Appendix N
Reconnaissance Level Cost Estimates for Strategy Concepts

CDM

Technical Memorandum

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From: *Nicole Rowan, CDM*
Susan Morea, CDM

Date: *June 4, 2010*

Subject: *Reconnaissance Level Cost Estimates for Agricultural and New Supply Strategy Concepts*

The Colorado Water Conservation Board (CWCB) and Interbasin Compact Committee (IBCC) are in the process of a continuing dialogue regarding Colorado's Water Supply Future. In June 2009, the CWCB published the draft report "Strategies for Colorado's Water Supply Future" that included a summary of potential agricultural transfer and new supply development concepts that may be a component of the portfolio used to meet Colorado's future water needs. For each concept, CWCB developed a description and reconnaissance level cost estimate. This technical memo includes an update of the descriptions and reconnaissance level cost estimates including the Green Mountain Reservoir and Blue Mesa concepts. This analysis does not include the Colorado River Reconnaissance concept.

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Section 1 – Overview of Agricultural Transfers and New Supply Development Strategies

As part of the strategy development and evaluation for the agricultural transfer and new supply development strategies, six concepts were considered. These concepts develop water supply in various locations and fall into two general categories:

- Traditional or alternative agricultural transfers from agricultural use to municipal use
- New water supply development from the Colorado River and/or its tributaries

The six water supply concepts are shown in Figure 1-1 below. There are two agricultural transfer concepts—one would deliver water from lower or middle Arkansas River to Reuter-Hess Reservoir and another that would deliver water from the lower or middle South Platte River downstream of Denver to the Brighton area. While agricultural transfers may occur on the West Slope, this study focuses on the East Slope because that is where the majority of past, present, and future transfers are likely to come from. On the West Slope, new appropriations, rather than acquisitions, are the primary focus. The four new water supply appropriation concepts that were studied are the Flaming Gorge concept, Yampa River concept, Green Mountain Reservoir concept, and Blue Mesa Reservoir concept.

This technical memorandum also builds on the recommendations set forth in the Statewide Water Supply Initiative (SWSI) Phase 2 from the Gap Technical Roundtable, which were as follows:

The mission of the Gap Technical Roundtable and a critical requirement of the Water for the 21st Century Act is to:

Foster cooperation among water suppliers and citizens in every water basin to examine and implement options to fill the gap between ongoing water planning and future water needs.

The Gap Technical Roundtable recommended the following strategies be evaluated:

1. Agricultural Transfers from the Arkansas and South Platte
2. Blue Mesa Pumpback
3. Colorado River Reconnaissance Study
4. Flaming Gorge Pipeline
5. Green Mountain Pumpback
6. Yampa Pumpback

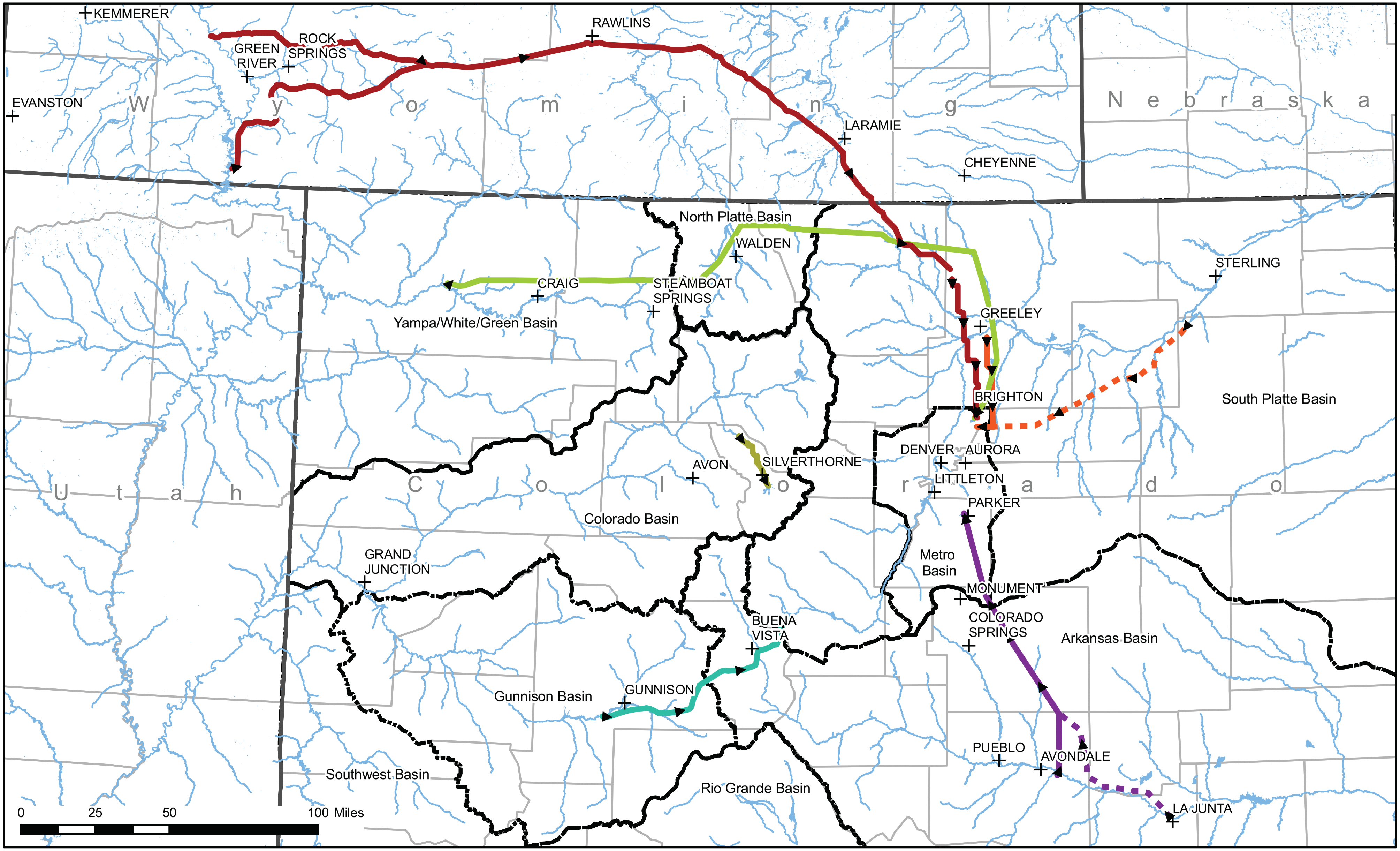

Figure 1-1. Overview of Agricultural Transfer and New Supply Development Concepts

*Note: Arrow indicates flow direction.

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The Gap Technical Roundtable recommended that future work should evaluate the options using similar assumptions and the group suggested that a more detailed evaluation of the options be performed. Many of these items have been addressed and are included in this technical memorandum. The general assumptions that were recommended by the Gap Technical Roundtable include:

- Delivery of similar water quality
- Common or comparable storage areas should be included for all options
- Common or comparable termination points should be included for all options
- There should be a range of water delivery; the suggested range was 100,000 - 175,000 - 250,000 acre-feet (AF)

The Technical Roundtable also suggested the following evaluation elements be included:

- Include Capital and Operation and Maintenance (O&M) costs as net present worth and annualized cost (infrastructure and operation and maintenance) and cost per AF
- Additional information should be developed that outlines some of the initial benefits, impacts, and attributes of the options
- Information and suggestions regarding base options (options that would be added to the major structural options) be obtained from the Basin Roundtables
- Conservation be considered in developing alternatives
- The Colorado Decision Support System (CDSS) be used to perform additional analysis of supply availability
- Additional information be included regarding existing storage and infrastructure opportunities
- Additional information be developed on storage requirements, miles of tunnels required, river crossings, permitting considerations (i.e., Federal Lands, Wilderness Areas, 1041 considerations, wetlands, etc.)
- Refine and develop critical agricultural needs and solutions
- Identify environmental and recreational enhancements

- Refine and develop local basin projects and needs in conjunction with major structural options

The purpose of the information presented in this technical memorandum is to provide basic information that is needed to begin strategy evaluation. This technical memorandum describes each concept listed above and the important elements that would need to be considered when developing the concept such as water source, conveyance, storage, and water quality issues. Section 3 of this technical memorandum provides reconnaissance level cost estimates for each concept presented in this technical memorandum. Several recent studies were reviewed in preparing this technical memorandum. These include:

- Blue River Pumpbacks and Wolcott Reservoir Alternatives Reconnaissance Study (Colorado River Water Conservation District et al. 2007)

- Arkansas River Renewable Water Economic Feasibility Study (Pikes Peak Regional Water Authority 2008)

- Rotational Land Fallowing-Water Leasing Program Engineering and Economic Feasibility Analysis (Lower Arkansas Valley Water Conservancy District 2007)

- Multi-Basin Water Supply Investigation (Northern Colorado Water Conservancy District 2006)

- Regional Water Master Plan (South Metro Water Supply Authority 2007)

- Upper Gunnison-Uncompahgre Basin Phase 1 Feasibility Study (Colorado Water Resources and Power Development Authority 1989)

In addition, recent information developed as part of the U.S. Army Corps of Engineers (USACE) Environmental Impact Statement (EIS) for the Regional Watershed Supply Project was reviewed (2009) (Flaming Gorge Concept). Because these studies were completed in different years, at varying levels of detail, and for different increments of water, a common set of engineering assumptions and costs was developed. The engineering assumptions are presented in the remainder of this section and the cost estimates are presented in Section 3. Again, the purpose of this analysis is to provide basic information to begin evaluating these agricultural transfers and new supply development strategies. Further evaluation beyond what is contained in this technical memorandum—such as evaluating each strategy's ability to meet the IBCC's vision goals—will be developed by CWCB in subsequent study efforts. In addition, the CWCB and IBCC are conducting analyses about other portions of the portfolio in addressing Colorado's future water needs such as conservation and identified projects and processes identified during SWSI. Finally, this technical memorandum does not provide an analysis of integration of Front Range infrastructure as this analysis is currently being examined by several Front Range entities.

1.1 Agricultural Transfer and New Supply Development Strategies Potential Water Source

This section of this technical memorandum summarizes potential sources of water for both the agricultural transfer concepts and the new supply development concepts. For the agricultural transfer concepts, the potential sources of water include a traditional agricultural to municipal water right transfers or an alternative agricultural transfer methods. For the new supply development concepts the water source would be developed by obtaining a new water right or contract for water from the Colorado River system.

1.1.1 Agricultural Transfer Potential Sources of Water Rights

Figures 1-2 and 1-3 show the potential water sources for the Arkansas and South Platte concepts. For the Arkansas River concept (Figure 1-2), two alignments were evaluated to deliver water from the lower Arkansas River to Reuter-Hess Reservoir in Parker, Colorado:

- Alignment 1 would divert water from the Arkansas River near Avondale, Colorado
- Alignment 2 would divert water from the Arkansas River near La Junta, Colorado

For the South Platte River concept (Figure 1-3) two alignments were evaluated to deliver water from the lower South Platte River downstream of Denver to the Brighton, Colorado area:

- Alignment 1 would divert water from the South Platte River near Greeley, Colorado
- Alignment 2 would divert water from the South Platte River near Sterling, Colorado

Meeting Colorado's future water needs through agricultural transfers may take a number of forms including:

- Acquisition and transfer by individual water providers and users.

- Acquisition and transfer on both a temporary and permanent basis. This may be accomplished via leasing and/or purchase.

- Implementation of coordinated activities to meet the needs of both agricultural and municipal uses.

These approaches and others will be utilized based on consideration of both river basin-specific conditions and the needs and desires of those involved in the transactions.

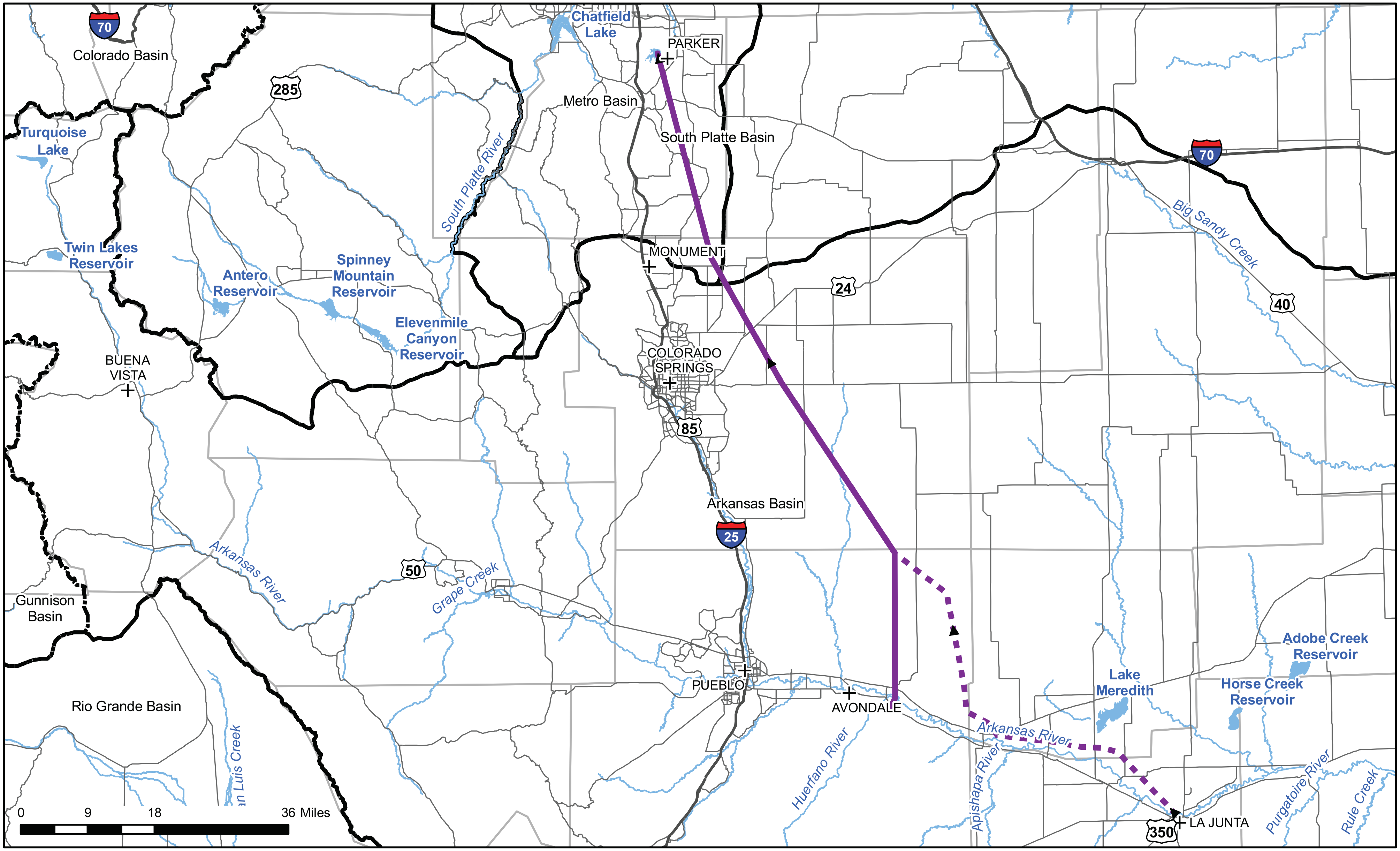

Figure 1-2. Arkansas River Agricultural Transfer Concept

Legend

- + City
- River and Stream
- Arkansas River Concept near Avondale, CO
- Highway
- Lake and Reservoir
- Arkansas River Concept near La Junta, CO
- Road
- Colorado Basins

*Note: Arrow indicates flow direction.

