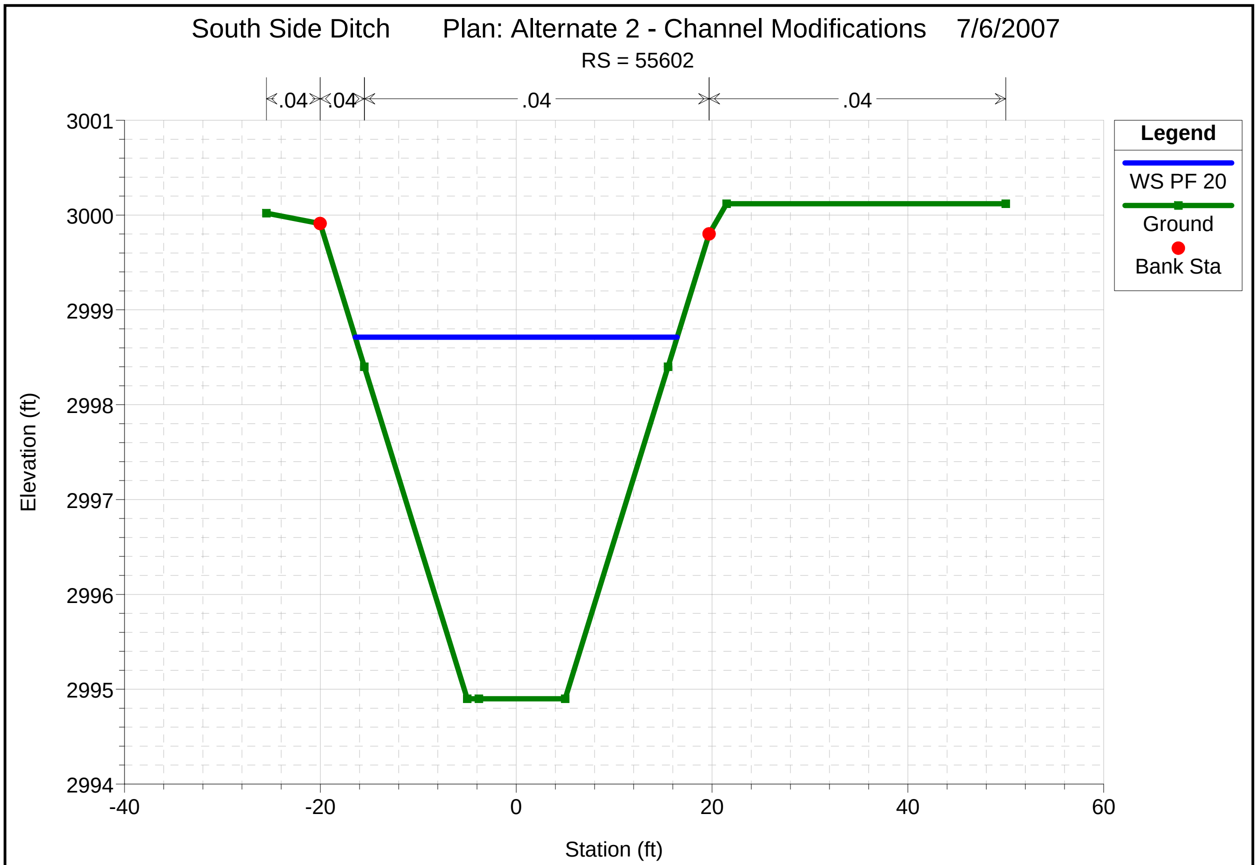

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 49368
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2995
2994
2993
2992
2991
2990
2989
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 54473
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3000
2999
2998
2997
2996
2995
2994
2993
-60
-40
-20
0
20
40
60
Station (ft)

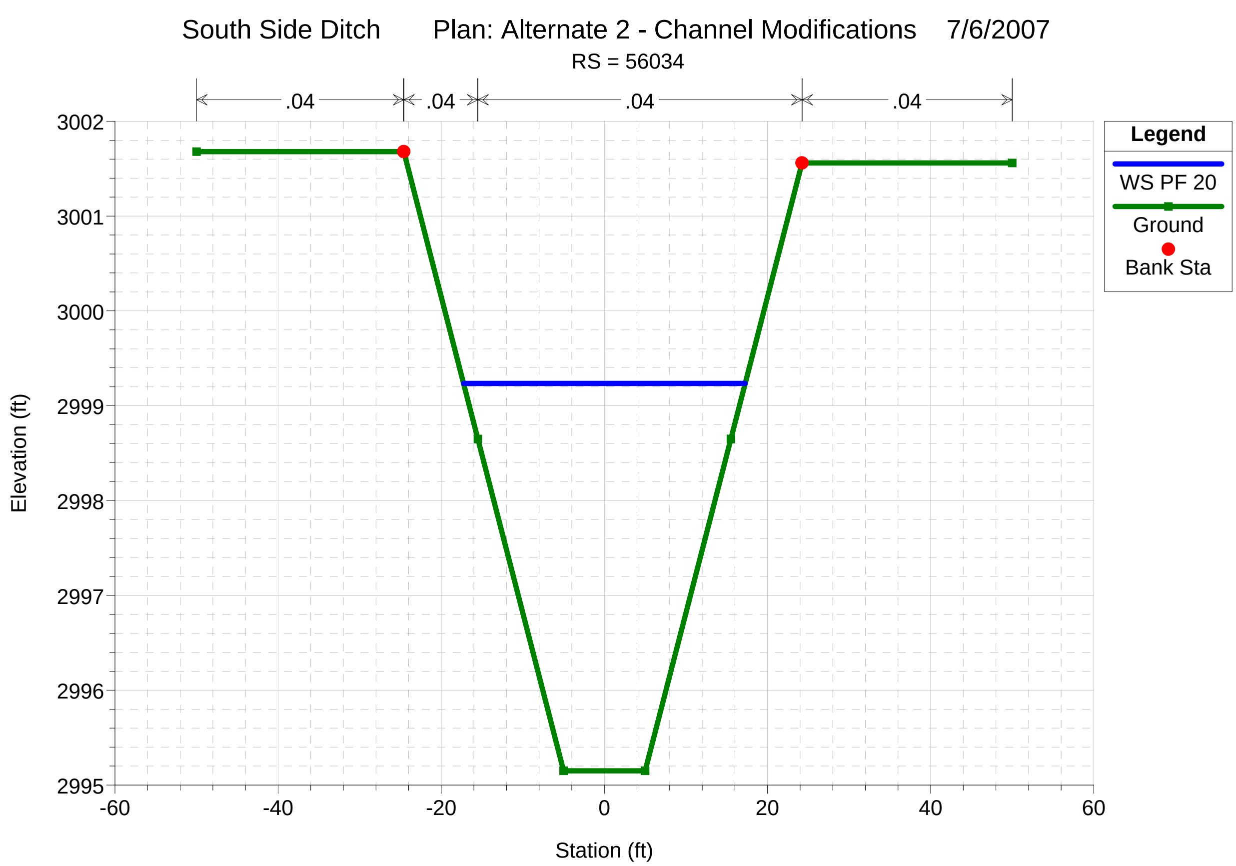

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 54523 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3001
3000
2999
2998
2997
2996
2995
2994
2993
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 54523 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3001
3000
2999
2998
2997
2996
2995
2994
2993
-40
-20
0
20
40
60
Station (ft)

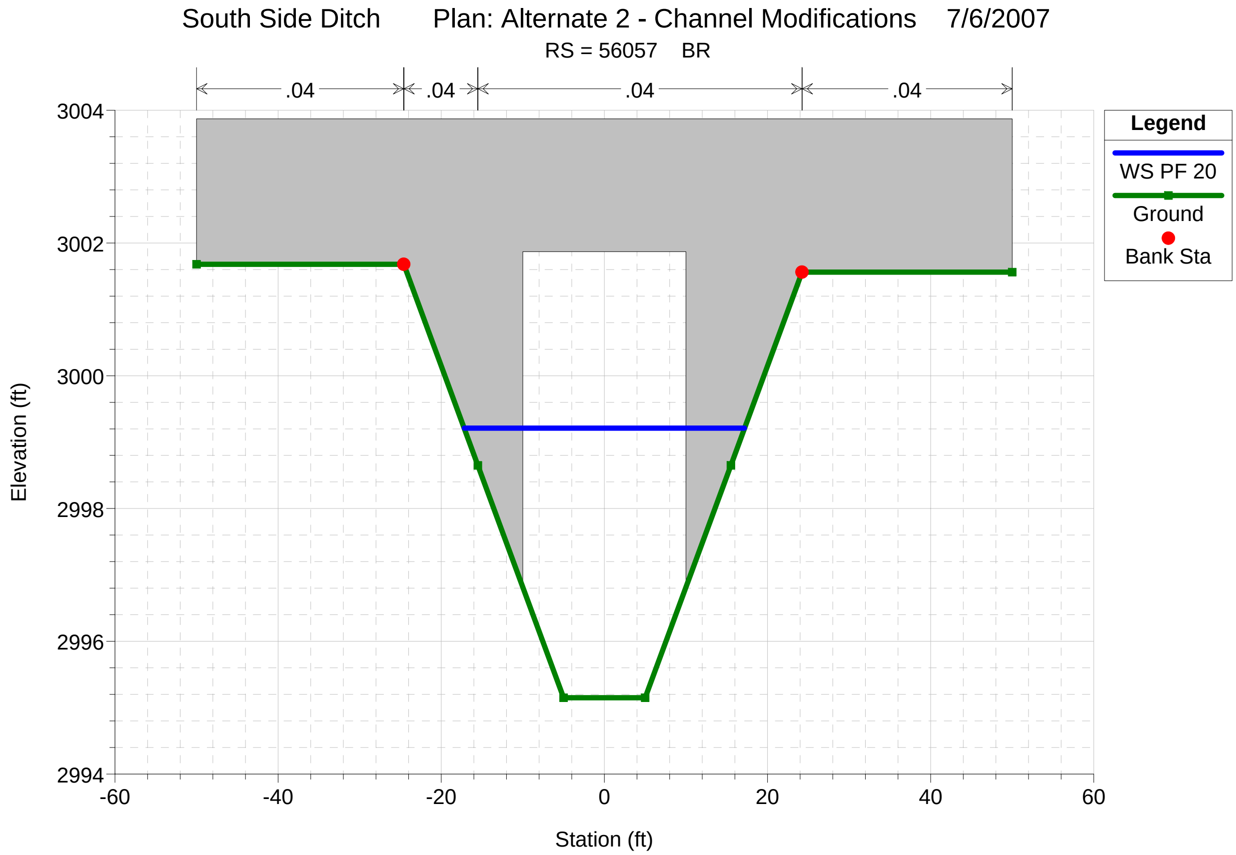

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 54573
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3000
2999
2998
2997
2996
2995
2994
2993
-40
-20
0
20
40
60
Station (ft)

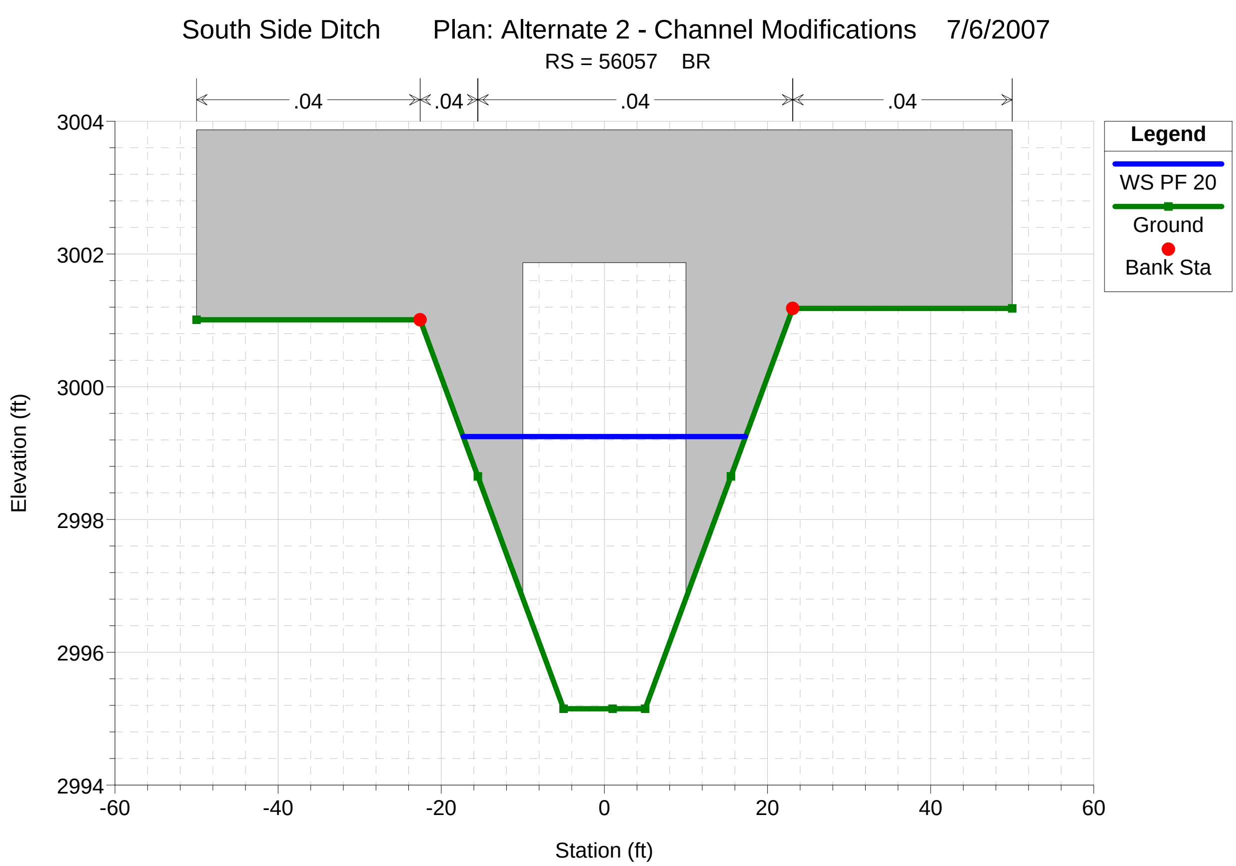


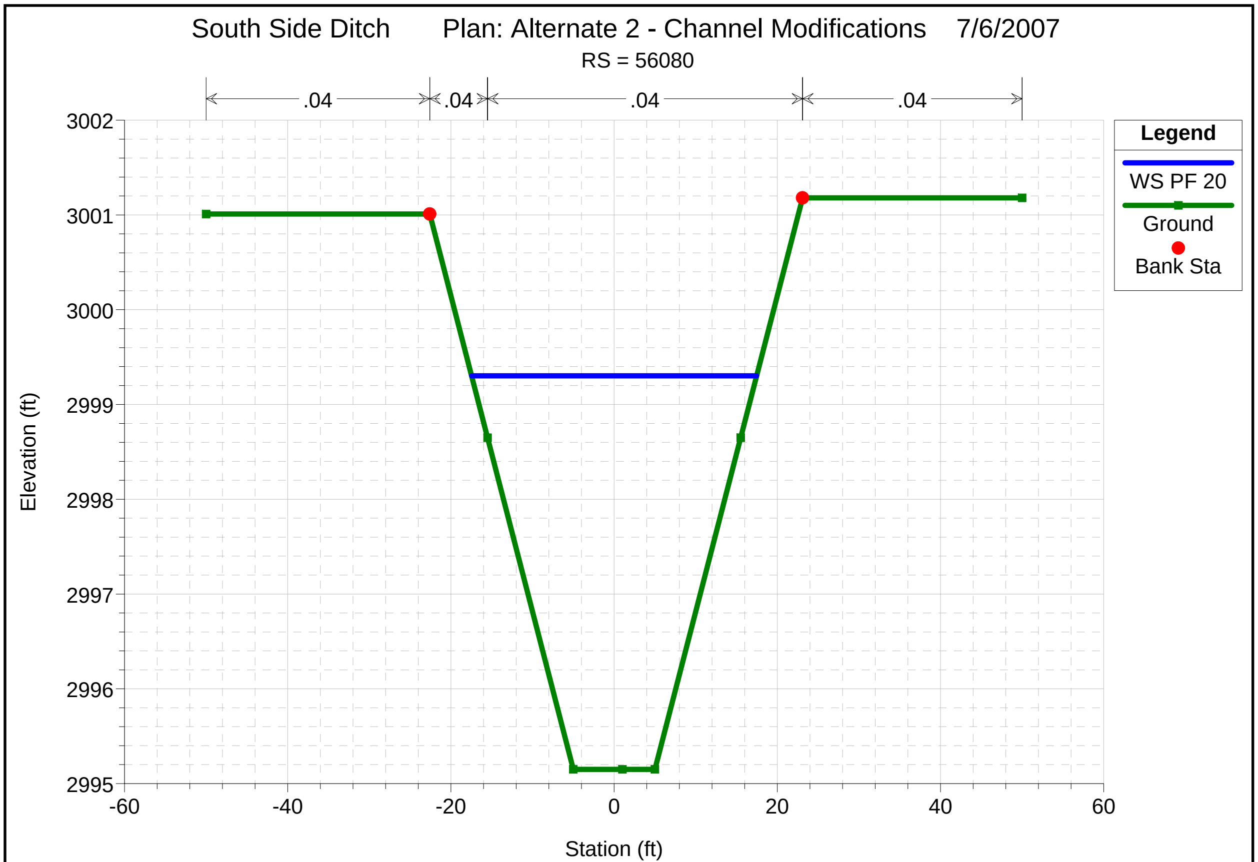
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 55602
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3001
3000
2999
2998
2997
2996
2995
2994
-40
-20
0
20
40
60
Station (ft)

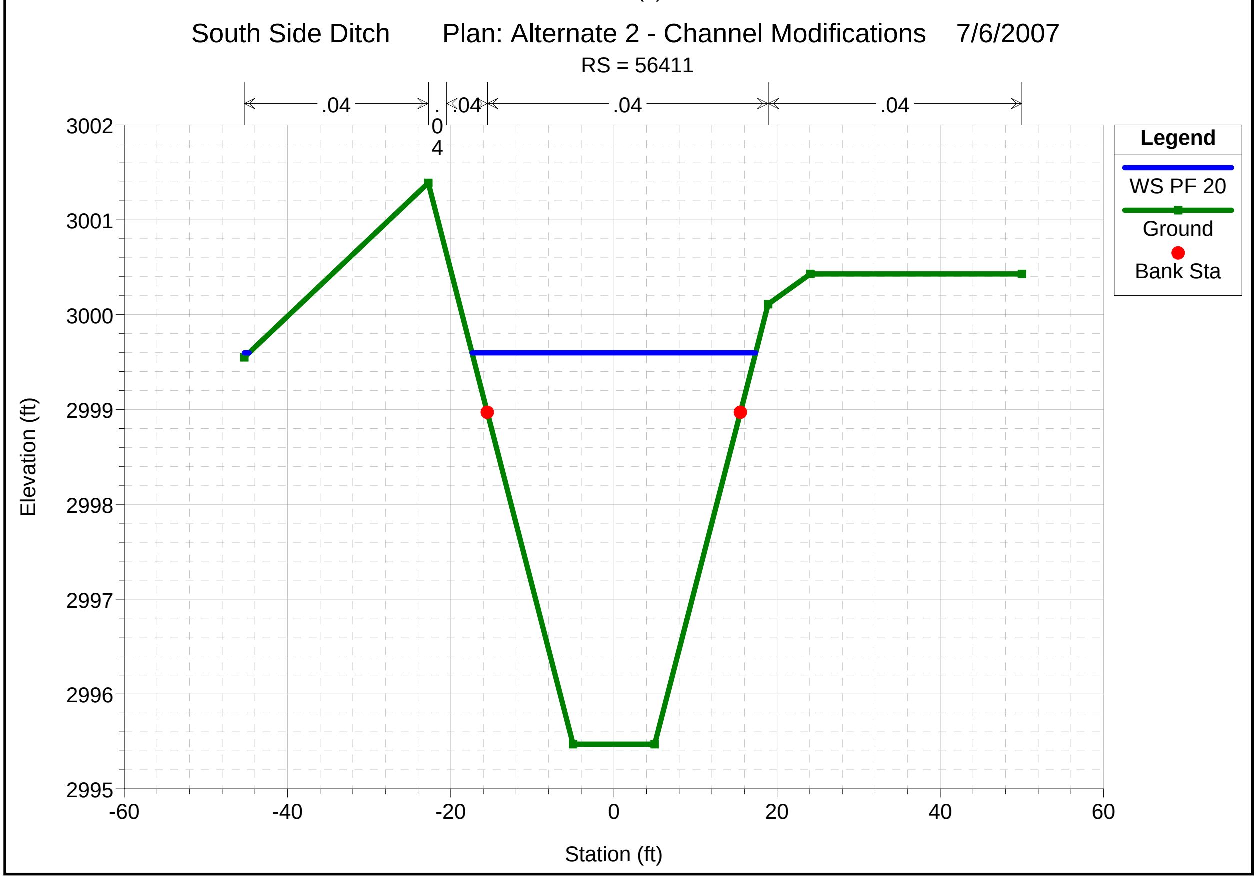


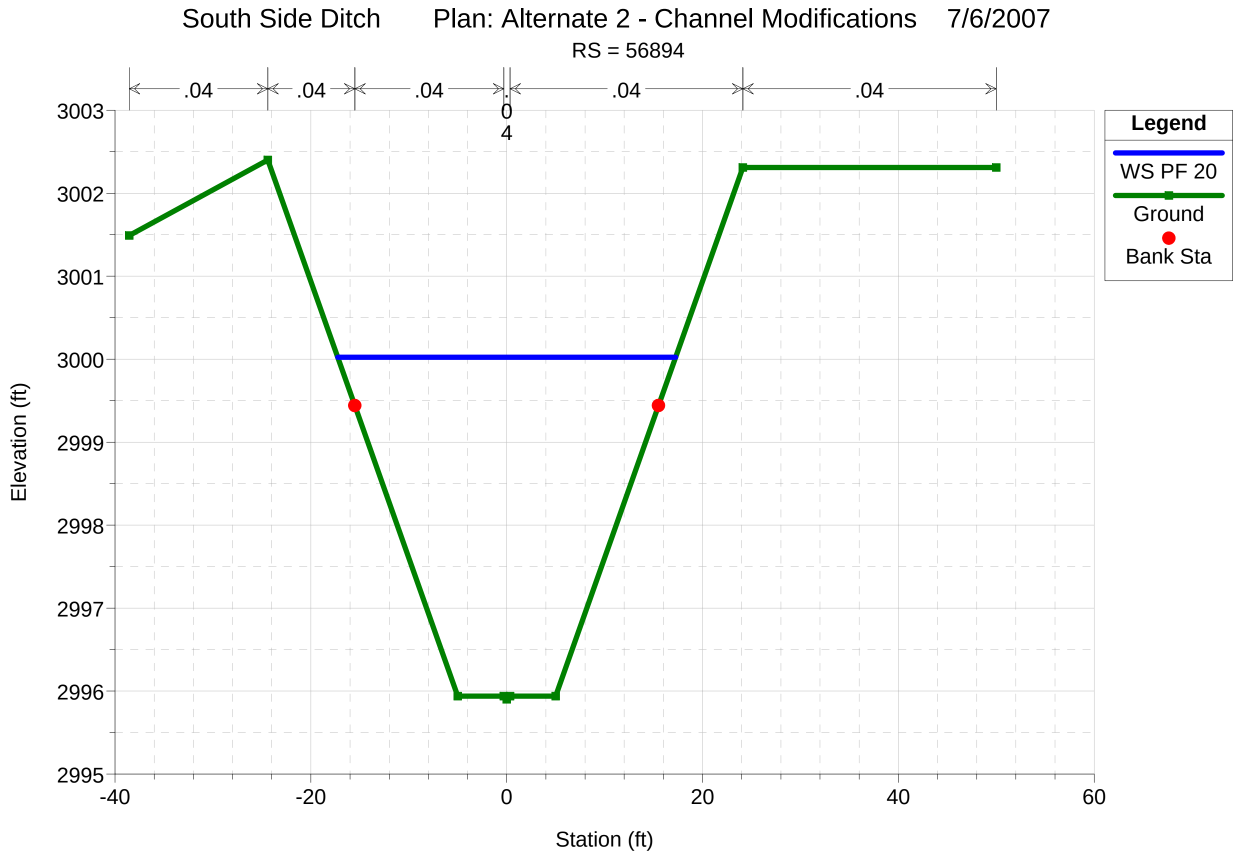
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 56034
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3002
3001
3000
2999
2998
2997
2996
2995
-60
-40
-20
0
20
40
60
Station (ft)

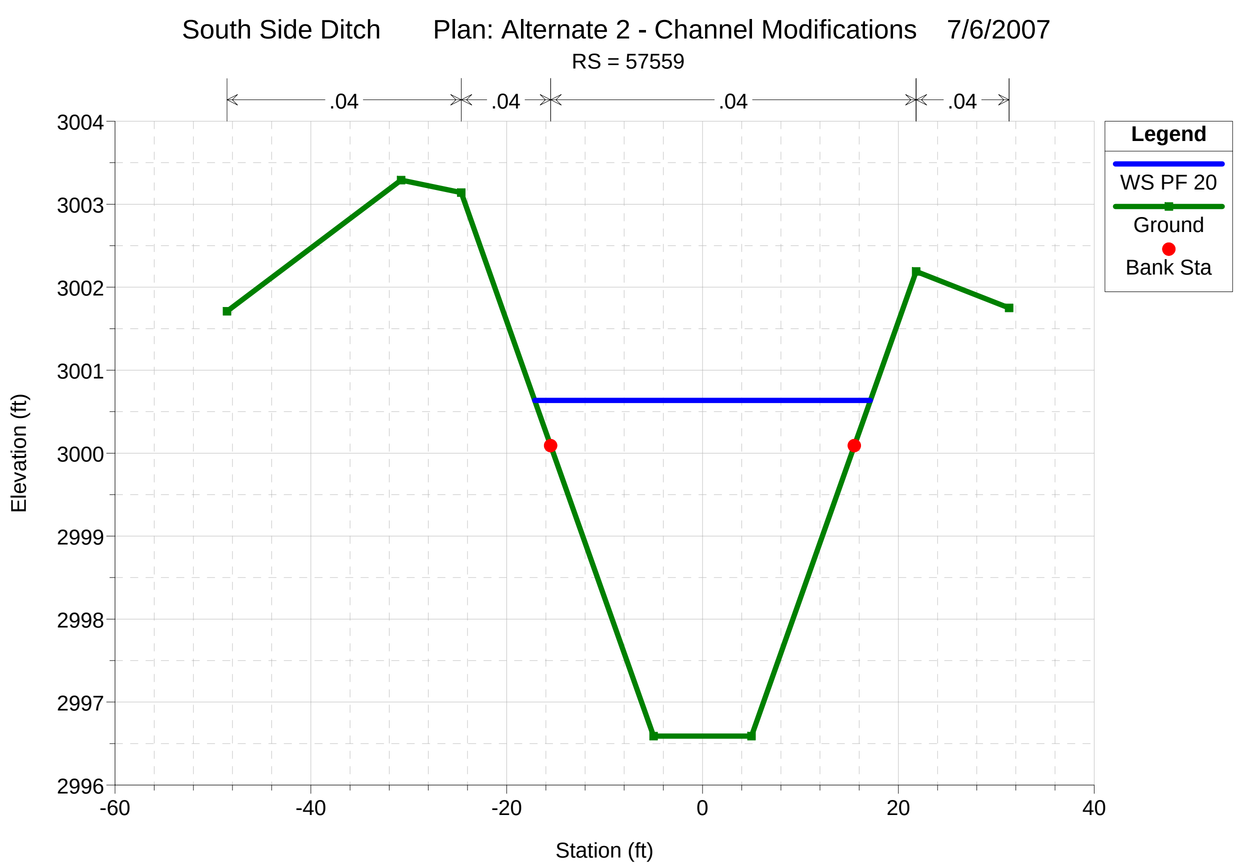

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 56057 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3004
3002
3000
2998
2996
2994
Station (ft)
-60
-40
-20
0
20
40
60

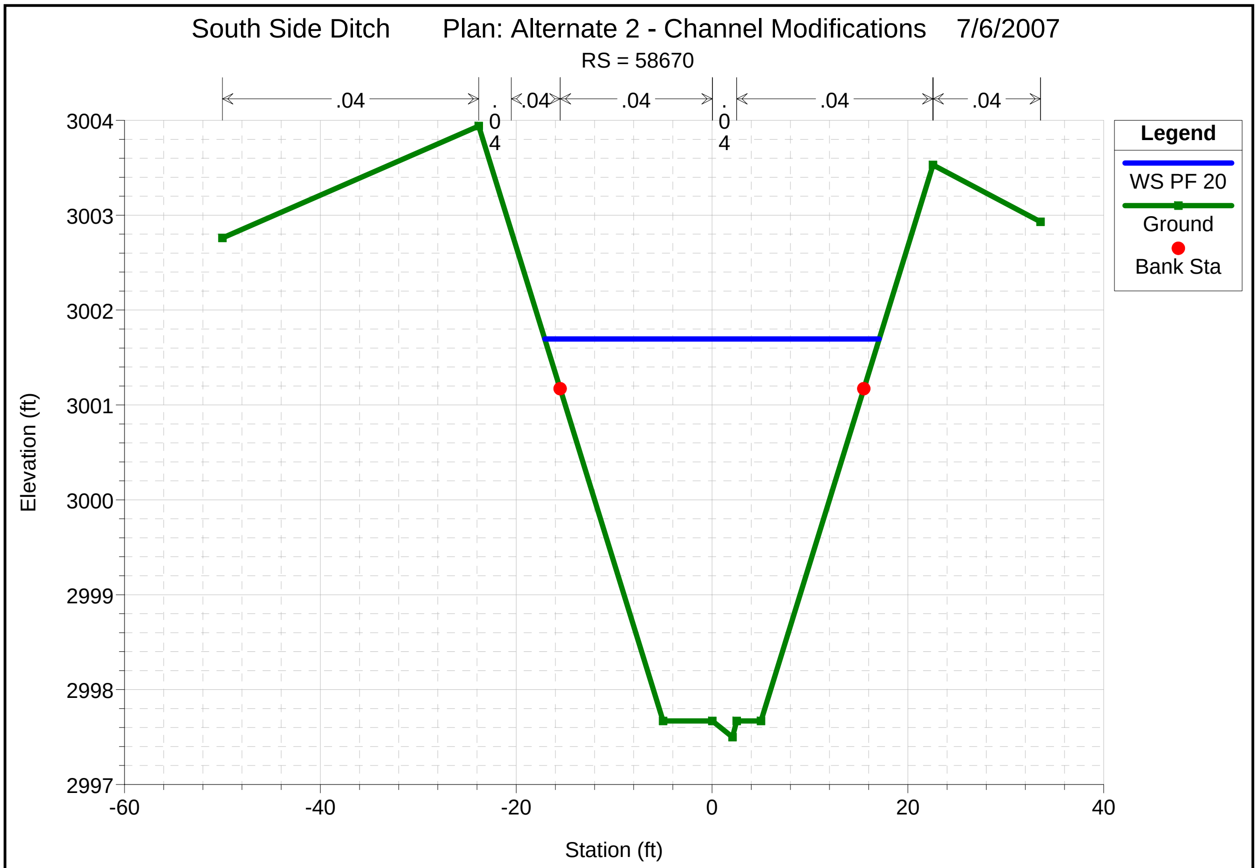

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 56057 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3004
3002
3000
2998
2996
2994
Station (ft)
-60
-40
-20
0
20
40
60


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 56080
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3002
3001
3000
2999
2998
2997
2996
2995
-60
-40
-20
0
20
40
60
Station (ft)

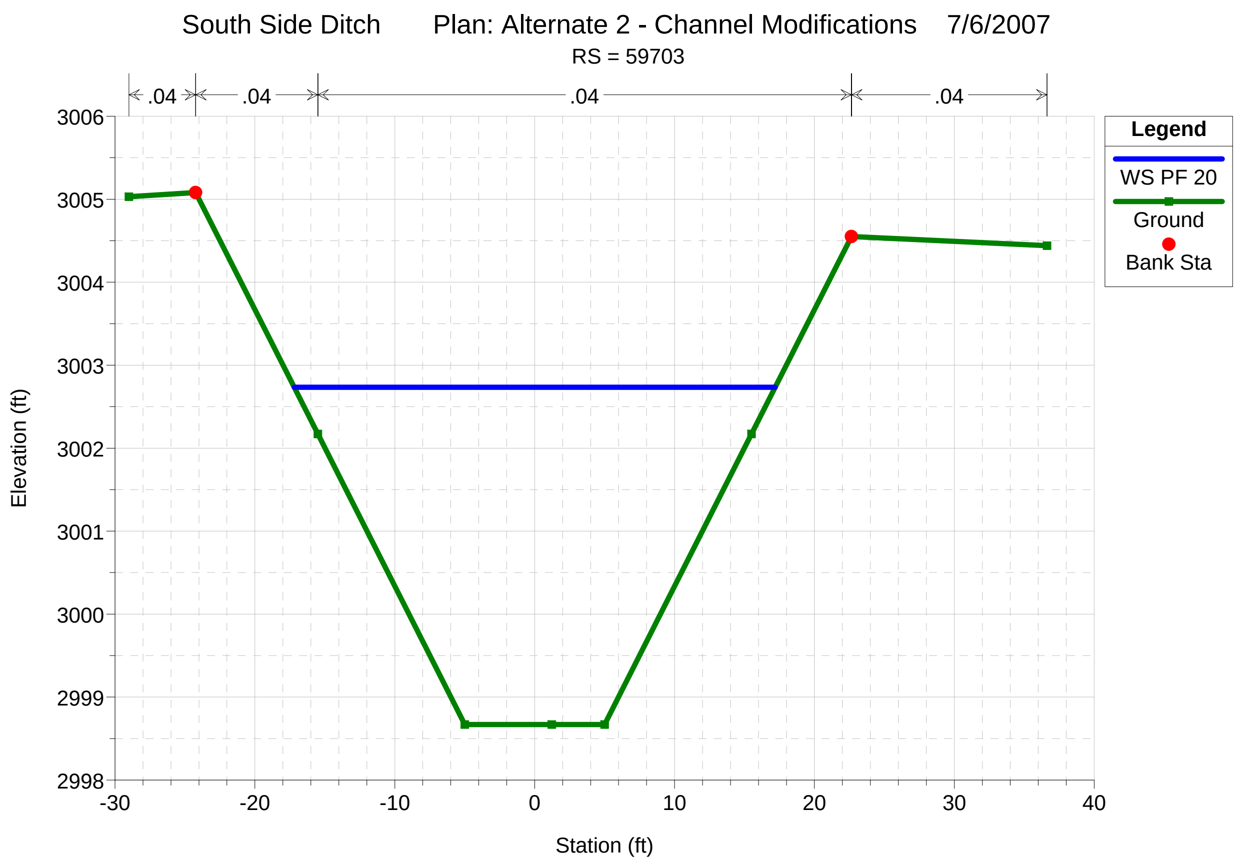

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 56411
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3002
3001
3000
2999
2998
2997
2996
2995
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 56894
.04
.04
.04
0
4
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3003
3002
3001
3000
2999
2998
2997
2996
2995
-40
-20
0
20
40
60
Station (ft)