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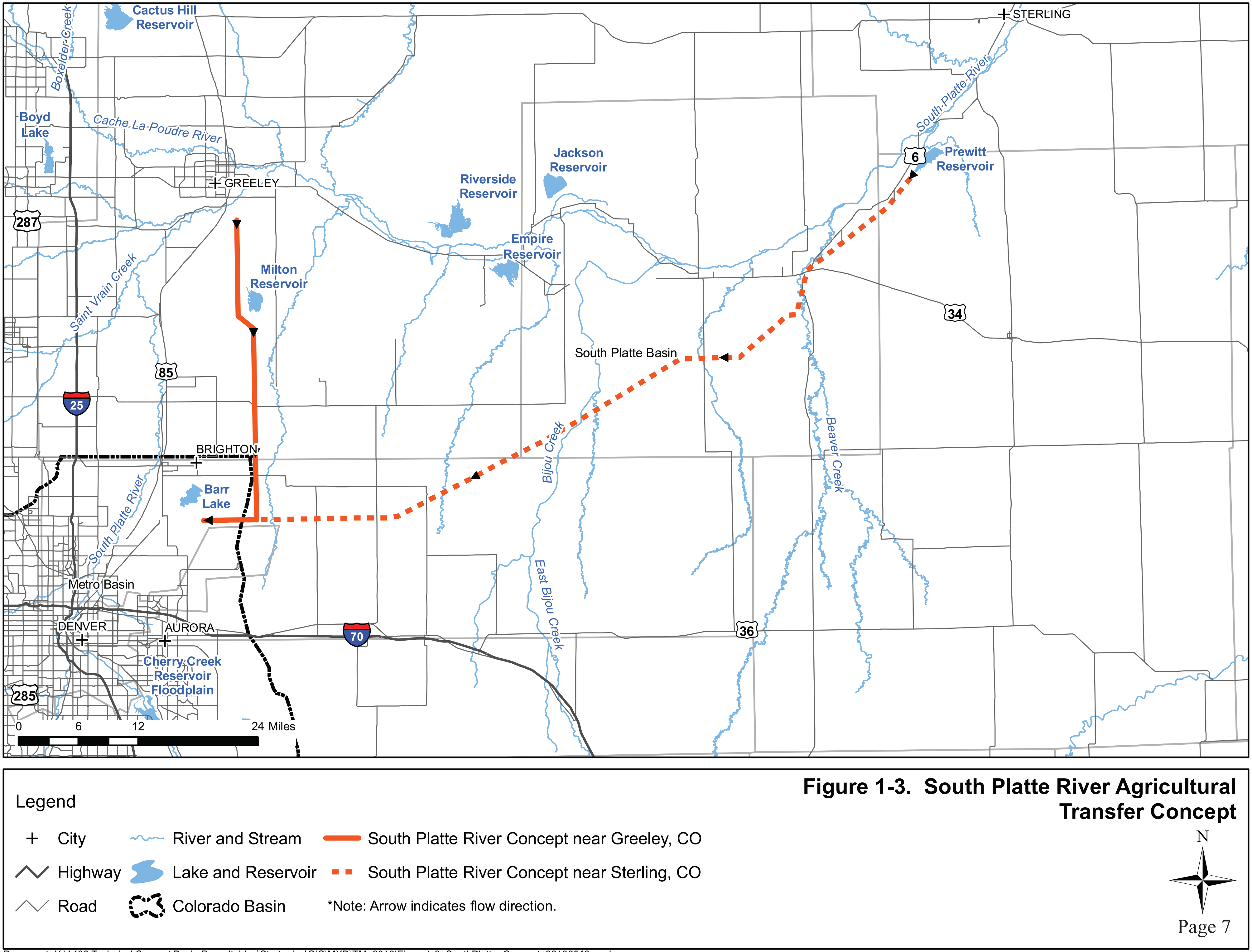

Figure 1-3. South Platte River Agricultural Transfer Concept

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1.1.2 New Supply Development Potential Sources of Water Rights

Figures 1-4 through 1-7 below show the potential water sources for the Flaming Gorge concept, Yampa River concept, Green Mountain Reservoir concept, and Blue Mesa Reservoir concept. The Flaming Gorge concept (Figure 1-4) would divert water out of Flaming Gorge Reservoir and Green River in Wyoming and deliver water to the Brighton, Colorado area. This concept potentially entails two diversion points:

- South diversion diverting directly from the existing Flaming Gorge Reservoir in the Green River close to the Utah Border
- North diversion upstream of the Flaming Gorge Reservoir

The Yampa River concept (Figure 1-5) would divert water from the Yampa River near Maybell, Colorado and deliver water to the Brighton, Colorado area.

In the Green Mountain Reservoir concept (Figure 1-6), water would be pumped from Green Mountain Reservoir on the Blue River and delivered to Dillon Reservoir. Water would be moved from Dillon Reservoir through existing infrastructure to the headwaters of the South Platte Basin. Additional new water rights would be acquired on the South Platte to supplement supplies from the pumpback. This concept also includes new storage on the West Slope to help meet West Slope water needs.

The Blue Mesa Reservoir concept (Figure 1-7) would pump water from Blue Mesa Reservoir to Antero Reservoir in the South Platte Basin. Water would be made available in Blue Mesa either through a contract with the Bureau of Reclamation (BOR) for a portion of the Aspinall marketable pool. This concept could potentially also provide supplies to the upper Gunnison basin.

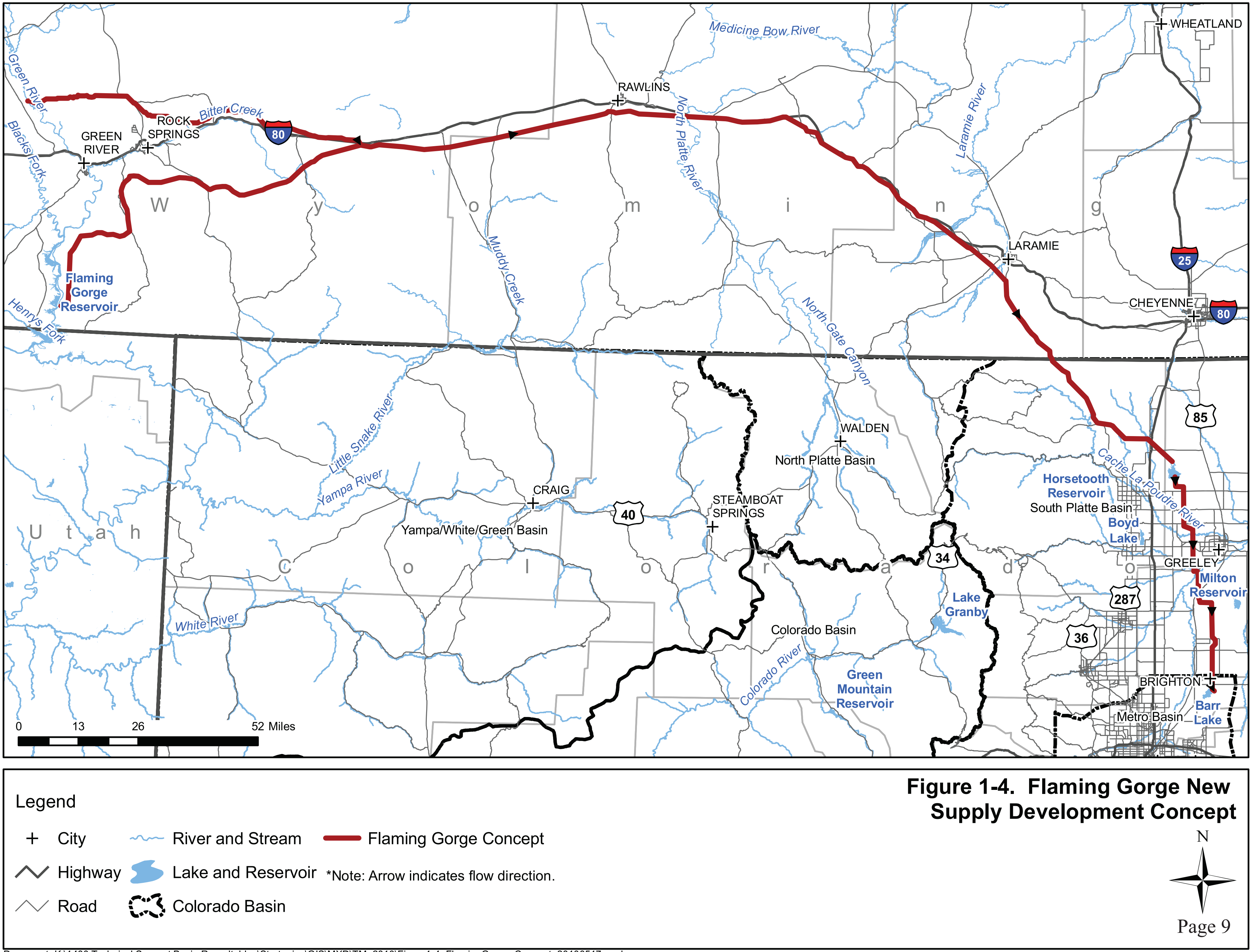

Figure 1-4. Flaming Gorge New Supply Development Concept

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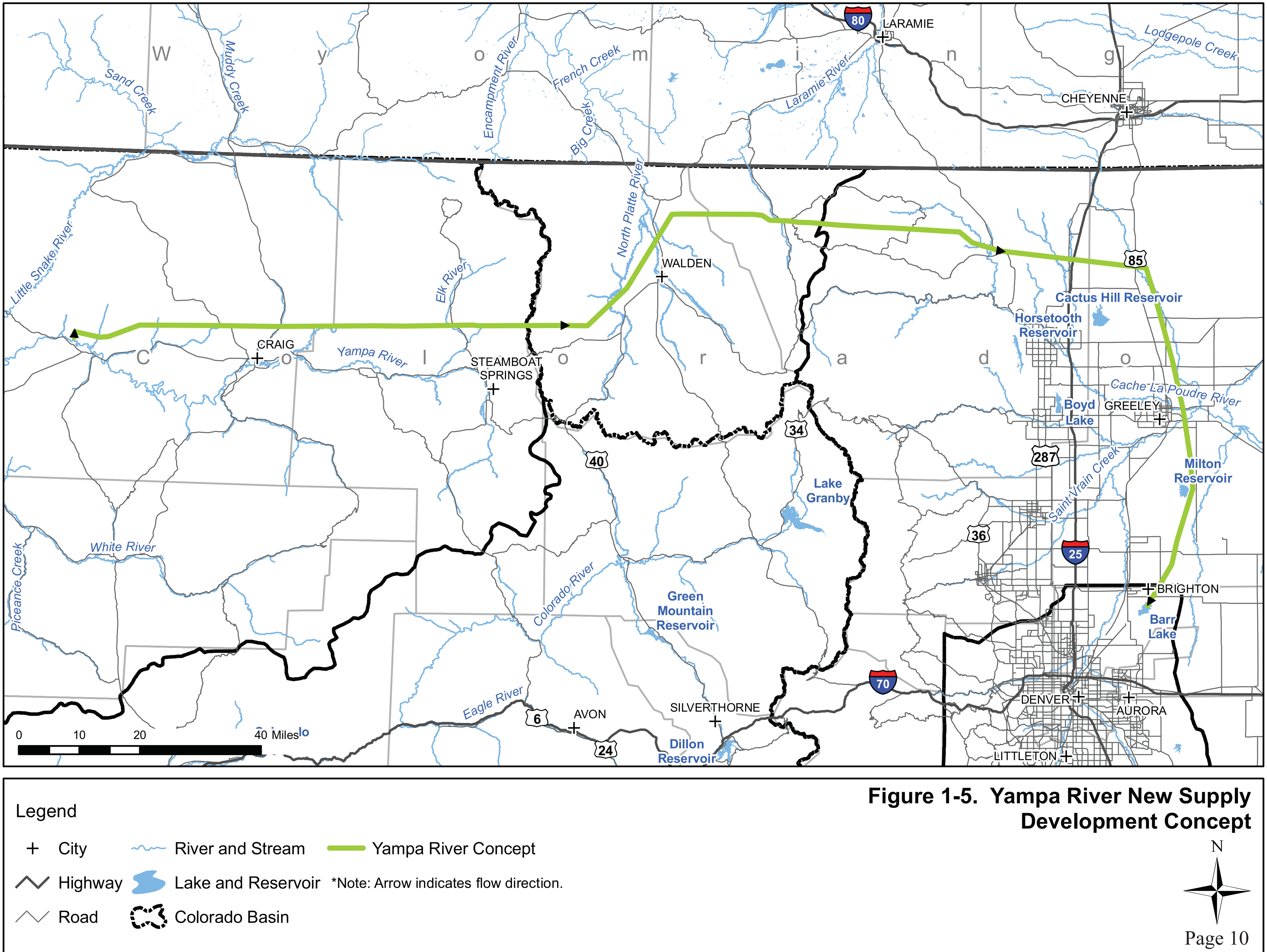

Figure 1-5. Yampa River New Supply Development Concept

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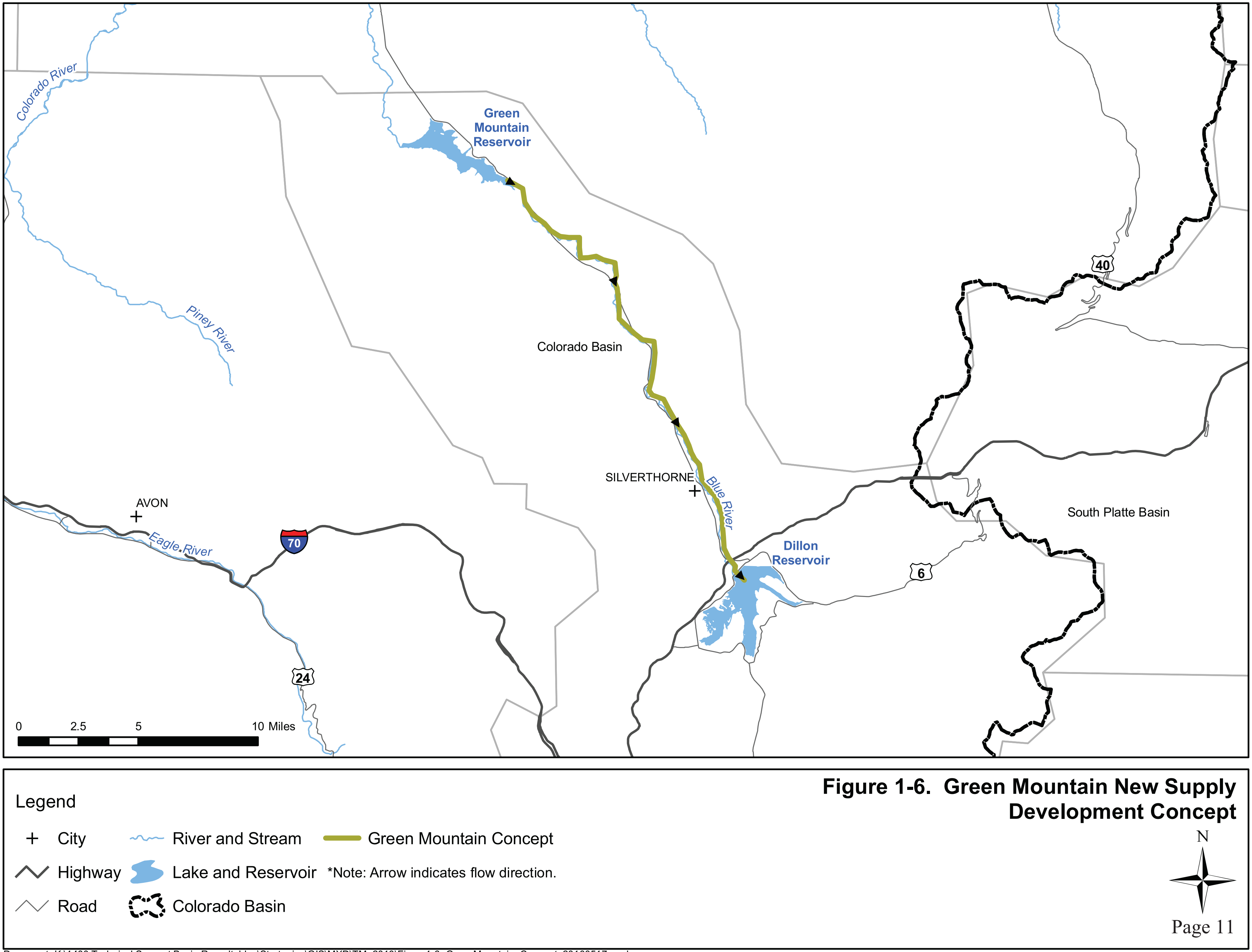

Figure 1-6. Green Mountain New Supply Development Concept

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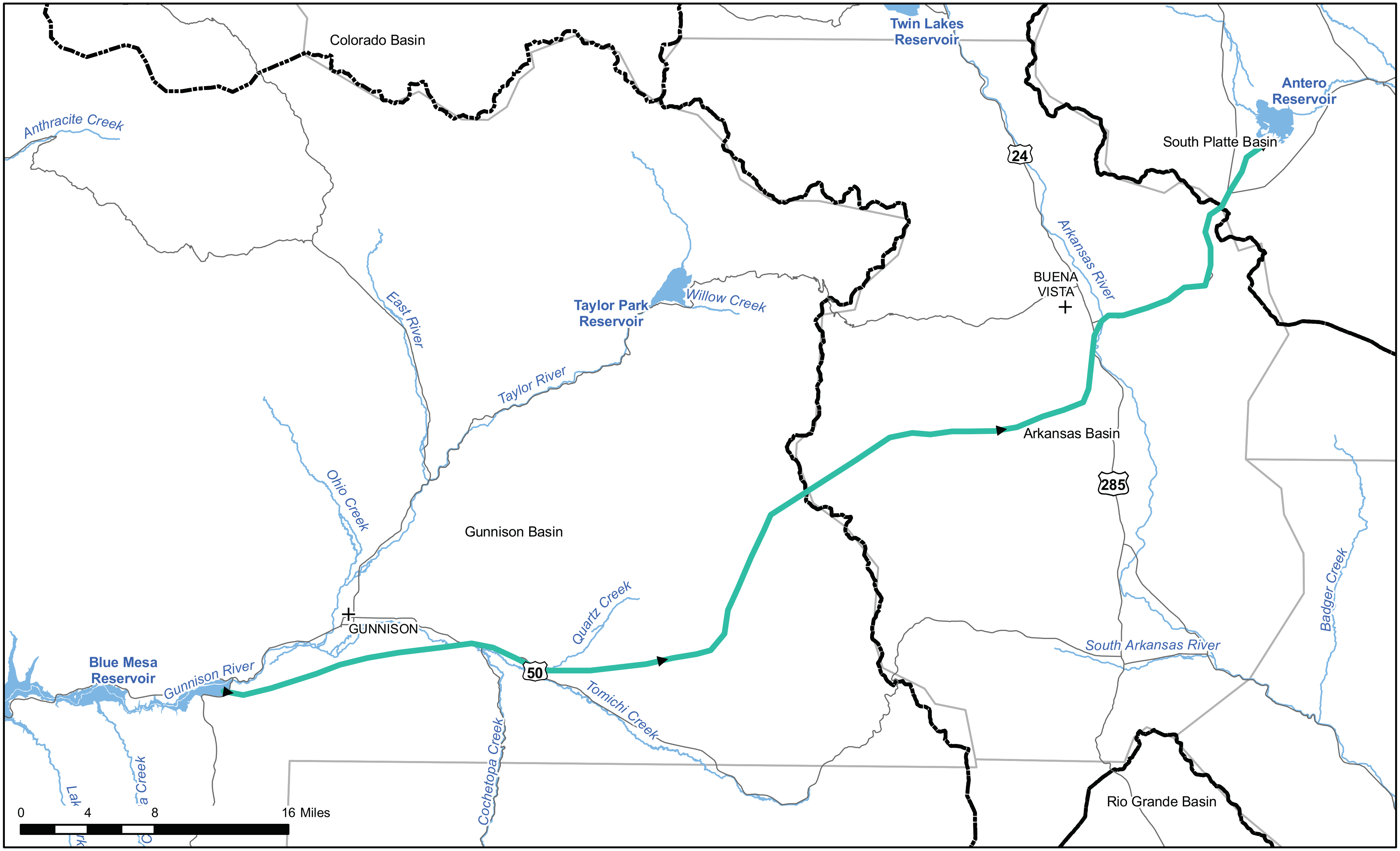

Legend

- City
- Highway
- Road
- River and Stream
- Lake and Reservoir
- Colorado Basin
- Blue Mesa Concept

*Note: Arrow indicates flow direction.

Figure 1-7. Blue Mesa New Supply Development Concept

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1.2 Agricultural Transfer and New Supply Development Strategies Attributes Overview

The basic attributes of each concept are summarized in Table 1-1. For each concept, Table 1-1 describes the water source, conveyance and storage, water quality and treatment considerations, and the technical implementability issues. For the Lower South Platte and Lower Arkansas concepts, the cost of water rights are likely to decrease the further the downstream diversion is from urban areas; however, conveyance costs will increase accordingly. For the Flaming Gorge, and Blue Mesa concepts, the water supply would be acquired through the BOR marketable for each reservoir. For the other new supply development concepts, the water supply acquisition would be a new appropriation. For both the Lower South Platte and Lower Arkansas concepts, reverse osmosis (RO) or advanced water treatment will be required due to source water quality. The Green Mountain, Flaming Gorge, Yampa River, and Blue Mesa Reservoir concepts would not require advanced water treatment. Other important attributes are summarized in more detail in Table 1-1.

Preliminary alignments for all of the concepts were shown in Figures 1-1 through 1-7. These figures show several different termination points for the pipelines; however, it was assumed that the new water supply from all of these concepts will ultimately be delivered to the south metropolitan Denver region. A common point of delivery is important for meaningful comparison of these concepts based on a common set of assumptions, and the south metropolitan Denver region is predicted to have the largest water supply gaps by 2030 (CWCB 2004). However, it should be noted that the concepts discussed in this technical memorandum could be used to address needs in other areas on the West Slope, in the Arkansas Basin, and in the Northern Metro Area of Denver. The general alignments for all of the concepts shown above were determined in previous studies that were presented at the beginning of this section. In order to remain consistent with the previous studies, the previously studied concept alignments were used for this comparative analysis. Only minor modifications of these alignments were made during this engineering analysis. The exception to this is the Blue Mesa Reservoir concept alignment, which was revised to make use of the existing Otero pump station.

Table 1-1 Agricultural Transfer and New Supply Development Concept Attributes

Concept	Water Source/ Water Rights	Conveyance and Storage	Water Quality and Treatment Costs	Technical Implementability
Lower South Platte	• South Platte agricultural water rights • Cost of water rights will likely decrease further downstream and away from urban areas	• Water pumped 36 to 84 miles with static pumping requirement of 700 to 1,300 feet • Conveyance costs will increase the further downstream • Firming storage required	• Water quality will decrease further downstream and treatment costs will increase • Expected Total Dissolved Solids (TDS) levels of 750 to 1,200 mg/L • RO or advanced water treatment will be required	• If land is permanently dried up from an agricultural transfer will require revegetation • Recent water quality legislation allows water quality impacts for transfers over 2000 AF to be reviewed as part of an agricultural transfer (C.R.S. 37-92-305 (4)(a)(V))
Lower Arkansas	• Arkansas agricultural water rights • Cost of water rights will likely decrease further downstream and away from urban areas • LAWCD has formed the Super Ditch as an alternative to traditional agricultural transfer	• Water pumped 96 to 133 miles with static pumping requirement of 3,100 to 3,600 feet • Conveyance costs will increase the further downstream • Firming storage required	• Water quality will decrease further downstream and treatment costs will increase • Expected TDS levels of 750 to 2,000 mg/L • RO or advanced water treatment will be required	• If land is permanently dried up from an agricultural transfer will require revegetation • Recent water quality legislation allows water quality impacts for transfers over 2000 AF to be reviewed as part of an agricultural transfer (C.R.S. 37-92-305 (4)(a)(V))

Table 1-1 Agricultural Transfer and New Supply Development Concept Attributes

Concept	Water Source/ Water Rights	Conveyance and Storage	Water Quality and Treatment Costs	Technical Implementability
Green Mountain	• Blue River water in the Colorado River basin as well as new South Platte water rights • Water would likely be a new appropriation unless Denver Water conditional rights can be used • New appropriation may require significant firming storage • Compact issues and legal availability need to be resolved or a new appropriation	• Water pumped 22 miles with static pumping requirement of 1,100 feet • Green Mountain storage will need to be replaced with other storage • Firming storage estimates vary significantly • Will depend on negotiations with Denver Water for terms of use of Dillon Reservoir and Roberts Tunnel • Conveyance on East Slope would be via South Platte River	• Relatively high water quality • Conventional treatment technology • Pumping high-phosphorus water to Dillon may be a concern	• Landslides in Green Mountain Reservoir from reservoir drawdown may limit ability to fully use storage in reservoir
Yampa	• New water rights appropriation • Compact issues and legal availability related to endangered fish need to be resolved for a new appropriation	• Estimated 500,000 AF of off-channel West Slope storage would need to be constructed • East Slope storage also required • Would require approximately 250 miles of pipeline, with static pumping requirement of 5,000 feet • Pumping, pipeline, and tunneling required to deliver water to northern area of South Platte basin • Conveyance on East Slope would be via pipelines to the south Denver metropolitan area	• Moderate water quality • Estimated water quality higher than Lower South Platte, Lower Arkansas, or Flaming Gorge • Conventional treatment technology	• Constructible and permittable West Slope diversion, storage sites, and pipeline routes need to be verified