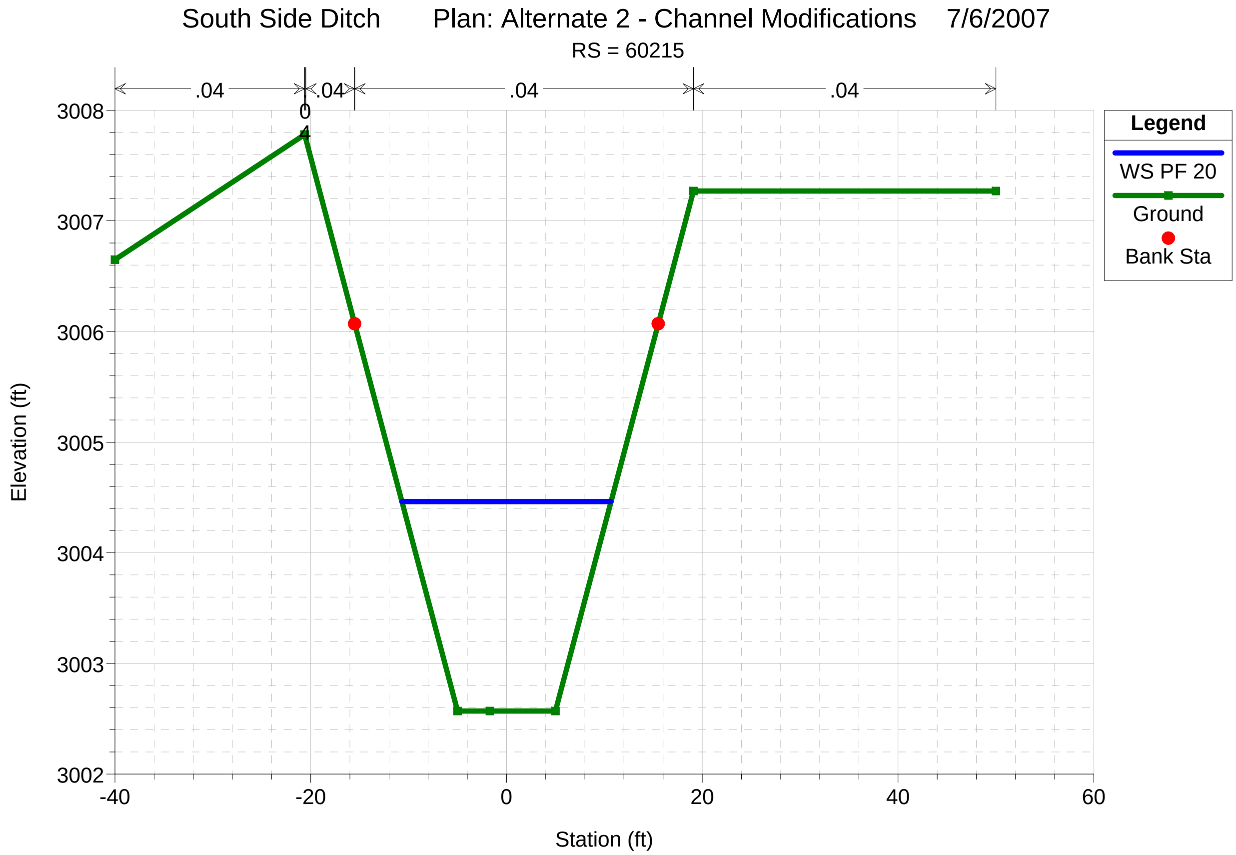

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 57559
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3004
3003
3002
3001
3000
2999
2998
2997
2996
-60
-40
-20
0
20
40
Station (ft)

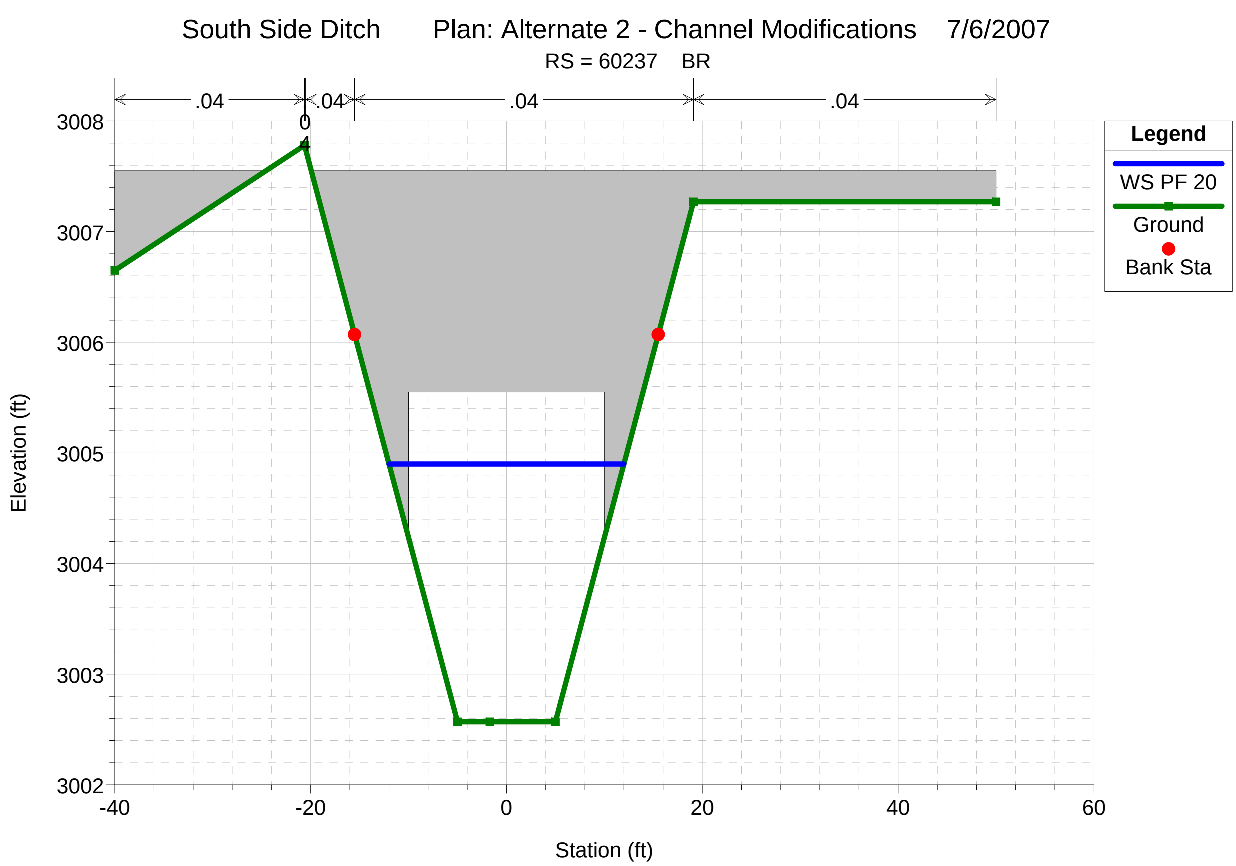


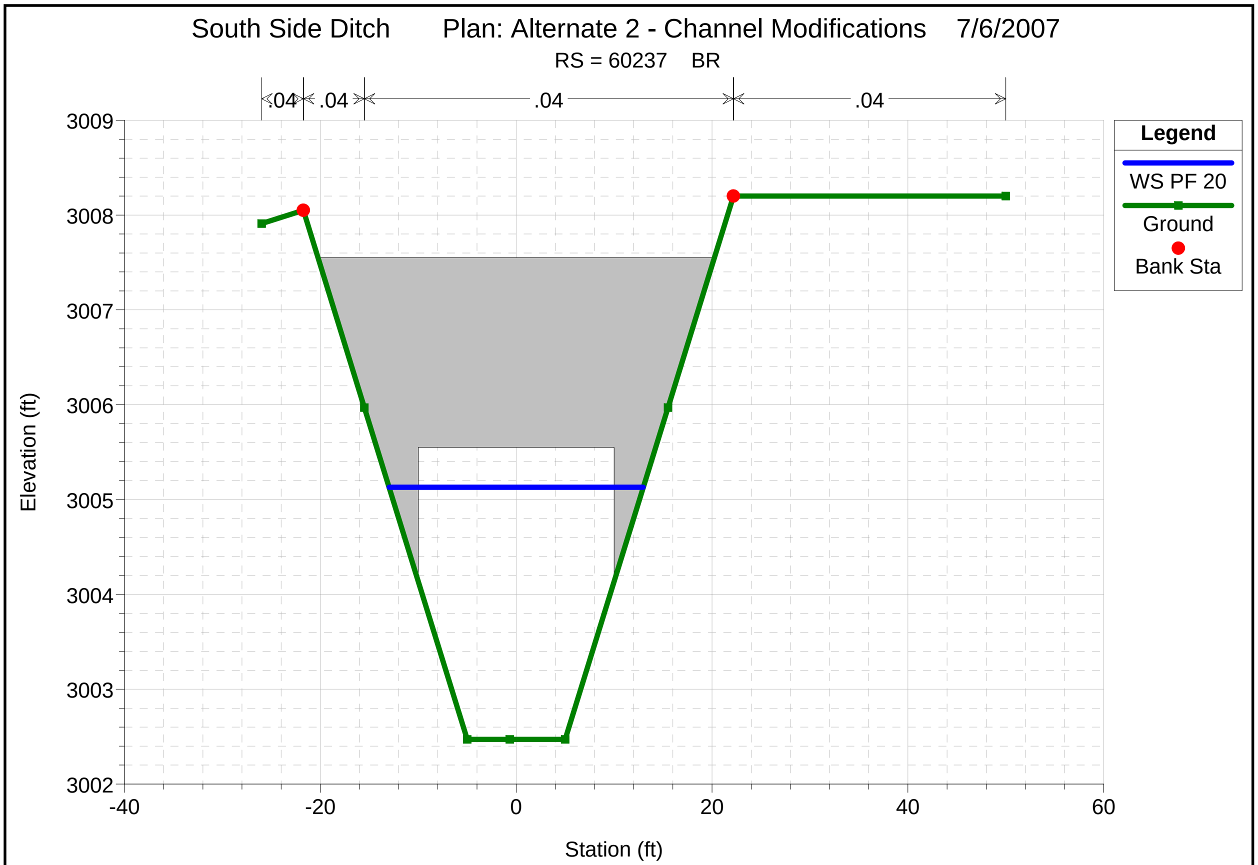
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 58670
.04
.04
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3004
3003
3002
3001
3000
2999
2998
2997
-60
-40
-20
0
20
40
Station (ft)

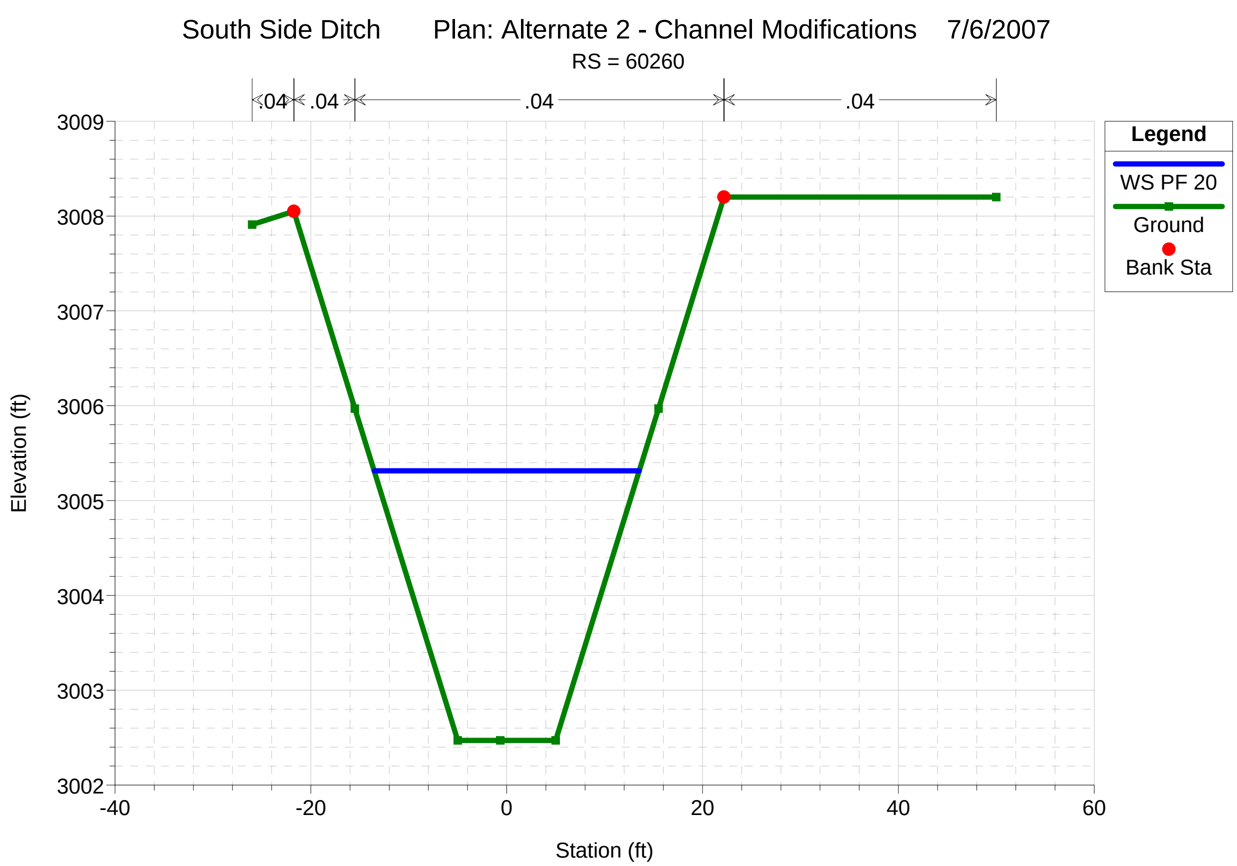


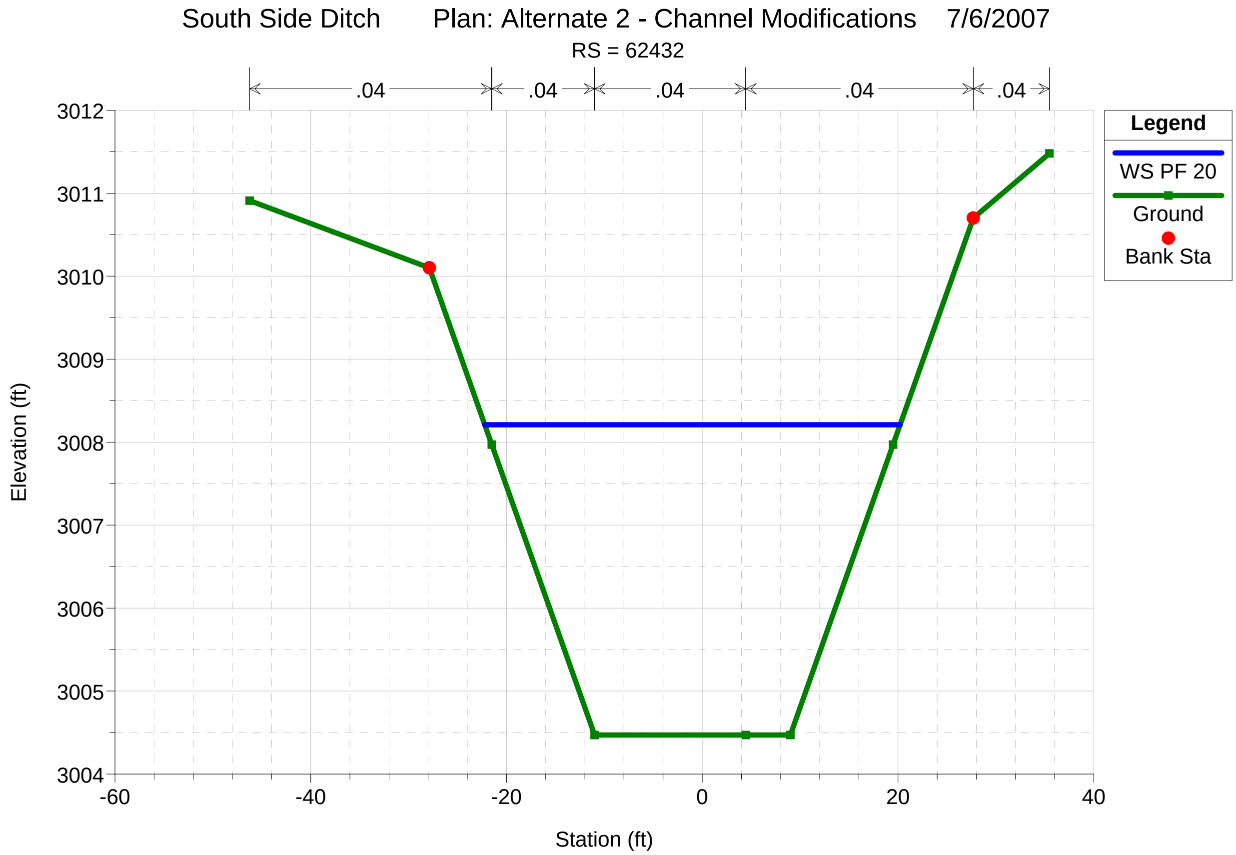
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 59703
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3006
3005
3004
3003
3002
3001
3000
2999
2998
-30
-20
-10
0
10
20
30
40
Station (ft)

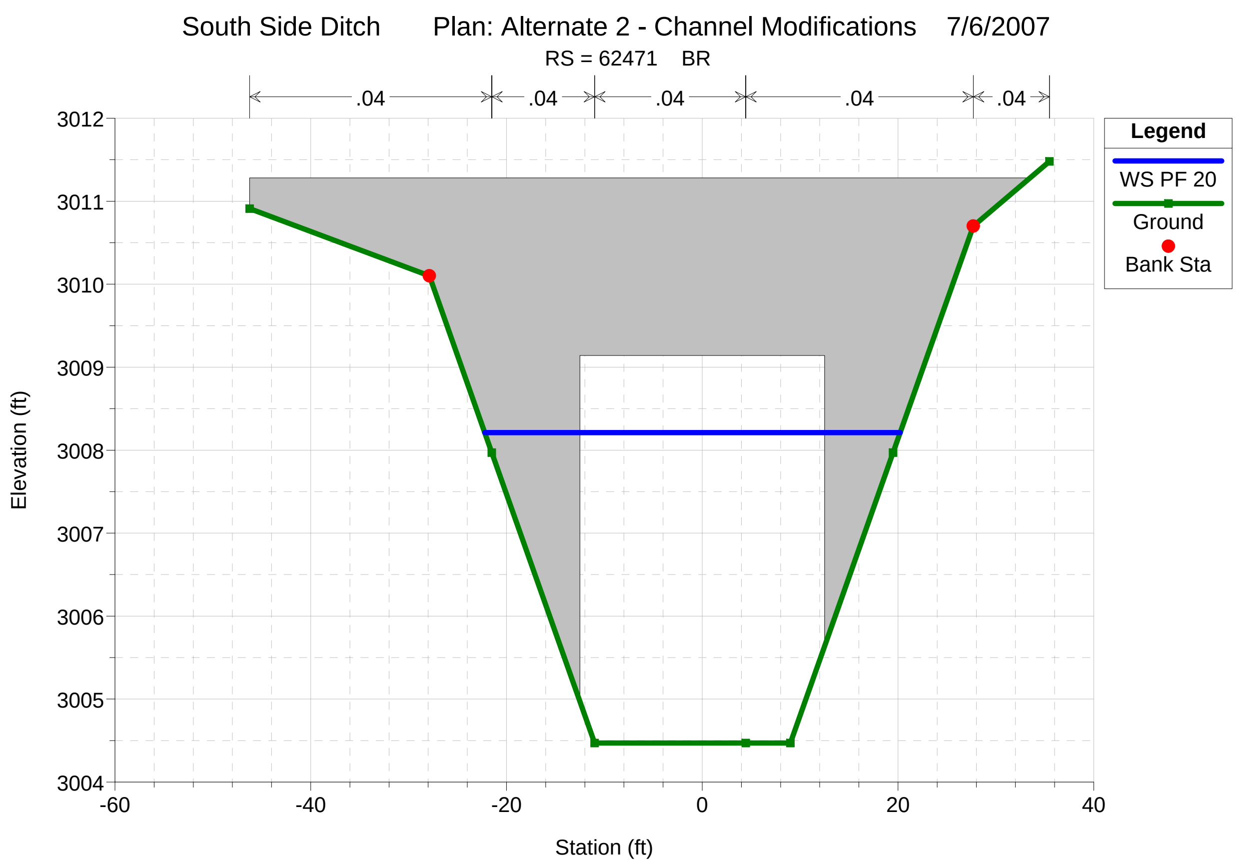

South Side Ditch
Plan: Alternate 2 - Channel Modifications
7/6/2007
RS = 60215
.04
.04
.04
.04
0
4
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3008
3007
3006
3005
3004
3003
3002
-40
-20
0
20
40
60
Station (ft)

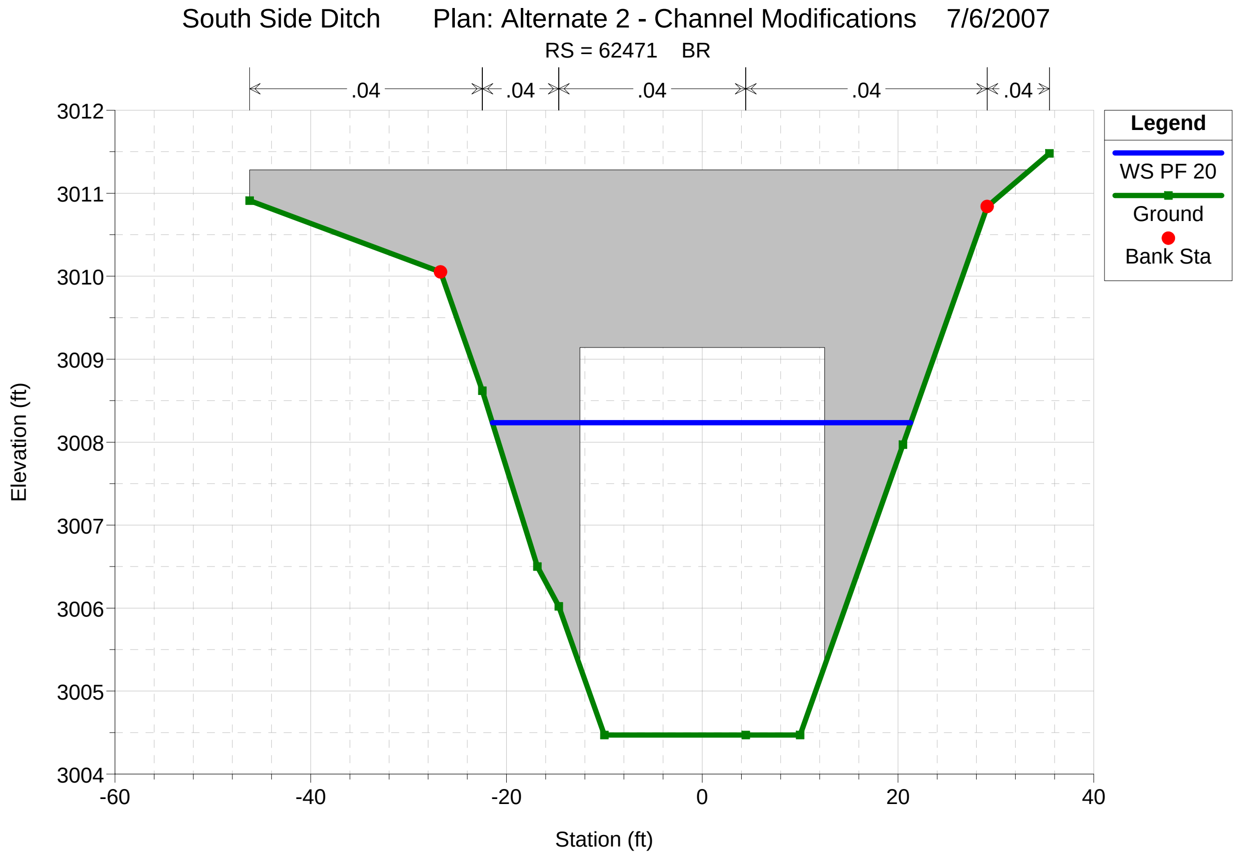

South Side Ditch
Plan: Alternate 2 - Channel Modifications
7/6/2007
RS = 60237 BR
.04
.04
.04
.04
0
4
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3008
3007
3006
3005
3004
3003
3002
-40
-20
0
20
40
60
Station (ft)

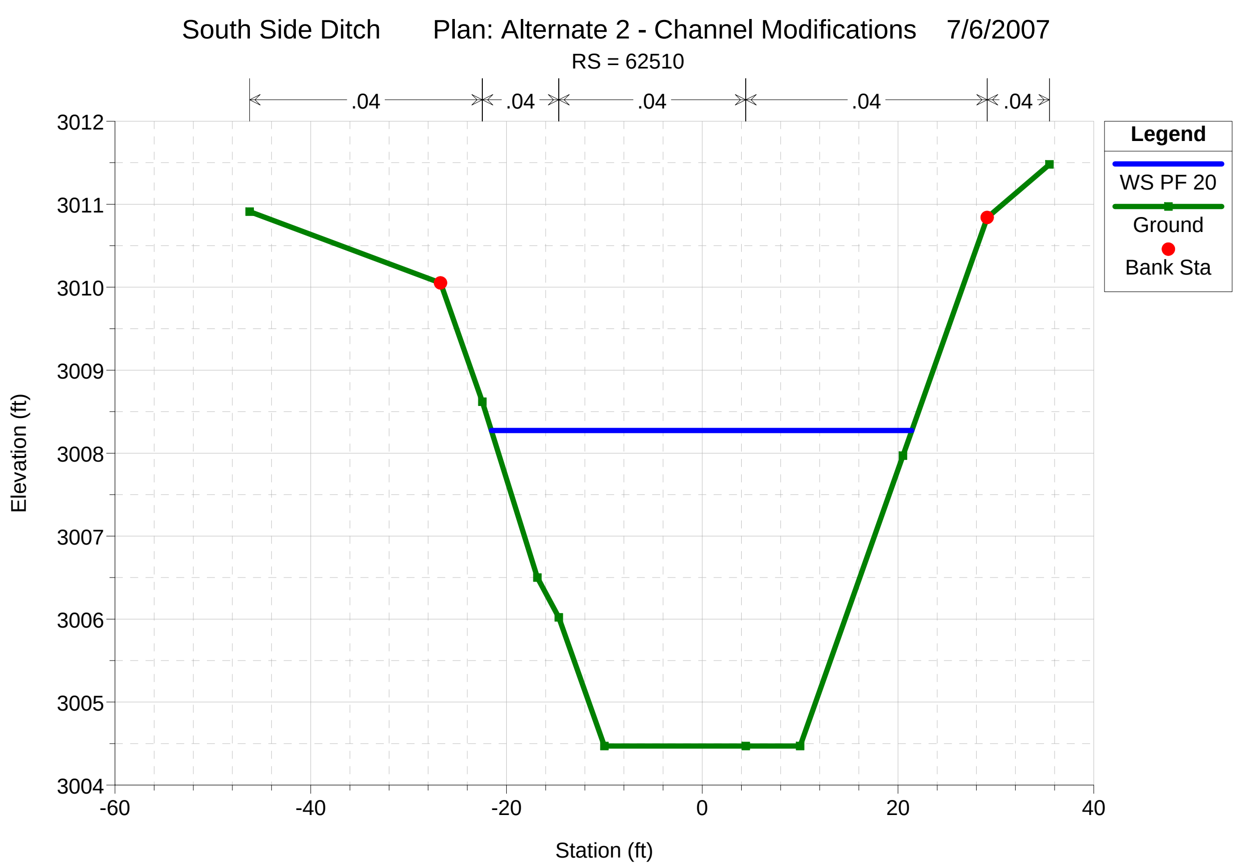

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 60237 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3009
3008
3007
3006
3005
3004
3003
3002
-40
-20
0
20
40
60

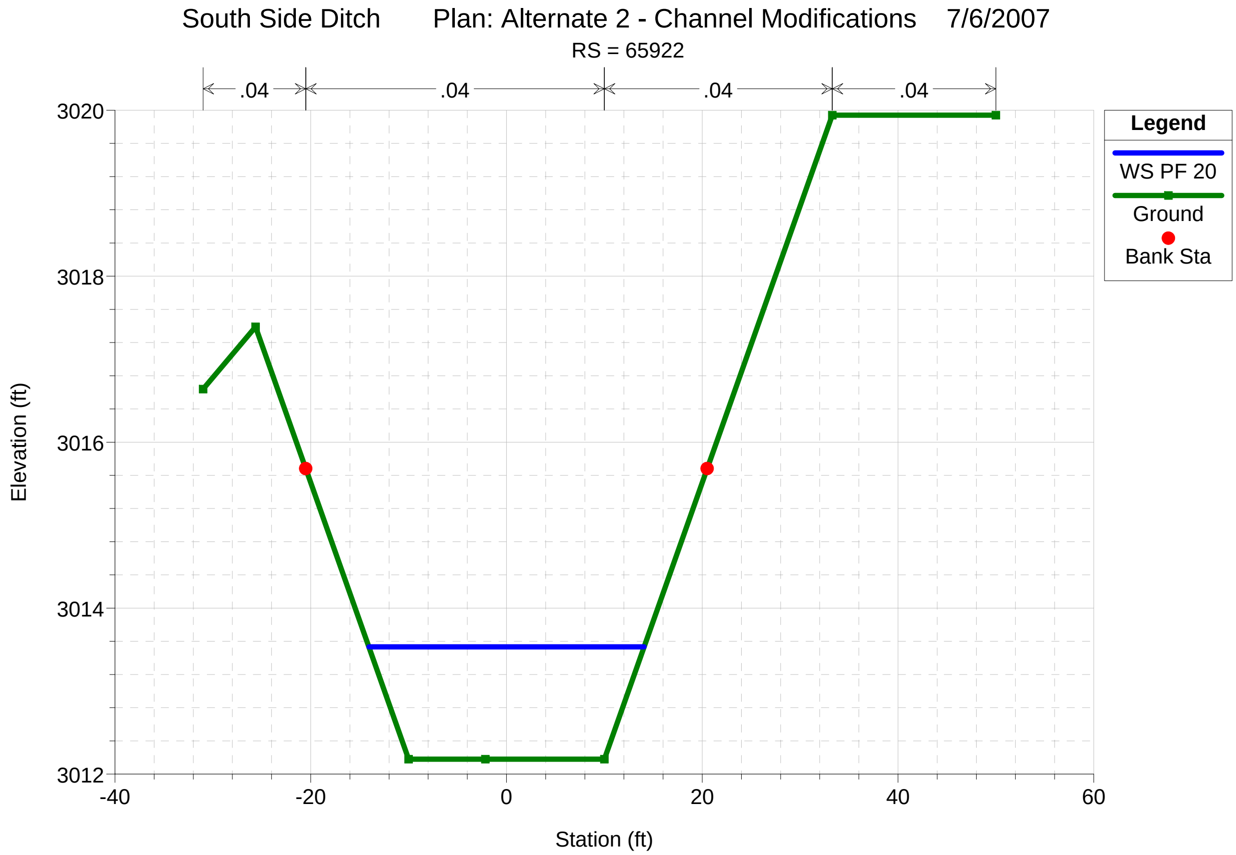

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 60260
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3009
3008
3007
3006
3005
3004
3003
3002
-40
-20
0
20
40
60

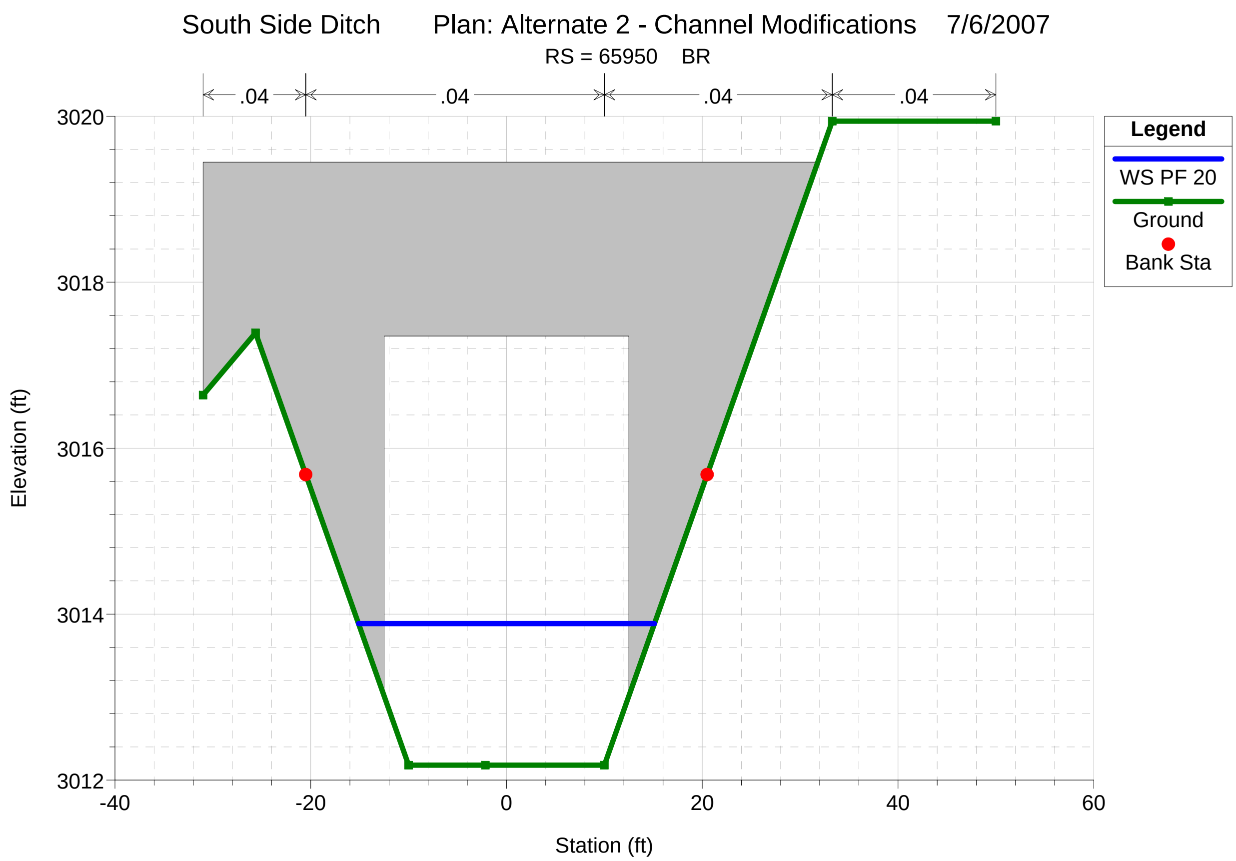

South Side Ditch
Plan: Alternate 2 - Channel Modifications
7/6/2007
RS = 62432
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3012
3011
3010
3009
3008
3007
3006
3005
3004
-60
-40
-20
0
20
40
Station (ft)