Table 1-1 Agricultural Transfer and New Supply Development Concept Attributes

Concept	Water Source/ Water Rights	Conveyance and Storage	Water Quality and Treatment Costs	Technical Implementability
Flaming Gorge	• Contract with BOR for water from the Flaming Gorge marketable pool, to the extent the BOR is willing to contract out of the pool and it is not opposed by other Colorado River basin states • Compact issues and legal availability and administration of depletions in Wyoming for use in Colorado need to be resolved	• Volume of firming storage required will be dependent on terms of BOR contract • Limited Flaming Gorge storage may be available • Volume of firming storage is unknown • 357 to 442 miles of pipeline to the south Denver metropolitan area with static pumping requirements of 1,400 to 3,100 feet	• Would likely require higher level of treatment than other West Slope options • TDS is higher than other West Slope options but lower than Lower South Platte or Arkansas • Conventional treatment technology	• Constructible and permittable West Slope diversion, storage sites, and pipeline routes need to be verified
Blue Mesa Reservoir	• Contract with BOR for water from the Aspinall pool • Possibility for new appropriation options influenced by Black Canyon reserved right and agreement with BOR or interruption of power generated by Aspinall Unit. • Compact issues and legal availability need to be resolved	• Volume of firming storage required will be dependent on terms of BOR contract • Limited or no Blue Mesa storage may be available • 81 miles of pipeline with static pumping requirement of 3,400 feet • Conveyance on East Slope would be via South Platte and Arkansas Rivers	• Relatively high water quality • Conventional treatment technology	• Constructible and permittable West Slope diversion, storage sites, and pipeline routes need to be verified

As shown in Figure 1-1, the South Platte, Flaming Gorge, and Yampa alignments used in this study convey water to the Brighton area. It was assumed supplies could be conveyed from Brighton to the south metropolitan area, through shared future projects and/or existing projects such as the East Cherry Creek Valley Northern Pipeline and the City of Aurora Prairie Waters Pipeline. This reach of pipeline was not considered in this study as it does not help to differentiate between these three concepts and would be an equally small cost to any of the projects. The Arkansas alignments deliver to Reuter-Hess Reservoir near Parker in the south Denver metropolitan area. The Green Mountain project will convey water to the Denver area using existing Denver Water infrastructure within the South Platte Basin. Similarly, the Blue Mesa Reservoir concept will convey water from Antero Reservoir to the Denver area using existing infrastructure within the Arkansas and South Platte basins.

Section 2 – Concept Size Options and Facility Requirements

With the exception of the Green Mountain concept, each of the agricultural transfer and new supply development concepts were evaluated based on three options:

- Option 1: delivery of 100,000 acre-feet per year (AFY) constructed in a single phase
- Option 2: delivery of 250,000 AFY constructed in a single phase
- Option 3: delivery of 250,000 AFY constructed with the first phase delivering 100,000 AFY and the second phase delivering the remaining 150,000 AFY

Key elements of each water supply concept were identified and evaluated using uniform assumptions to determine infrastructure requirements and sizing for the reconnaissance cost estimates. The assumptions and requirements of each concept are presented below for the following elements: water rights; firming storage; diversions; transmission facilities, including pipelines, tunneling, and pump stations; treatment facilities; and reuse infrastructure. Hydropower facilities were not considered for this technical memorandum, nor electrical power substation and transmission facilities.

The maximum expected water supply yield from the Green Mountain concept is 68,600 AFY, which is less than the Option 1 delivery of 100,000 AFY. Only one scenario, 68,600 AFY total deliveries constructed in a single phase, was evaluated for the Green Mountain concept. The total delivery of 68,600 consists of 42,500 from the pumpback, 10,500 from the new South Platte water right, and 19,800 AFY in west slope demands met, including 4,200 met by a decrease in Colorado Springs' substitution obligations.

Flaming Gorge is the only concept with two diversion points – the north diversion and the south diversion, as introduced in Section 1.1. It was assumed that the south diversion can convey 150,000 AFY and the north diversion can convey 100,000 AFY. Given this assumption, Option 1 was sized and costed assuming only the north diversion pipeline is constructed, Options 2 and 3 were sized and costed assuming both the north and south diversion pipelines are constructed.

2.1 Water Rights

As discussed in Section 1.1, for the agricultural transfer concepts water would be transferred from agricultural use to municipal use. For the new supply development concepts new water rights would need to be acquired and for Flaming Gorge and Blue Mesa a contract would need to be established for portions of the marketable pools. For the new water supply development concepts, filing for a new water right would be required. The agricultural transfer concepts would require water rights purchase and obtaining the legal transfer of use, which require Colorado Water Court review.

2.2 Firming Storage

The availability of surface water supplies varies greatly in Colorado as annual water supplies are dependent upon the quantity of winter snowfall and the timing of the snowmelt in the spring and summer. Colorado's rivers typically have 2 to 4 months of elevated streamflows, which constitutes the window to divert and store the majority of available water supplies. Therefore, water storage is an important component of any water supply project, especially for large-scale, long-distance pipelines, as a future project would need to supply a relatively constant supply of water to the Front Range of Colorado to meet future municipal and industrial demands.

As the availability of the river supplies comes within a few months, and municipal supplies are needed year round, a storage reservoir would, at a minimum, need to store almost the entire volume of each of the concept options. In addition, the quantity of snowfall varies greatly from year to year and storing excess water in wet and average years would help provide a reliable supply for dry and very dry years, when the full supply might not be available.

For the purpose of this planning level analysis it was assumed that a storage-to-yield ratio of 2:1 would be required for the agricultural transfer concepts. This assumption is based on the variability described above as well as variability between potential reservoir locations. As will be described in Section 3, the purchasing of senior agricultural rights was evaluated, which will help water supply reliability in dry and very dry years when yields for junior users are often significantly curtailed. Thus, for both the Arkansas River concept and the South Platte River concept, the Option 1 storage volumes were evaluated at 200,000 AF and the Options 2 and 3 storage volumes were evaluated at 500,000 AF. Specific locations and reservoir sites were not evaluated for this analysis, as the location of the specific water rights purchased would greatly affect which reservoir locations would be optimal for future water supplies.

The firming storage requirements varied for the four new water supply development concepts. The Flaming Gorge concept South Diversion would divert water directly from the existing Flaming Gorge Reservoir and would not require additional firming storage. For the North Diversion of Flaming Gorge concept, it was assumed that a storage to yield ratio of 2:1 would be required and the storage volume for Options 1, 2, and 3 were all evaluated at 200,000 AF. It was assumed that a storage-to-yield ratio of 2:1 would be required for the Yampa River and Blue Mesa concepts. The Yampa River and Blue Mesa concepts' Option 1 storage volume was evaluated at 200,000 AF and the Option 2 and 3 storage volumes were evaluated at 500,000 AF. For the Green Mountain Reservoir concept, firming storage of 85,000 AF was assumed based on previous reports. Specific locations and reservoir sites were not evaluated for this analysis, as the location of the specific diversion location was not known, which would greatly affect which reservoir locations would be optimal for future water supplies.

2.3 Transmission Facilities

Transmission facilities consist of pipelines, tunnels, and pump stations. The basis for sizing each of these elements was review of the proposed supply and discharge locations, proposed general alignments for the conveyance facilities, and the development of a preliminary hydraulic gradeline (HGL) based on the lift required to transfer the flows. Initial approximate locations for the pump stations were identified based on the topography along the proposed routes, maximum reasonable lifts for each pump station, and the trade-off between using tunnels through certain reaches and using pump stations and pipelines. The initial sizing was based on the different lift and flow requirements. The results of this hydraulic analysis were used to determine pressure class requirements and tunneling lengths and depths. As noted in Section 1, alignments for each concept were selected from previous studies—one alignment was evaluated for each of the Flaming Gorge, Yampa River, Green Mountain, and Blue Mesa concepts, and two alignments were evaluated for each of the Arkansas and South Platte concepts. Transmission facilities were evaluated separately for each scenario and for each alignment. Option 3 (250,000 AFY in two phases) was assumed to consist of two parallel pipelines with shared tunnels and pump stations.

All transmission facilities were sized to convey greater than the average selected target flow for each scenario, allowing for the total annual volume to be delivered if all infrastructure was available 90 percent of the time. Applying this peaking factor (1.1) allows the target annual volumes to be delivered despite downtime for routine maintenance and unexpected events such as pump station power outages.

2.3.1 Hydraulic Analysis

The alignments were brought into *ArcGIS* and were split into station points every 100 feet. The station points were then assigned an elevation based on the U.S. Geological Survey (USGS) National Elevation Dataset (NED) for Colorado and Wyoming. The elevation data were then used to make profiles for all of the alignments, which were used to complete the HGL analysis. HGLs were developed for each concept and are shown in Figures 2-1 through 2-8 below. The pipeline profile was assumed to follow the ground elevation, with approximately 8 feet of cover. The exception was where the ground surface required pipe slopes greater than 15 percent, in which case the pipeline was buried deeper to reduce slopes, or where tunnels were used instead of the pipelines.

The HGLs shown in Figures 2-1 through 2-8 were based on Option 2 (250,000 AFY in a single phase 114-inch pipe with the same peaking factor of 1.1 used to size the transmission facilities), except for the Green Mountain HGL, which was based on the only option (68,600 AFY in a single-phase 48-inch pipeline with a peaking factor of 1.1). The friction loss in the pipelines and tunnels was estimated using the Hazen-Williams equation with a C-factor of 130. This C-factor is conservative for new pipe, but is a reasonable estimation of pipe conditions after 50 years, which is the anticipated project life. The HGL analysis was based only on one option because the difference in friction losses between options, which have similar velocities, is not significant. Where available (Yampa [Northern Colorado Water Conservancy District 2006] and Flaming Gorge south diversion and main pipelines [USACE 2009]), pump station locations and total dynamic head (TDH) values were initially used from previous reports in order to approximate requirements for pumping as well as tunneling. Pump station locations and TDH values were then revised to maintain minimum pipeline pressures of 10 pounds per square inch (psi) and maximum pressures of about 350 psi while maintaining a reasonable balance between pumping and tunneling.

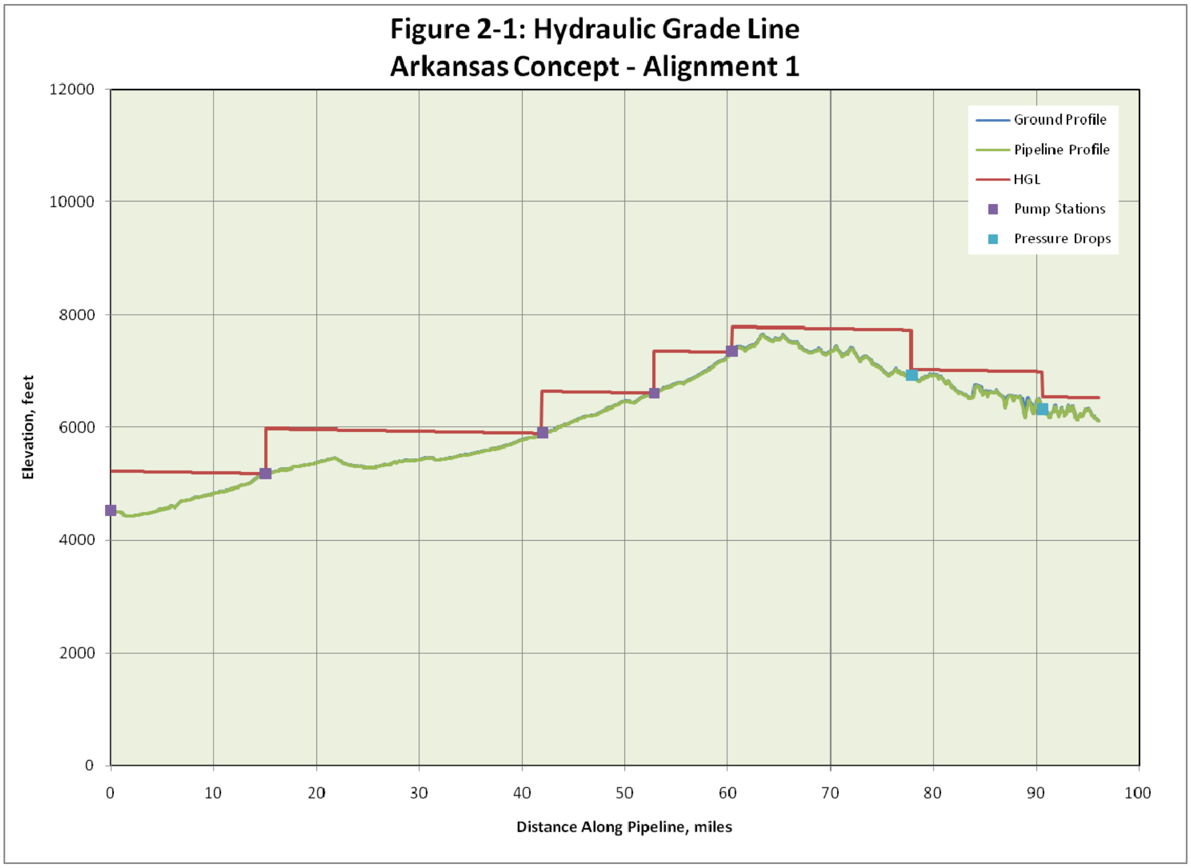


Figure 2-1: Hydraulic Grade Line
Arkansas Concept - Alignment 1
Elevation, feet
Distance Along Pipeline, miles
Ground Profile
Pipeline Profile
HGL
Pump Stations
Pressure Drops
0
2000
4000
6000
8000
10000
12000
0
10
20
30
40
50
60
70
80
90
100

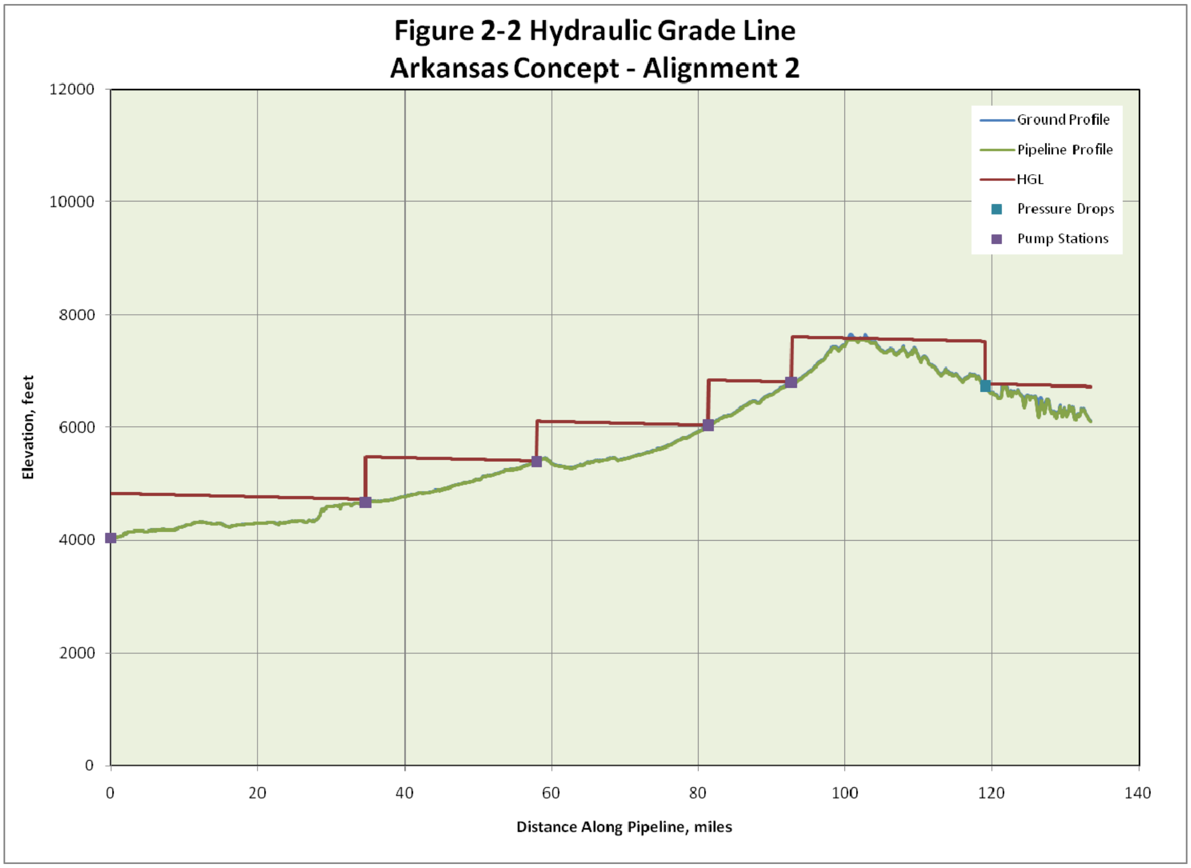


Figure 2-2 Hydraulic Grade Line
Arkansas Concept - Alignment 2
Ground Profile
Pipeline Profile
HGL
Pressure Drops
Pump Stations
Elevation, feet
12000
10000
8000
6000
4000
2000
0
0
20
40
60
80
100
120
140
Distance Along Pipeline, miles

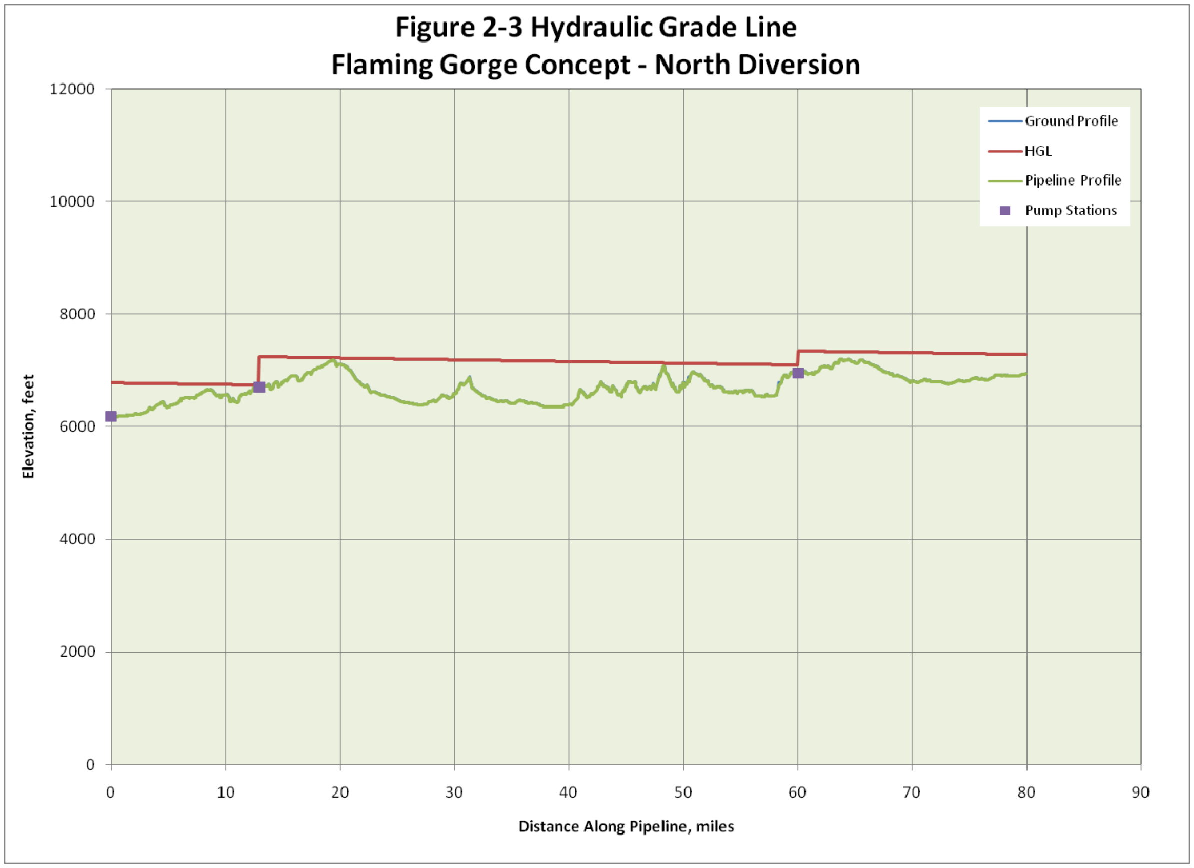


Figure 2-3 Hydraulic Grade Line
Flaming Gorge Concept - North Diversion
Ground Profile
HGL
Pipeline Profile
Pump Stations
Elevation, feet
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
60
70
80
90
Distance Along Pipeline, miles

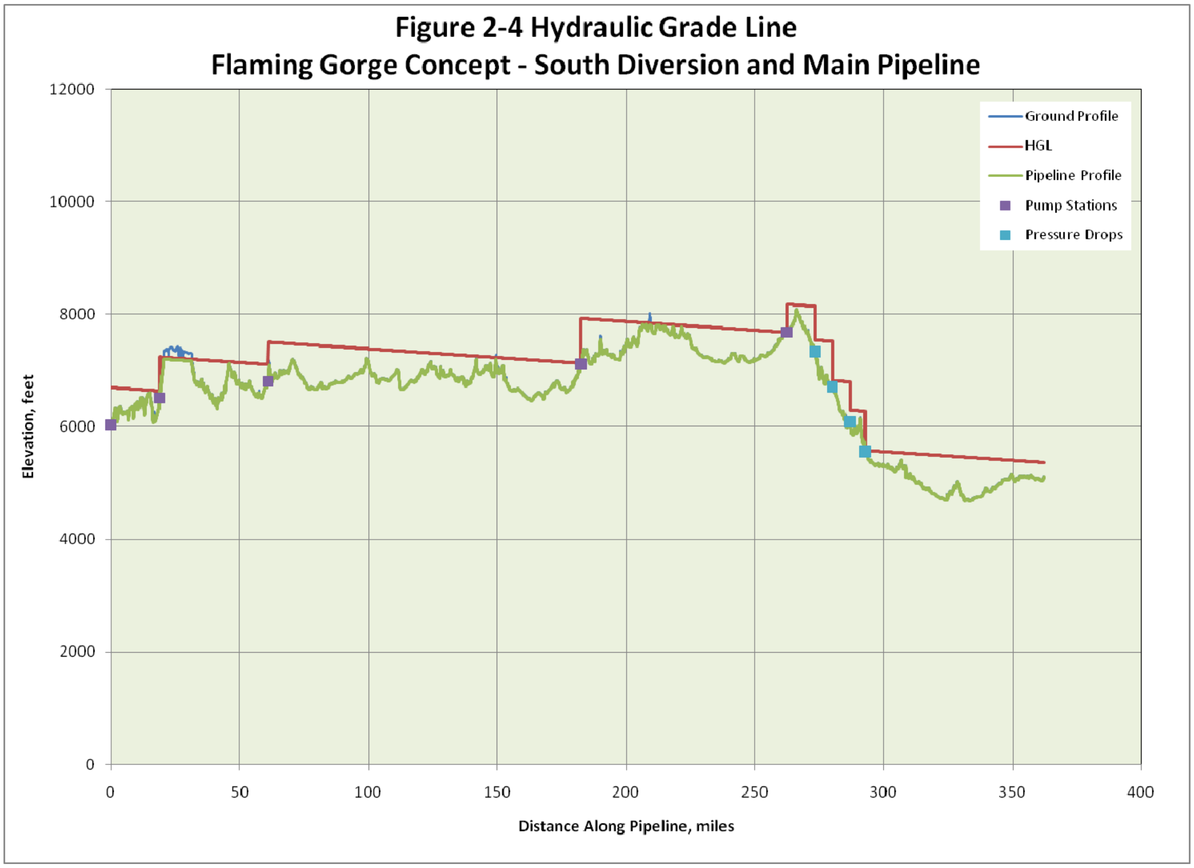


Figure 2-4 Hydraulic Grade Line
Flaming Gorge Concept - South Diversion and Main Pipeline
Ground Profile
HGL
Pipeline Profile
Pump Stations
Pressure Drops
Elevation, feet
0
2000
4000
6000
8000
10000
12000
0
50
100
150
200
250
300
350
400
Distance Along Pipeline, miles

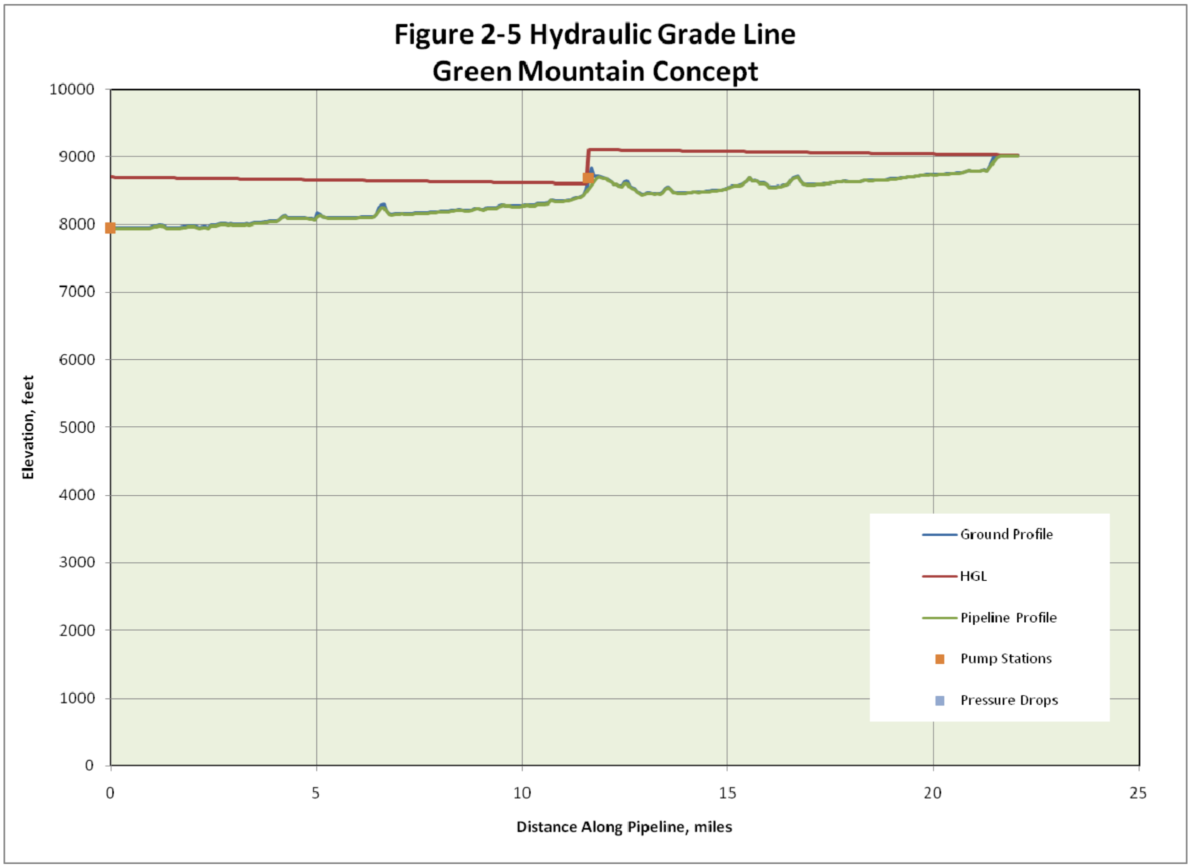


Figure 2-5 Hydraulic Grade Line
Green Mountain Concept
Elevation, feet
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
Distance Along Pipeline, miles
Ground Profile
HGL
Pipeline Profile
Pump Stations
Pressure Drops