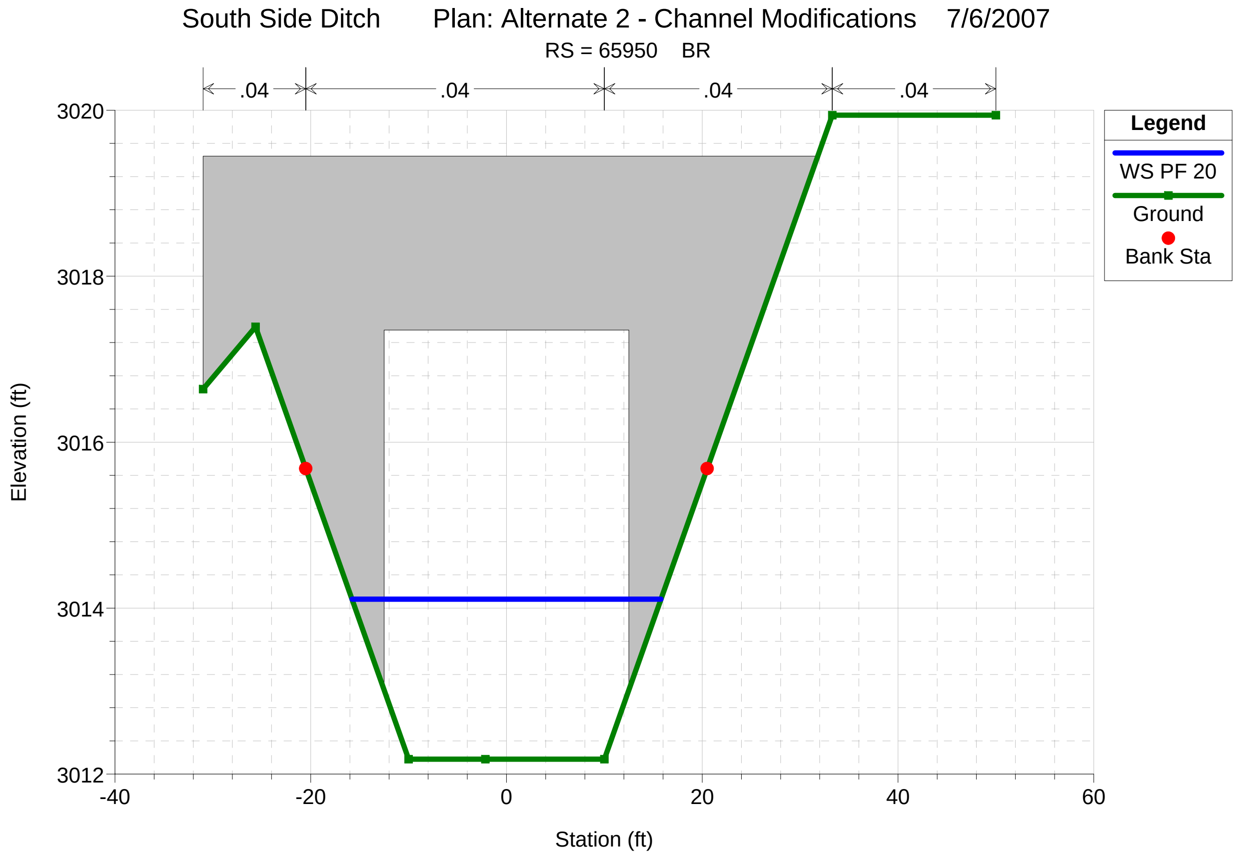

South Side Ditch
Plan: Alternate 2 - Channel Modifications
7/6/2007
RS = 62471 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3012
3011
3010
3009
3008
3007
3006
3005
3004
-60
-40
-20
0
20
40
Station (ft)

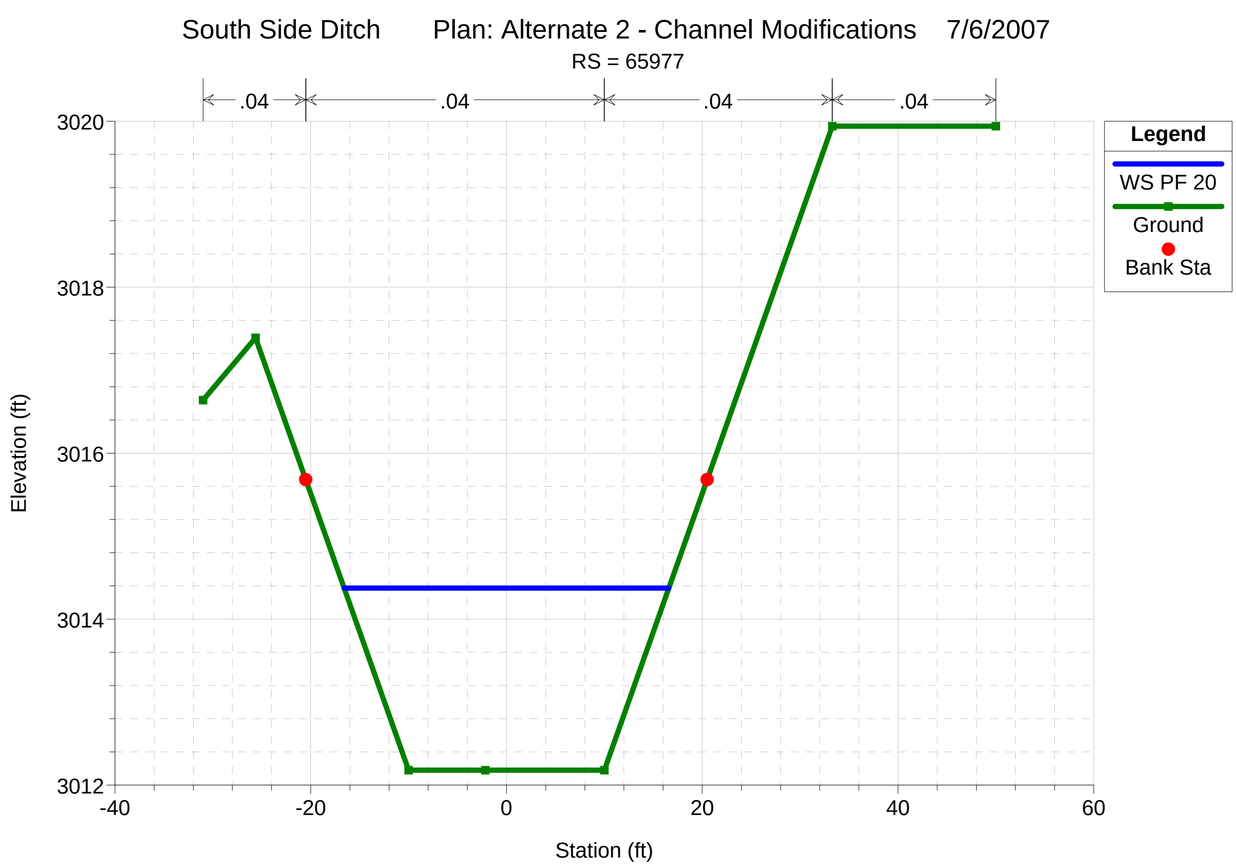

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 62471 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3012
3011
3010
3009
3008
3007
3006
3005
3004
-60
-40
-20
0
20
40
Station (ft)

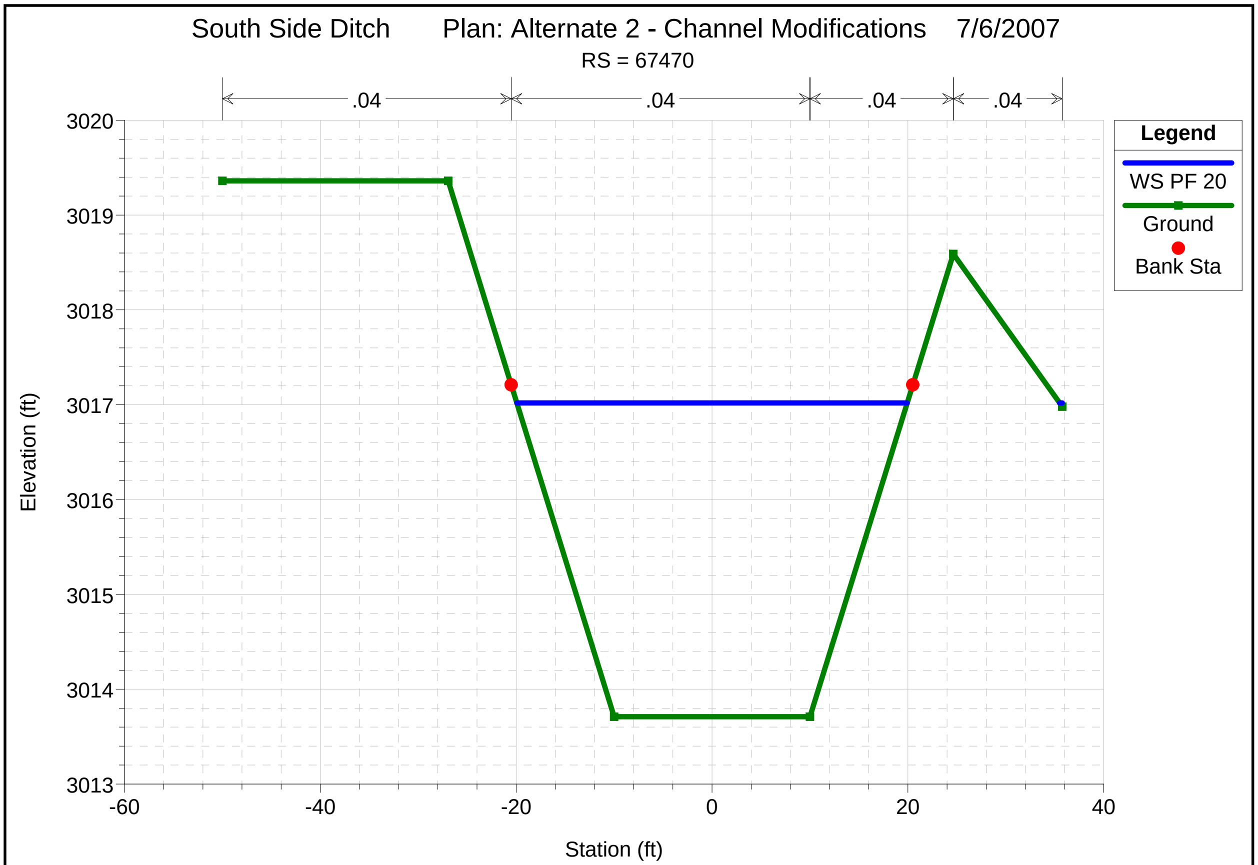

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 62510
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3012
3011
3010
3009
3008
3007
3006
3005
3004
-60
-40
-20
0
20
40
Station (ft)

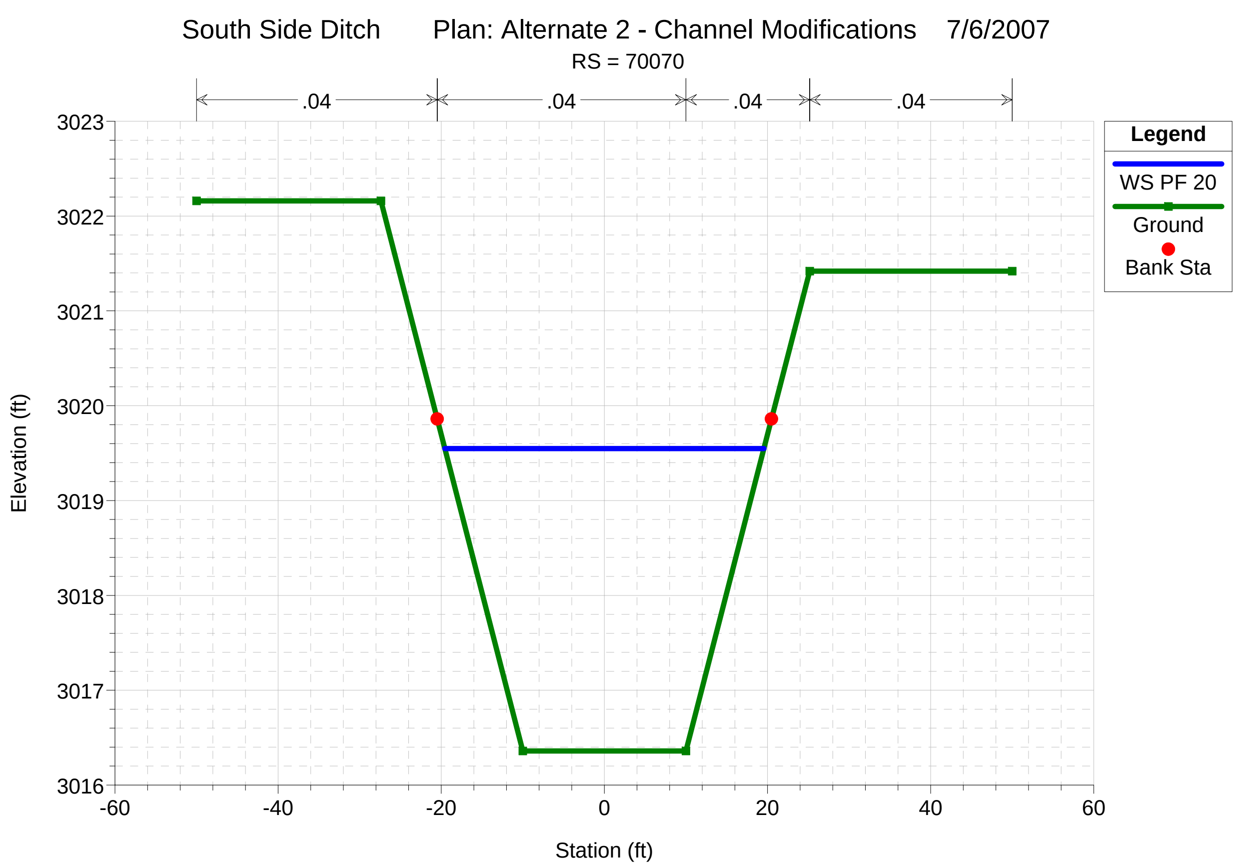

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 65922
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3020
3018
3016
3014
3012
-40
-20
0
20
40
60
Station (ft)

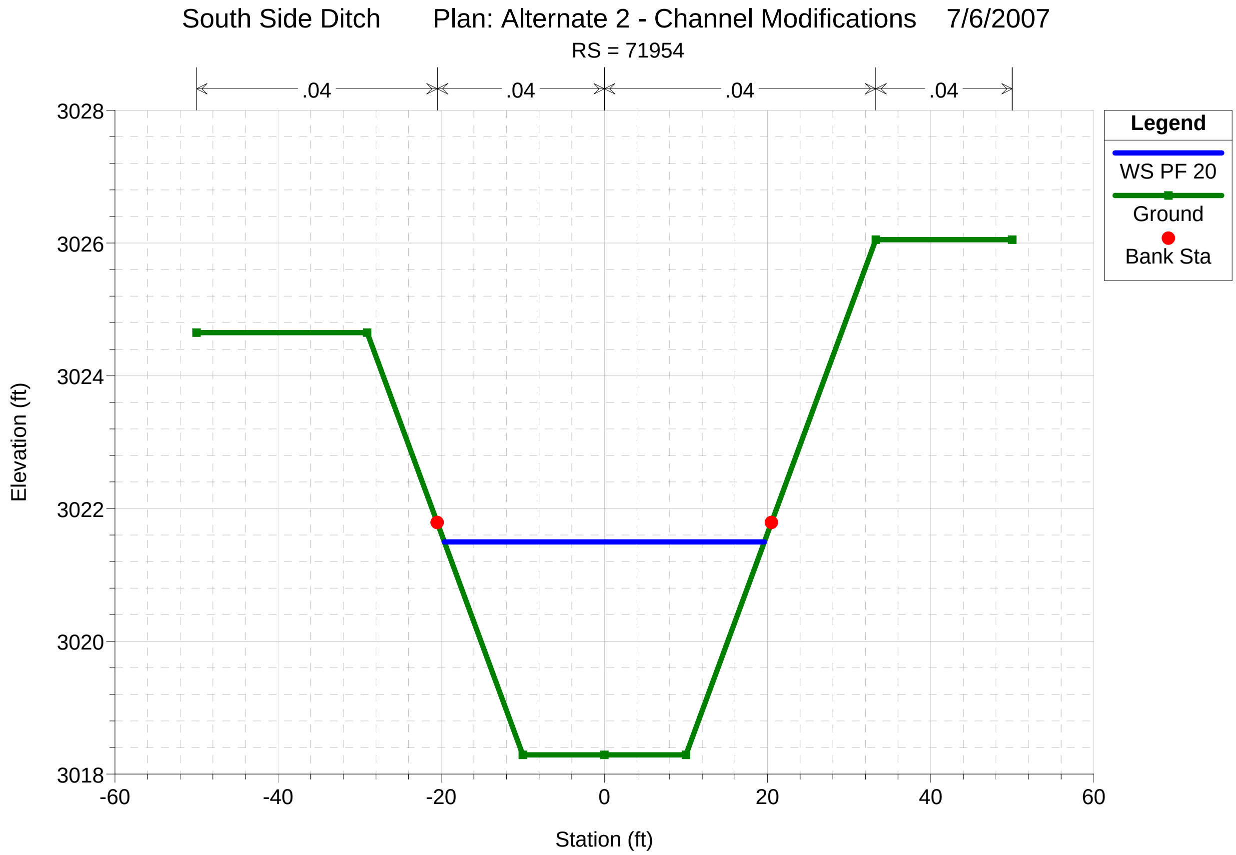

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 65950 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3020
3018
3016
3014
3012
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 65950 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3020
3018
3016
3014
3012
-40
-20
0
20
40
60
Station (ft)

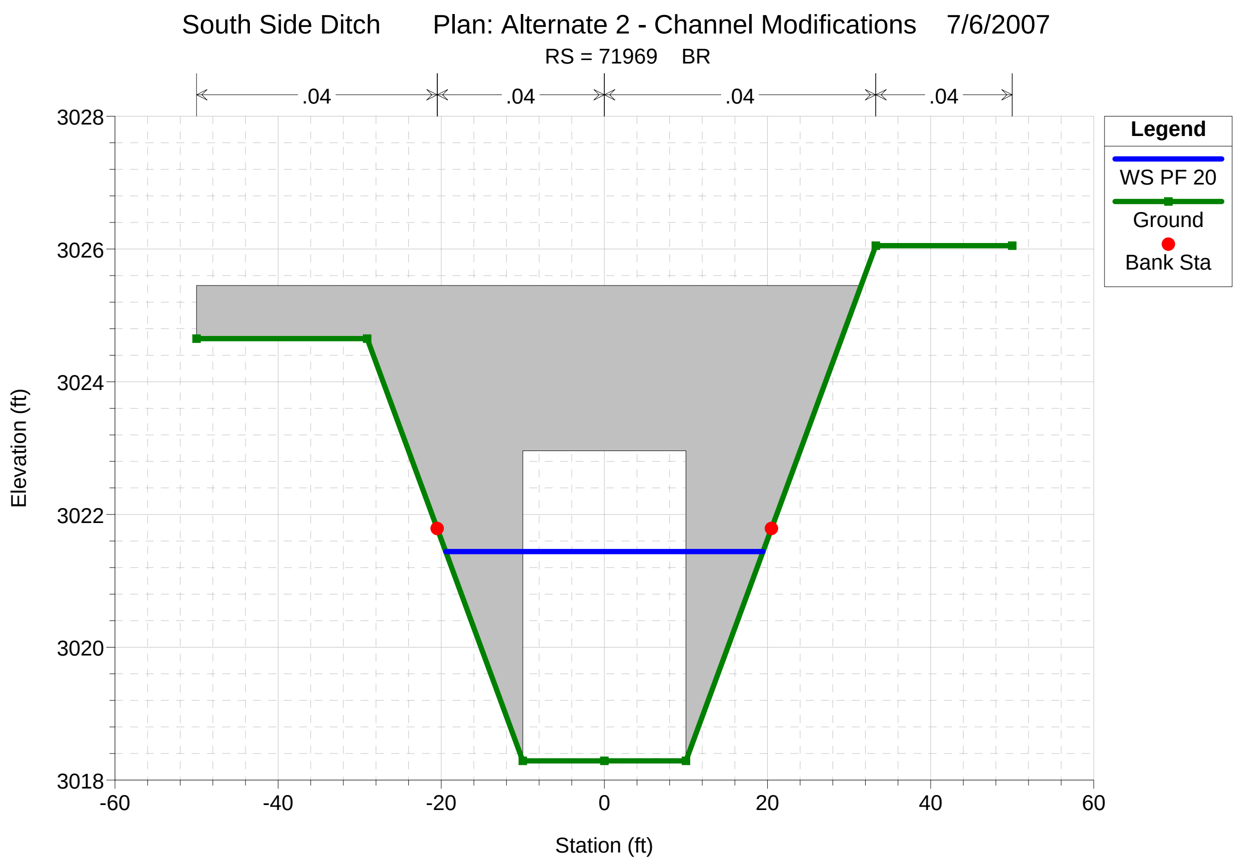

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 65977
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3020
3018
3016
3014
3012
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 67470
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3020
3019
3018
3017
3016
3015
3014
3013
-60
-40
-20
0
20
40
Station (ft)

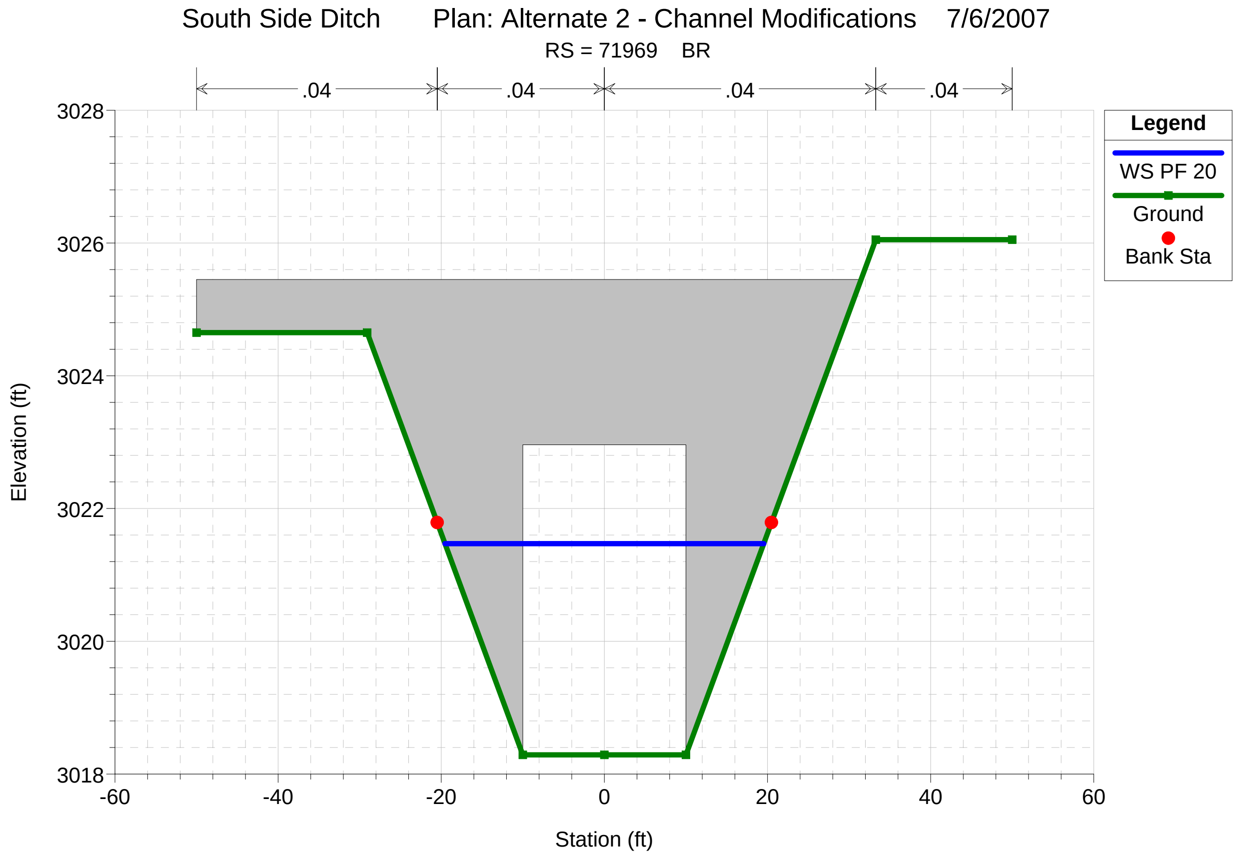

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 70070
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3023
3022
3021
3020
3019
3018
3017
3016
-60
-40
-20
0
20
40
60
Station (ft)

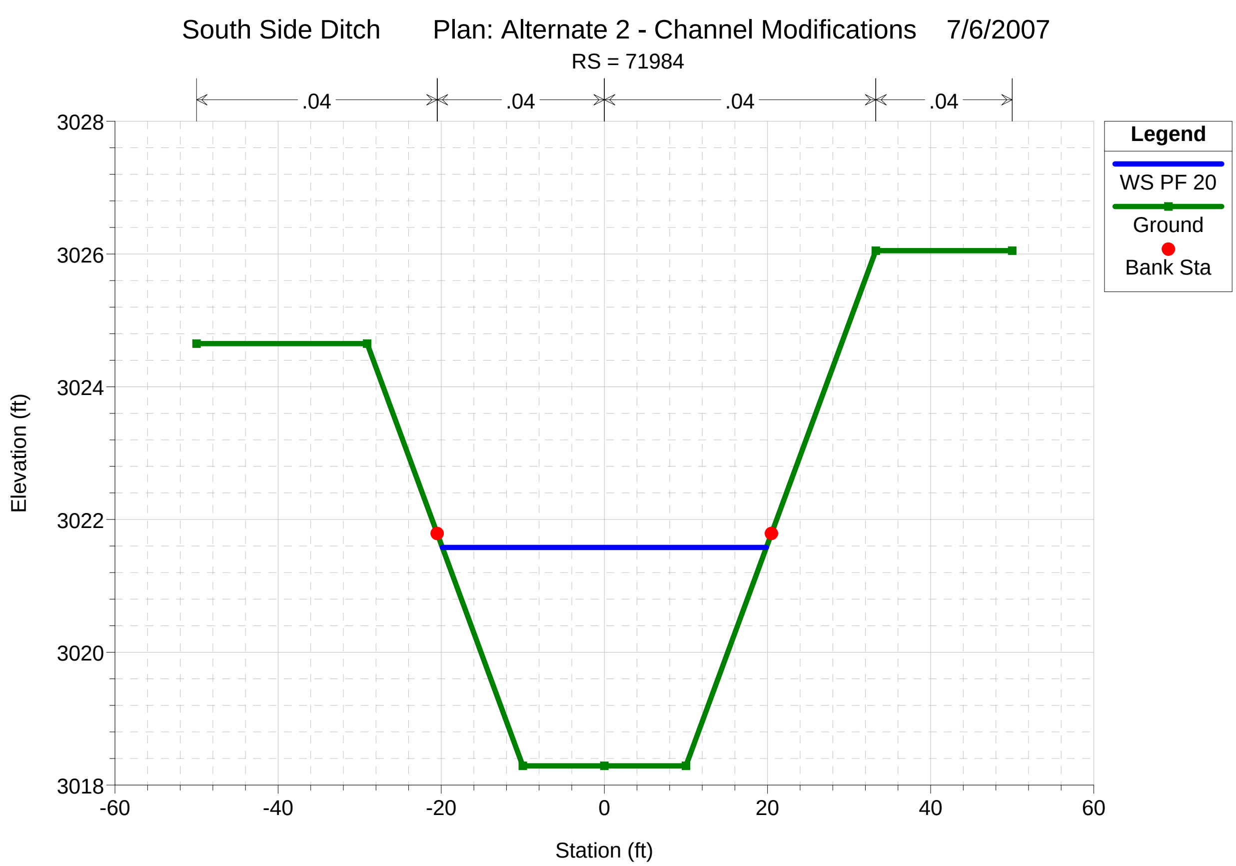


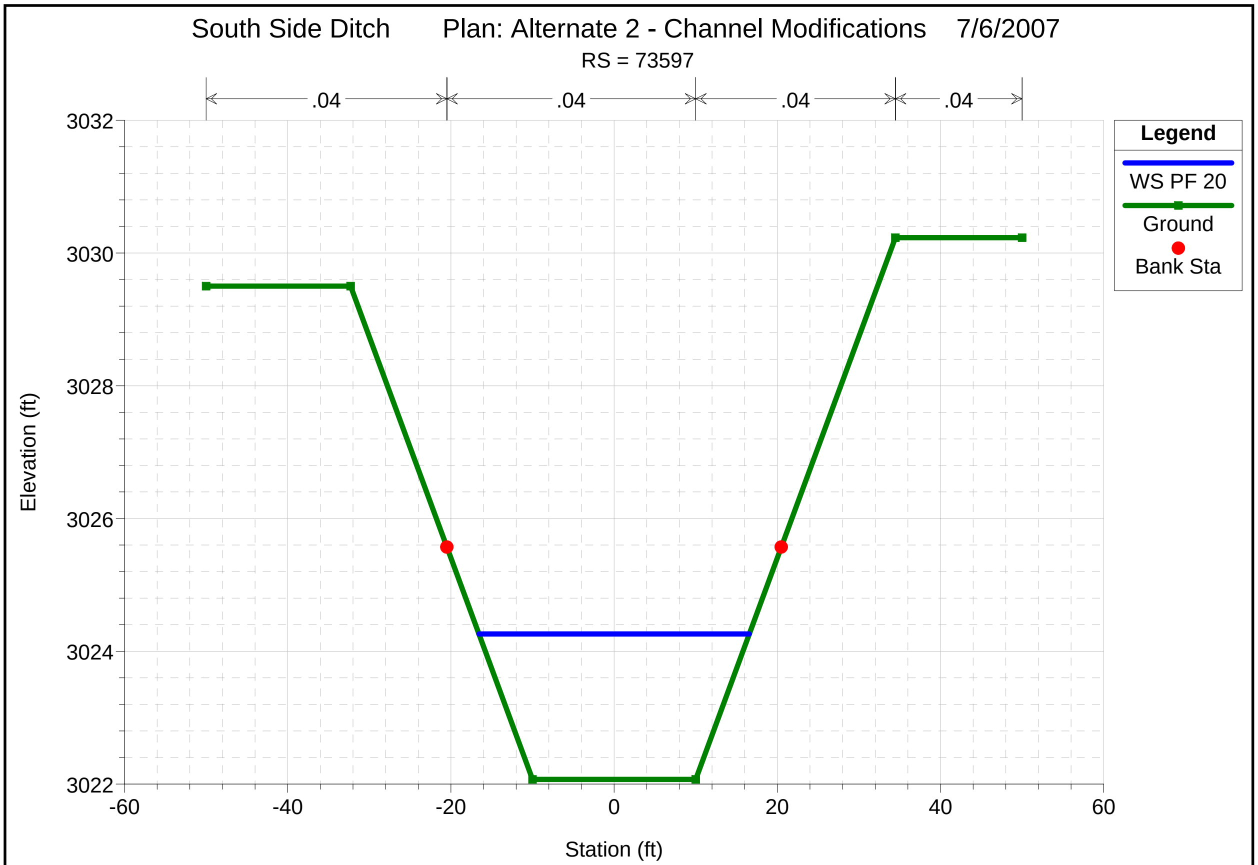
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 71954
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3028
3026
3024
3022
3020
3018
-60
-40
-20
0
20
40
60
Station (ft)

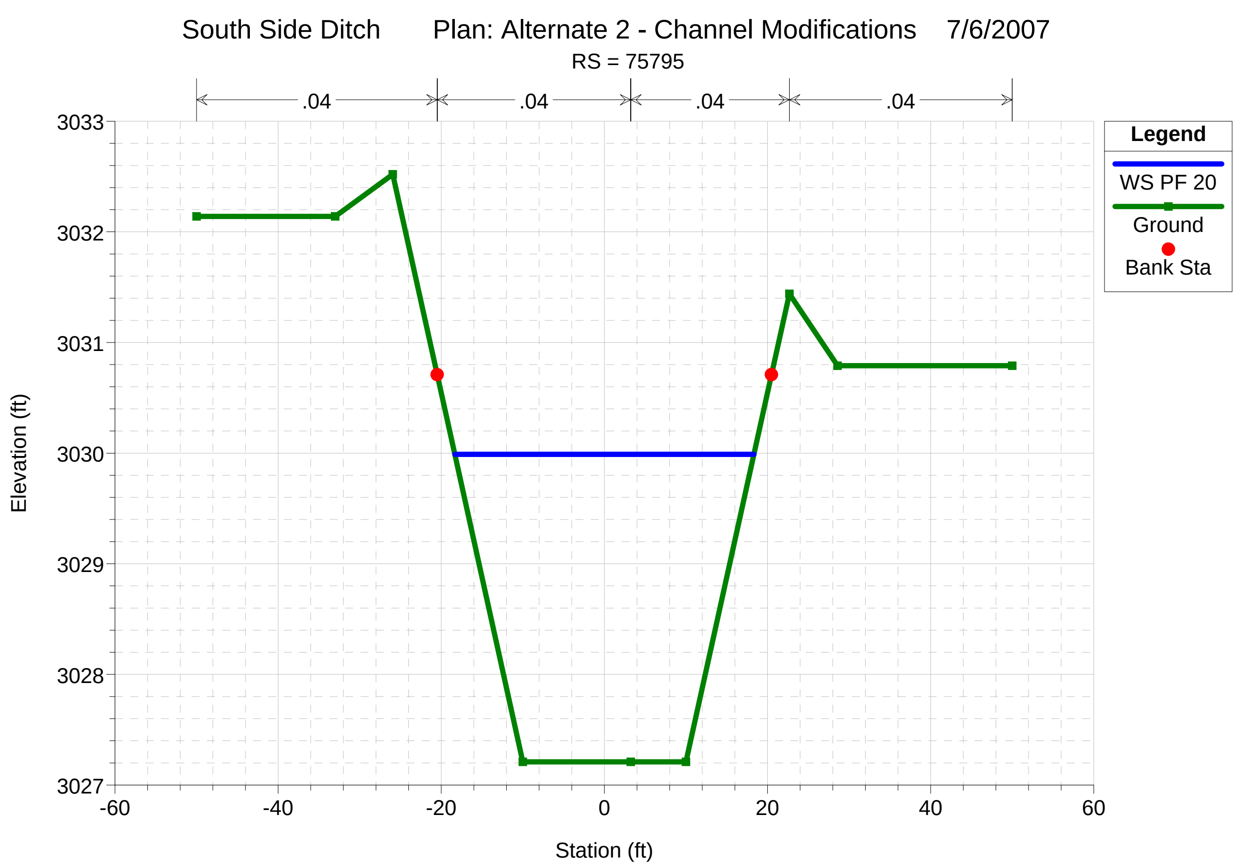


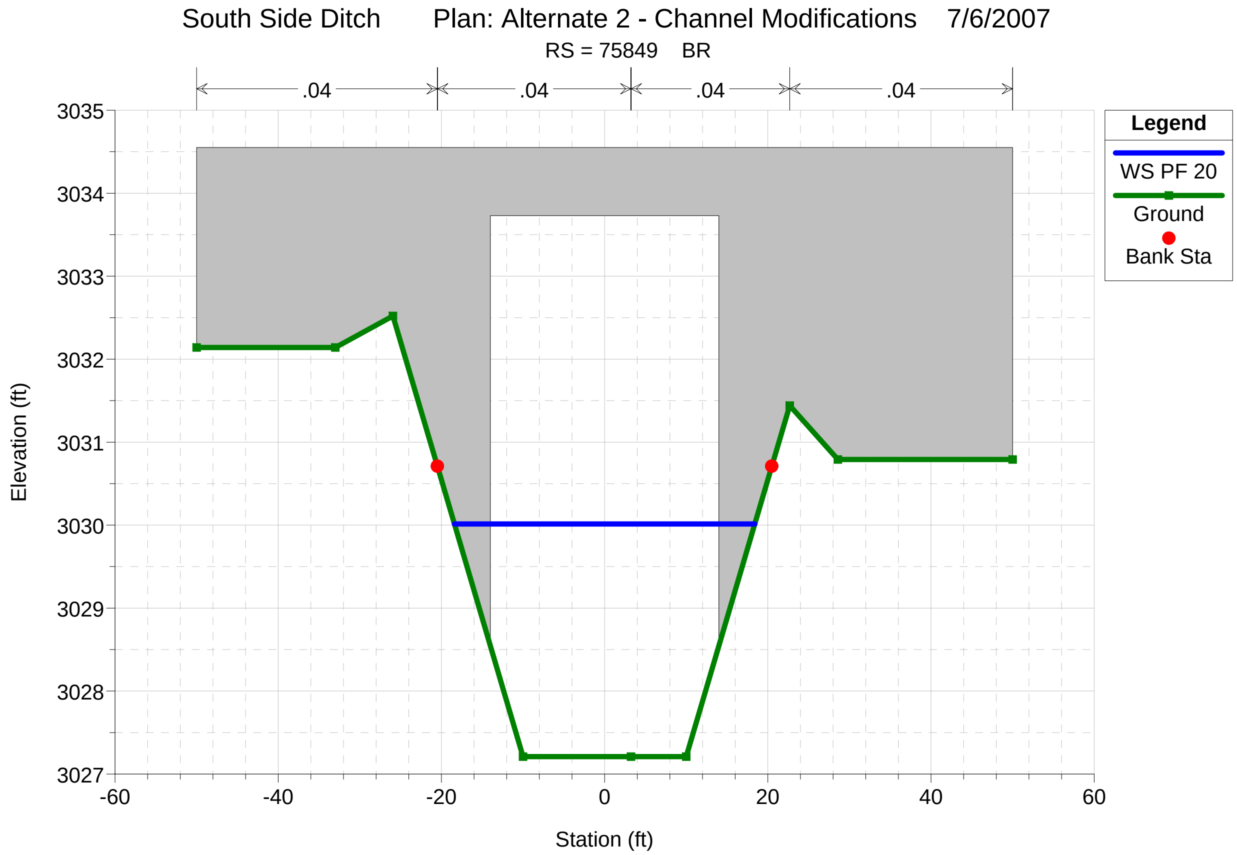
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 71969 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3028
3026
3024
3022
3020
3018
-60
-40
-20
0
20
40
60
Station (ft)

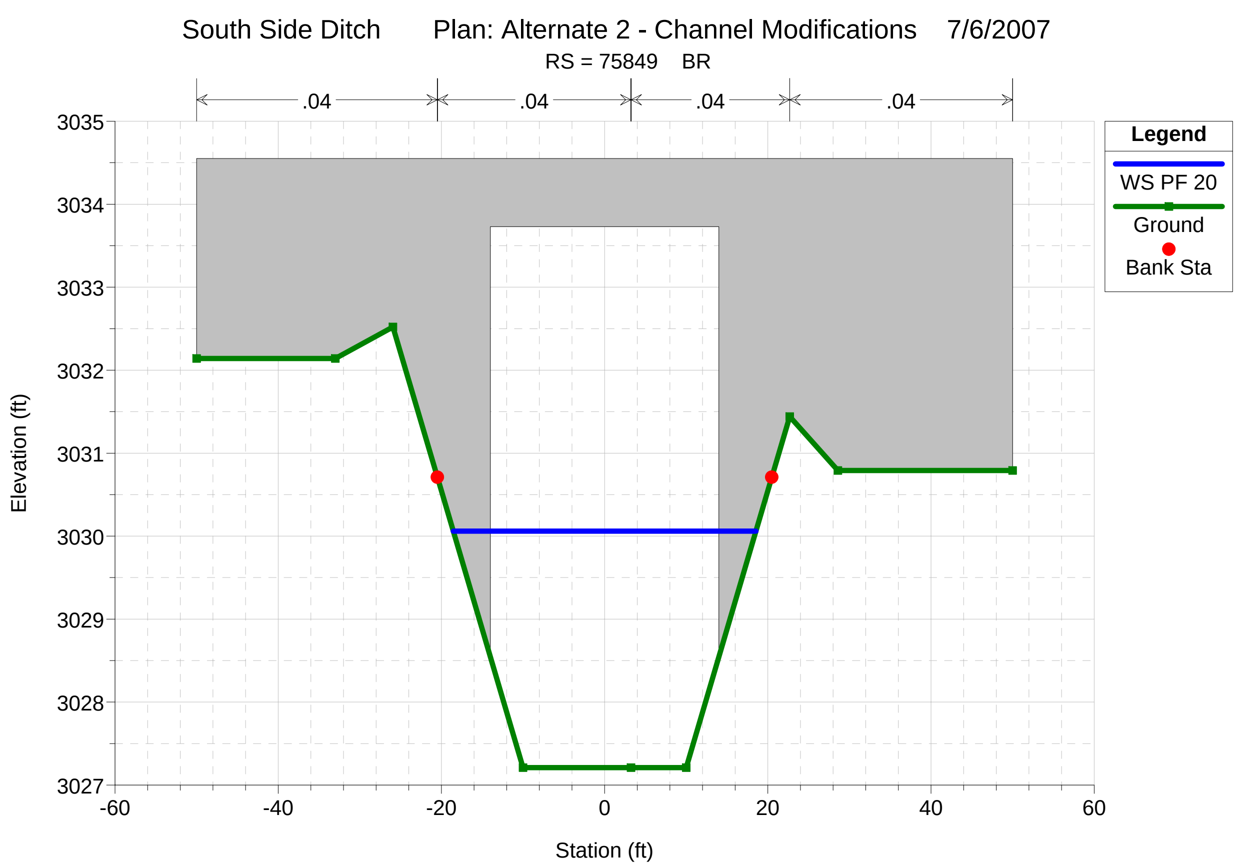

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 71969 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3028
3026
3024
3022
3020
3018
-60
-40
-20
0
20
40
60
Station (ft)

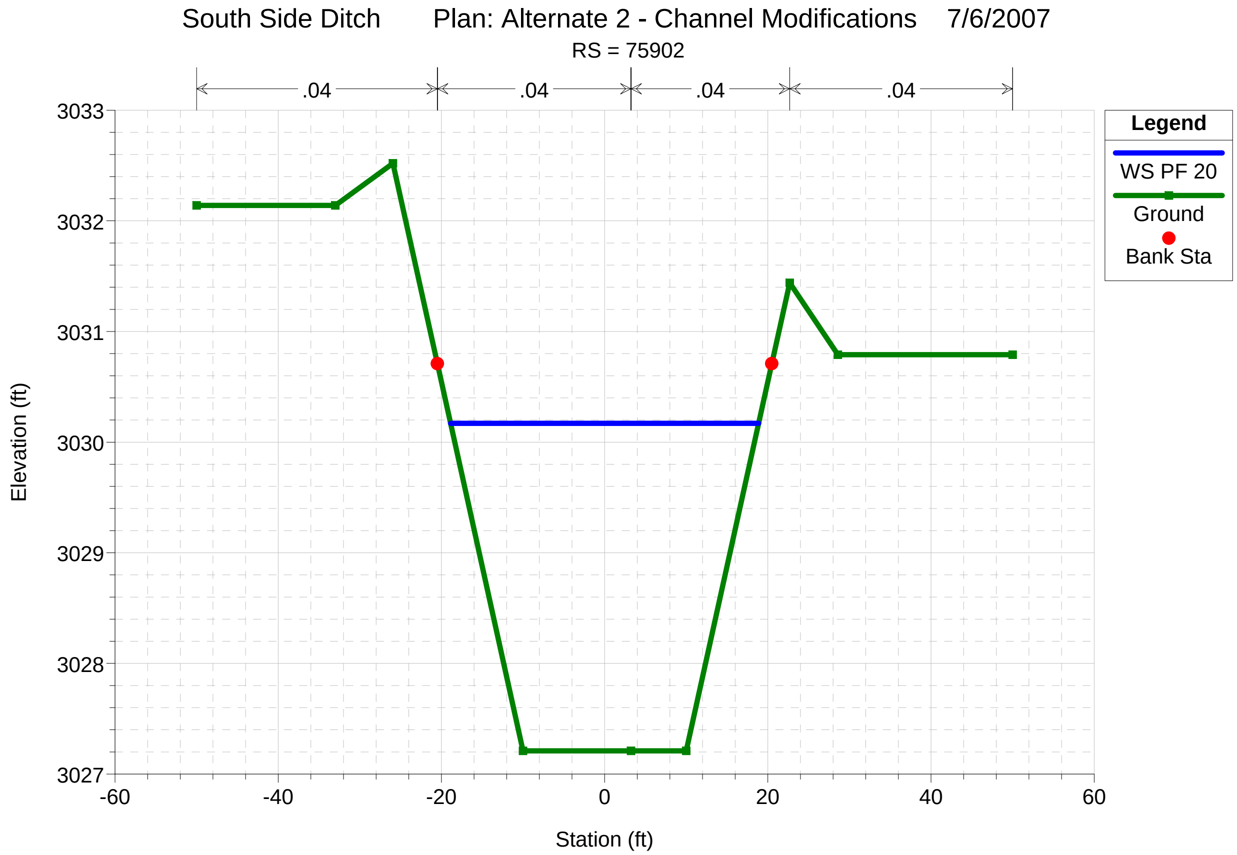

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 71984
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3028
3026
3024
3022
3020
3018
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 73597
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3032
3030
3028
3026
3024
3022
-60
-40
-20
0
20
40
60
Station (ft)

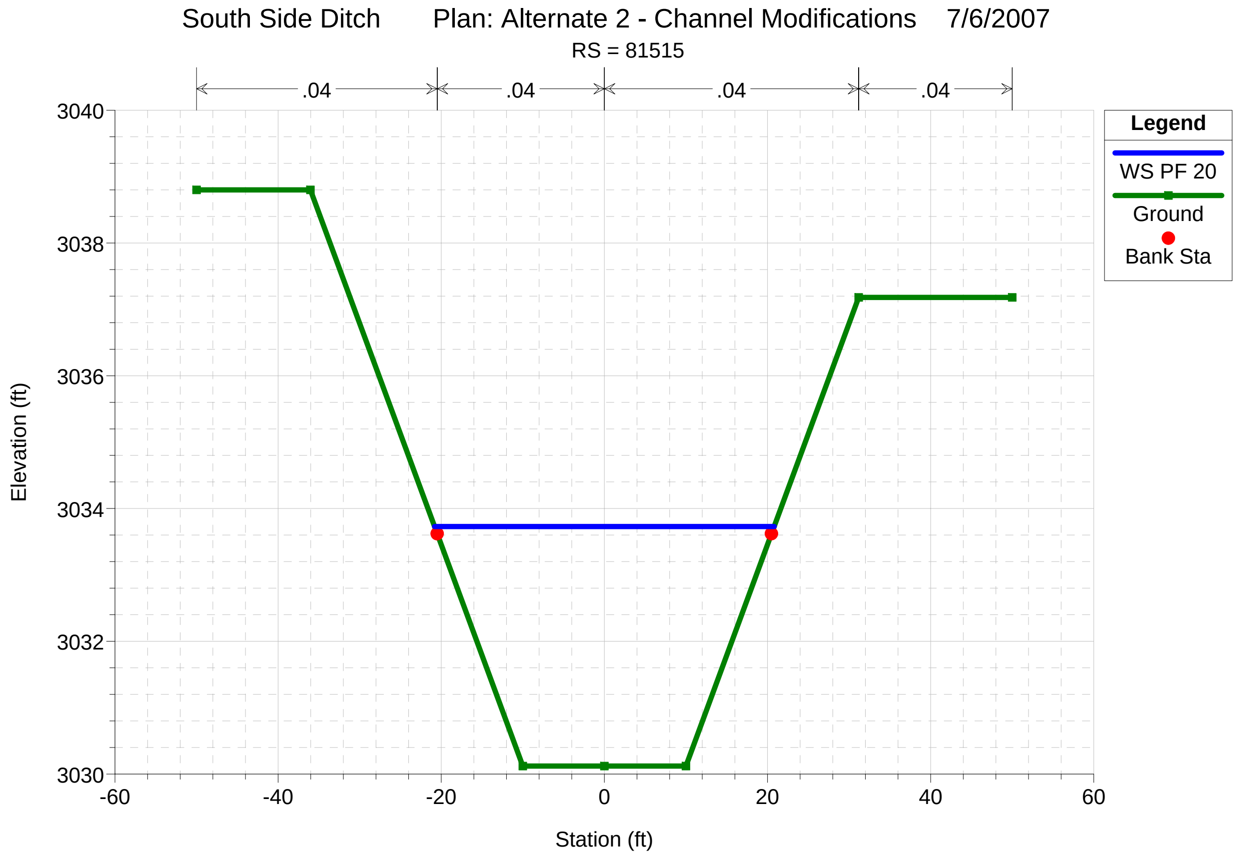

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 75795
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3033
3032
3031
3030
3029
3028
3027
-60
-40
-20
0
20
40
60
Station (ft)

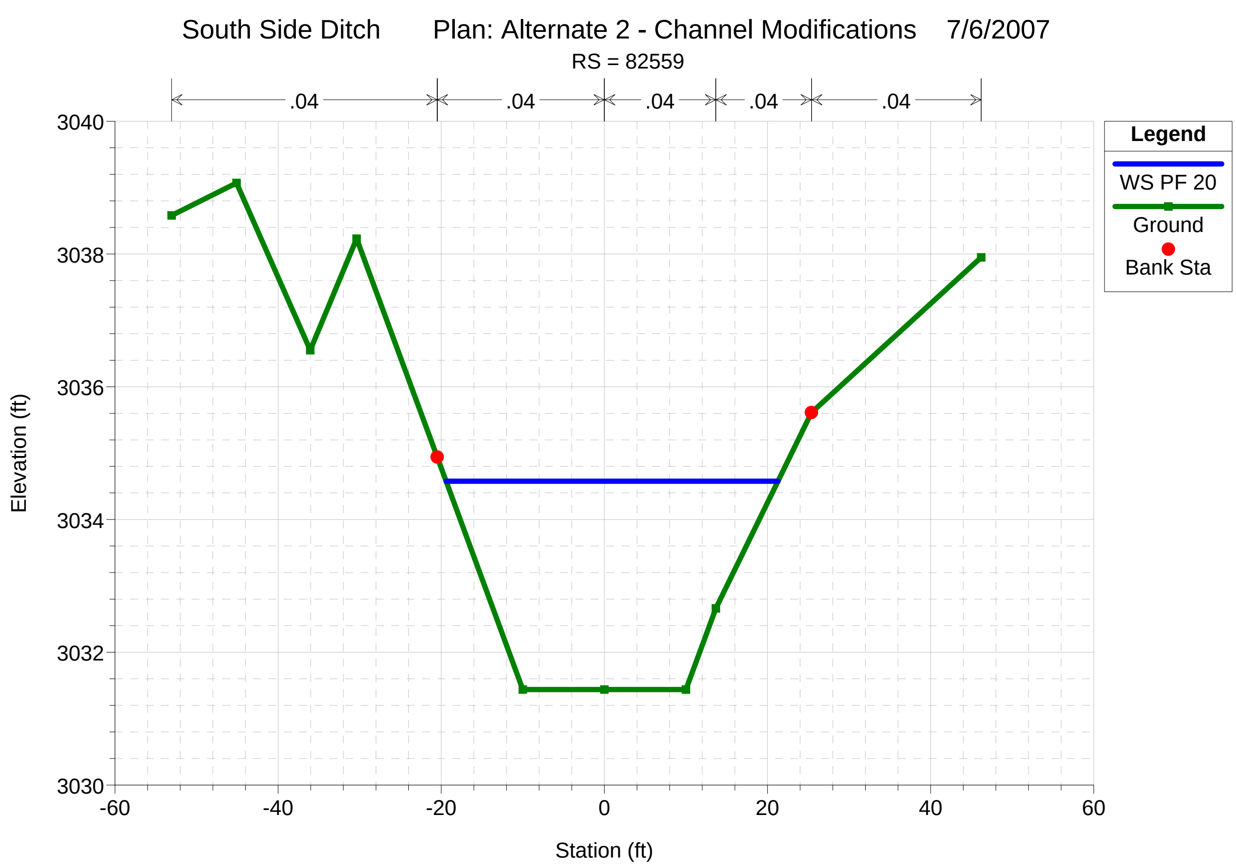

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 75849 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3035
3034
3033
3032
3031
3030
3029
3028
3027
-60
-40
-20
0
20
40
60
Station (ft)

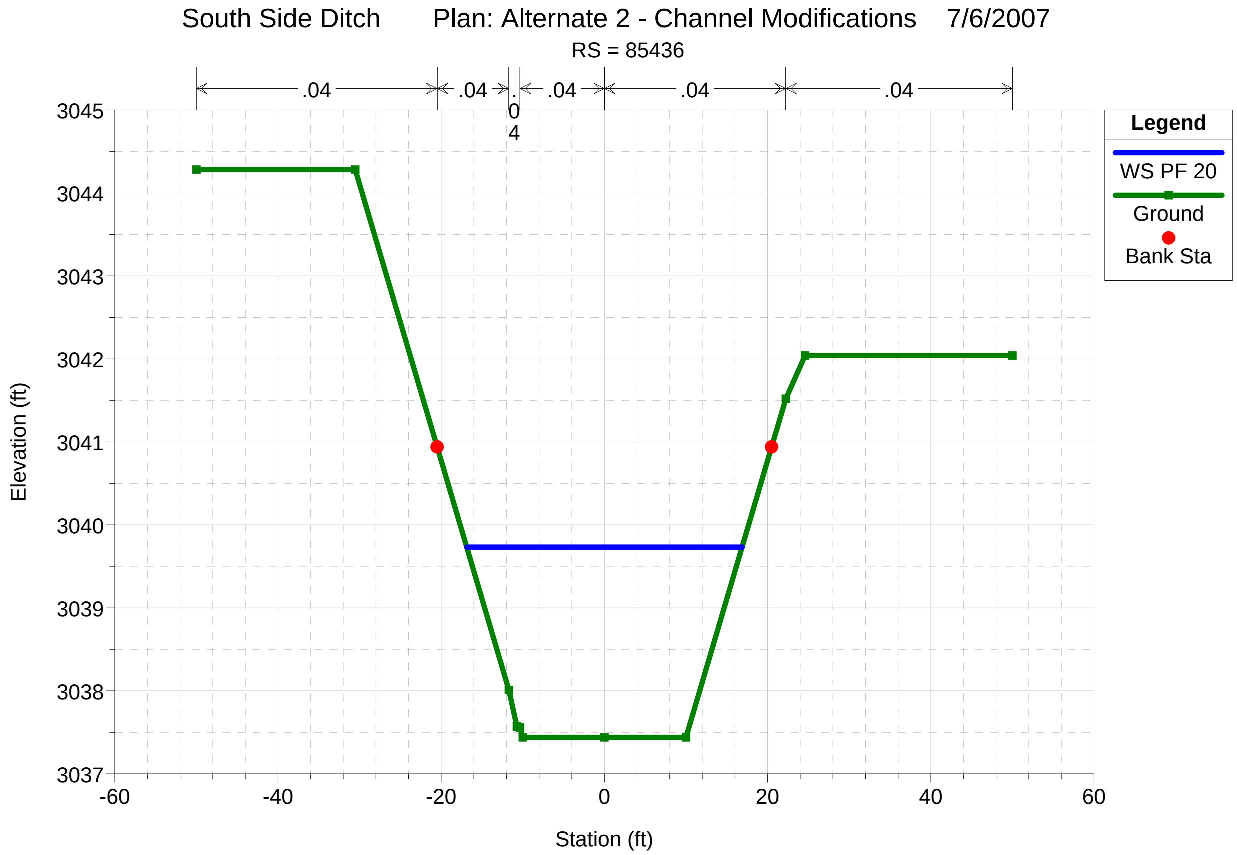

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 75849 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3035
3034
3033
3032
3031
3030
3029
3028
3027
-60
-40
-20
0
20
40
60
Station (ft)

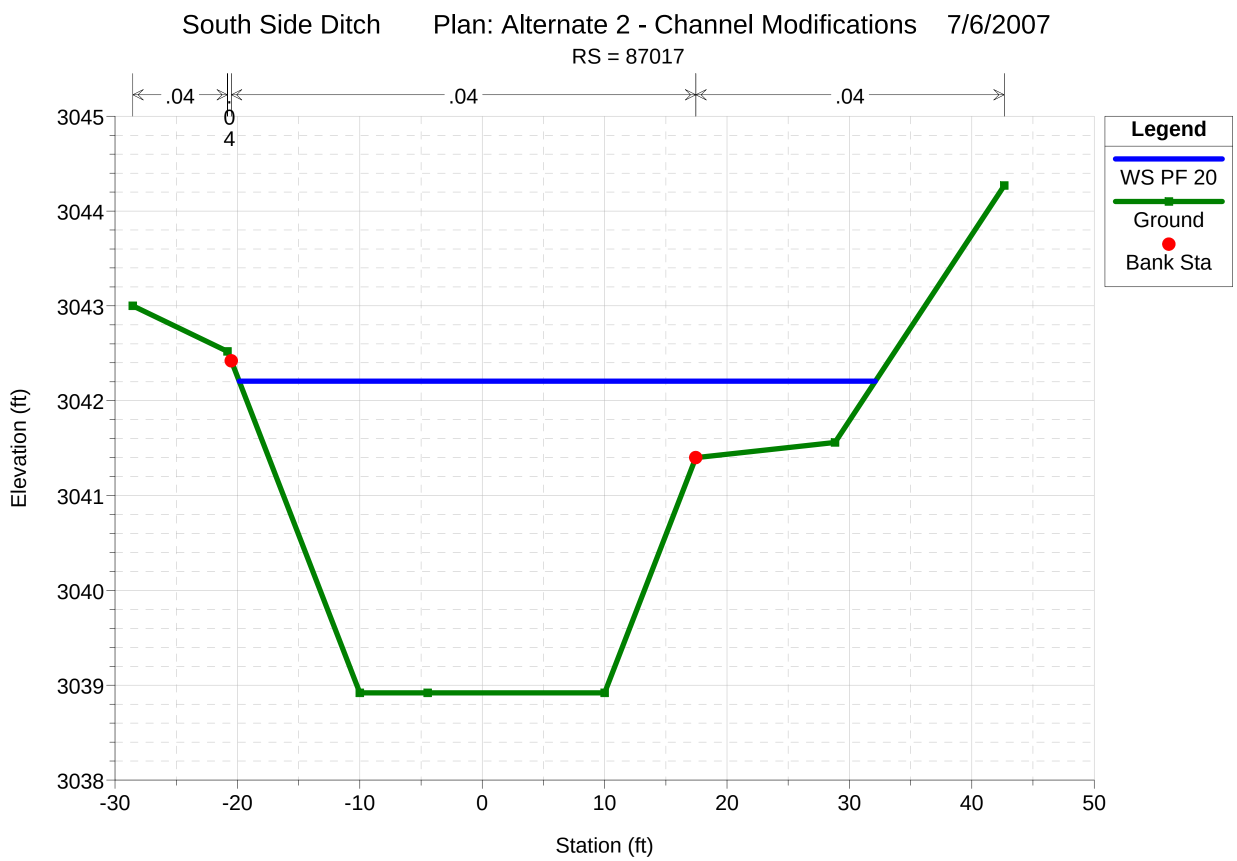

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 75902
.04
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
WS PF 20
Ground
Bank Sta

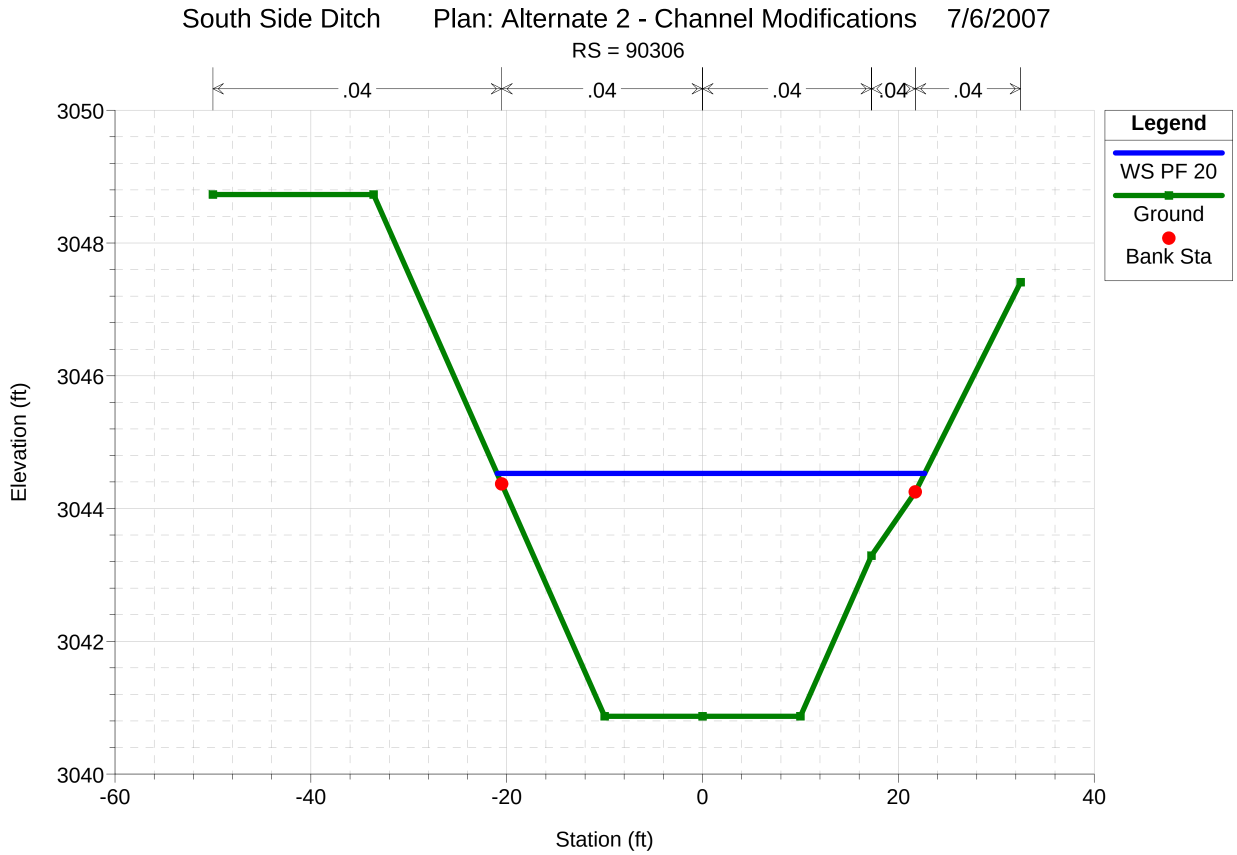

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 79455
.04
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
WS PF 20
Ground
Bank Sta

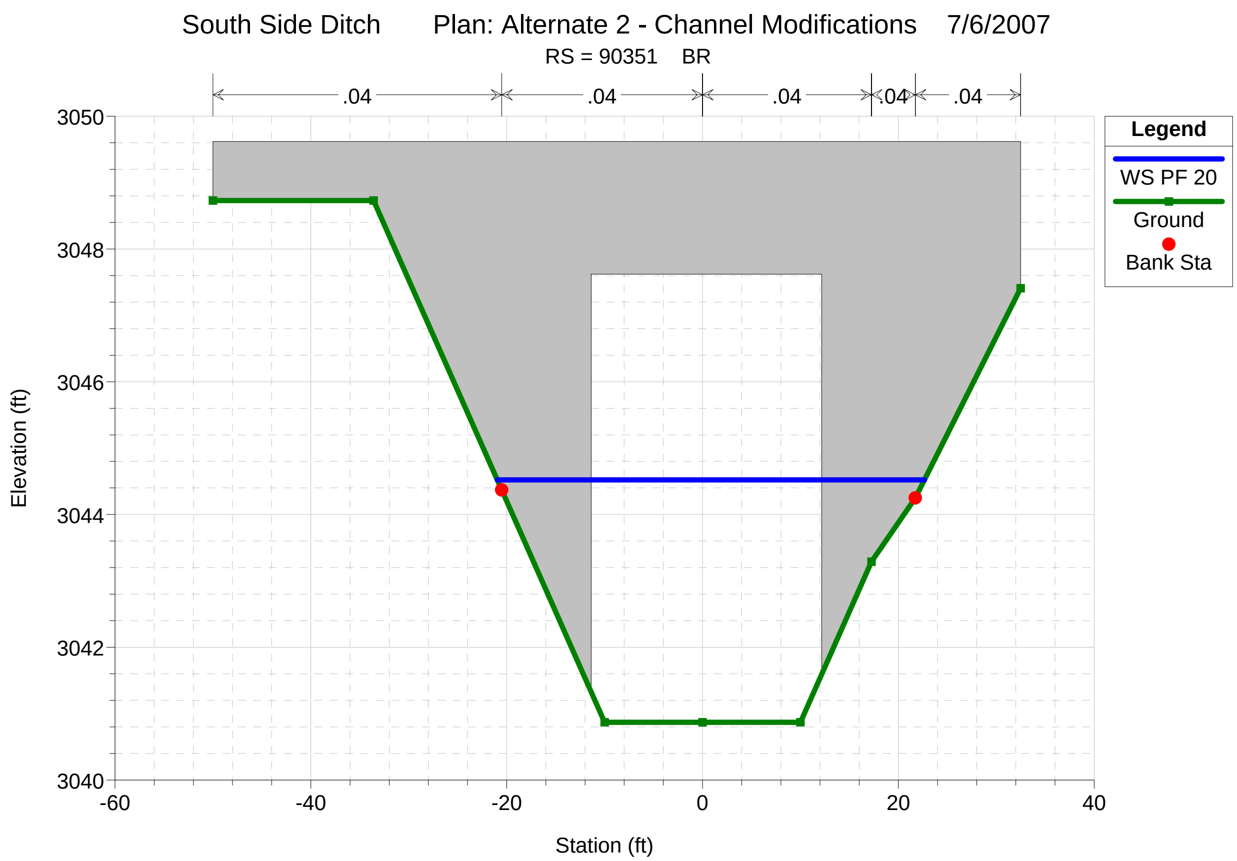

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 81515
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3040
3038
3036
3034
3032
3030
-60
-40
-20
0
20
40
60
Station (ft)

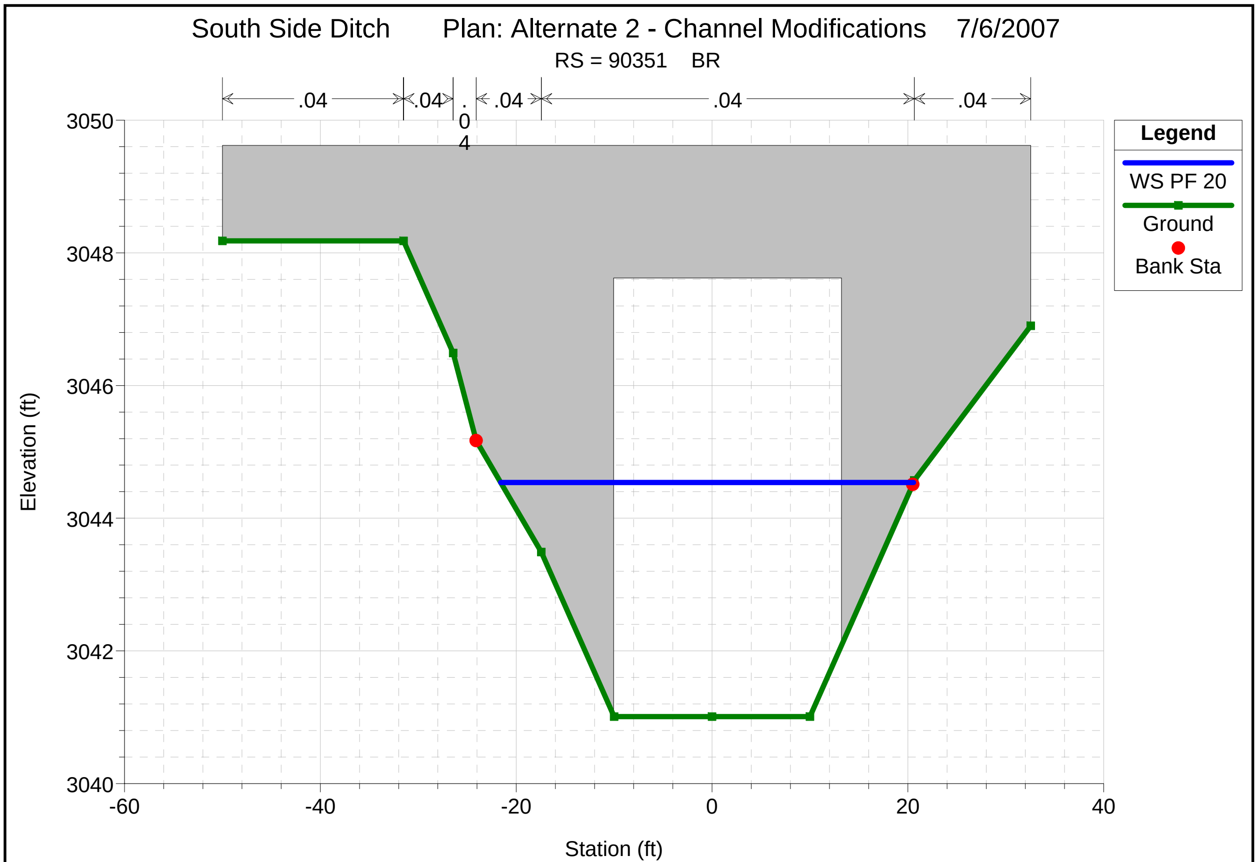

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 82559
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3040
3038
3036
3034
3032
3030
-60
-40
-20
0
20
40
60
Station (ft)

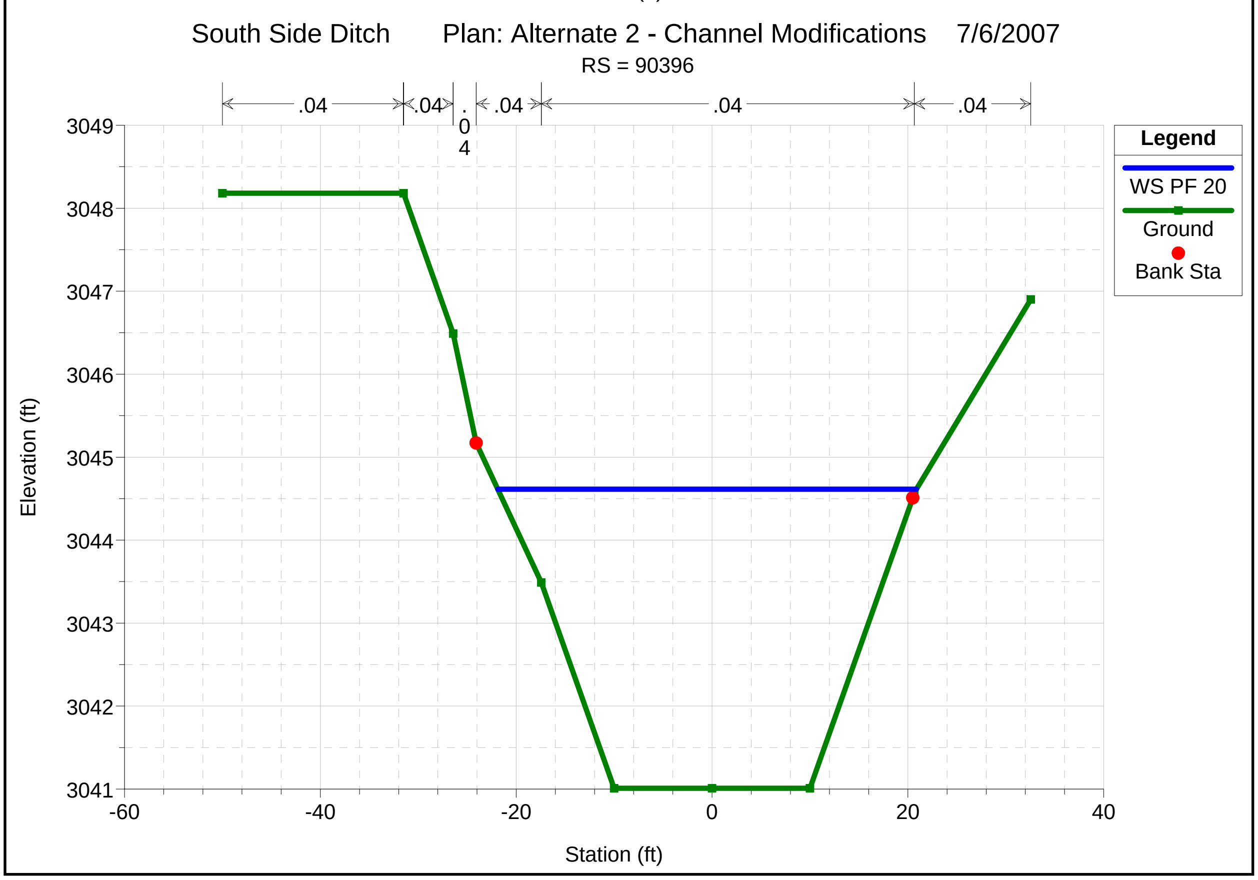

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 85436
.04
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3045
3044
3043
3042
3041
3040
3039
3038
3037
-60
-40
-20
0
20
40
60