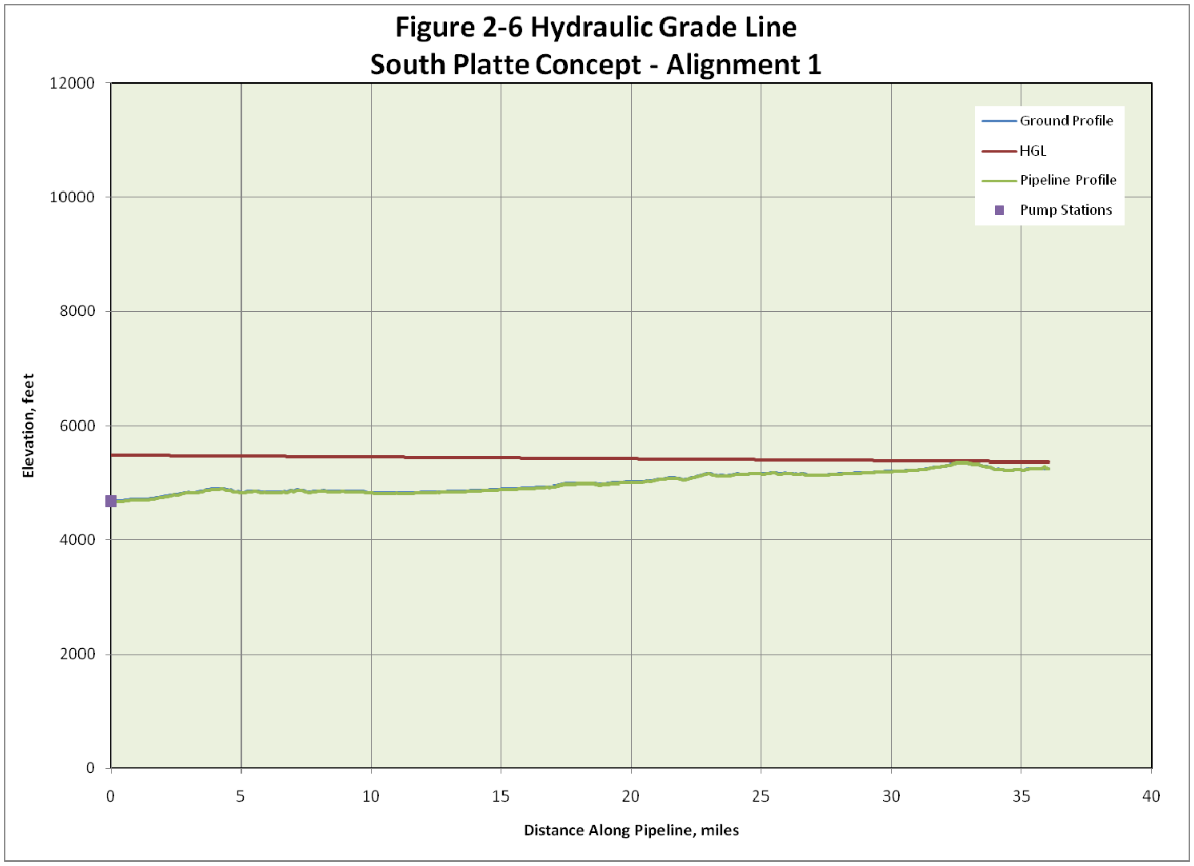


Figure 2-6 Hydraulic Grade Line
South Platte Concept - Alignment 1
Ground Profile
HGL
Pipeline Profile
Pump Stations
Elevation, feet
Distance Along Pipeline, miles
12000
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
30
35
40

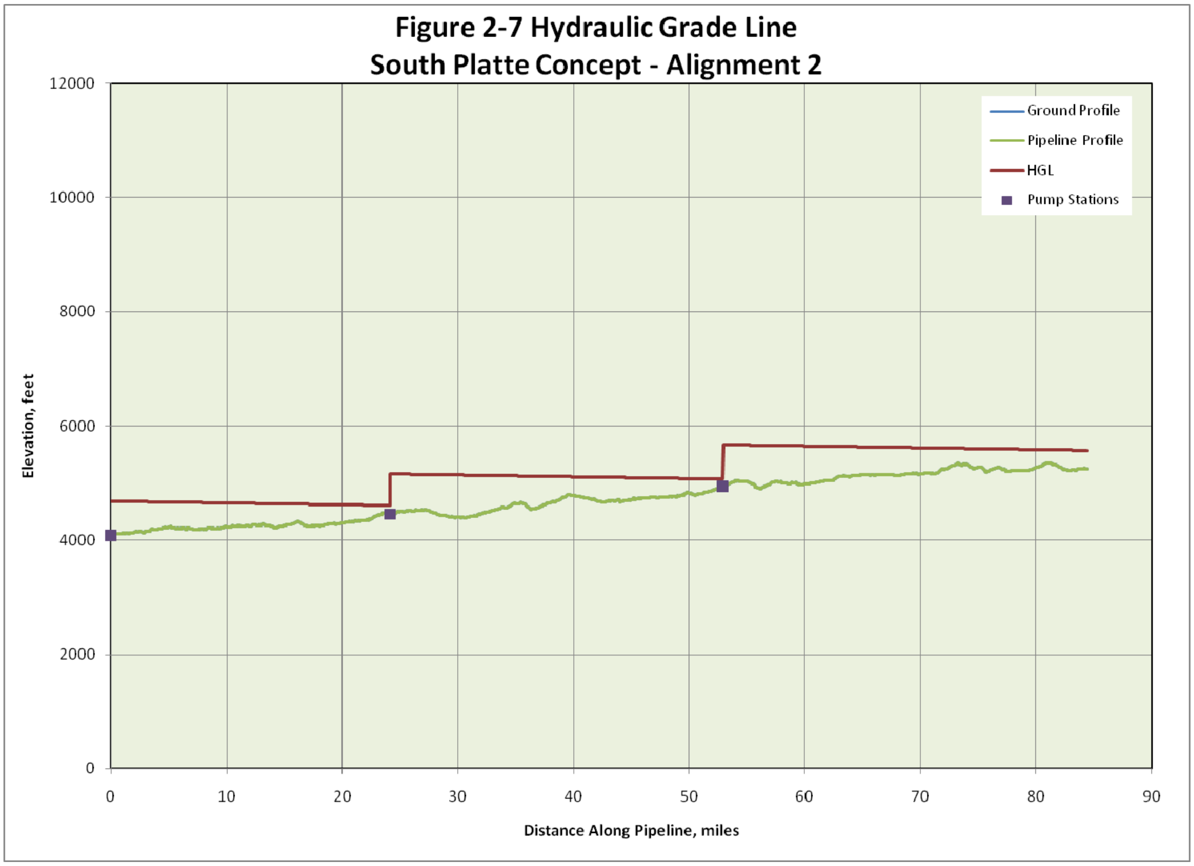


Figure 2-7 Hydraulic Grade Line
South Platte Concept - Alignment 2
Ground Profile
Pipeline Profile
HGL
Pump Stations
Elevation, feet
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
60
70
80
90
Distance Along Pipeline, miles

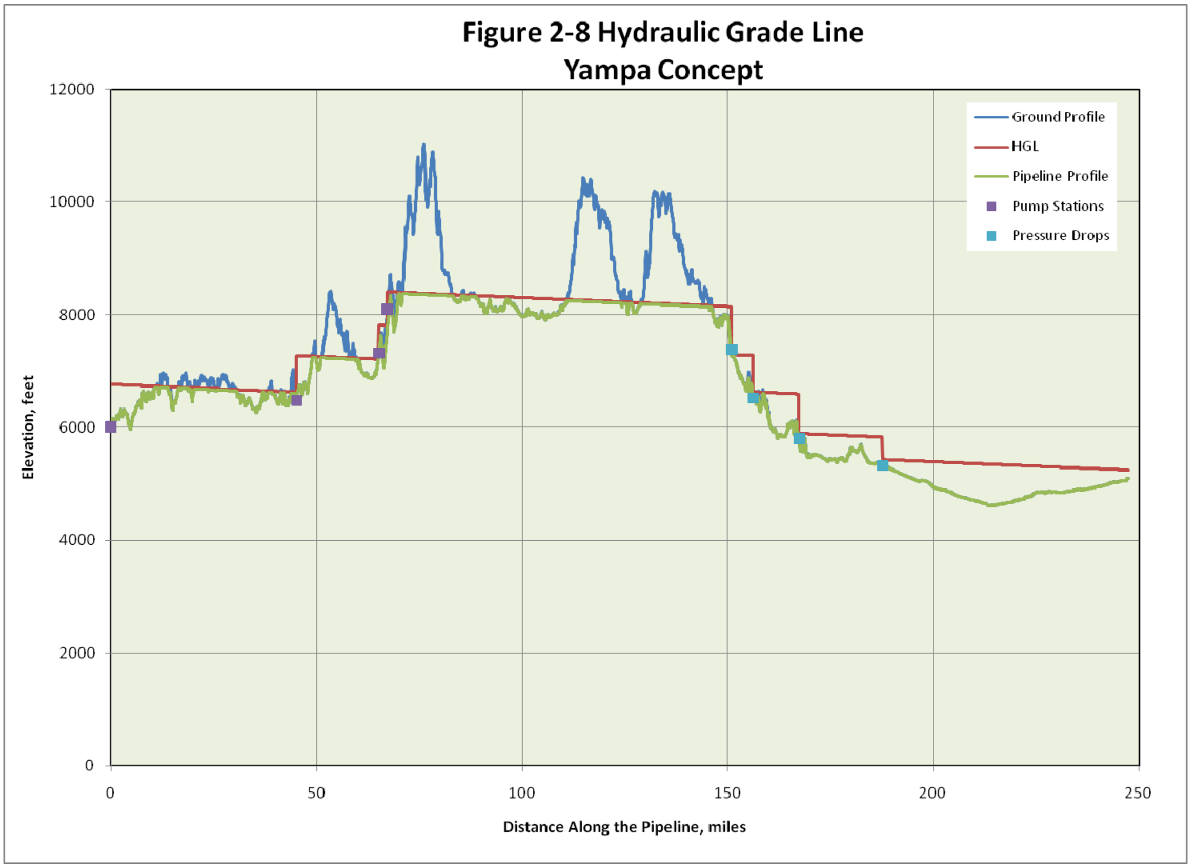


Figure 2-8 Hydraulic Grade Line
Yampa Concept
Ground Profile
HGL
Pipeline Profile
Pump Stations
Pressure Drops
Elevation, feet
Distance Along the Pipeline, miles
0
2000
4000
6000
8000
10000
12000
0
50
100
150
200
250

For some sections of the alignments the pressures needed to be reduced as the ground elevation dropped. The HGLs shown in Figures 2-1 through 2-8 include pressure drop points where needed. These are included to constrain pressures to reasonable values and used to analyze pipe pressure class requirements. One possible way to accomplish the required reduction in head is through hydropower facilities, which were evaluated in previous reports for the Flaming Gorge (USACE 2009), and Yampa (Northern Colorado Water Conservancy District 2006) concepts. Pressure drop requirements are summarized in Table 2-1.

Table 2-1 Pressure Drop Summary

Concepts	No. Pressure Drop Facilities	Total head reduction (psi)	Total pressure blow-off (feet)
Arkansas 1	2	1,150	2,653
Arkansas 2	1	750	1,730
Blue Mesa	3	3,900	1,700
Flaming Gorge	4	2,500	5,768
Yampa	4	2,600	5,998

*Note: No pressure drop facilities were required for either South Platte alignment or the Green Mountain concept

Most of the concept alignments have widely varying slopes, which affects excavation or tunneling costs. The HGL analysis was also used to determine the portion of each alignment where ground slopes exceeded 10 percent. For this analysis an escalation factor was used to represent the increased difficulty for these reaches and the increased installation costs. Table 2-2 summarizes the percent of each alignment with ground slopes greater than 10 percent.

Table 2-2 Ground Slope Summary

Concept		Percentage of length with ground slope above 10%
Arkansas	Alignment 1	3
	Alignment 2	2
Blue Mesa		18
Flaming Gorge	Main Pipeline	4
	North Diversion Pipeline	4
	South Diversion Pipeline	4
Green Mountain		6
South Platte	Alignment 1	0
	Alignment 2	0
Yampa		9

2.3.2 Pipelines

For planning purposes the pipelines were sized based on maintaining the flow velocity below 5.5 feet per second (fps) at the peak design flow of 1.1 times the average annual flow for each scenario. Table 2-3 shows the diameters and velocities for each scenario. All concepts are assumed to use the same flows and pipeline diameters. As discussed above, the Flaming Gorge concept south diversion was assumed to convey 150,000 AFY (Options 1 and 3) and the north diversion was assumed to convey 100,000 AFY (Options 2 and 3); all other concepts have a single diversion point. Each segment of pipeline was then evaluated to stay within 150, 250, or 350 psi class pipe pressure requirements, based on the difference between the HGL and the pipeline elevation. Table 2-4 summarizes pressure classes by pipeline.

Table 2-3 Pipeline Diameters and Velocities

Option	Capacity (AFY)	Peak Capacity (AFY)	Pipeline diameter (in)	Velocity, peak (fps)
1 and 3	100,000	110,000	72	5.4
2	250,000	275,000	114	5.4
3	150,000	165,000	90	5.2
Green Mountain	42,500	46,750	48	5.1

Table 2-4 Pressure Classes

Concept		Pressure Class (%)		
		150 psi	250 psi	350 psi
Arkansas	Alignment 1	34	38	28
	Alignment 2	32	34	34
Blue Mesa		44	32	24
Flaming Gorge	Main Pipeline	35	42	23
	North Diversion Pipeline	29	47	24
	South Diversion Pipeline	20	49	31
Green Mountain		17	52	31
South Platte	Alignment 1	40	22	39
	Alignment 2	24	52	25
Yampa		52	31	17

2.3.3 Pump Stations

Possible locations for the pump stations were based on identifying accessible locations for construction, and the maximum allowable pressure in the pipelines where tunnels were not used in lieu of pumps and pipelines. Table 2-5 summarizes the number of pump stations and total required pumping head for each concept, and Table 2-6 shows the location and TDH of each pump station along each alignment. Pump station horsepower requirements were calculated for both peak and non-peak flows, as shown in Table 2-7. Horsepower calculations were based on an assumed combined pump and motor efficiency of 72 percent.