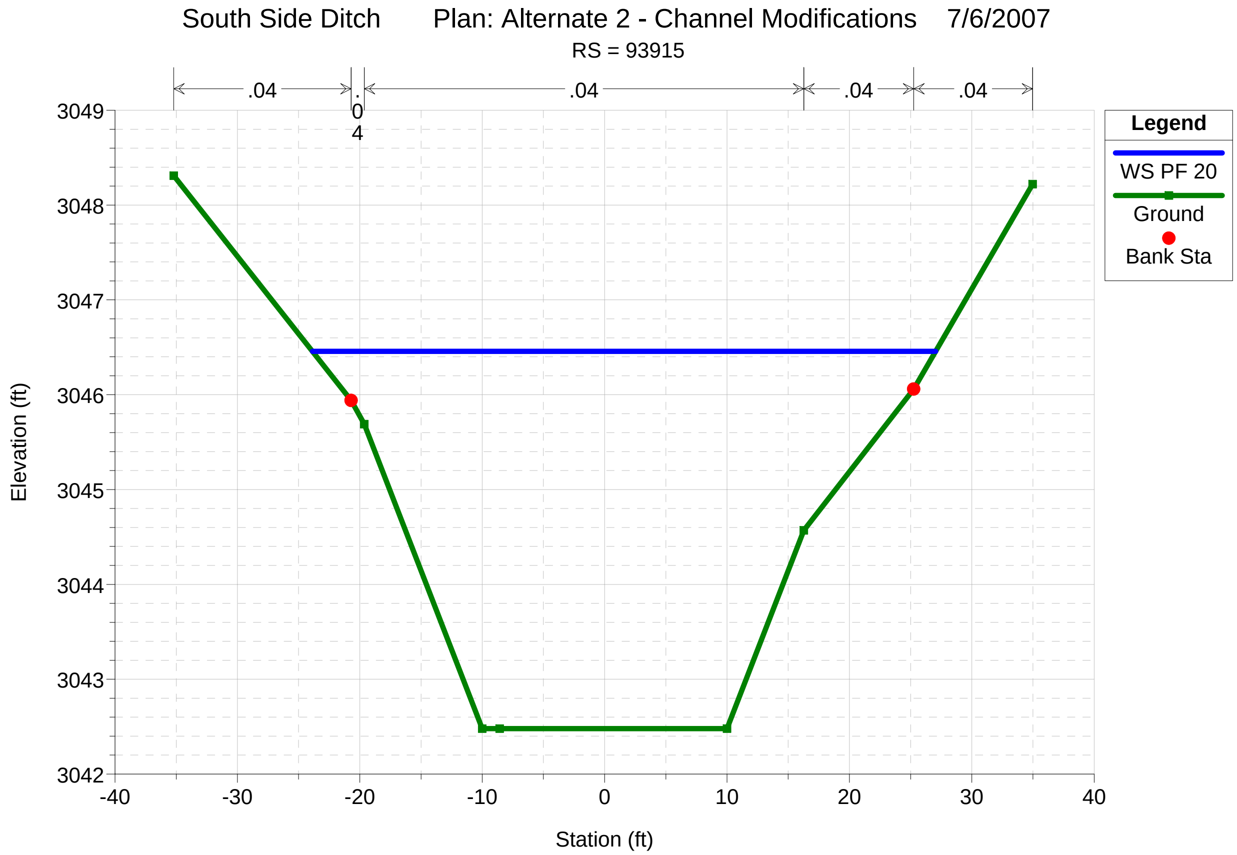

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 87017
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3045
3044
3043
3042
3041
3040
3039
3038
-30
-20
-10
0
10
20
30
40
50


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 90306
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3050
3048
3046
3044
3042
3040
-60
-40
-20
0
20
40

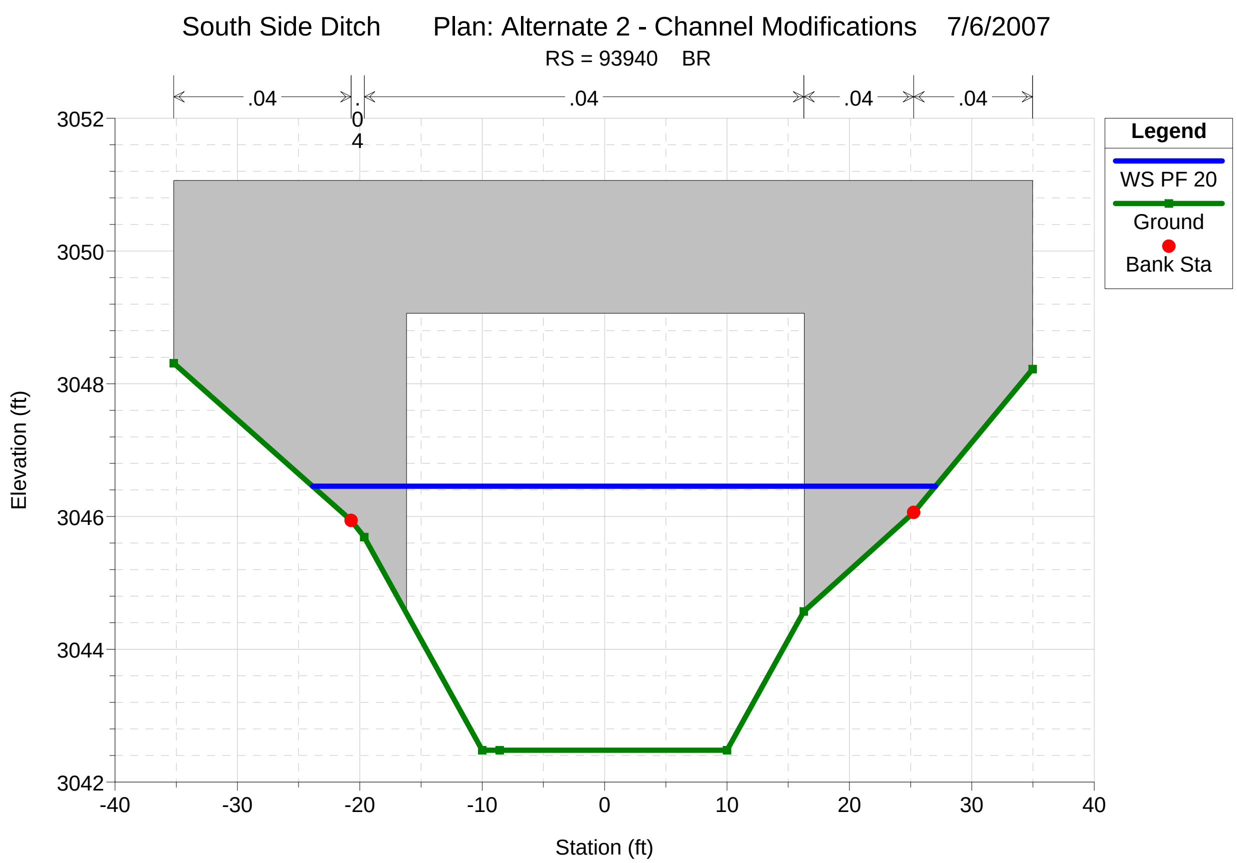

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 90351 BR
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3050
3048
3046
3044
3042
3040
-60
-40
-20
0
20
40


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 90351 BR
.04
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3040
3042
3044
3046
3048
3050
-60
-40
-20
0
20
40

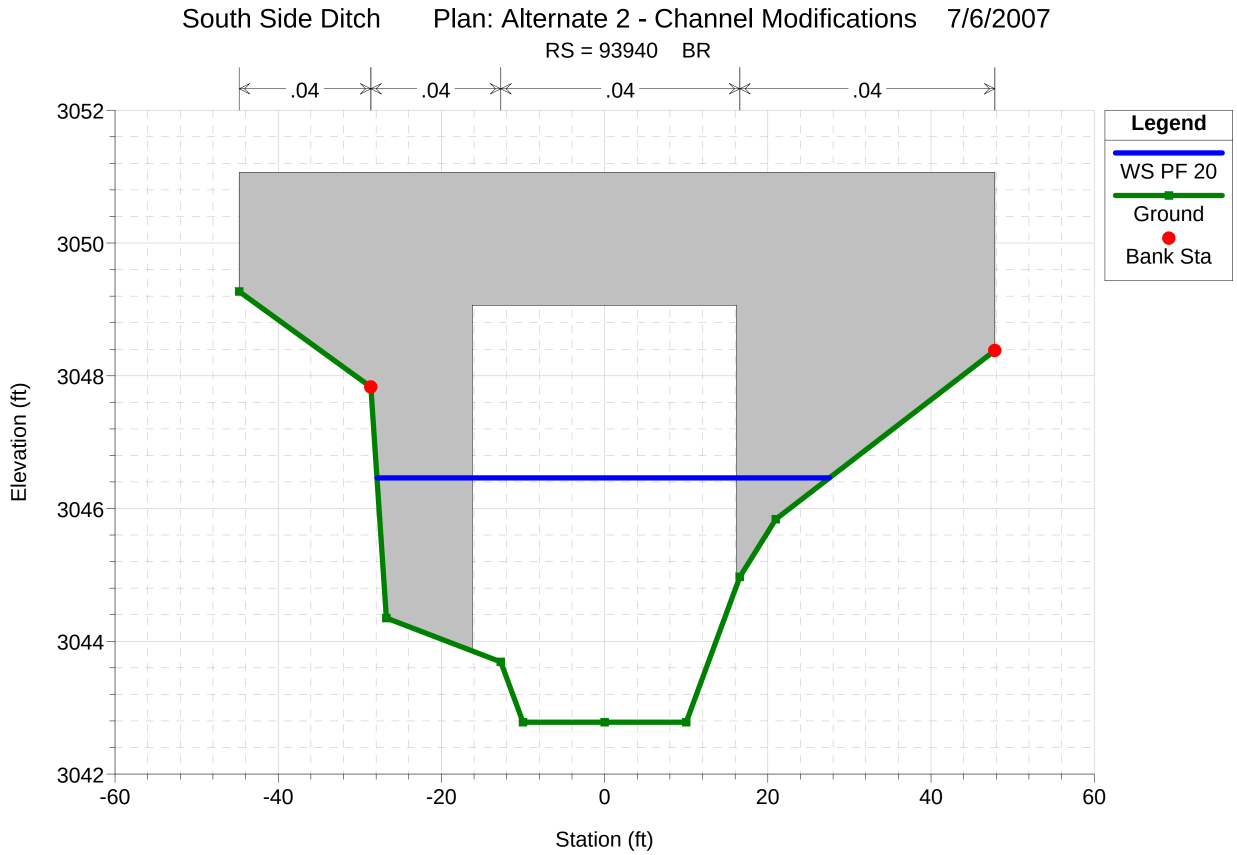

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 90396
.04
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3041
3042
3043
3044
3045
3046
3047
3048
3049
-60
-40
-20
0
20
40



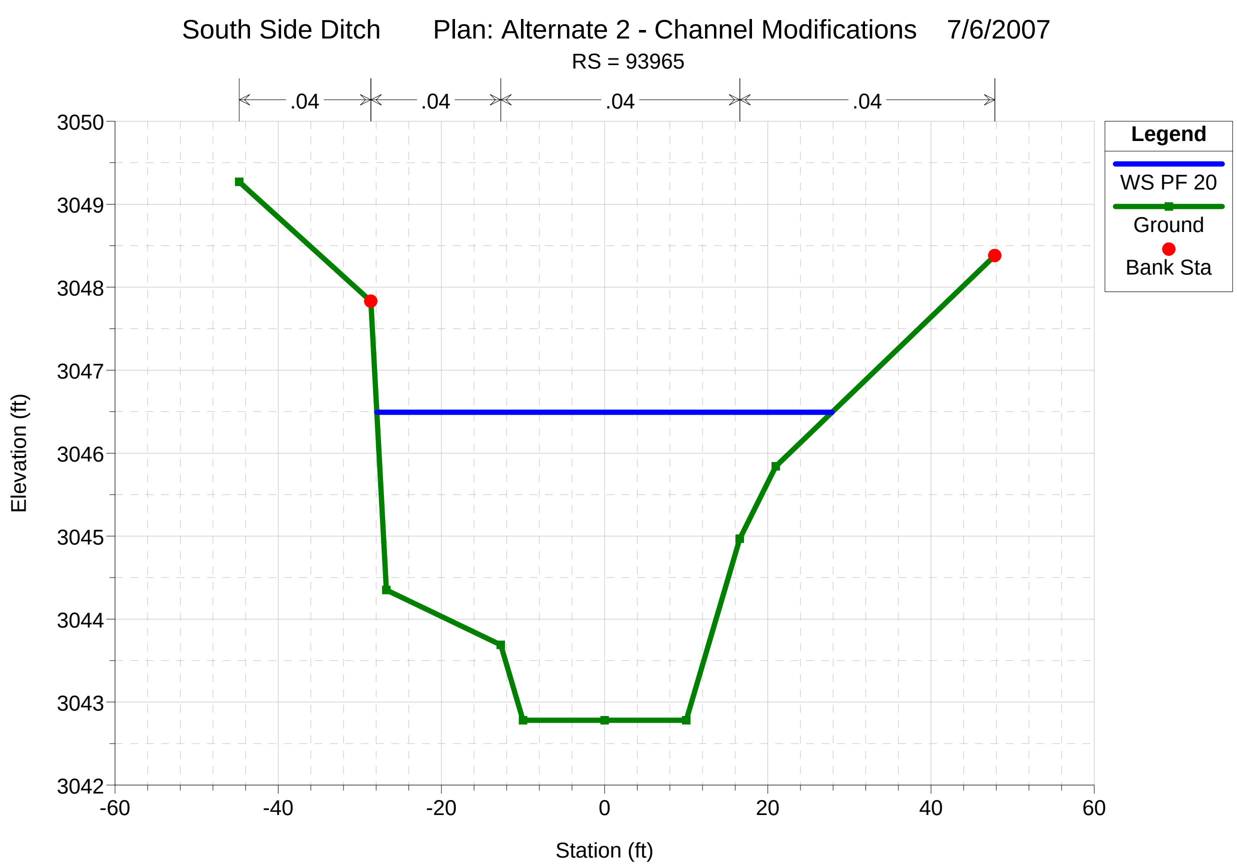
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 93915
.04
.
0
4
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3049
3048
3047
3046
3045
3044
3043
3042
-40
-30
-20
-10
0
10
20
30
40



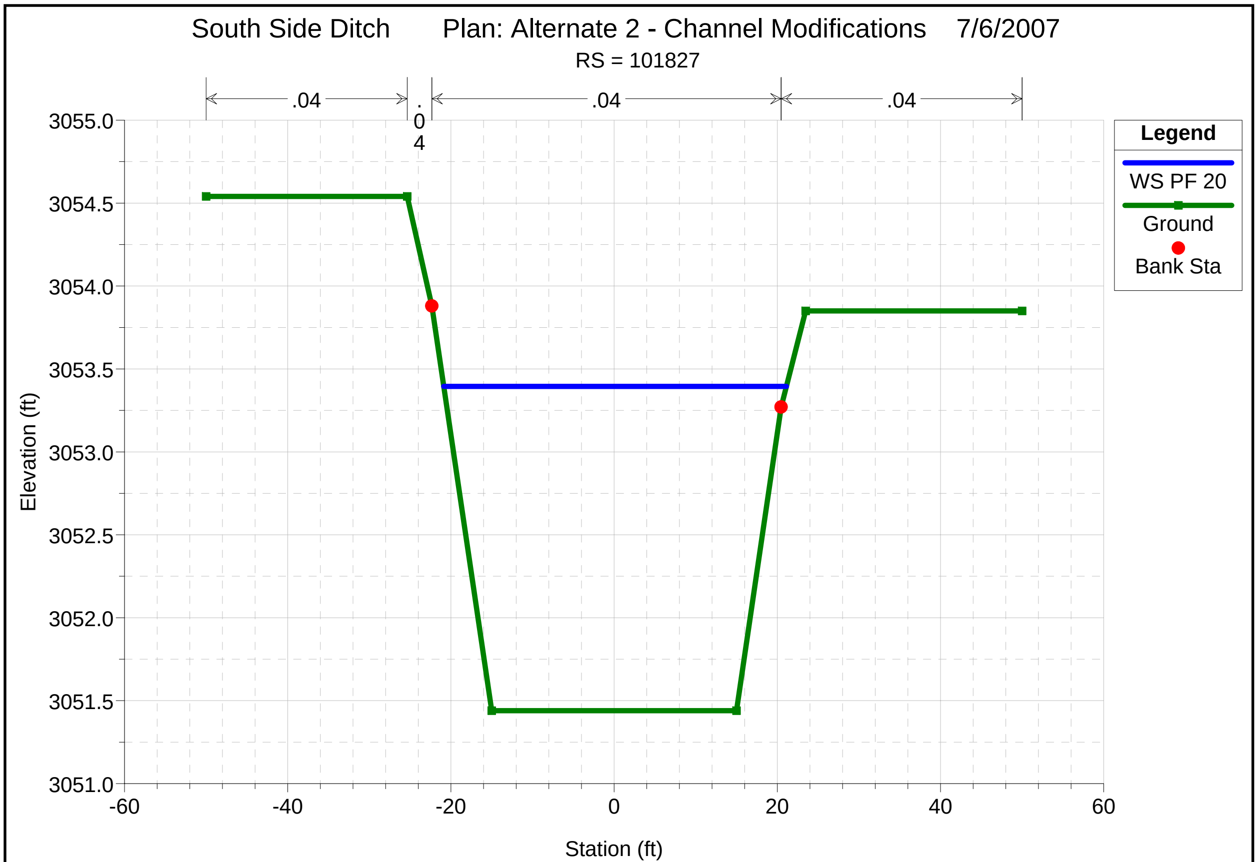
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 93940 BR
.04
.
0
4
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3052
3050
3048
3046
3044
3042
-40
-30
-20
-10
0
10
20
30
40

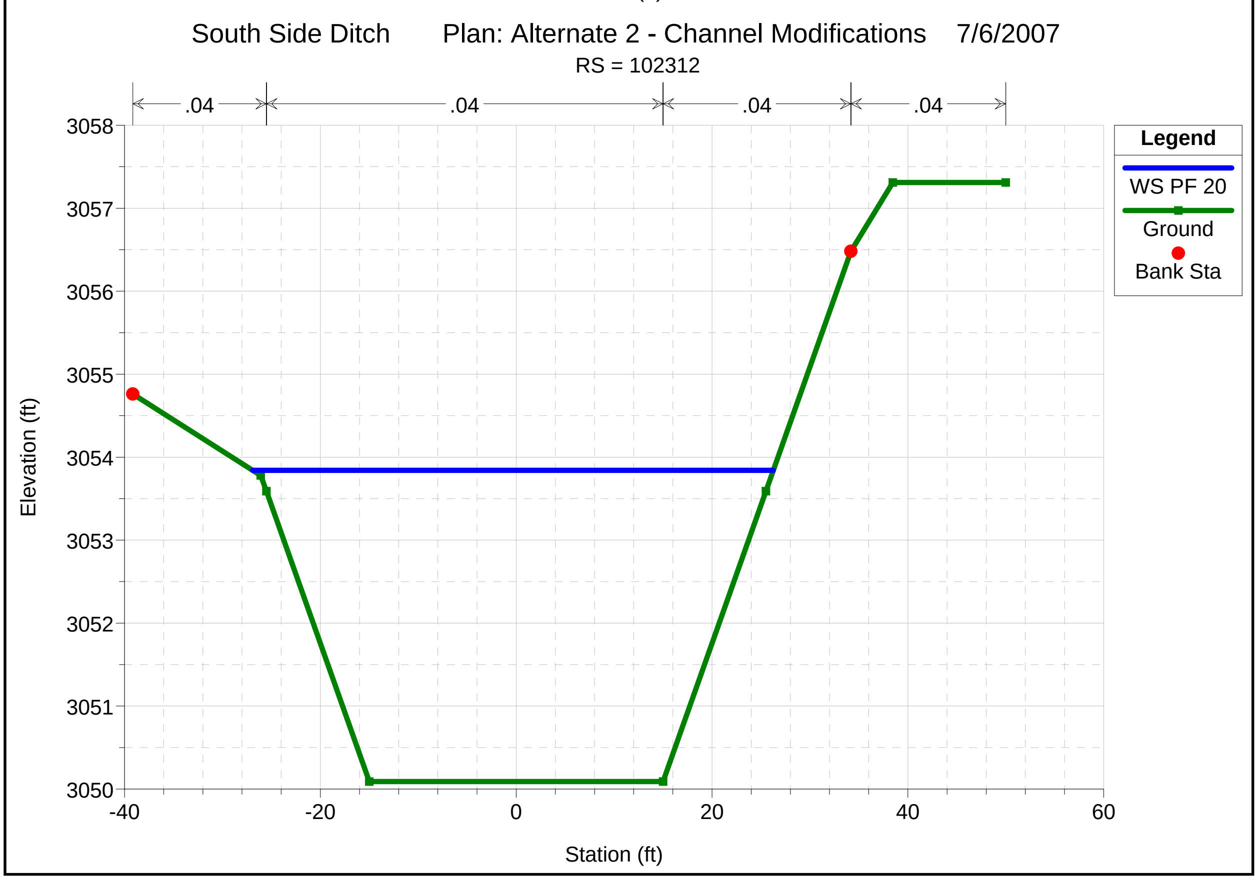


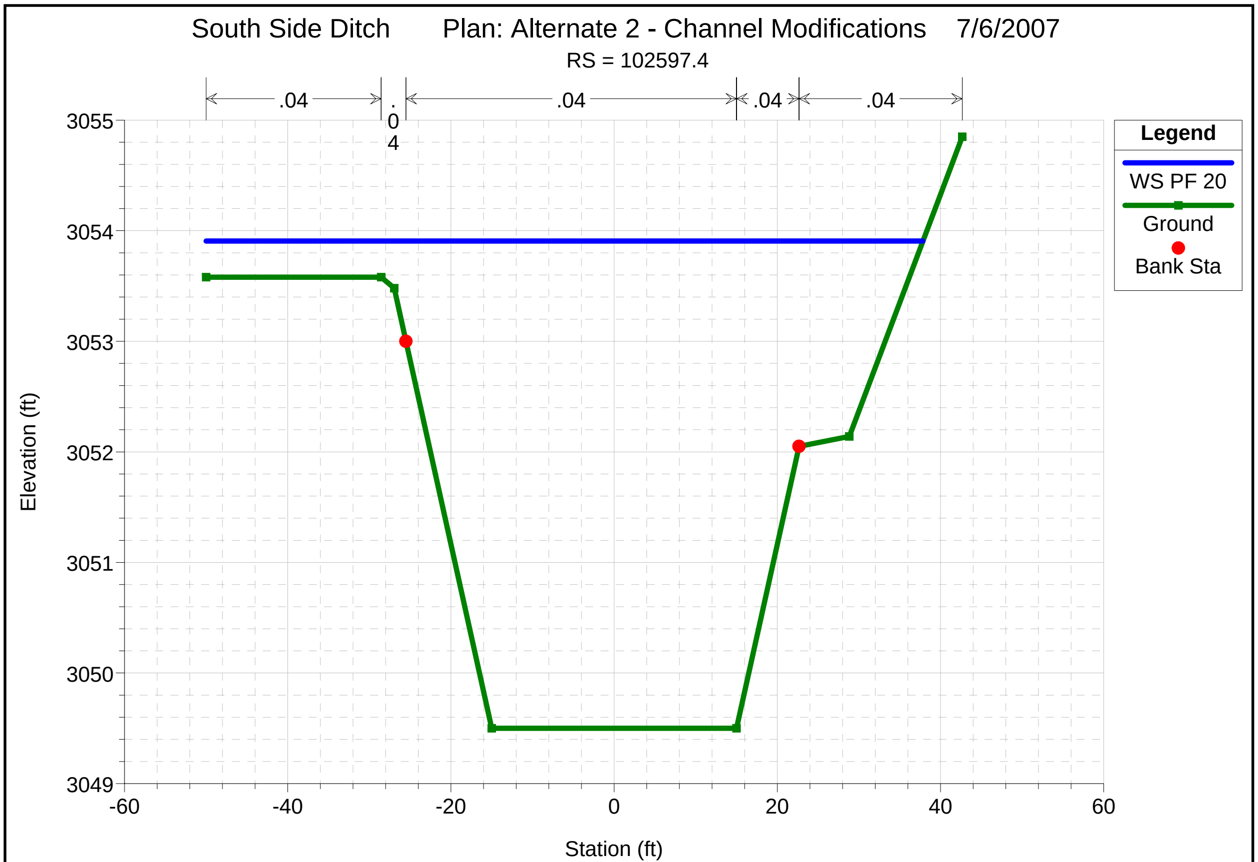
South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 93940 BR
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3052
3050
3048
3046
3044
3042
-60
-40
-20
0
20
40
60
Station (ft)

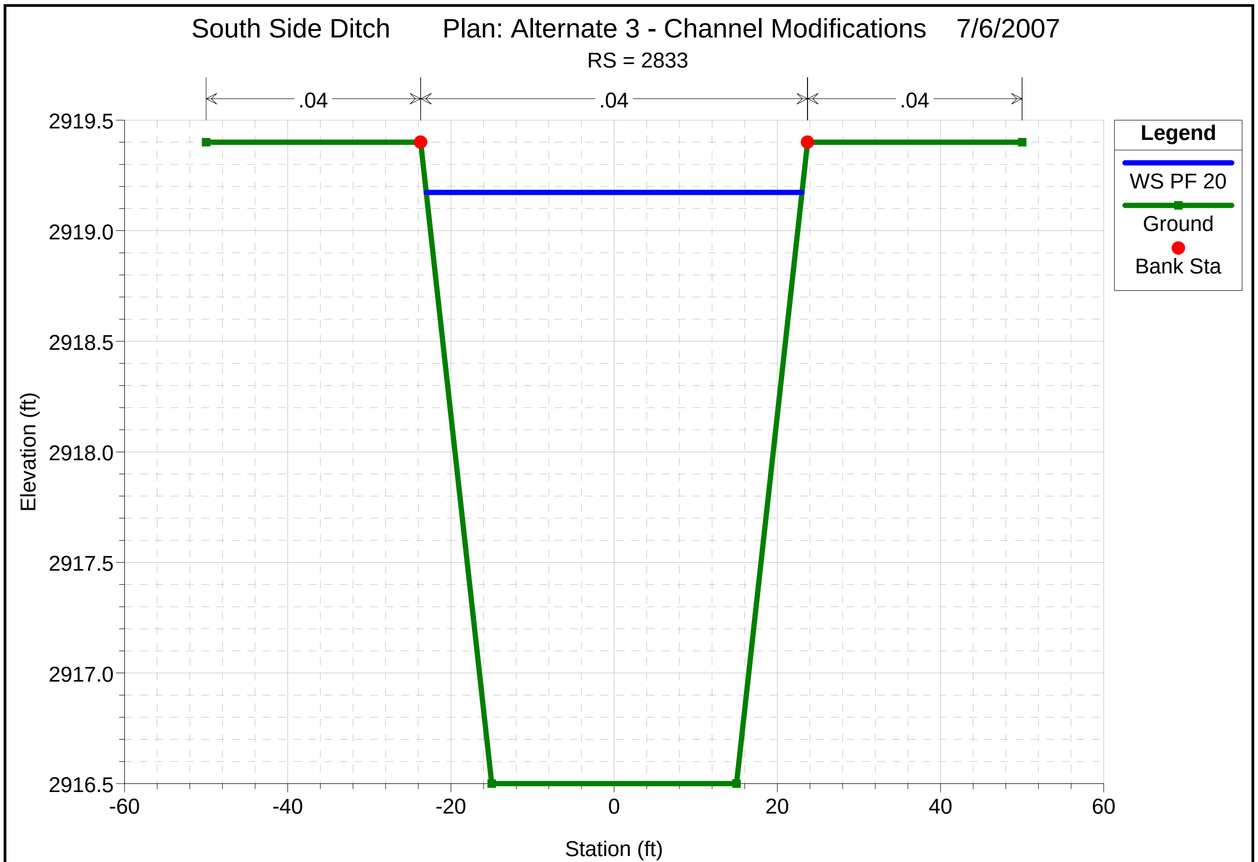


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 93965
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3050
3049
3048
3047
3046
3045
3044
3043
3042
-60
-40
-20
0
20
40
60
Station (ft)

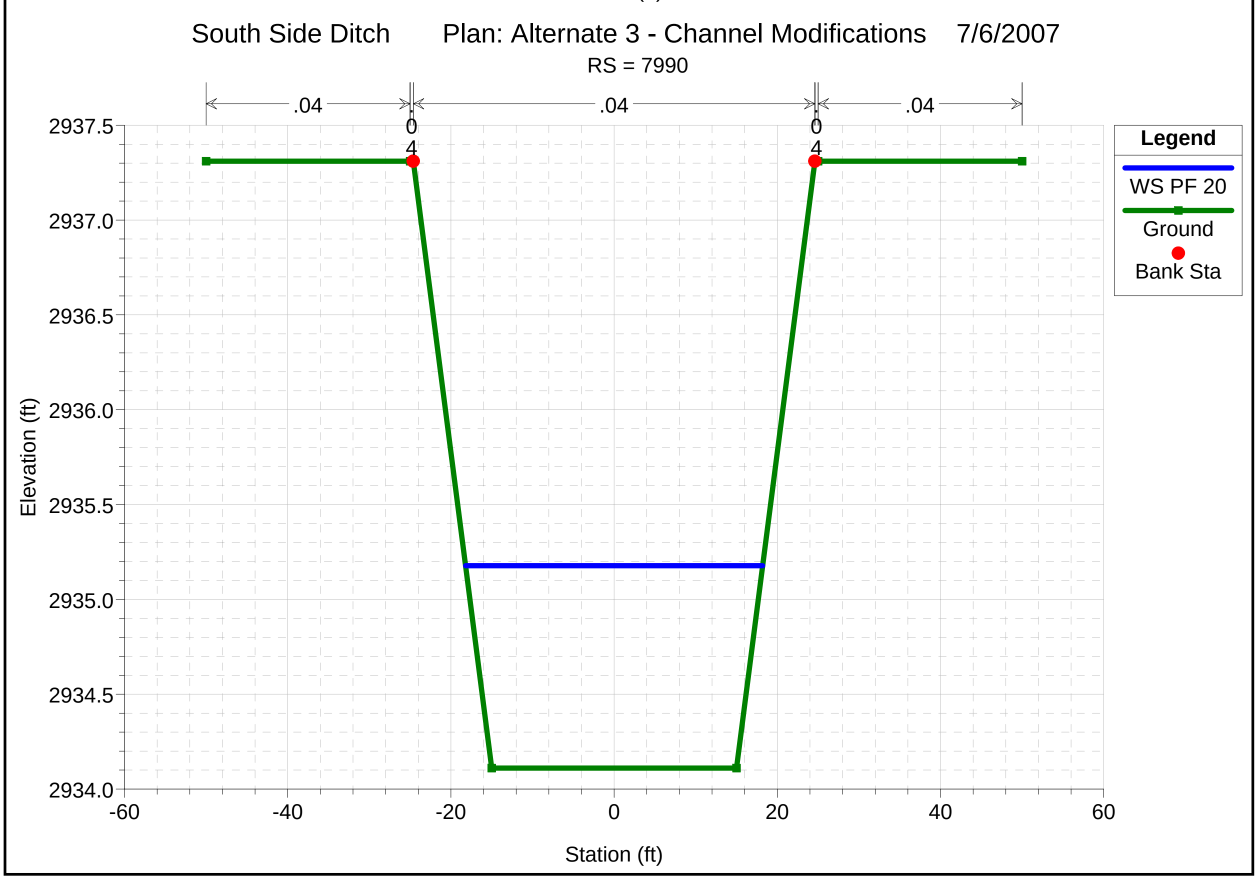

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 101827
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3055.0
3054.5
3054.0
3053.5
3053.0
3052.5
3052.0
3051.5
3051.0
-60
-40
-20
0
20
40
60


South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 102312
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
Station (ft)
3058
3057
3056
3055
3054
3053
3052
3051
3050
-40
-20
0
20
40
60

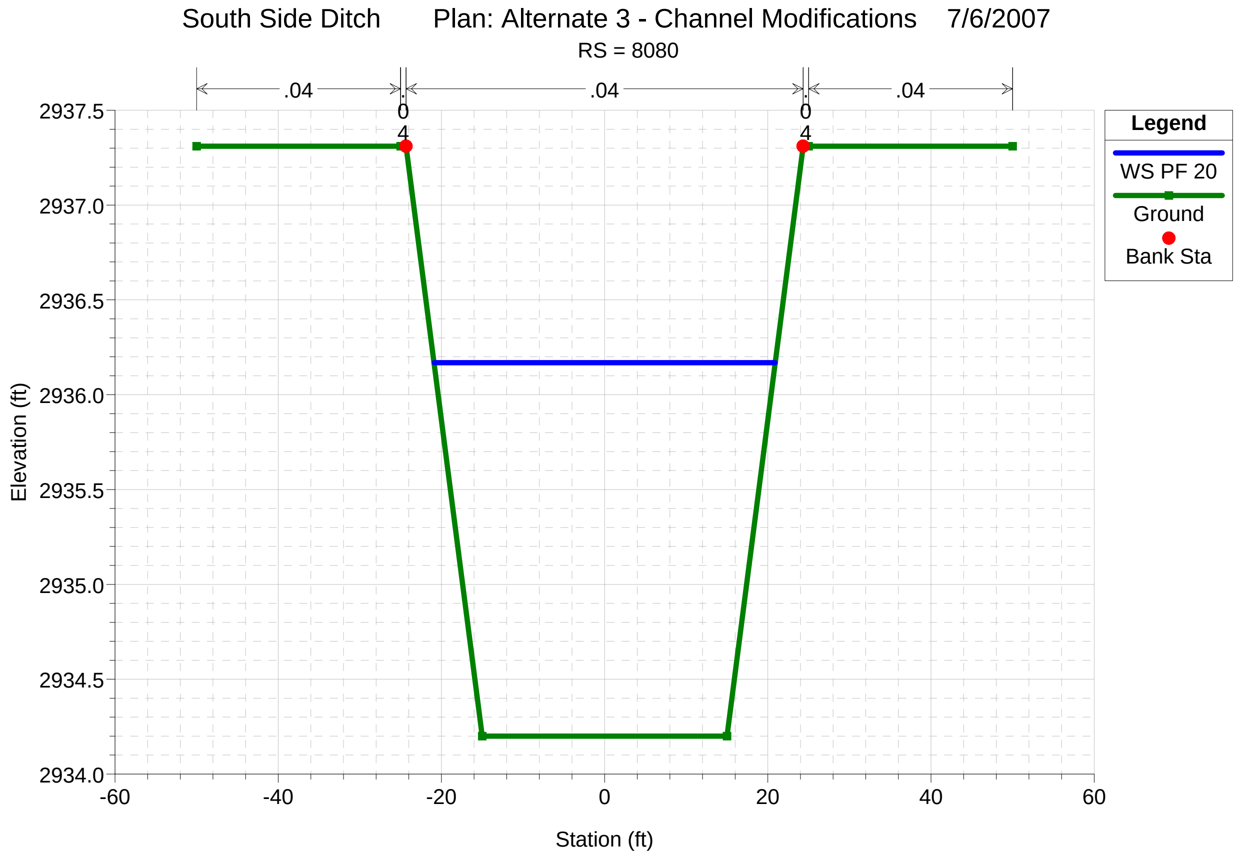

South Side Ditch Plan: Alternate 2 - Channel Modifications 7/6/2007
RS = 102597.4
.04
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
3055
3054
3053
3052
3051
3050
3049
-60
-40
-20
0
20
40
60
Station (ft)

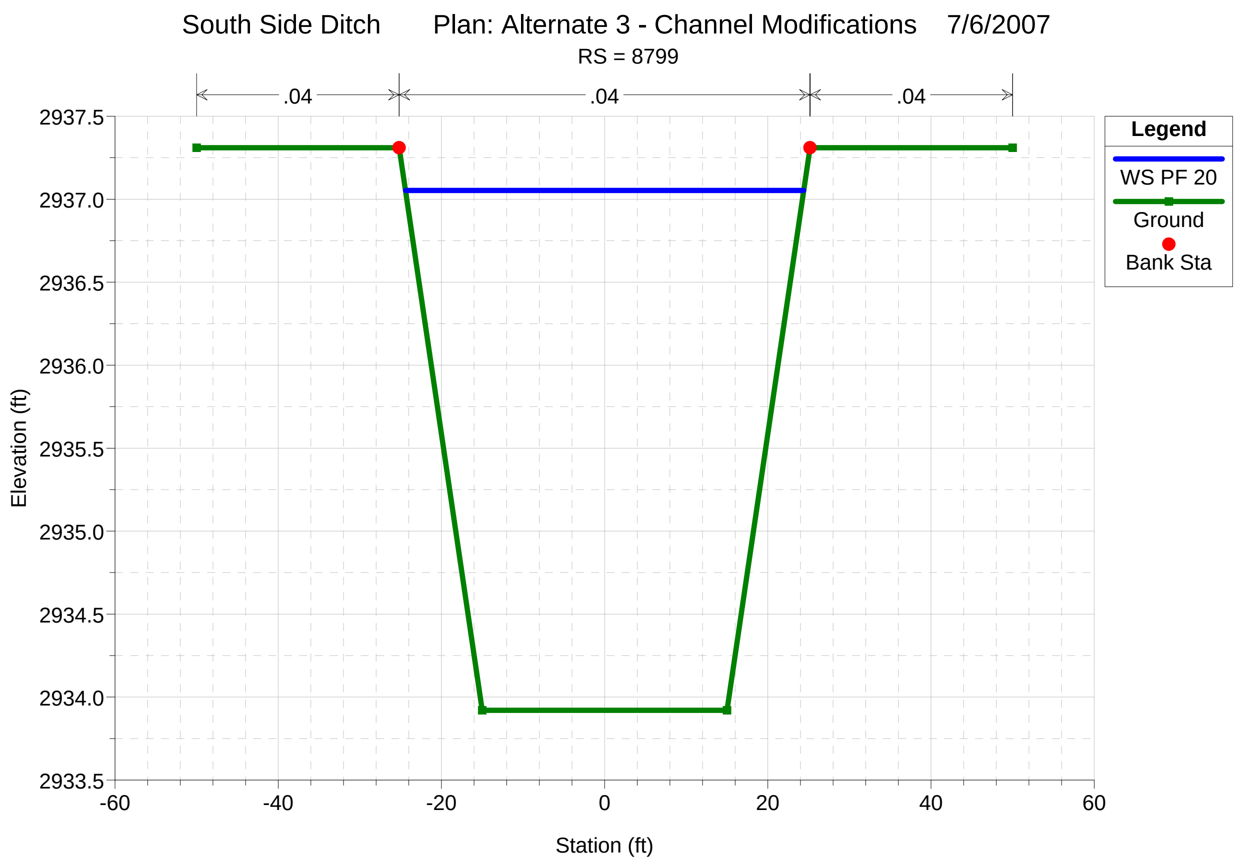


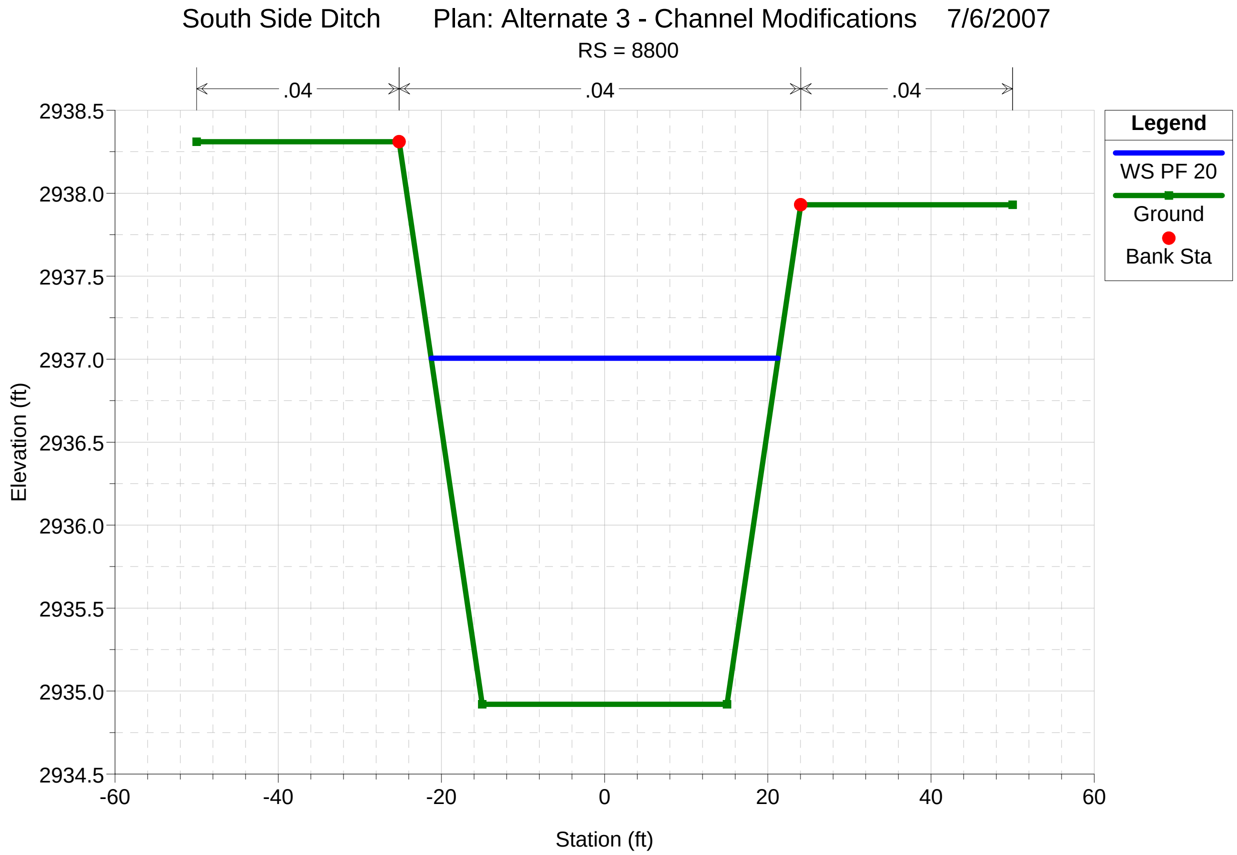
South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
RS = 2833
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
2919.5
2919.0
2918.5
2918.0
2917.5
2917.0
2916.5
Elevation (ft)
-60
-40
-20
0
20
40
60
Station (ft)

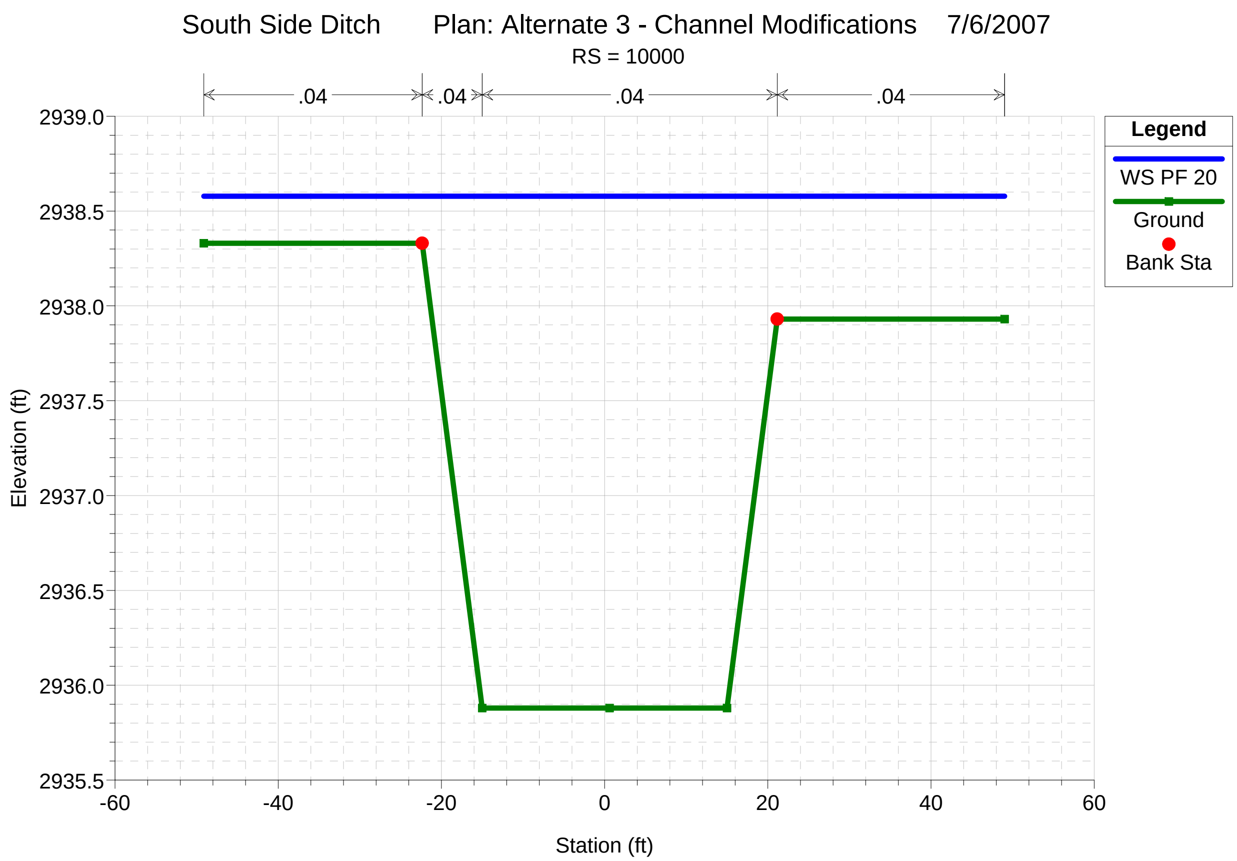


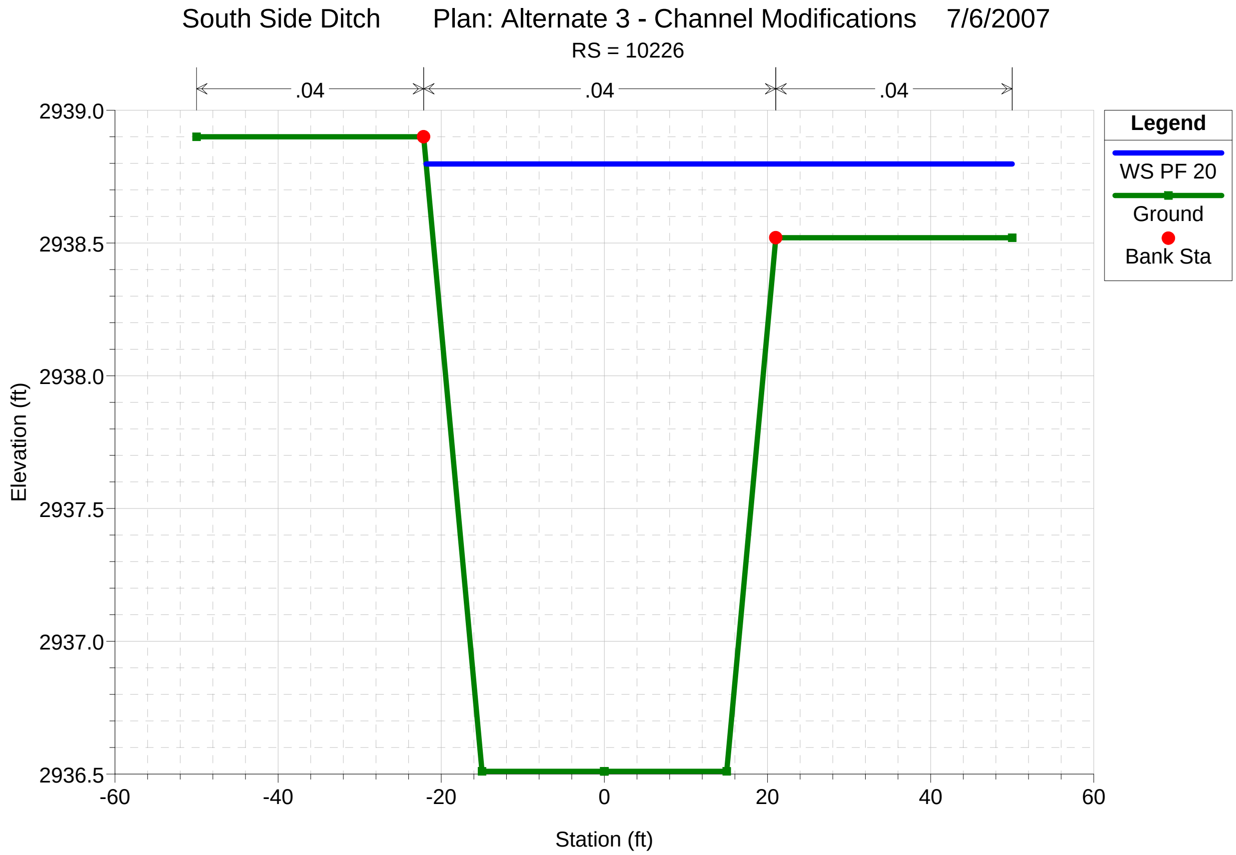
South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
RS = 7990
.04
0
4
.04
0
4
.04
Legend
WS PF 20
Ground
Bank Sta
2937.5
2937.0
2936.5
2936.0
2935.5
2935.0
2934.5
2934.0
Elevation (ft)
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
RS = 8080
.04
.04
.04
0
4
0
4
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2937.5
2937.0
2936.5
2936.0
2935.5
2935.0
2934.5
2934.0
-60
-40
-20
0
20
40
60
Station (ft)

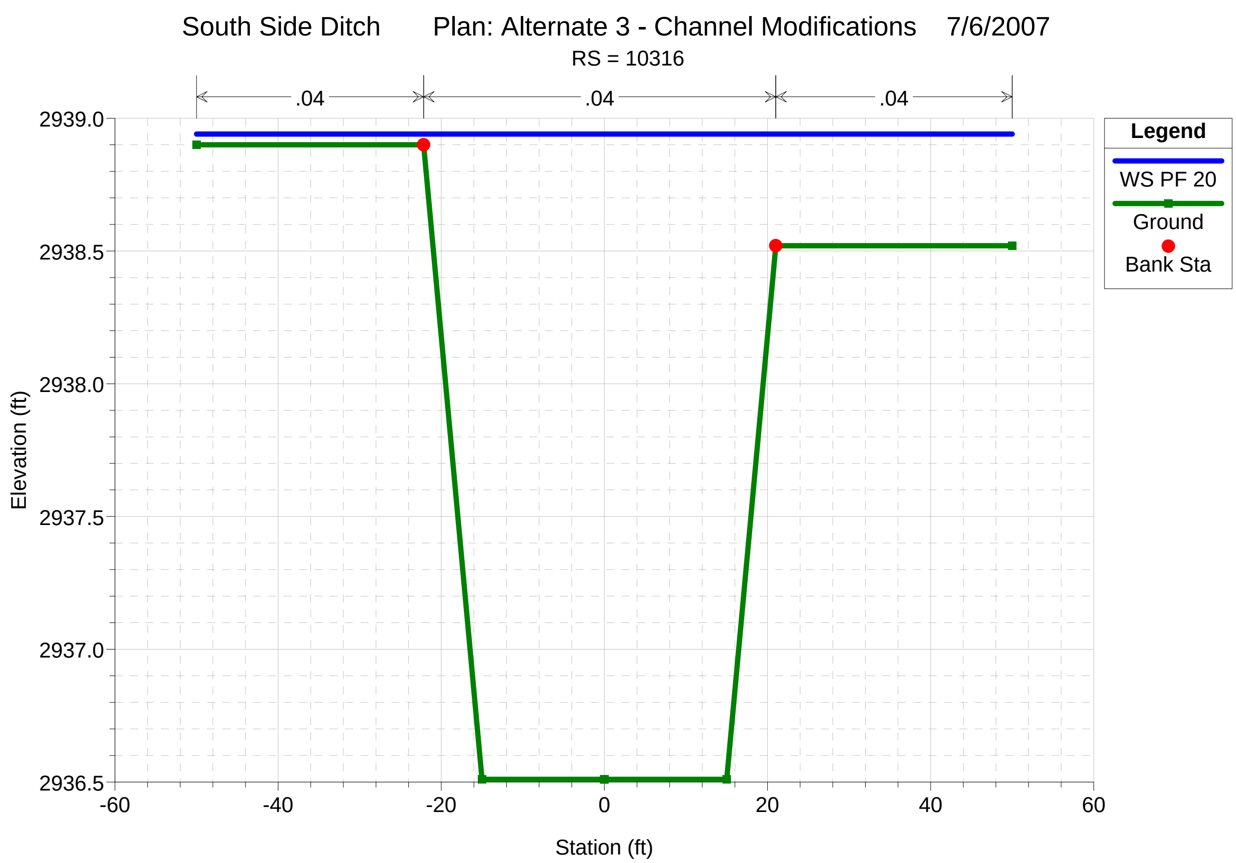

South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
RS = 8799
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2937.5
2937.0
2936.5
2936.0
2935.5
2935.0
2934.5
2934.0
2933.5
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch
Plan: Alternate 3 - Channel Modifications
7/6/2007
RS = 8800
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2938.5
2938.0
2937.5
2937.0
2936.5
2936.0
2935.5
2935.0
2934.5
-60
-40
-20
0
20
40
60
Station (ft)

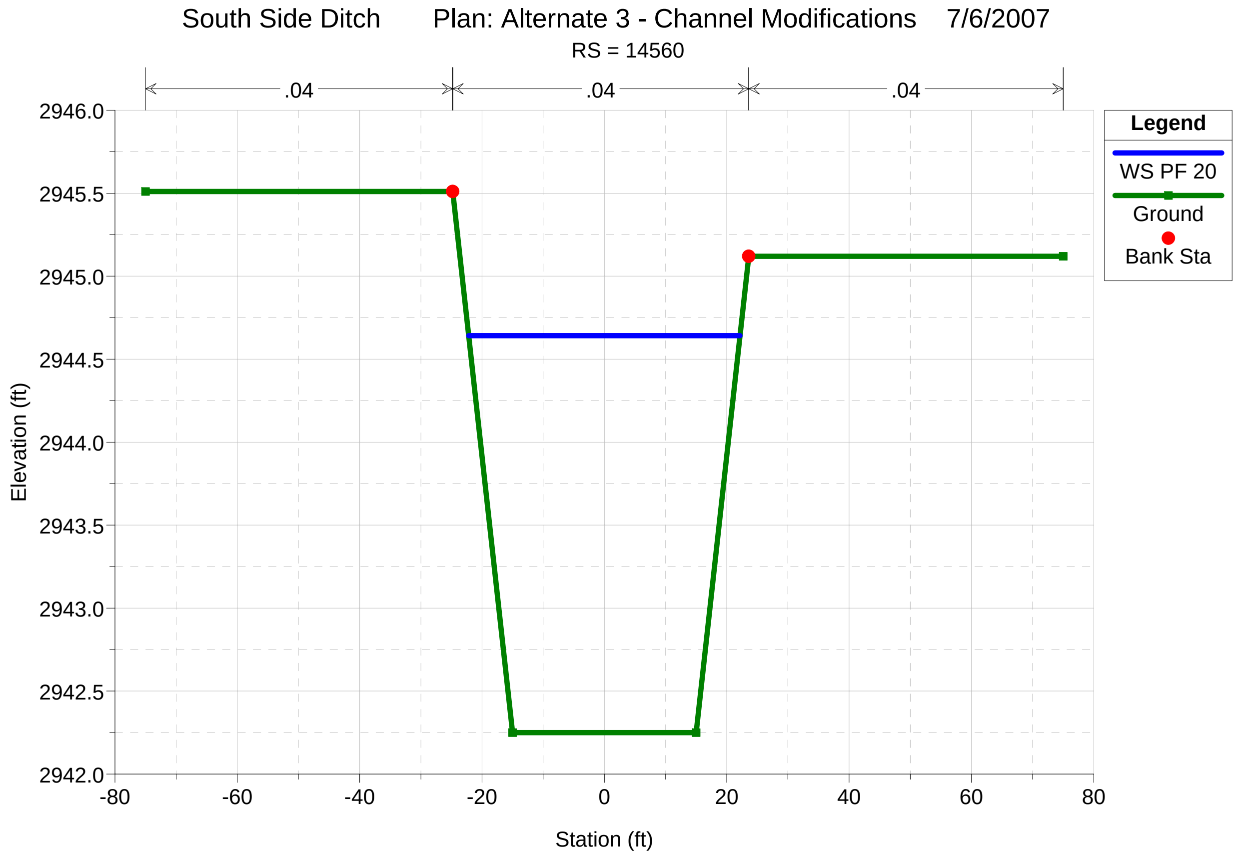

South Side Ditch
Plan: Alternate 3 - Channel Modifications
7/6/2007
RS = 10000
.04
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2939.0
2938.5
2938.0
2937.5
2937.0
2936.5
2936.0
2935.5
-60
-40
-20
0
20
40
60
Station (ft)

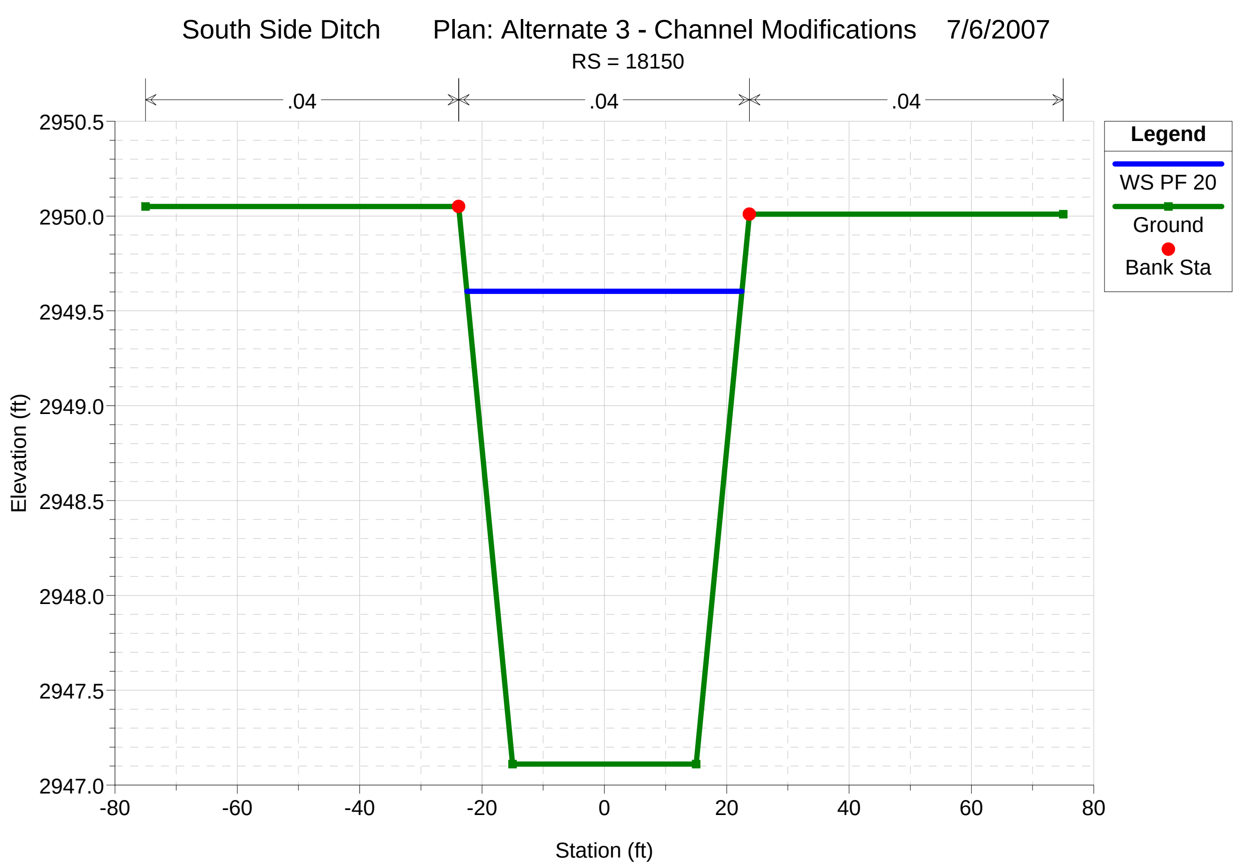


South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
RS = 10226
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2939.0
2938.5
2938.0
2937.5
2937.0
2936.5
-60
-40
-20
0
20
40
60
Station (ft)



South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
RS = 10316
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2939.0
2938.5
2938.0
2937.5
2937.0
2936.5
-60
-40
-20
0
20
40
60
Station (ft)


South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
RS = 14560
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2946.0
2945.5
2945.0
2944.5
2944.0
2943.5
2943.0
2942.5
2942.0
-80
-60
-40
-20
0
20
40
60
80
Station (ft)


South Side Ditch Plan: Alternate 3 - Channel Modifications 7/6/2007
RS = 18150
.04
.04
.04
Legend
WS PF 20
Ground
Bank Sta
Elevation (ft)
2950.5
2950.0
2949.5
2949.0
2948.5
2948.0
2947.5
2947.0
-80
-60
-40
-20
0
20
40
60
80
Station (ft)

HEC-RAS Plan: Alt 1 Chan Mod   River: South Side Ditch   Reach: 1   Profile: PF 20

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	18150	PF 20	200.00	2947.11	2948.18	2948.18	2948.67	0.024223	5.64	35.44	36.41	1.01
1	16194	PF 20	200.00	2937.11	2939.44		2939.52	0.001634	2.32	86.07	43.96	0.29
1	15732	PF 20	200.00	2936.29	2938.78		2938.85	0.001285	2.14	93.37	44.95	0.26
1	15178	PF 20	200.00	2935.49	2938.16	2936.56	2938.22	0.001000	1.97	101.65	46.04	0.23

HEC-RAS Plan: Alt 2 Chan Mod River: South Side Ditch Reach: 2 Profile: PF 20

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
2	102597.4	PF 20	200.00	3049.50	3053.91		3053.92	0.000131	1.03	211.81	87.84	0.09
2	102312	PF 20	200.00	3050.09	3053.84		3053.87	0.000300	1.29	154.77	53.16	0.13
2	101827	PF 20	200.00	3051.44	3053.40		3053.52	0.002977	2.85	70.13	42.00	0.39
2	93965	PF 20	200.00	3042.78	3046.49	3044.17	3046.52	0.000420	1.40	143.29	55.79	0.15
2	93940		Bridge									
2	93915	PF 20	200.00	3042.48	3046.46		3046.49	0.000421	1.52	132.92	50.91	0.16
2	90396	PF 20	200.00	3041.01	3044.61	3042.37	3044.66	0.000663	1.79	111.57	42.75	0.19
2	90351		Bridge									
2	90306	PF 20	200.00	3040.87	3044.53		3044.58	0.000606	1.75	114.56	43.66	0.19
2	87017	PF 20	200.00	3038.92	3042.21		3042.27	0.000822	1.98	106.50	51.98	0.22
2	85436	PF 20	200.00	3037.44	3039.73		3039.90	0.003517	3.24	61.66	33.75	0.42
2	82559	PF 20	200.00	3031.44	3034.58		3034.65	0.001104	2.13	94.09	40.70	0.25
2	81515	PF 20	200.00	3030.12	3033.73		3033.78	0.000644	1.80	111.19	41.64	0.19
2	79455	PF 20	200.00	3028.70	3032.68		3032.72	0.000416	1.58	128.09	47.23	0.16
2	75902	PF 20	200.00	3027.21	3030.17	3028.56	3030.26	0.001379	2.34	85.50	37.76	0.27
2	75849		Bridge									
2	75795	PF 20	200.00	3027.21	3029.99		3030.09	0.001741	2.54	78.78	36.68	0.31
2	73597	PF 20	200.00	3022.07	3024.26		3024.45	0.004148	3.43	58.23	33.15	0.46
2	71984	PF 20	200.00	3018.29	3021.58	3019.64	3021.64	0.000931	2.04	98.22	39.73	0.23
2	71969		Bridge									
2	71954	PF 20	200.00	3018.29	3021.50		3021.57	0.001022	2.10	95.02	39.25	0.24
2	70070	PF 20	200.00	3016.36	3019.55		3019.62	0.001046	2.12	94.25	39.13	0.24
2	67470	PF 20	200.00	3013.71	3017.02		3017.08	0.000910	2.02	99.05	40.13	0.23
2	65977	PF 20	200.00	3012.18	3014.37	3013.53	3014.56	0.004138	3.43	58.28	33.16	0.46
2	65950		Bridge									
2	65922	PF 20	200.00	3012.18	3013.53	3013.53	3014.12	0.022986	6.15	32.55	28.12	1.01
2	62510	PF 20	200.00	3004.47	3008.27	3005.82	3008.32	0.000526	1.66	120.39	42.95	0.17
2	62471		Bridge									
2	62432	PF 20	200.00	3004.47	3008.21		3008.26	0.000573	1.71	116.76	42.44	0.18
2	60260	PF 20	200.00	3002.47	3005.31	3004.37	3005.54	0.004489	3.80	52.70	27.06	0.48
2	60237		Bridge									
2	60215	PF 20	200.00	3002.57	3004.46	3004.46	3005.17	0.022033	6.74	29.68	21.36	1.01
2	59703	PF 20	200.00	2998.67	3002.73		3002.81	0.001037	2.22	90.16	34.38	0.24
2	58670	PF 20	200.00	2997.50	3001.70		3001.78	0.000966	2.26	89.08	34.15	0.24
2	57559	PF 20	200.00	2996.59	3000.64		3000.71	0.000949	2.25	89.56	34.27	0.23
2	56894	PF 20	200.00	2995.90	3000.02		3000.10	0.000908	2.22	90.86	34.50	0.23
2	56411	PF 20	200.00	2995.47	2999.60		2999.67	0.000862	2.19	92.42	35.35	0.22
2	56080	PF 20	200.00	2995.15	2999.30	2997.04	2999.37	0.000946	2.14	93.24	34.91	0.23
2	56057		Bridge									
2	56034	PF 20	200.00	2995.15	2999.24		2999.31	0.001013	2.20	90.94	34.51	0.24
2	55602	PF 20	200.00	2994.90	2998.71		2998.81	0.001353	2.45	81.74	32.87	0.27
2	54573	PF 20	200.00	2993.53	2996.94	2995.43	2997.07	0.002161	2.91	68.83	30.43	0.34
2	54523		Bridge									
2	54473	PF 20	200.00	2993.53	2996.77		2996.82	0.000687	1.78	112.39	44.43	0.20
2	49368	PF 20	200.00	2989.28	2991.97		2992.05	0.001342	2.25	89.09	41.16	0.27
2	47818	PF 20	200.00	2986.83	2989.04	2988.02	2989.17	0.002718	2.86	69.94	38.27	0.37
2	47760		Bridge									
2	47703	PF 20	200.00	2986.83	2988.02	2988.02	2988.56	0.023795	5.90	33.93	32.13	1.01
2	46530	PF 20	200.00	2982.19	2985.37	2983.38	2985.42	0.000733	1.82	109.89	44.09	0.20
2	46483		Culvert									
2	46436	PF 20	200.00	2982.19	2984.82		2984.88	0.001065	2.01	99.51	45.76	0.24
2	41706	PF 20	200.00	2977.40	2980.13		2980.19	0.000925	1.92	104.38	46.39	0.23
2	40381	PF 20	200.00	2976.06	2979.21	2977.13	2979.25	0.000557	1.61	124.23	48.90	0.18
2	40334		Bridge									
2	40287	PF 20	200.00	2976.06	2978.54		2978.61	0.001308	2.16	92.81	44.87	0.26
2	37625	PF 20	200.00	2972.72	2975.29	2973.79	2975.36	0.001145	2.06	97.08	45.44	0.25
2	37560		Culvert									
2	37495	PF 20	200.00	2972.72	2975.16		2975.23	0.001386	2.20	90.99	44.63	0.27
2	33933	PF 20	200.00	2968.62	2971.45	2969.69	2971.50	0.000820	1.84	108.78	46.96	0.21
2	33908		Bridge									
2	33883	PF 20	200.00	2968.62	2971.38		2971.43	0.000897	1.90	105.48	46.54	0.22
2	30756	PF 20	200.00	2964.58	2966.51		2966.64	0.003159	2.90	69.01	41.57	0.40
2	25326	PF 20	200.00	2957.56	2960.74	2958.63	2960.78	0.000536	1.59	125.91	49.10	0.17
2	25310		Bridge									
2	25294	PF 20	200.00	2957.56	2959.86		2959.94	0.001715	2.36	84.68	43.77	0.30
2	24773	PF 20	200.00	2956.70	2958.77		2958.88	0.002482	2.67	74.79	42.40	0.35
2	22063	PF 20	200.00	2952.23	2954.97	2953.30	2955.03	0.000914	1.91	104.82	46.45	0.22
2	21998		Culvert									
2	21933	PF 20	200.00	2952.23	2954.74		2954.81	0.001247	2.12	94.31	45.07	0.26
2	20590	PF 20	200.00	2950.41	2952.58		2952.68	0.002092	2.53	79.20	43.02	0.33
2	18150.*	PF 20	200.00	2947.11	2950.16	2948.18	2950.20	0.000590	1.65	133.08	150.00	0.18
2	14560	PF 20	200.00	2942.25	2943.32	2943.32	2943.81	0.024206	5.64	35.45	36.41	1.01
2	10316	PF 20	200.00	2936.51	2941.29	2937.57	2941.29	0.000048	0.69	338.42	100.00	0.06
2	10271		Culvert									
2	10226	PF 20	200.00	2936.51	2938.69		2938.78	0.001990	2.49	84.29	71.52	0.32
2	10000.*	PF 20	200.00	2935.88	2938.38	2936.95	2938.44	0.001113	2.04	107.36	98.14	0.25
2	6132	PF 20	200.00	2925.17	2926.25	2926.25	2926.73	0.024262	5.57	35.88	37.63	1.01
2	4513	PF 20	200.00	2914.50	2917.17	2915.57	2917.23	0.001001	1.97	101.63	46.04	0.23

HEC-RAS Plan: Alt 3 Chan Mod River: South Side Ditch Reach: 3 Profile: PF 20

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	18150	PF 20	200.00	2947.11	2949.60		2949.68	0.001281	2.14	93.46	44.97	0.26
3	14560	PF 20	200.00	2942.25	2944.64		2944.72	0.001485	2.25	88.90	44.35	0.28
3	10316	PF 20	200.00	2936.51	2938.94		2939.01	0.001237	2.11	103.65	100.00	0.26
3	10226	PF 20	200.00	2936.51	2938.80		2938.88	0.001614	2.32	92.23	71.85	0.29
3	10000	PF 20	200.00	2935.88	2938.58		2938.63	0.000768	1.80	126.82	98.14	0.21
3	8800	PF 20	200.00	2934.92	2937.01		2937.12	0.002401	2.64	75.63	42.52	0.35
3	8799	PF 20	200.00	2933.92	2937.05		2937.09	0.000568	1.62	123.40	48.79	0.18
3	8080	PF 20	200.00	2934.20	2936.17		2936.29	0.002940	2.83	70.68	41.81	0.38
3	7990	PF 20	200.00	2934.11	2935.18	2935.18	2935.67	0.024225	5.64	35.44	36.40	1.01
3	2833	PF 20	200.00	2916.50	2919.17	2917.57	2919.23	0.001001	1.97	101.62	46.04	0.23

Appendix C
Soils Gradation Tests

Summary of Laboratory Testing

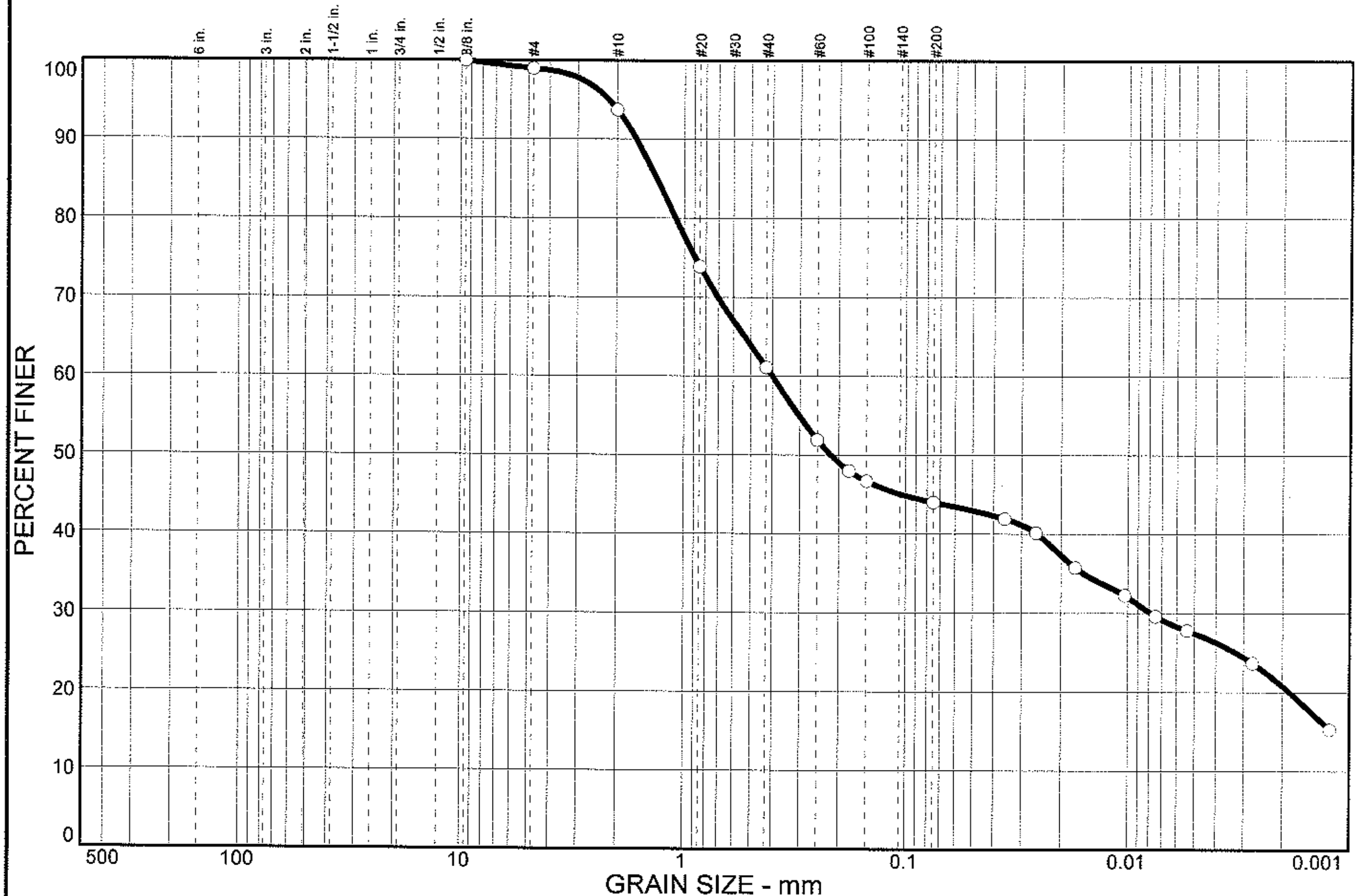
SLT 22205

Alpha-Omega Geotech, Inc.
1701 State Avenue
Kansas City, KS 66102
Office: (913) 371-0000 Fax: (913) 371-6710
Website: www.aogeotech.com

PROJECT NAME: Feasibilty Study #1, South Side Ditch
PROJECT LOCATION:
PROJECT NUMBER: 7-104T
DATE: 1/8/2007

Boring Number	Sample Number	Depth or Elevation	Description	Natural Moisture (%)	Dry Unit Weight (pcf)	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI	USCS Class.	% Passing No. 200	Unconfined Compression PSF	%e	% Swell	Remarks
	Bucket-1		Silty sand						SM	44.0				Please see the attached Hydrometer Analysis Test Report.
	Bucket-2		Poorly graded sand						SP	2.4				Please see the attached Grain Size Test Report.
	Bucket-3		Poorly graded sand with silt and gravel						SP-SM	6.0				Please see the attached Grain Size Test Report.
	Bucket-4		Silty sand						SM	24.7				Please see the attached Hydrometer Analysis Test Report.
	Bucket-5		Silty sand						SM	26.8				Please see the attached Hydrometer Analysis Test Report.