Table 2-5 Pump Station Summary

Concept		No. of Pump Stations	Total Pumping Head Requirements (ft)
Arkansas	Alignment 1	5	3,450
	Alignment 2	5	3,850
Blue Mesa		6	3,700
Flaming Gorge	Main Pipeline	2	1,300
	North Diversion Pipeline	3	1,350
	South Diversion Pipeline	3	1,650
Green Mountain		2	1,250
South Platte	Alignment 1	1	800
	Alignment 2	3	1,750
Yampa		4	2,600

Table 2-6 Pump Stations

Concept		Pump Station ID	Distance Along Alignment (miles)	TDH (ft)
Arkansas	Alignment 1	AK1-PS1	0	700
		AK1-PS2	15	800
		AK1-PS3	42	750
		AK1-PS4	53	750
		AK1-PS5	60	450
	Alignment 2	AK2-PS1	0	800
		AK2-PS2	35	750
		AK2-PS3	58	700
		AK2-PS4	81	800
		AK2-PS5	93	800
Blue Mesa		BM-PS1	0	700
		BM-PS1	21	750
		BM-PS1	25	650
		BM-PS1	31	550
		BM-PS1	34	300
		BM-PS1	69	750

Table 2-6 Pump Stations

Concept		Pump Station ID	Distance Along Alignment (miles)	TDH (ft)
Flaming Gorge	Main Pipeline	M-PS1	87	800
		M-PS2	167	500
	North Diversion Pipeline	ND-PS1	0	600
		ND-PS2	13	500
		ND-PS3	60	250
	South Diversion Pipeline	SD-PS1	0	650
		SD-PS2	19	600
		SD-PS3	61	400
Green Mountain		GM-PS1	0	750
		GM-PS2	12	500
South Platte	Alignment 1	SP1-PS1	0	800
		SP2-PS1	0	600
	Alignment 2	SP2-PS2	24	550
		SP2-PS3	53	600
Yampa		Y-PS1	0	750
		Y-PS2	45	650
		Y-PS3	65	600
		Y-PS4	67	600

Table 2-7 Total Pumping Horsepower Requirements

		Average (hp)			Peak (hp)		
		Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Arkansas	Alignment 1	75,000	188,000	188,000	85,000	212,000	127,000
	Alignment 2	84,000	209,000	209,000	95,000	237,000	142,000
Blue Mesa		83,000	228,000	137,000	91,000	207,000	124,000
Flaming Gorge		58,000	154,000	154,000	65,000	174,000	174,000
Green Mountain		12,000	--	--	13,000	--	--
South Platte	Alignment 1	17,000	43,000	43,000	20,000	49,000	30,000
	Alignment 2	38,000	95,000	95,000	43,000	108,000	65,000
Yampa		57,000	141,000	141,000	64,000	160,000	160,000

2.3.4 Tunnels

The identification of where installation of tunnel reaches would occur rather than pipelines was also based on the HGL analysis. It was assumed that tunneling methods were used anywhere that the pipeline depth of bury was greater than 20 feet. As noted in Section 2.3, pump stations and tunneling for Flaming Gorge and Yampa followed previous studies as closely as possible within the uniform hydraulic criteria used for this analysis. For the Arkansas and South Platte alignments, tunneling was kept to a minimum and only used in small areas of particularly steep slopes. This results in significantly less tunneling for these two projects than for Yampa, which is reasonable because the elevation gain and slopes of the South Platte and Arkansas concepts are significantly less than those of the Yampa concept.

Tunnels longer than 3,000 feet were assumed to be constructed with a tunnel boring machine (TBM) and shorter tunnels were assumed to be constructed using hand mining methods. The 3,000 feet was used as the break point for this determination based on the unit cost analysis; 3,000 feet is the approximate length at which hand mining costs are equal to TBM costs. Total tunnel lengths and average overburden depths for each pipeline are summarized in Table 2-8.

Table 2-8 Tunneling Summary

Concept		Total Tunnel Length (mi)	Average Tunnel Overburden (ft)	Max Overburden (ft)	Max Tunnel Length (mi)
Arkansas	Alignment 1	1	60	160	0.4
	Alignment 2	4	60	150	0.9
Blue Mesa		81	510	2500	7.5
Flaming Gorge	Main Pipeline	3	70	210	0.8
	North Diversion	1	40	100	0.2
	South Diversion	13	140	250	11.3
Green Mountain		1	57	270	0.4
Yampa		84	700	2,660	15.1

*Note: The South Platte alignments do not require tunneling

2.4 Diversions

Diversion structures were sized at three times the average annual flow for each scenario. Most of the diversion structures would be constructed off of the respective concept rivers, but as noted in Section 1, diversions are located in different places for different scenarios for the Flaming Gorge concept. Option 1 assumes all 100,000 AFY are drawn from the north diversion and Options 2 and 3 assume an additional 150,000 AFY from the south diversion. Conceptually, the diversion structures would be used to convey available water supplies through the intake structure to the firming storage reservoir (if required as described in Section 2.2) where the first pump station for each concept (shown in Table 2-6) would begin the conveyance towards the specific concept delivery area. The Blue Mesa and Green Mountain concepts entail diverting and pumping directly from the respective reservoirs.

2.5 Treatment

The raw water qualities vary widely between each of the described projects and therefore require various levels of treatment. For the purpose of this analysis, the main water quality parameter used to determine the required level of treatment to treat the raw water for potable municipal supply was total dissolved solids (TDS) in milligrams/liter (mg/L). Table 2-9 shows representative raw water TDS values for each of the analyzed projects.

Table 2-9 Representative Raw Water Supply TDS Values

Concept	Raw Water TDS (mg/L)
South Platte River (CWCB 2007)	1,000
Arkansas River (CWCB 2007)	1,200
Blue Mesa (USEPA 2010)	150
Flaming Gorge Reservoir (USACE 2009)	400
Green Mountain (USEPA 2010)	140
Yampa River (Northern Colorado Water Conservancy District 2006)	150

Waters with TDS less than 500 milligrams per liter (mg/L) could be treated with conventional treatment, which could include flocculation and sedimentation, filtration, and disinfection. For this analysis the treated water quality TDS goal was 300 mg/L. For raw waters with TDS values greater than 500 mg/L advanced treatment would be required that includes flocculation and sedimentation, RO filtration, blending of bypass water, advanced oxidation/ disinfection, and zero liquids discharge (ZLD) of membrane concentrate. As with conventional treatment, the final treated water quality TDS goal was 300 mg/L.

It was assumed that the regional supplies brought to the Front Range would be delivered with a maximum peaking capacity of 1.1 and a consistent supply would be available during the majority of each year. Periods of downtime would occur only during unexpected events and for required scheduled maintenance. Therefore, for water treatment facility sizing, it was assumed new regional supplies would be treated and used to meet municipal base demands and would not be used to meet peak demand, reducing the required plant capacity.

For water treatment sizing it was assumed that blend water would be available on the Front Range to reduce the TDS of the new regional supply, which would reduce the amount of RO filtration required on some of the regional supplies. The blend water was assumed to have a TDS of 300 mg/L and would be blended at a ratio of 30 percent blend water and 70 percent new regional supply. Table 2-10 shows the raw water TDS, pre-treated blended TDS, treatment type, and facility size for Options 1, 2, and 3. For Green Mountain, treatment was assumed to be required for the entire volume of new supply of 68,600 AFY, not only the portion brought to the Front Range.

Table 2-10 Summary of Concept Water Qualities and Facility Sizing

Concept	Raw Water TDS (mg/L)	Pre-treated Blended TDS (mg/L)	Type of Treatment	Option 1 Capacity (mgd)	Option 2 Capacity (mgd)	Option 3 Capacity (mgd)
South Platte River	1,000	790	RO with ZLD	90	220	90 / 220
Arkansas River	1,200	930	RO with ZLD	90	220	90 / 220
Blue Mesa	150	240	Conventional	90	220	90 / 220
Flaming Gorge Reservoir	400	370	Conventional	90	220	90 / 220
Green Mountain	140	190	Conventional	60	--	--
Yampa River	150	240	Conventional	90	220	90 / 220

The purpose of this simplified analysis using planning level facilities and assumptions described above allowed for the comparison of different treatment processes and cost analysis of the required treatment processes previously described in this section. It should be noted that detailed analyses of water quality, type of treatment, and facility sizing and layout will need to be completed if a regional water supply is selected in the future.

2.6 Reuse

In order to account for reuse, a generalized approach was taken to account for required infrastructure for both direct non-potable reuse and indirect potable reuse. The water supply provided by the new supply development concepts would be considered fully consumable and the historic consumptive use of the water supply provided by the agricultural transfer concepts would also be fully consumable. Because all of the water supplies would be fully consumable and the project supplies would be delivered to the same general Front Range area, the reused component of this analysis was not used to differentiate the different water supply concepts. Instead, the reuse portion of the analysis was used to identify the planning level costs that will be required in the future to help meet the 2050 water needs in Colorado.

The reuse analysis assumed a maximum of 45 percent of the original water supply volume would be available for reuse as wastewater effluent (Town of Castle Rock 2008), which generally accounts for water supply transmission losses, water treatment losses, treatment losses, distribution losses, municipal and industrial (M&I) consumptive use, and lawn irrigation return flows. Assuming wastewater effluent would meet water quality requirements it would be immediately available for direct non-potable supplies. Studies for individual municipalities would be required to plan and project individual municipal usage of available direct non-potable supplies. Volumes of wastewater effluent are fairly consistent throughout the year, while non-potable demands are primarily needed in the summer. Future analyses would include the infrastructure and storage required to deliver and firm non-potable supplies as well as the location and timing of major non-potable demands. For this technical memorandum it was assumed that 10 percent of the available 45 percent would be used for single use non-potable demand to generally account for both single use direct non-potable demands and multiple use indirect potable demands. These percentages were arbitrarily selected to generally analyze the cost implications of reusing water supplies to the legal and practical extent possible. Detailed future analyses will be required to optimize how reusable water supplies are best used to meet future demands.

The remaining 90 percent of the 45 percent of reusable effluent would be used for indirect potable demand. The indirect potable supply could be used in a number of ways including diverting reusable effluent to municipal water supply storage facilities or discharging reusable effluent to a major river or tributary in the Front Range area for transportation to an alternate point of diversion with stream losses and used in similar fashion to extinction. For this analysis, it was assumed that reusable effluent would be discharged to a major river or tributary, subjected to a 7 percent stream loss, and accounted for up to six times before being used to extinction. Table 2-11 below shows the expected direct non-potable and indirect potable reuse volumes for all of the concepts. For Green Mountain, only the volume delivered to the Front Range (53,000 AFY) was assumed to be reused.

Table 2-11 Expected Direct Non-potable and Indirect Potable Reuse Volumes

Option	Annual Volume (AF)	Direct Non-Potable Reuse Volume (AF)	Indirect Potable Reuse Volume (AF)	Total Volume of Reuse Water (AF)
Option 1	100,000	4,500	60,300	64,800
Option 1 – Green Mountain	53,000	2,400	31,900	34,200
Option 2	250,000	11,300	150,600	161,900
Option 3	100,000 / 250,000	4,500 / 11,300	60,300 / 150,600	64,800 / 161,900

The described methodology for reuse is simplistic, and intended for a reconnaissance level analysis. Further site-specific analysis would be required to optimize reuse. Future demands will require that fully reusable supplies are fully consumed to the practical extent possible. The projected volumes will be used for planning level costs as described in Section 3.

Section 3 – Reconnaissance Level Cost Estimates

Developing reconnaissance level costs is one element of the strategy evaluation process. The IBCC and CWCB are currently considering other factors in addition to cost as part of their visioning process. This process has included developing vision goals of which cost effectiveness is one element in the overall visioning process. Reconnaissance level costs were developed for the following water supply and delivery concepts:

1. Middle and Lower South Platte
2. Middle and Lower Arkansas
3. Yampa River
4. Flaming Gorge

5. Green Mountain Reservoir
6. Blue Mesa Reservoir
7. Conservation

Costs were developed for the first five of these concepts for each of the three options outlined in Section 1:

- Option 1: delivery of 100,000 AFY constructed in a single phase, or delivery of 68,600 AFY constructed in a single phase for the Green Mountain concept

- Option 2: delivery of 250,000 AFY constructed in a single phase

- Option 3: delivery of 250,000 AFY constructed with the first phase delivering 100,000 AFY and the second phase delivering the remaining 150,000 AFY

A unit cost-based methodology was used to develop capital costs for planning year 2009 for all concepts. Unit cost values and contingency factors for various project components were developed based on a variety of sources, including existing reports when available, a national construction cost database, data from other recent projects, and professional opinions. It is important to note these costs were developed for planning level comparison of concepts; it is not guaranteed that these costs will not vary from contractors' bids or final costs. However, these planning level costs are appropriate for the initial planning level comparison of future regional projects as well as in comparing the individual projects with one another on an equitable basis.