Particle Size Distribution Report



% + 3"	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.0	5.3	32.6	17.1	16.6	27.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375 in.	100.0		
#4	99.0		
#10	93.7		
#20	73.9		
#40	61.1		
#60	51.9		
#80	48.0		
#100	46.7		
#200	44.0		

* (no specification provided)

Material Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.33 D_{60}= 0.400 D_{50}= 0.218
D_{30}= 0.0079 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

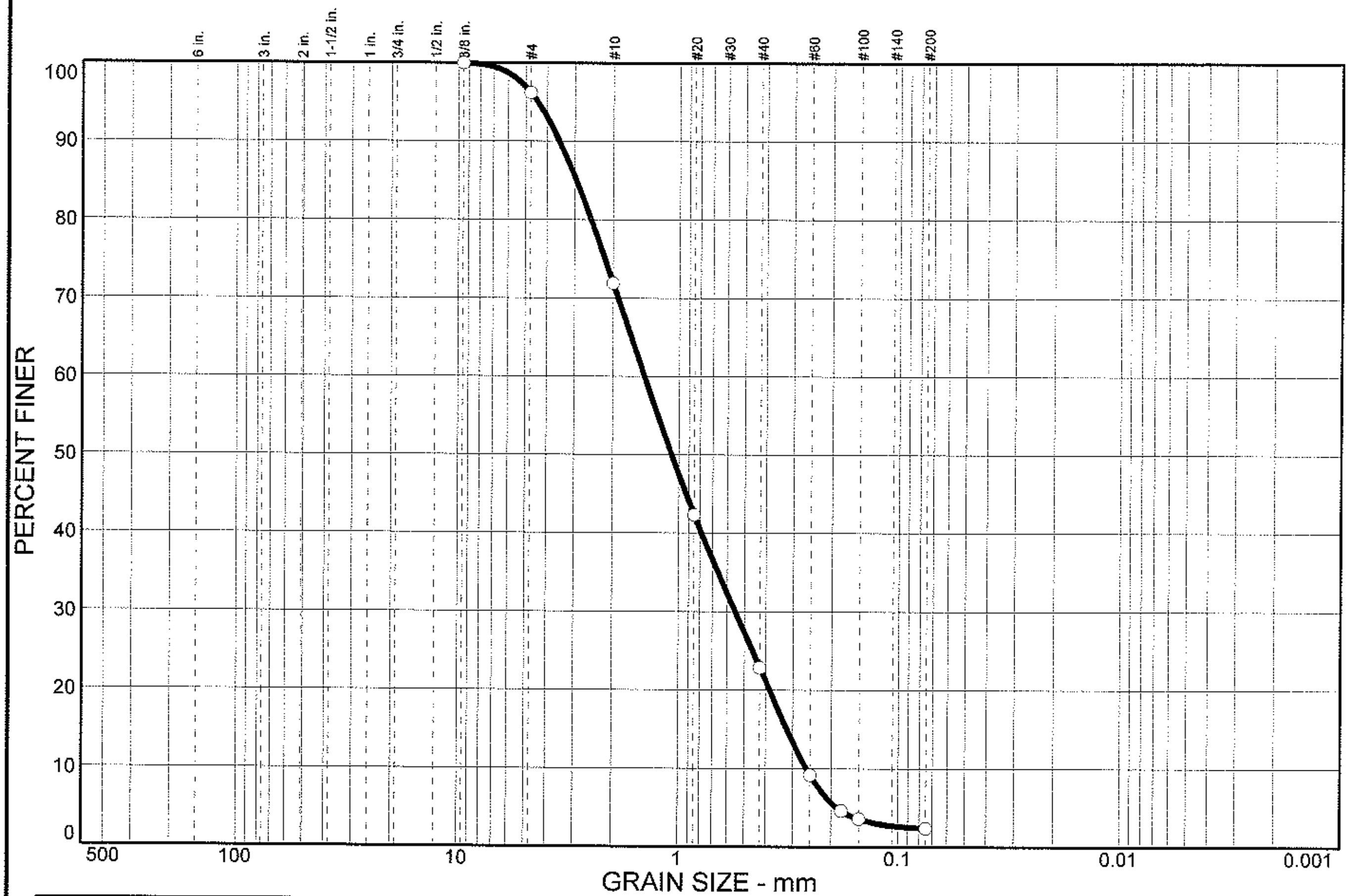
F.M.=0.54

Sample No.: Bucket-1 **Source of Sample:** **Date:** 1/9/07
Location: **Elev./Depth:**

Alpha-Omega Geotech, Inc.

Client: Burns & McDonnell
Project: Feasibility Study #1, South Side Ditch
Project No: 7-104T **Figure** 1 of 1

Particle Size Distribution Report



% + 3"	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	3.8	24.3	49.0	20.5	2.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375 in.	100.0		
#4	96.2		
#10	71.9		
#20	42.3		
#40	22.9		
#60	9.2		
#80	4.6		
#100	3.6		
#200	2.4		

* (no specification provided)

Material Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 2.96 D_{60}= 1.43 D_{50}= 1.08
D_{30}= 0.551 D_{15}= 0.320 D_{10}= 0.260
C_u= 5.52 C_c= 0.82

Classification

USCS= SP AASHTO=

Remarks

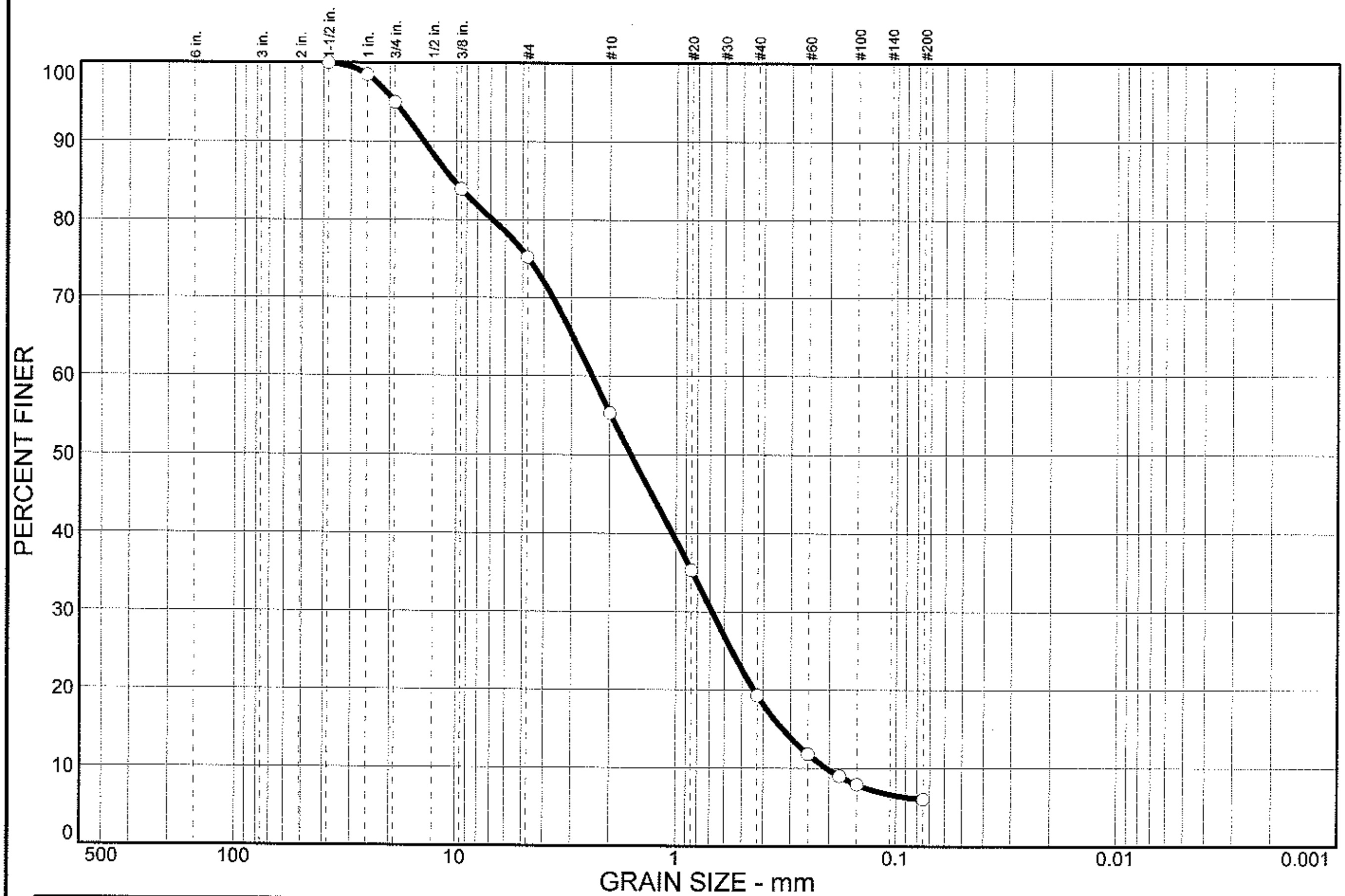
F.M.=1.00

Sample No.: Bucket-2 **Source of Sample:** **Date:** 1/8/07
Location: **Elev./Depth:**

Alpha-Omega Geotech, Inc.

Client: Burns & McDonnell
Project: Feasibility Study #1, South Side Ditch
Project No: 7-104T **Figure** 1 of 1

Particle Size Distribution Report



% + 3"	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	5.0	19.8	19.9	36.0	13.3	6.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5 in.	100.0		
1 in.	98.5		
.75 in.	95.0		
.375 in.	83.9		
#4	75.2		
#10	55.3		
#20	35.3		
#40	19.3		
#60	11.8		
#80	9.0		
#100	7.9		
#200	6.0		

* (no specification provided)

Material Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 10.3 D_{60}= 2.41 D_{50}= 1.60
D_{30}= 0.684 D_{15}= 0.326 D_{10}= 0.206
C_u= 11.73 C_c= 0.94

Classification

USCS= SP-SM AASHTO=

Remarks

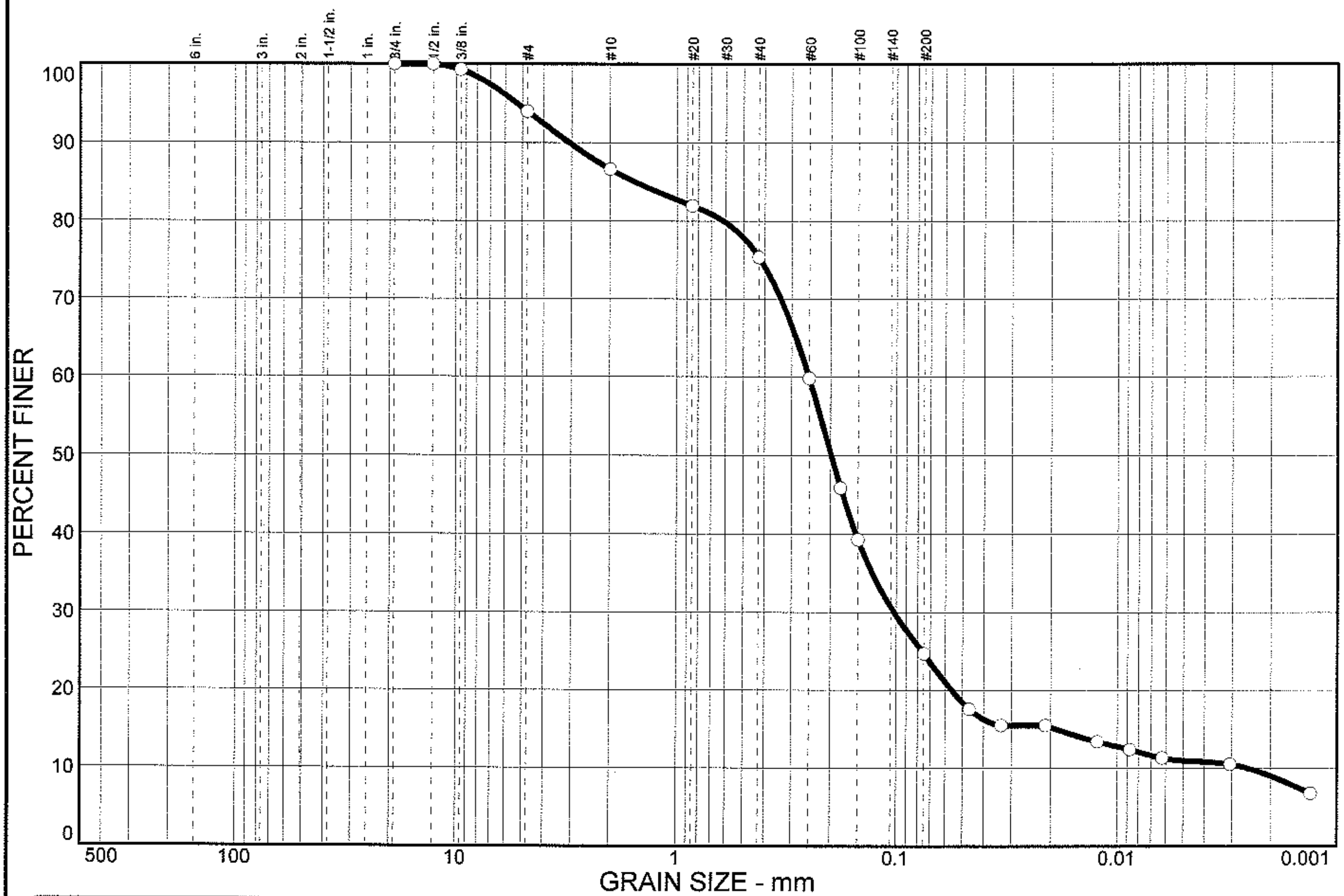
F.M.=1.38

Sample No.: Bucket-3 **Source of Sample:** **Date:** 1/8/07
Location: **Elev./Depth:**

Alpha-Omega Geotech, Inc.

Client: Burns & McDonnell
Project: Feasibility Study #1, South Side Ditch
Project No: 7-104T **Figure** 1 of 1

Particle Size Distribution Report



% + 3"	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	6.0	7.4	11.3	50.6	13.7	11.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	100.0		
.5 in.	100.0		
.375 in.	99.3		
#4	94.0		
#10	86.6		
#20	81.9		
#40	75.3		
#60	59.8		
#80	45.9		
#100	39.3		
#200	24.7		

* (no specification provided)

Material Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.55 D_{60}= 0.251 D_{50}= 0.199
D_{30}= 0.103 D_{15}= 0.0188 D_{10}= 0.0025
C_u= 98.79 C_c= 16.45

Classification

USCS= SM AASHTO=

Remarks

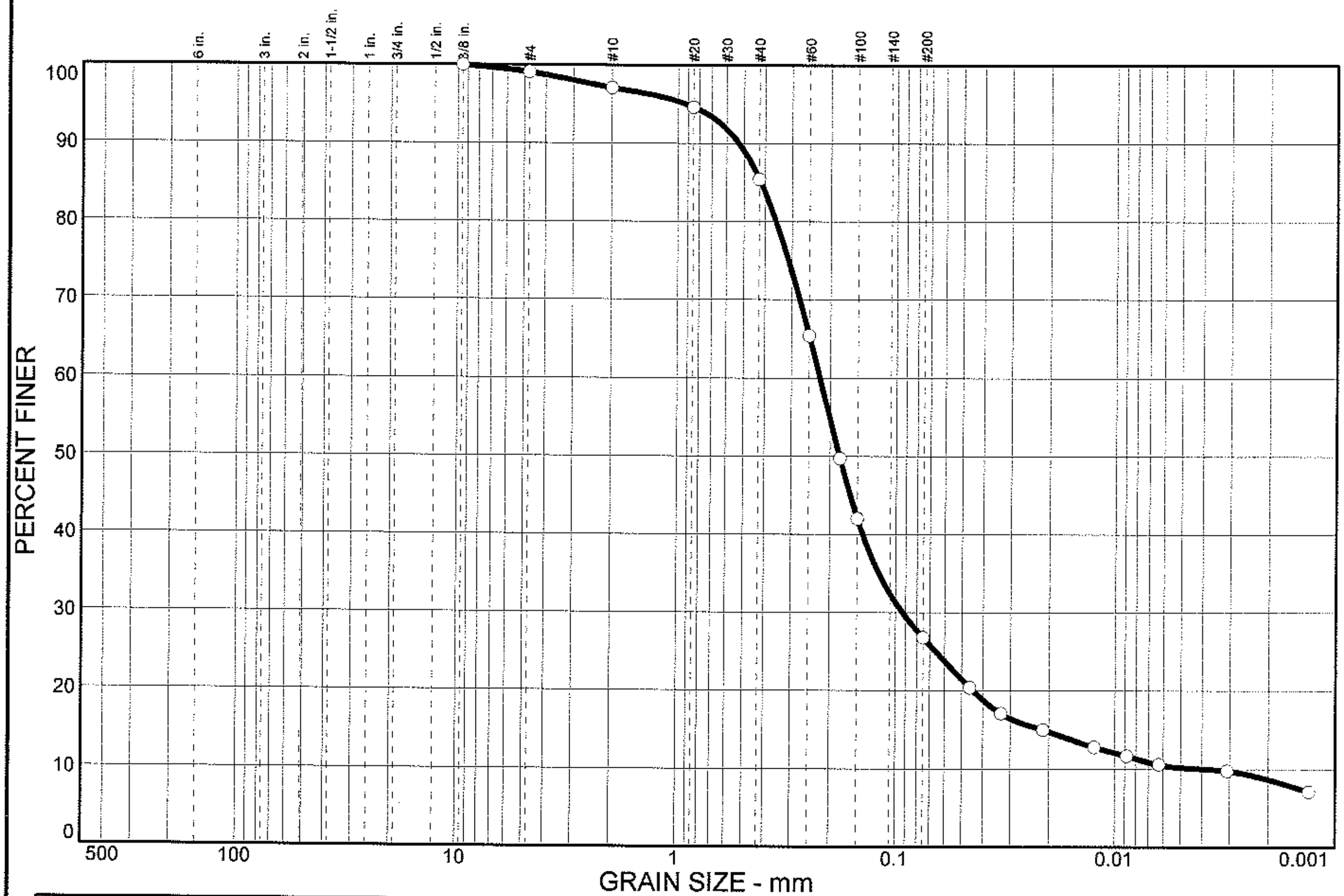
F.M.=0.67

Sample No.: Bucket-4 **Source of Sample:** **Date:** 1/9/07
Location: **Elev./Depth:**

Alpha-Omega Geotech, Inc.

Client: Burns & McDonnell
Project: Feasibility Study #1, South Side Ditch
Project No: 7-104T **Figure** 1 of 1

Particle Size Distribution Report



% + 3"	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.9	2.0	11.7	58.6	16.6	10.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375 in.	100.0		
#4	99.1		
#10	97.1		
#20	94.6		
#40	85.4		
#60	65.4		
#80	49.7		
#100	42.0		
#200	26.8		

* (no specification provided)

Material Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.419 D_{60}= 0.223 D_{50}= 0.181
D_{30}= 0.0931 D_{15}= 0.0212 D_{10}= 0.0037
C_u= 60.23 C_c= 10.47

Classification

USCS= SM AASHTO=

Remarks

F.M.=0.59

Sample No.: Bucket-5 **Source of Sample:** **Date:** 1/9/07
Location: **Elev./Depth:**

Alpha-Omega Geotech, Inc.

Client: Burns & McDonnell
Project: Feasibility Study #1, South Side Ditch
Project No: 7-104T **Figure** 1 of 1

Appendix D
Flow Data

Summary of Results **South Side Ditch** **Unlined Channel**

Arkansas River Node	Annual Flow (ac-ft)			Annual Upstream Gain (Loss) (ac-ft)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	83,357	643	313,103	-2,112	-6,878	724
Alt. 1 Return Point	56,767	840	245,415	-8,643	-25,506	197
Alt. 2 Return Point	56,023	857	243,914	-744	-2,295	18
Farmer's Ditch Diversion	56,827	868	243,038	804	-1,338	4,747
Garden City Ditch Diversion	27,894	71	166,143	-79	-1,173	471
Garden City	27,358	182	161,022	-536	-5,121	3,222
Total				-38,966	-95,960	-7,898

Ditch Name	Annual Diversion (ac-ft)			Annual Ditch Return (ac-ft) [1]			Annual Ditch Losses (ac-ft) [2]		
	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
Amazon	18,755	0	51,513	0	0	0	---	---	---
Southside	17,947	0	51,000	0	0	0	3,946	0	9,637
Great Eastern	55,843	10,171	132,813	0	0	0	---	---	---
Farmer's [3]	25,712	818	70,875	0	0	0	0	0	0
Garden City	3,142	0	8,565	0	0	0	---	---	---
Total	121,400	11,443	310,535				3,946	0	9,637

Total Gain (Loss)	
Avg	-42,913
Min	-99,476
Max	-14,701

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results | **Channel Return Alternate 1** | **Unlined Channel**

Arkansas River Node	Annual Flow (ac-ft) Average	Minimum	Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Minimum	Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	92,548	643	374,911	-2,167	-6,705	454
Alt. 1 Return Point	67,094	281	321,550	-5,129	-15,873	745
Alt. 2 Return Point	66,497	298	319,883	-597	-1,497	18
Farmer's Ditch Diversion	67,388	309	319,010	891	-873	4,771
Garden City Ditch Diversion	47,137	73	277,243	-423	-1,877	339
Garden City	44,964	194	268,974	-2,172	-8,942	1,149
Total				-37,253	-79,963	-8,732

Ditch Name	Annual Diversion (ac-ft) Average	Minimum	Maximum	Annual Ditch Return (ac-ft) [1] Average	Minimum	Maximum	Annual Ditch Losses (ac-ft) [2] Average	Minimum	Maximum
Amazon	15,367	0	30,000	0	0	0	---	---	---
Southside	15,027	0	30,000	0	0	0	3,424	0	6,184
Great Eastern	49,985	10,625	113,158	0	0	0	---	---	---
Farmer's [3]	23,955	635	44,714	18,656	76	36,887	5,298	559	7,827
Garden City	19,828	259	40,110	0	0	0	---	---	---
Total	124,162	11,520	256,471				8,722	559	13,842

Total Gain (Loss)	
Avg	-45,976
Min	-92,468
Max	-15,260

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results | **Channel Return Alternate 2** | **Unlined Channel**

Arkansas River Node	Annual Flow (ac-ft) Average	Annual Flow (ac-ft) Minimum	Annual Flow (ac-ft) Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Annual Upstream Gain (Loss) (ac-ft) Minimum	Annual Upstream Gain (Loss) (ac-ft) Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	92,430	643	374,886	-2,166	-6,755	454
Alt. 1 Return Point	48,345	204	284,638	-5,010	-15,873	745
Alt. 2 Return Point	66,238	277	319,495	-370	-1,398	173
Farmer's Ditch Diversion	67,135	287	318,450	897	-873	4,771
Garden City Ditch Diversion	47,147	73	277,031	-431	-1,877	330
Garden City	44,946	194	268,762	-2,201	-8,949	983
Total				-36,939	-78,807	-8,532

Ditch Name	Annual Diversion (ac-ft) Average	Annual Diversion (ac-ft) Minimum	Annual Diversion (ac-ft) Maximum	Annual Ditch Return (ac-ft) [1] Average	Annual Ditch Return (ac-ft) [1] Minimum	Annual Ditch Return (ac-ft) [1] Maximum	Annual Ditch Losses (ac-ft) [2] Average	Annual Ditch Losses (ac-ft) [2] Minimum	Annual Ditch Losses (ac-ft) [2] Maximum
Amazon	15,417	0	30,000	0	0	0	---	---	---
Southside	15,095	0	30,000	0	0	0	3,451	0	6,188
Great Eastern	50,054	10,625	113,153	0	0	0	---	---	---
Farmer's [3]	23,980	635	44,724	18,264	55	36,254	5,716	580	8,470
Garden City	19,556	238	39,737	0	0	0	---	---	---
Total	124,103	11,498	255,996				9,167	580	14,480

Total Gain (Loss)	
Avg	-46,106
Min	-93,067
Max	-15,281

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results **Channel Return Alternate 3** **Unlined Channel**

Arkansas River Node	Annual Flow (ac-ft) Average	Annual Flow (ac-ft) Minimum	Annual Flow (ac-ft) Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Annual Upstream Gain (Loss) (ac-ft) Minimum	Annual Upstream Gain (Loss) (ac-ft) Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	92,282	643	376,220	-2,244	-7,234	431
Alt. 1 Return Point	48,736	204	288,172	-4,772	-15,375	745
Alt. 2 Return Point	48,352	222	286,789	-384	-1,383	69
Farmer's Ditch Diversion	67,619	281	322,371	1,010	-807	4,858
Garden City Ditch Diversion	48,056	73	281,210	-604	-1,821	244
Garden City	45,061	194	273,218	-2,994	-8,525	121
Total				-37,645	-93,475	-8,511

Ditch Name	Annual Diversion (ac-ft) Average	Annual Diversion (ac-ft) Minimum	Annual Diversion (ac-ft) Maximum	Annual Ditch Return (ac-ft) [1] Average	Annual Ditch Return (ac-ft) [1] Minimum	Annual Ditch Return (ac-ft) [1] Maximum	Annual Ditch Losses (ac-ft) [2] Average	Annual Ditch Losses (ac-ft) [2] Minimum	Annual Ditch Losses (ac-ft) [2] Maximum
Amazon	15,295	0	30,331	0	0	0	---	---	---
Southside	14,729	0	30,000	0	0	0	3,139	0	5,765
Great Eastern	50,246	9,952	113,469	0	0	0	---	---	---
Farmer's [3]	24,044	635	45,264	18,257	48	36,389	5,787	587	8,875
Garden City	18,960	231	39,089	0	0	0	---	---	---
Total	123,275	11,492	256,412				8,926	587	14,466

Total Gain (Loss)	
Avg	-46,571
Min	-102,349
Max	-15,288

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results **South Side Ditch** **Fly Ash Lining Option**

Arkansas River Node	Annual Flow (ac-ft) Average	Minimum	Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Minimum	Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	83,357	643	313,103	-2,112	-6,878	724
Alt. 1 Return Point	56,767	840	245,415	-8,643	-25,506	197
Alt. 2 Return Point	56,023	857	243,914	-744	-2,295	18
Farmer's Ditch Diversion	56,827	868	243,038	804	-1,338	4,747
Garden City Ditch Diversion	27,894	71	166,143	-79	-1,173	471
Garden City	27,358	182	161,022	-536	-5,121	3,222
Total				-38,966	-95,960	-7,898

Ditch Name	Annual Diversion (ac-ft) Average	Minimum	Maximum	Annual Ditch Return (ac-ft) [1] Average	Minimum	Maximum	Annual Ditch Losses (ac-ft) [2] Average	Minimum	Maximum
Amazon	18,755	0	51,513	0	0	0	---	---	---
Southside	17,947	0	51,000	0	0	0	830	0	1,972
Great Eastern	55,843	10,171	132,813	0	0	0	---	---	---
Farmer's [3]	25,712	818	70,875	0	0	0	0	0	0
Garden City	3,142	0	8,565	0	0	0	---	---	---
Total	121,400	11,443	310,535				830	0	1,972

Total Gain (Loss)	
Avg	-39,796
Min	-96,665
Max	-9,429

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results **Channel Return Alternate 1** **Fly Ash Lining Option**

Arkansas River Node	Annual Flow (ac-ft) Average	Annual Flow (ac-ft) Minimum	Annual Flow (ac-ft) Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Annual Upstream Gain (Loss) (ac-ft) Minimum	Annual Upstream Gain (Loss) (ac-ft) Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	92,611	643	374,947	-2,176	-6,788	454
Alt. 1 Return Point	71,407	675	327,802	-5,088	-15,873	745
Alt. 2 Return Point	70,803	693	326,038	-604	-1,501	18
Farmer's Ditch Diversion	71,691	703	325,162	888	-875	4,771
Garden City Ditch Diversion	48,004	73	279,578	-423	-1,877	337
Garden City	45,835	194	271,309	-2,170	-8,751	1,033
Total				-37,229	-78,989	-8,572

Ditch Name	Annual Diversion (ac-ft) Average	Annual Diversion (ac-ft) Minimum	Annual Diversion (ac-ft) Maximum	Annual Ditch Return (ac-ft) [1] Average	Annual Ditch Return (ac-ft) [1] Minimum	Annual Ditch Return (ac-ft) [1] Maximum	Annual Ditch Losses (ac-ft) [2] Average	Annual Ditch Losses (ac-ft) [2] Minimum	Annual Ditch Losses (ac-ft) [2] Maximum
Amazon	15,364	0	30,000	0	0	0	---	---	---
Southside	14,992	0	30,000	0	0	0	725	0	1,249
Great Eastern	49,917	10,625	112,918	0	0	0	---	---	---
Farmer's [3]	23,867	635	44,654	22,743	471	43,103	1,123	165	1,561
Garden City	23,264	653	43,975	0	0	0	---	---	---
Total	127,404	11,914	260,583				1,848	165	2,785

Total Gain (Loss)	
Avg	-39,077
Min	-81,312
Max	-11,343

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results **Channel Return Alternate 2** **Fly Ash Lining Option**

Arkansas River Node	Annual Flow (ac-ft)			Annual Upstream Gain (Loss) (ac-ft)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	92,568	643	374,947	-2,174	-6,820	454
Alt. 1 Return Point	48,597	204	284,699	-5,010	-15,873	745
Alt. 2 Return Point	70,904	680	326,259	-367	-1,398	157
Farmer's Ditch Diversion	71,793	690	325,122	889	-875	4,771
Garden City Ditch Diversion	48,133	73	279,591	-428	-1,877	306
Garden City	45,936	194	271,322	-2,196	-8,755	859
Total				-36,942	-78,531	-8,337

Ditch Name	Annual Diversion (ac-ft)			Annual Ditch Return (ac-ft) [1]			Annual Ditch Losses (ac-ft) [2]		
	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
Amazon	15,389	0	30,000	0	0	0	---	---	---
Southside	15,059	0	30,000	0	0	0	729	0	1,249
Great Eastern	49,937	10,625	112,935	0	0	0	---	---	---
Farmer's [3]	23,901	635	44,654	22,674	458	42,958	1,227	178	1,707
Garden City	23,232	640	43,905	0	0	0	---	---	---
Total	127,519	11,901	260,603				1,957	178	2,928

Total Gain (Loss)	
Avg	-38,899
Min	-81,410
Max	-11,253

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results | **Channel Return Alternate 3** | **Fly Ash Lining Option**

Arkansas River Node	Annual Flow (ac-ft) Average	Annual Flow (ac-ft) Minimum	Annual Flow (ac-ft) Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Annual Upstream Gain (Loss) (ac-ft) Minimum	Annual Upstream Gain (Loss) (ac-ft) Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	93,040	643	377,470	-2,247	-7,226	366
Alt. 1 Return Point	49,901	204	290,582	-5,024	-15,512	439
Alt. 2 Return Point	49,496	222	289,186	-405	-1,396	42
Farmer's Ditch Diversion	72,819	685	331,745	997	-814	4,846
Garden City Ditch Diversion	50,005	73	286,078	-599	-1,835	243
Garden City	46,989	194	278,146	-3,016	-8,435	121
Total				-37,949	-92,686	-8,481

Ditch Name	Annual Diversion (ac-ft) Average	Annual Diversion (ac-ft) Minimum	Annual Diversion (ac-ft) Maximum	Annual Ditch Return (ac-ft) [1] Average	Annual Ditch Return (ac-ft) [1] Minimum	Annual Ditch Return (ac-ft) [1] Maximum	Annual Ditch Losses (ac-ft) [2] Average	Annual Ditch Losses (ac-ft) [2] Minimum	Annual Ditch Losses (ac-ft) [2] Maximum
Amazon	15,062	0	30,178	0	0	0	---	---	---
Southside	14,601	0	30,000	0	0	0	649	0	1,153
Great Eastern	49,719	8,940	112,854	0	0	0	---	---	---
Farmer's [3]	23,514	635	45,168	22,325	453	43,373	1,189	182	1,796
Garden City	22,215	636	43,560	0	0	0	---	---	---
Total	125,110	11,896	260,501				1,838	182	2,939

Total Gain (Loss)	
Avg	-39,787
Min	-94,553
Max	-11,420

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results **South Side Ditch** **Other Lining Options**

Arkansas River Node	Annual Flow (ac-ft)			Annual Upstream Gain (Loss) (ac-ft)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	83,357	643	313,103	-2,112	-6,878	724
Alt. 1 Return Point	56,767	840	245,415	-8,643	-25,506	197
Alt. 2 Return Point	56,023	857	243,914	-744	-2,295	18
Farmer's Ditch Diversion	56,827	868	243,038	804	-1,338	4,747
Garden City Ditch Diversion	27,894	71	166,143	-79	-1,173	471
Garden City	27,358	182	161,022	-536	-5,121	3,222
Total				-38,966	-95,960	-7,898

Ditch Name	Annual Diversion (ac-ft)			Annual Ditch Return (ac-ft) [1]			Annual Ditch Losses (ac-ft) [2]		
	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
Amazon	18,755	0	51,513	0	0	0	---	---	---
Southside	17,947	0	51,000	0	0	0	0	0	0
Great Eastern	55,843	10,171	132,813	0	0	0	---	---	---
Farmer's [3]	25,712	818	70,875	0	0	0	0	0	0
Garden City	3,142	0	8,565	0	0	0	---	---	---
Total	121,400	11,443	310,535				0	0	0

Total Gain (Loss)	
Avg	-38,966
Min	-95,960
Max	-7,898

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results **Channel Return Alternate 1** **Other Lining Options**

Arkansas River Node	Annual Flow (ac-ft) Average	Minimum	Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Minimum	Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	92,699	643	374,947	-2,179	-6,788	454
Alt. 1 Return Point	72,614	840	329,353	-5,106	-15,873	745
Alt. 2 Return Point	72,008	857	327,574	-606	-1,501	18
Farmer's Ditch Diversion	72,894	868	326,698	886	-875	4,771
Garden City Ditch Diversion	48,290	73	280,238	-428	-1,877	340
Garden City	46,116	194	271,969	-2,173	-8,683	1,033
Total				-37,263	-78,964	-8,580

Ditch Name	Annual Diversion (ac-ft) Average	Minimum	Maximum	Annual Ditch Return (ac-ft) [1] Average	Minimum	Maximum	Annual Ditch Losses (ac-ft) [2] Average	Minimum	Maximum
Amazon	15,347	0	30,000	0	0	0	---	---	---
Southside	14,979	0	30,000	0	0	0	0	0	0
Great Eastern	49,842	10,625	112,442	0	0	0	---	---	---
Farmer's [3]	23,846	635	44,654	23,846	635	44,654	0	0	0
Garden City	24,176	818	44,815	0	0	0	---	---	---
Total	128,191	12,079	261,258				0	0	0

Total Gain (Loss)	
Avg	-37,263
Min	-78,964
Max	-8,580

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results **Channel Return Alternate 2** **Other Lining Options**

Arkansas River Node	Annual Flow (ac-ft) Average	Minimum	Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Minimum	Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	92,721	643	375,008	-2,178	-6,772	454
Alt. 1 Return Point	48,780	204	284,760	-5,102	-15,873	745
Alt. 2 Return Point	72,233	857	327,968	-375	-1,398	157
Farmer's Ditch Diversion	73,119	868	326,864	886	-873	4,771
Garden City Ditch Diversion	48,529	73	280,535	-455	-1,882	289
Garden City	46,315	194	272,334	-2,214	-8,793	977
Total				-37,094	-78,538	-8,582

Ditch Name	Annual Diversion (ac-ft) Average	Minimum	Maximum	Annual Ditch Return (ac-ft) [1] Average	Minimum	Maximum	Annual Ditch Losses (ac-ft) [2] Average	Minimum	Maximum
Amazon	15,362	0	30,000	0	0	0	---	---	---
Southside	15,011	0	30,000	0	0	0	0	0	0
Great Eastern	49,807	10,625	112,278	0	0	0	---	---	---
Farmer's [3]	23,827	635	44,606	23,827	635	44,606	0	0	0
Garden City	24,135	818	44,823	0	0	0	---	---	---
Total	128,142	12,079	261,138				0	0	0

Total Gain (Loss)	
Avg	-37,094
Min	-78,538
Max	-8,582

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Summary of Results | **Channel Return Alternate 3** | **Other Lining Options**

Arkansas River Node	Annual Flow (ac-ft) Average	Minimum	Maximum	Annual Upstream Gain (Loss) (ac-ft) Average	Minimum	Maximum
Coolidge (State Line)	187,724	26,338	527,744	0	0	0
Syracuse	180,818	20,803	522,020	-6,906	-20,590	8,285
Amazon Ditch Diversion	160,068	11,227	500,636	-20,750	-43,193	-9,038
Southside Ditch Diversion	93,366	643	377,668	-2,253	-7,127	366
Alt. 1 Return Point	50,246	204	290,727	-5,188	-15,566	286
Alt. 2 Return Point	49,826	222	289,326	-420	-1,401	28
Farmer's Ditch Diversion	74,194	868	333,572	990	-817	4,842
Garden City Ditch Diversion	50,498	73	287,312	-635	-1,849	253
Garden City	47,500	194	279,366	-2,998	-8,492	121
Total				-38,160	-92,885	-8,641

Ditch Name	Annual Diversion (ac-ft) Average	Minimum	Maximum	Annual Ditch Return (ac-ft) [1] Average	Minimum	Maximum	Annual Ditch Losses (ac-ft) [2] Average	Minimum	Maximum
Amazon	15,031	0	30,165	0	0	0	---	---	---
Southside	14,553	0	30,000	0	0	0	0	0	0
Great Eastern	49,418	8,799	112,655	0	0	0	---	---	---
Farmer's [3]	23,379	635	45,063	23,379	635	45,063	0	0	0
Garden City	23,062	818	44,883	0	0	0	---	---	---
Total	125,442	12,079	261,449				0	0	0

Total Gain (Loss)	
Avg	-38,160
Min	-92,885
Max	-8,641

1. Normal ditch return flows not considered. Return flows shown are for returns from Southside Ditch under alternate delivery options.
2. Ditch losses were evaluated for Southside Ditch only.
3. For alternate delivery options, diversions, return flow and losses shown are actually for Southside Ditch when transporting water for Farmer's Ditch.

Appendix E

Opinion of Probable Cost

Table E.1
Opinion of Probable Cost for
Phase 1 - Alternate 1
Channel Improvements

Description	Quan	Unit	Unit Price	Total
Demolish 7' Diam. Culvert		LF	$43.02	$0
Demolish 9' Diam. Culvert		LF	$56.58	$0
Excavation	3,325	CY	$1.58	$5,300
Backfill and Compaction	0	CY	$2.44	$0
Fill (Excess Material)	3,325	CY	$1.73	$5,800
Seeding	9	AC	$893.00	$7,900
Return Structure	1	EA	$75,000.00	$75,000
New Diversion Structure	0	EA	$15,000.00	$0
Excavation (Cattle Crossing)	625	CY	$1.58	$1,000
Excess Material (Cattle Crossing)	625	CY	$1.73	$1,100
New Bridge (Cattle Crossing)	1,288	SF	$75.00	$96,600
Seeding (Cattle Crossing)	0.21	AC	$893.00	$200
New Bridge	1,479	SF	$75.00	$110,900
Subtotal				**$303,800**
Mobilization and Demobilization	1	LS	5%	$15,200
Erosion and Sediment Control	1	LS	2%	$6,100
Contingency	1	LS	25%	$76,000
OPINION OF COST				**$401,100**

Table E.2
Opinion of Probable Cost for
Phase 1 - Alternate 2
Channel Improvements

Description	Quan	Unit	Unit Price	Total
Demolish 7' Diam. Culvert		LF	$43.02	$0
Demolish 9' Diam. Culvert		LF	$56.58	$0
Excavation	45,671	CY	$1.58	$72,200
Backfill and Compaction	178	CY	$2.44	$400
Fill (Excess Material)	45,493	CY	$1.73	$78,700
Seeding	31	AC	$893.00	$27,600
Return Structure	1	EA	$75,000.00	$75,000
New Diversion Structure	1	EA	$15,000.00	$15,000
New Bridge	2,240	SF	$75.00	$168,000
New Bridge	2,240	SF	$75.00	$168,000
New Bridge	1,680	SF	$75.00	$126,000
Subtotal				**$730,900**
Mobilization and Demobilization	1	LS	5%	$36,500
Erosion and Sediment Control	1	LS	2%	$14,600
Contingency	1	LS	25%	$182,700
OPINION OF COST				**$964,700**

Table E.3
Opinion of Probable Cost for
Phase 1 - Alternate 3
Channel Improvements

Description	Quan	Unit	Unit Price	Total
Demolish 7' Diam. Culvert		LF	$43.02	$0
Demolish 9' Diam. Culvert		LF	$56.58	$0
Excavation	57,400	CY	$1.58	$90,700
Backfill and Compaction	178	CY	$2.44	$400
Fill (Excess Material)	57,221	CY	$1.73	$99,000
Seeding	37	AC	$893.00	$33,100
Return Structure	1	EA	$75,000.00	$75,000
New Diversion Structure	1	EA	$15,000.00	$15,000
New Bridge	2,240	SF	$75.00	$168,000
New Bridge	2,240	SF	$75.00	$168,000
New Bridge	2,240	SF	$75.00	$168,000
New Bridge	1,680	SF	$75.00	$126,000
Subtotal				**$943,200**
Mobilization and Demobilization	1	LS	5%	$47,200
Erosion and Sediment Control	1	LS	2%	$18,900
Contingency	1	LS	25%	$235,800
OPINION OF COST				**$1,245,100**

Table E.4
Opinion of Probable Cost for
Phase 2
Channel Improvements

Description	Quan	Unit	Unit Price	Total
Demolish 7' Diam. Culvert		LF	$43.02	$0
Demolish 9' Diam. Culvert		LF	$56.58	$0
Excavation	142,638	CY	$1.58	$225,500
Backfill and Compaction	768	CY	$2.44	$1,900
Fill (Excess Material)	141,870	CY	$1.73	$245,400
Seeding	68	AC	$893.00	$60,900
Return Structure	0	EA	$75,000.00	$0
New Diversion Structure	7	EA	$15,000.00	$105,000
New Bridge		SF	$75.00	$0
New Bridge		SF	$75.00	$0
New Bridge		SF	$75.00	$0
Subtotal				**$638,700**
Mobilization and Demobilization	1	LS	5%	$31,900
Erosion and Sediment Control	1	LS	2%	$12,800
Contingency	1	LS	25%	$159,700
OPINION OF COST				**$843,100**

Table E.5
Opinion of Probable Cost for
Phase 3
Channel Improvements

Description	Quan	Unit	Unit Price	Total
Demolish 7' Diam. Culvert		LF	$43.02	$0
Demolish 9' Diam. Culvert		LF	$56.58	$0
Excavation	105,651	CY	$1.58	$167,000
Backfill and Compaction	9	CY	$2.44	$0
Fill (Excess Material)	105,643	CY	$1.73	$182,800
Seeding	63	AC	$893.00	$55,900
Return Structure	0	EA	$75,000.00	$0
New Diversion Structure	7	EA	$15,000.00	$105,000
New Bridge		SF	$75.00	$0
New Bridge		SF	$75.00	$0
New Bridge		SF	$75.00	$0
Subtotal				**$510,700**
Mobilization and Demobilization	1	LS	5%	$25,500
Erosion and Sediment Control	1	LS	2%	$10,200
Contingency	1	LS	25%	$127,700
OPINION OF COST				**$674,100**

Table E.6
Opinion of Probable Cost for
Phase 4
Channel Improvements

Description	Quan	Unit	Unit Price	Total
Demolish 7' Diam. Culvert		LF	$43.02	$0
Demolish 9' Diam. Culvert		LF	$56.58	$0
Excavation	40,549	CY	$1.58	$64,100
Backfill and Compaction	0	CY	$2.44	$0
Fill (Excess Material)	40,549	CY	$1.73	$70,100
Seeding	61	AC	$893.00	$54,200
Return Structure	0	EA	$75,000.00	$0
New Diversion Structure	2	EA	$15,000.00	$30,000
New Bridge		SF	$75.00	$0
New Bridge		SF	$75.00	$0
New Bridge		SF	$75.00	$0
Subtotal				**$218,400**
Mobilization and Demobilization	1	LS	5%	$10,900
Erosion and Sediment Control	1	LS	2%	$4,400
Contingency	1	LS	25%	$54,600
OPINION OF COST				**$288,300**

Table E.7
Opinion of Probable Cost for
Phase 1 - Alternate 1
Concrete Liner

Description	Quan	Unit	Unit Price	Total
Excavation	2,054	CY	$1.58	$3,200
Fill (Excess Material)	2,054	CY	$1.73	$3,600
Concrete Channel Liner	2,054	CY	$320.00	$657,300
Backfill and Compaction	0	CY	$2.44	$0
Seeding Credit	4	AC	-$893.00	-$4,000
Subtotal				**$660,100**
Mobilization and Demobilization	1	LS	5%	$33,000
Erosion and Sediment Control	1	LS	2%	$13,200
Contingency		LS	25%	$165,000
OPINION OF COST				**$871,300**

Table E.8
Opinion of Probable Cost for
Phase 1 - Alternate 2
Concrete Liner

Description	Quan	Unit	Unit Price	Total
Excavation	7,215	CY	$1.58	$11,400
Fill (Excess Material)	7,215	CY	$1.73	$12,500
Concrete Channel Liner	7,215	CY	$320.00	$2,308,600
Backfill and Compaction	0	CY	$2.44	$0
Seeding Credit	16	AC	-$893.00	-$13,900
Subtotal				**$2,318,600**
Mobilization and Demobilization	1	LS	5%	$115,900
Erosion and Sediment Control	1	LS	2%	$46,400
Contingency	1	LS	25%	$579,700
OPINION OF COST				**$3,060,600**

Table E.9
Opinion of Probable Cost for
Phase 1 - Alternate 3
Concrete Liner

Description	Quan	Unit	Unit Price	Total
Excavation	8,652	CY	$1.58	$13,700
Fill (Excess Material)	8,652	CY	$1.73	$15,000
Concrete Channel Liner	8,652	CY	$320.00	$2,768,600
Backfill and Compaction	0	CY	$2.44	$0
Seeding Credit	19	AC	-$893.00	-$16,700
Subtotal				**$2,780,600**
Mobilization and Demobilization	1	LS	5%	$139,000
Erosion and Sediment Control	1	LS	2%	$55,600
Contingency	1	LS	25%	$695,200
OPINION OF COST				**$3,670,400**

Table E.10
Opinion of Probable Cost for
Phase 2
Concrete Liner

Description	Quan	Unit	Unit Price	Total
Excavation	16,732	CY	$1.58	$26,500
Fill (Excess Material)	16,732	CY	$1.73	$28,900
Concrete Channel Liner	16,732	CY	$320.00	$5,354,400
Backfill and Compaction	0	CY	$2.44	$0
Seeding Credit	33	AC	-$893.00	-$29,700
Subtotal				**$5,380,100**
Mobilization and Demobilization	1	LS	5%	$269,000
Erosion and Sediment Control	1	LS	2%	$107,600
Contingency	1	LS	25%	$1,345,000
OPINION OF COST				**$7,101,700**

Table E.11
Opinion of Probable Cost for
Phase 3
Concrete Liner

Description	Quan	Unit	Unit Price	Total
Excavation	12,543	CY	$1.58	$19,800
Fill (Excess Material)	12,543	CY	$1.73	$21,700
Concrete Channel Liner	12,543	CY	$320.00	$4,013,700
Backfill and Compaction	0	CY	$2.44	$0
Seeding Credit	32	AC	-$893.00	-$28,300
Subtotal				**$4,026,900**
Mobilization and Demobilization	1	LS	5%	$201,300
Erosion and Sediment Control	1	LS	2%	$80,500
Contingency	1	LS	25%	$1,006,700
OPINION OF COST				**$5,315,400**

Table E.12
Opinion of Probable Cost for
Phase 4
Concrete Liner

Description	Quan	Unit	Unit Price	Total
Excavation	13,251	CY	$1.58	$21,000
Fill (Excess Material)	13,251	CY	$1.73	$22,900
Concrete Channel Liner	13,251	CY	$320.00	$4,240,400
Backfill and Compaction	0	CY	$2.44	$0
Seeding Credit	30	AC	-$893.00	-$27,200
Subtotal				**$4,257,100**
Mobilization and Demobilization	1	LS	5%	$212,900
Erosion and Sediment Control	1	LS	2%	$85,100
Contingency	1	LS	25%	$1,064,300
OPINION OF COST				**$5,619,400**

Table E.13
Opinion of Probable Cost for
Phase 1 - Alternate 1
Earthen Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	6,144	CY	$1.58	$9,700
Backfill & Compact Liner Overburden	6,144	CY	$2.44	$15,000
Excavate 12" for Earthen Liner	7,138	CY	$1.58	$11,300
Borrow Material	8,209	CY	$9.45	$77,600
Haul, 40 Mile Round Trip	8,209	CY	$18.00	$147,800
Backfill & Compact Liner	8,209	CY	$1.58	$13,000
Fill (Excess Material)	7,138	CY	$1.73	$12,300
Subtotal				**$286,700**
Mobilization and Demobilization	1	LS	5%	$14,300
Erosion and Sediment Control	1	LS	2%	$5,700
Contingency		LS	25%	$71,700
OPINION OF COST				**$378,400**

Table E.14
Opinion of Probable Cost for
Phase 1 - Alternate 2
Earthen Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	40,234	CY	$1.58	$63,600
Backfill & Compact Liner Overburden	40,234	CY	$2.44	$98,200
Excavate 12" for Earthen Liner	30,758	CY	$1.58	$48,600
Borrow Material	35,372	CY	$9.45	$334,300
Haul, 40 Mile Round Trip	35,372	CY	$18.00	$636,700
Backfill & Compact Liner	35,372	CY	$1.58	$55,900
Fill (Excess Material)	30,758	CY	$1.73	$53,200
Subtotal				**$1,290,500**
Mobilization and Demobilization	1	LS	5%	$64,500
Erosion and Sediment Control	1	LS	2%	$25,800
Contingency	1	LS	25%	$322,600
OPINION OF COST				**$1,703,400**

Table E.15
Opinion of Probable Cost for
Phase 1 - Alternate 3
Earthen Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	48,955	CY	$1.58	$77,300
Backfill & Compact Liner Overburden	48,955	CY	$2.44	$119,400
Excavate 12" for Earthen Liner	37,373	CY	$1.58	$59,000
Borrow Material	42,979	CY	$9.45	$406,200
Haul, 40 Mile Round Trip	42,979	CY	$18.00	$773,600
Backfill & Compact Liner	42,979	CY	$1.58	$67,900
Fill (Excess Material)	37,373	CY	$1.73	$64,700
Subtotal				**$1,568,100**
Mobilization and Demobilization	1	LS	5%	$78,400
Erosion and Sediment Control	1	LS	2%	$31,400
Contingency	1	LS	25%	$392,000
OPINION OF COST				**$2,069,900**

Table E.16
Opinion of Probable Cost for
Phase 2
Earthen Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	102,756	CY	$1.58	$162,400
Backfill & Compact Liner Overburden	102,756	CY	$2.44	$250,700
Excavate 12" for Earthen Liner	77,267	CY	$1.58	$122,100
Borrow Material	88,857	CY	$9.45	$839,700
Haul, 40 Mile Round Trip	88,857	CY	$18.00	$1,599,400
Backfill & Compact Liner	88,857	CY	$1.58	$140,400
Fill (Excess Material)	77,267	CY	$1.73	$133,700
Subtotal				**$3,248,400**
Mobilization and Demobilization	1	LS	5%	$162,400
Erosion and Sediment Control	1	LS	2%	$65,000
Contingency	1	LS	25%	$812,100
OPINION OF COST				**$4,287,900**

Table E.17
Opinion of Probable Cost for
Phase 3
Earthen Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	94,932	CY	$1.58	$150,000
Backfill & Compact Liner Overburden	94,932	CY	$2.44	$231,600
Excavate 12" for Earthen Liner	71,427	CY	$1.58	$112,900
Borrow Material	82,141	CY	$9.45	$776,200
Haul, 40 Mile Round Trip	82,141	CY	$18.00	$1,478,500
Backfill & Compact Liner	82,141	CY	$1.58	$129,800
Fill (Excess Material)	71,427	CY	$1.73	$123,600
Subtotal				**$3,002,600**
Mobilization and Demobilization	1	LS	5%	$150,100
Erosion and Sediment Control	1	LS	2%	$60,100
Contingency	1	LS	25%	$750,700
OPINION OF COST				**$3,963,500**

Table E.18
Opinion of Probable Cost for
Phase 4
Earthen Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	80,419	CY	$1.58	$127,100
Backfill & Compact Liner Overburden	80,419	CY	$2.44	$196,200
Excavate 12" for Earthen Liner	64,015	CY	$1.58	$101,100
Borrow Material	73,617	CY	$9.45	$695,700
Haul, 40 Mile Round Trip	73,617	CY	$18.00	$1,325,100
Backfill & Compact Liner	73,617	CY	$1.58	$116,300
Fill (Excess Material)	64,015	CY	$1.73	$110,700
Subtotal				**$2,672,200**
Mobilization and Demobilization	1	LS	5%	$133,600
Erosion and Sediment Control	1	LS	2%	$53,400
Contingency	1	LS	25%	$668,100
OPINION OF COST				**$3,527,300**

Table E.19
Opinion of Probable Cost for
Phase 1 - Alternate 1
Bentonite/Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	6,144	CY	$1.58	$9,700
Backfill & Compact Liner Overburden	6,144	CY	$2.44	$15,000
Soil Mixing and Compaction	7,138	CY	$4.16	$29,700
Bentonite (5% by Weight)	578	TON	$100.00	$57,800
Subtotal				**$112,200**
Mobilization and Demobilization	1	LS	5%	$5,600
Erosion and Sediment Control	1	LS	2%	$2,200
Contingency		LS	25%	$28,100
OPINION OF COST				**$148,100**

Table E.20
Opinion of Probable Cost for
Phase 1 - Alternate 2
Bentonite/Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	40,234	CY	$1.58	$63,600
Backfill & Compact Liner Overburden	40,234	CY	$2.44	$98,200
Soil Mixing and Compaction	30,758	CY	$4.16	$128,000
Bentonite (5% by Weight)	2,491	TON	$100.00	$249,100
Subtotal				**$538,900**
Mobilization and Demobilization	1	LS	5%	$26,900
Erosion and Sediment Control	1	LS	2%	$10,800
Contingency	1	LS	25%	$134,700
OPINION OF COST				**$711,300**

Table E.21
Opinion of Probable Cost for
Phase 1 - Alternate 3
Bentonite/Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	48,955	CY	$1.58	$77,300
Backfill & Compact Liner Overburden	48,955	CY	$2.44	$119,400
Soil Mixing and Compaction	37,373	CY	$4.16	$155,500
Bentonite (5% by Weight)	3,027	TON	$100.00	$302,700
Subtotal				**$654,900**
Mobilization and Demobilization	1	LS	5%	$32,700
Erosion and Sediment Control	1	LS	2%	$13,100
Contingency	1	LS	25%	$163,700
OPINION OF COST				**$864,400**

Table E.22
Opinion of Probable Cost for
Phase 2
Bentonite/Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	102,756	CY	$1.58	$162,400
Backfill & Compact Liner Overburden	102,756	CY	$2.44	$250,700
Soil Mixing and Compaction	77,267	CY	$4.16	$321,400
Bentonite (5% by Weight)	6,259	TON	$100.00	$625,900
Subtotal				**$1,360,400**
Mobilization and Demobilization	1	LS	5%	$68,000
Erosion and Sediment Control	1	LS	2%	$27,200
Contingency	1	LS	25%	$340,100
OPINION OF COST				**$1,795,700**

Table E.23
Opinion of Probable Cost for
Phase 3
Bentonite/Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	94,932	CY	$1.58	$150,000
Backfill & Compact Liner Overburden	94,932	CY	$2.44	$231,600
Soil Mixing and Compaction	71,427	CY	$4.16	$297,100
Bentonite (5% by Weight)	5,786	TON	$100.00	$578,600
Subtotal				**$1,257,300**
Mobilization and Demobilization	1	LS	5%	$62,900
Erosion and Sediment Control	1	LS	2%	$25,100
Contingency	1	LS	25%	$314,300
OPINION OF COST				**$1,659,600**

Table E.24
Opinion of Probable Cost for
Phase 4
Bentonite/Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	80,419	CY	$1.58	$127,100
Backfill & Compact Liner Overburden	80,419	CY	$2.44	$196,200
Soil Mixing and Compaction	64,015	CY	$4.16	$266,300
Bentonite (5% by Weight)	5,185	TON	$100.00	$518,500
Subtotal				**$1,108,100**
Mobilization and Demobilization	1	LS	5%	$55,400
Erosion and Sediment Control	1	LS	2%	$22,200
Contingency	1	LS	25%	$277,000
OPINION OF COST				**$1,462,700**

Table E.25
Opinion of Probable Cost for
Phase 1 - Alternate 1
Synthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	6,144	CY	$1.58	$9,700
Backfill & Compact Liner Overburden	6,144	CY	$2.44	$15,000
Synthetic Liner	31,287	SY	$4.50	$140,800
Subtotal				**$165,500**
Mobilization and Demobilization	1	LS	5%	$8,300
Erosion and Sediment Control	1	LS	2%	$3,300
Contingency		LS	25%	$41,400
OPINION OF COST				**$218,500**

Table E.26
Opinion of Probable Cost for
Phase 1 - Alternate 2
Synthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	40,234	CY	$1.58	$63,600
Backfill & Compact Liner Overburden	40,234	CY	$2.44	$98,200
Synthetic Liner	88,065	SY	$4.50	$396,300
Subtotal				**$558,100**
Mobilization and Demobilization	1	LS	5%	$27,900
Erosion and Sediment Control	1	LS	2%	$11,200
Contingency	1	LS	25%	$139,500
OPINION OF COST				**$736,700**

Table E.27
Opinion of Probable Cost for
Phase 1 - Alternate 3
Synthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	48,955	CY	$1.58	$77,300
Backfill & Compact Liner Overburden	48,955	CY	$2.44	$119,400
Synthetic Liner	103,935	SY	$4.50	$467,700
Subtotal				**$664,400**
Mobilization and Demobilization	1	LS	5%	$33,200
Erosion and Sediment Control	1	LS	2%	$13,300
Contingency	1	LS	25%	$166,100
OPINION OF COST				**$877,000**

Table E.28
Opinion of Probable Cost for
Phase 2
Synthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	102,756	CY	$1.58	$162,400
Backfill & Compact Liner Overburden	102,756	CY	$2.44	$250,700
Synthetic Liner	221,097	SY	$4.50	$994,900
Subtotal				**$1,408,000**
Mobilization and Demobilization	1	LS	5%	$70,400
Erosion and Sediment Control	1	LS	2%	$28,200
Contingency	1	LS	25%	$352,000
OPINION OF COST				**$1,858,600**

Table E.29
Opinion of Probable Cost for
Phase 3
Synthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	94,932	CY	$1.58	$150,000
Backfill & Compact Liner Overburden	94,932	CY	$2.44	$231,600
Synthetic Liner	204,472	SY	$4.50	$920,100
Subtotal				**$1,301,700**
Mobilization and Demobilization	1	LS	5%	$65,100
Erosion and Sediment Control	1	LS	2%	$26,000
Contingency	1	LS	25%	$325,400
OPINION OF COST				**$1,718,200**

Table E.30
Opinion of Probable Cost for
Phase 4
Synthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	80,419	CY	$1.58	$127,100
Backfill & Compact Liner Overburden	80,419	CY	$2.44	$196,200
Synthetic Liner	186,868	SY	$4.50	$840,900
Subtotal				**$1,164,200**
Mobilization and Demobilization	1	LS	5%	$58,200
Erosion and Sediment Control	1	LS	2%	$23,300
Contingency	1	LS	25%	$291,100
OPINION OF COST				**$1,536,800**

Table E.31
Opinion of Probable Cost for
Phase 1 - Alternate 1
Geosynthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	6,144	CY	$1.58	$9,700
Backfill & Compact Liner Overburden	6,144	CY	$2.44	$15,000
Geosynthetic Liner	31,287	SY	$7.20	$225,300
Subtotal				**$250,000**
Mobilization and Demobilization	1	LS	5%	$12,500
Erosion and Sediment Control	1	LS	2%	$5,000
Contingency		LS	25%	$62,500
OPINION OF COST				**$330,000**

Table E.32
Opinion of Probable Cost for
Phase 1 - Alternate 2
Geosynthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	40,234	CY	$1.58	$63,600
Backfill & Compact Liner Overburden	40,234	CY	$2.44	$98,200
Geosynthetic Liner	88,065	SY	$7.20	$634,100
Subtotal				**$795,900**
Mobilization and Demobilization	1	LS	5%	$39,800
Erosion and Sediment Control	1	LS	2%	$15,900
Contingency	1	LS	25%	$199,000
OPINION OF COST				**$1,050,600**

Table E.33
Opinion of Probable Cost for
Phase 1 - Alternate 3
Geosynthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	48,955	CY	$1.58	$77,300
Backfill & Compact Liner Overburden	48,955	CY	$2.44	$119,400
Geosynthetic Liner	103,935	SY	$7.20	$748,300
Subtotal				**$945,000**
Mobilization and Demobilization	1	LS	5%	$47,300
Erosion and Sediment Control	1	LS	2%	$18,900
Contingency	1	LS	25%	$236,300
OPINION OF COST				**$1,247,500**

Table E.34
Opinion of Probable Cost for
Phase 2
Geosynthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	102,756	CY	$1.58	$162,400
Backfill & Compact Liner Overburden	102,756	CY	$2.44	$250,700
Geosynthetic Liner	221,097	SY	$7.20	$1,591,900
Subtotal				**$2,005,000**
Mobilization and Demobilization	1	LS	5%	$100,300
Erosion and Sediment Control	1	LS	2%	$40,100
Contingency	1	LS	25%	$501,300
OPINION OF COST				**$2,646,700**

Table E.35
Opinion of Probable Cost for
Phase 3
Geosynthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	94,932	CY	$1.58	$150,000
Backfill & Compact Liner Overburden	94,932	CY	$2.44	$231,600
Geosynthetic Liner	204,472	SY	$7.20	$1,472,200
Subtotal				**$1,853,800**
Mobilization and Demobilization	1	LS	5%	$92,700
Erosion and Sediment Control	1	LS	2%	$37,100
Contingency	1	LS	25%	$463,500
OPINION OF COST				**$2,447,100**

Table E.36
Opinion of Probable Cost for
Phase 4
Geosynthetic Liner

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	80,419	CY	$1.58	$127,100
Backfill & Compact Liner Overburden	80,419	CY	$2.44	$196,200
Geosynthetic Liner	186,868	SY	$7.20	$1,345,500
Subtotal				**$1,668,800**
Mobilization and Demobilization	1	LS	5%	$83,400
Erosion and Sediment Control	1	LS	2%	$33,400
Contingency	1	LS	25%	$417,200
OPINION OF COST				**$2,202,800**

Table E.37
Opinion of Probable Cost for
Phase 1 - Alternate 1
Fly Ash / Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	6,144	CY	$1.58	$9,700
Backfill & Compact Liner Overburden	6,144	CY	$2.44	$15,000
Soil Mixing and Compaction	7,138	CY	$4.16	$29,700
Fly Ash (10% by Weight)	1,156	TON	$40.00	$46,300
Subtotal				**$100,700**
Mobilization and Demobilization	1	LS	5%	$5,000
Erosion and Sediment Control	1	LS	2%	$2,000
Contingency		LS	25%	$25,200
OPINION OF COST				**$132,900**

Table E.38
Opinion of Probable Cost for
Phase 1 - Alternate 2
Fly Ash / Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	40,234	CY	$1.58	$63,600
Backfill & Compact Liner Overburden	40,234	CY	$2.44	$98,200
Soil Mixing and Compaction	30,758	CY	$4.16	$128,000
Fly Ash (10% by Weight)	4,983	TON	$40.00	$199,300
Subtotal				**$489,100**
Mobilization and Demobilization	1	LS	5%	$24,500
Erosion and Sediment Control	1	LS	2%	$9,800
Contingency	1	LS	25%	$122,300
OPINION OF COST				**$645,700**

Table E.39
Opinion of Probable Cost for
Phase 1 - Alternate 3
Fly Ash / Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	48,955	CY	$1.58	$77,300
Backfill & Compact Liner Overburden	48,955	CY	$2.44	$119,400
Soil Mixing and Compaction	37,373	CY	$4.16	$155,500
Fly Ash (10% by Weight)	6,054	TON	$40.00	$242,200
Subtotal				**$594,400**
Mobilization and Demobilization	1	LS	5%	$29,700
Erosion and Sediment Control	1	LS	2%	$11,900
Contingency	1	LS	25%	$148,600
OPINION OF COST				**$784,600**

Table E.40
Opinion of Probable Cost for
Phase 2
Fly Ash / Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	102,756	CY	$1.58	$162,400
Backfill & Compact Liner Overburden	102,756	CY	$2.44	$250,700
Soil Mixing and Compaction	77,267	CY	$4.16	$321,400
Fly Ash (10% by Weight)	12,517	TON	$40.00	$500,700
Subtotal				**$1,235,200**
Mobilization and Demobilization	1	LS	5%	$61,800
Erosion and Sediment Control	1	LS	2%	$24,700
Contingency	1	LS	25%	$308,800
OPINION OF COST				**$1,630,500**

Table E.41
Opinion of Probable Cost for
Phase 3
Fly Ash / Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	94,932	CY	$1.58	$150,000
Backfill & Compact Liner Overburden	94,932	CY	$2.44	$231,600
Soil Mixing and Compaction	71,427	CY	$4.16	$297,100
Fly Ash (10% by Weight)	11,571	TON	$40.00	$462,800
Subtotal				**$1,141,500**
Mobilization and Demobilization	1	LS	5%	$57,100
Erosion and Sediment Control	1	LS	2%	$22,800
Contingency	1	LS	25%	$285,400
OPINION OF COST				**$1,506,800**

Table E.42
Opinion of Probable Cost for
Phase 4
Fly Ash / Soil Matrix

Description	Quan	Unit	Unit Price	Total
Excavate 18" Liner Overburden	80,419	CY	$1.58	$127,100
Backfill & Compact Liner Overburden	80,419	CY	$2.44	$196,200
Soil Mixing and Compaction	64,015	CY	$4.16	$266,300
Fly Ash (10% by Weight)	10,370	TON	$40.00	$414,800
Subtotal				**$1,004,400**
Mobilization and Demobilization	1	LS	5%	$50,200
Erosion and Sediment Control	1	LS	2%	$20,100
Contingency	1	LS	25%	$251,100
OPINION OF COST				**$1,325,800**