3.1 Capital Cost Assumptions for the Agricultural Transfer and New Supply Development Strategies

Capital costs were developed for the following components of the agricultural transfer and new supply development concepts:

- Water rights
- Firming storage
- Transmission facilities (pipelines, tunnels, pump stations, diversions and appurtenances, and easements)
- Water treatment
- Reuse

The costs being presented in this section are based on feasibility level planning and sizing of facilities. There are a significant number of unknown factors, or changes in the projects that will occur as they are further refined that cannot be specifically anticipated at this time. These factors include final alignments of transmission facilities, sizing, and location of pump stations and storage facilities, market conditions at the time of construction, competitive bidding or negotiating terms, or other costs and mitigations associated with the concepts as they are further developed. To address this uncertainty we have included a contingency of 30 percent in the development of the capital cost estimates. In addition to the contingency, a factor for other soft costs including engineering, legal, and administrative (ELA) work has also been included. The ELA factor is distinct from the contingency because it is intended to cover costs that are almost certain to be incurred, as opposed to inflating relatively certain costs to address uncertainty and variability. The ELA factor includes EIS costs. Estimated costs for environmental mitigation were not addressed as more detailed analyses will need to be completed to assess environmental impacts, as those future impacts will likely be very site-specific and vary greatly between all projects. However, the costs for necessary permitting work (including EIS, which are estimated to cost $10 million per project [Peter 2009]) are included in the ELA costs. The range of ELA costs for the concepts are $20 million (Green Mountain Concepts) to $920 million (Flaming Gorge). For the purposes of this planning effort the ELA factor was assumed to be 20 percent of the total pipeline and pump station capital cost. Including both the general contingency and ELA cost, the total capital cost for pipelines and pump stations is increased by a total of 50 percent.

Due to the wide range of sources used in developing the different types of cost, for some of the facilities types the above contingencies and other soft costs were not included. Where they have not been included this has been specifically identified in the text.

There are a wide range of percentages that could be used for the contingency and ELA factors. These factors discussed above provide a reasonable basis for the comparison of the alternative concepts.

3.1.1 Water Rights

For the new water supply development concepts, filing for a new water right would be required. The capital costs for the ELA work required to file for a new junior water right vary widely. It was assumed that a filing of a large regional project as described in this technical memorandum would draw general opposition and would be required to go through Colorado Water Court as well as the Federal 404 Permit process, which would require an EIS (which is not included in the water rights cost, but is included in the legal costs of the pipeline costs) before permitting would be completed. It was estimated that $4 million would cover the costs of the water rights filing for each new water supply development regardless of project size (i.e., 68,600 AFY or 100,000 AFY versus 250,000 AFY) (Cech, Frank, Helton, Ward, and Williamsen 2009).

For the agricultural transfer concepts, costs include the water rights purchase and obtaining the legal transfer of use, which require Colorado Water Court review. Costs for agricultural water transfer vary widely. Senior agricultural rights are more expensive than junior water rights and the physical location of the available supply will be important once individual entities in the future try to determine how specific ditch rights can be captured, exchanged, transferred, and used in their current system infrastructure. A survey of recent sale prices for a variety of junior and senior ditches within the South Platte and Arkansas River basins were analyzed (Cech, Frank, Helton, Ward, and Williamsen 2009). For this study it was assumed that senior agricultural water rights, which historically may not have been diverted in the Denver area, would be sold for $15,000/AF of consumptive use in the South Platte River basin and $7,000/AF of consumptive use in the Arkansas River basin. These unit costs include the ELA costs to convert the agricultural use to municipal use, but would require firming storage and transmission pipelines to the Denver area, which are described below.

3.1.2 Firming Storage

Storage of diverted and delivered supplies would be required as discussed in Section 2.2 and capital cost estimates were based upon historic data collected from the Colorado Division of Water Resource Spreadsheet Database of new dams built in Colorado since 1995. The reservoirs analyzed for this study vary in size from 50,000 AF to 500,000 AF. The unit costs include the construction components of the dam, which include outlet works, reservoir clearing, and land acquisition. Estimated costs for environmental mitigation were not addressed as more detailed analyses will need to be completed to assess environmental impacts. Future impacts will likely be very site-specific and vary greatly between all projects. The unit cost is considered conservative and was not escalated as the unit cost accounts for expected economy-of-scale type cost savings in ELA costs as well as dam construction costs. The unit cost of $1,000/AF was applied to diversion reservoirs, while Front Range delivery reservoirs had a unit cost of $1,200/AF applied for costing purposes.

No cost was assumed for additional diversion or transmission facilities to convey supplies to and from storage.

3.1.3 Transmission Facilities

Transmission facilities are a major component of the new supply development and agricultural transfer concepts. Transmission facilities include pipelines, diversions, appurtenances, tunnels, pump stations, and easements; diversion, appurtenance, and easement costs are included in overall pipeline costs for summary purposes. The unit costs for each facility type are discussed in the remainder of this section. Pipeline installation, land, and easement costs were separated into urban and rural components. The new supply development and agricultural transfer concepts were assumed to include 90 percent rural construction and 10 percent urban for these cost estimates presented in this section.

Pipelines

Pipeline unit costs were developed by analyzing a nationwide and Colorado-specific construction costs database and material unit costs. The database uses a customized blend of labor, material, equipment, and subcontract components that are updated based on personnel experience and vendor surveys. The database is nationwide, but uses local material and labor rate costs. Labor is calculated based on assembly of a standard crew and standard labor productivities, which are adjusted to the nationwide labor union hourly rates.

Using this database, base unit costs for pipelines (not including tunnels) were developed for the 72-, 90-, and 114-inch diameter steel pipe required for the capacity of each option. Separate base costs are developed for urban and rural areas. These base unit costs assume straightforward installation, assuming ideal conditions for pipeline construction such as average soil conditions, no steep slope, easy site access, and no space constraints. These unit costs assumed 150 psi pressure class steel pipe, with a steel price of $1.25/pound. The base unit costs were then escalated to account for difficult or steep terrain and higher pressure classes.

To escalate for difficult terrain, two basic assumptions were made: productivity rates (feet of pipe laid per day) in "difficult" terrain were half of those assumed in the base costs; and productivity rates were two-thirds of the base in areas where ground slopes exceed 10 percent. The "difficult" terrain accounts for areas that present construction challenges such as access difficulties and difficult soil or rock conditions. The portion of the total unit base cost comprising installation was then escalated accordingly. All concepts were assumed to include 30 percent difficult terrain, the percentage of ground slope greater than 10 percent, which was determined for each alignment based on a geographic information system (GIS) evaluation, as described in Section 2.3.1.

To escalate for pressure classes, manufacturers' data were used to determine the thickness of each pressure class for each diameter in order to determine the additional material requirements. The increase in unit cost of pressure class pipe above 150 psi was determined based on this additional material and the steel cost of $1.25/pound used to develop the base unit cost in linear feet ($/LF).

Table 3-1 shows base unit costs by diameter, the portion of the base unit costs attributable to installation, and the addition to unit costs for pressure class. The installation portion of the cost includes labor for tasks including excavation, welding, pipe cleaning, marking, testing, and backfilling, as well as equipment costs, but does not include repaving costs, or property or easement acquisition; these costs are included in the overall costs but are not escalated based on difficult or steep terrain.

Table 3-1 Base Unit Costs and Adjustments

	Base Unit Cost - Rural ($/LF)			Base Unit Cost - Urban ($/LF)			Installation portion of base unit cost ($/LF)	
Diameter (in)	150 psi	250 psi	350 psi	150 psi	250 psi	350 psi	Rural	Urban
48	$320	$380	$490	$500	$550	$400	$70	$190
72	$630	$1,060	$930	$820	$1,250	$1,120	$180	$340
90	$940	$1,600	$1,400	$1,210	$1,870	$1,670	$260	$500
96	$1,120	$1,870	$1,650	$1,420	$2,180	$1,950	$280	$560
114	$1,490	$2,550	$2,230	$1,900	$2,960	$2,640	$350	$710

Final costs for each concept were developed based on these unit costs, the slope and pressure class characteristics for each alignment presented in Section 2, the installation assumptions presented in this section, and assuming that each alignment is 90 percent rural construction and 10 percent urban construction. Final adjusted unit costs, accounting for difficult terrain, steep areas, and pressure classes, are presented in Table 3-2.

Table 3-2 Final Unit Costs by Concept

Concept		Option 1		Option 2		Option 3	
		Rural Unit Cost ($/LF)	Urban Unit Cost ($/LF)	Rural Unit Cost ($/LF)	Urban Unit Cost ($/LF)	Rural Unit Cost ($/LF)	Urban Unit Cost ($/LF)
Arkansas	Alignment 1	$820	$1,060	$1,930	$2,450	$1,230	$1,570
	Alignment 2	$830	$1,070	$1,970	$2,490	$1,250	$1,600
Blue Mesa		$810	$1,070	$1920	$2480	$1,220	$1,590
Flaming Gorge	Main Pipeline	$810	$1,050	$1,910	$2,440	$1,910	$2,440
	North Diversion Pipeline	$820	$1,060	$820	$1,060	$ -	$ -
	South Diversion Pipeline	$ -	$ -	$1,270	$1,620	$1,270	$1,620
Green Mountain		$420	$610	$ -	$ -	$ -	$ -
South Platte	Alignment 1	$820	$1,070	$1,950	$2,470	$1,240	$1,580
	Alignment 2	$820	$1,060	$1,940	$2,460	$1,230	$1,580
Yampa		$780	$1,030	$1,840	$2,380	$1,170	$1,530

Tunnels

Combinations of unit costs were developed for tunneling. Per-tunnel and per-foot unit costs were developed for both TBM and hand mining methods. The per-tunnel unit costs include mobilization, demobilization, and work shaft construction; the per-foot unit costs cover excavation and lining. Per-tunnel costs are applied to each discrete section of tunnel, so that each tunnel segment is separated from the next by portions of pipeline constructed with conventional excavation methods. As noted in Section 2, the two methods have the same cost at approximately 3,000 feet, so tunnels longer than 3,000 feet were assumed to be constructed with a TBM while shorter tunnels were assumed to be constructed using hand mining methods. Tunneling unit costs are presented in Table 3-3. These tunneling costs are increased by 5 percent in the final cost estimate to account for dewatering, power, and access road costs.

Table 3-3 Tunneling Baseline and Unit Costs

	Unit Costs (Excavation, Lining, Corrosion protection $/LF)	Mobilization	Demobilization	Shafts	Total per-tunnel
		$ / tunnel			
TBM	$ 1,500	$3,700,000	$ 500,000	$2,900,000	$ 7,100,000
Hand-mine	$ 3,300	$ 260,000	$ 110,000	$1,300,000	$ 1,600,000

Pump Stations

Pump station unit costs included the cost per horsepower for the construction of the pump station, with additional costs for land and operational storage. Pump station unit costs are summarized in Table 3-4. Pump station sizing was based on the peaked horsepower requirements presented in Section 2.3.3. Land costing assumes 3 acres of land per pump station, and maintains the assumption that 90 percent of the land is rural for each concept. For total pump stations per alignment, see Table 1-6. The total required storage volume is assumed to be 5 percent of daily flow

Table 3-4 Pump Station Cost Components

Cost Component	Unit	Cost
Pump Station Land - rural	$/ac	$7,000
Pump Station Land - urban	$/ac	$70,000
Storage Tank	$/gal	$0.67
Pump Station	$/hp	$1,200

Diversions and Appurtenances

Diversions were estimated to cost $5,200 per cubic foot per day (cfs). As noted in Section 2, diversions were sized based on three times the average flow for each option. Appurtenances, such as pipe fittings, valves, vaults, and cathodic protection, were assumed to add an additional 5 percent to the total pipeline costs. Diversion and appurtenance costs are included in total pipeline costs. Diversion unit costs were the same for all concepts, regardless of whether the point of diversion was in-stream or in a reservoir.

Easements

It was assumed for costing purposes that all concept alignments would require both temporary construction easements and permanent maintenance access easements for their entire length. This assumption is conservative because portions of alignments following major roads may fall within existing right-of-ways. Unit costs for permanent easements were assumed to be one-half of the cost of purchasing land, and unit costs for temporary easements were assumed based on professional experience and judgment. The base costs for both temporary and permanent easements on a per-acre basis are provided in Table 3-5; final unit costs per linear foot are based on the per-acre costs and assumed widths that vary with pipeline diameter are presented in Table 3-6. The final per-foot cost for easements includes both temporary and permanent easement costs. Easement costs were not applied to tunnel lengths and are included in total pipeline costs.

Table 3-5 Easement Base Unit Costs

Cost component	$/ac
Urban Permanent Easement	$35,000
Rural Permanent Easement	$3,500
Urban Temporary Easement	$5,000
Rural Temporary Easement	$ 2,000

Table 3-6 Final Easement Unit Costs

	Easement Width		Total Cost ($/LF)	
Pipeline Diameter (in)	Temporary	Permanent	Urban	Rural
48	70	30	$32	$6
72	70	50	$48	$7
90	70	70	$64	$9
114	70	70	$64	$9

3.1.4 Water Treatment

Reconnaissance level treatment technology capital costs were developed based on knowledge of recently constructed and operating water treatment plants in Colorado. It should be noted that specific treatment processes and technologies vary based on water quality and costs may change based on detailed analyses of raw water quality and water treatment goals. For this technical memorandum, the main focus was on reducing the TDS of treated water to 300 mg/L. Table 3-7 shows the base unit costs for the various levels of treatment. Capital unit costs include buildings, treatment facilities, high service pump stations, operational storage, mechanical, and electrical facilities.

Table 3-7 Treatment Technology Base Capital Unit Costs

Treatment Technology	Cost ($/gal)
Conventional Treatment	$1.90
Reverse Osmosis	$3.75
Zero Liquid Discharge	$16.00
Disinfection of bypass water	$1.00

For each water source, blended water supplies with TDS less than 500 mg/L were assigned the conventional treatment unit cost. For water sources with blended water supply TDS greater than 500 mg/L the percentages of water treated with RO and disinfected bypass were evaluated with a final treated TDS of 300 mg/L. It was assumed that only 15 percent of the RO volume would be concentrate and require further treatment with ZLD. Therefore, for each water supply an adjusted overall unit cost was calculated, specific to the raw water TDS concentrations. Higher TDS concentrations require more RO and consequentially more ZLD treatment. Table 3-8 shows the final treatment unit costs per project. Treatment costs are considered conservative and were not escalated.

Table 3-8 Final Treatment Capital Unit Cost per Concept

Concept	Raw Water TDS (mg/L)	Pre-treated Blended TDS (mg/L)	Type of Treatment	Treatment Unit Cost ($/gal)
South Platte	1,200	1000	RO with ZLD	$4.40
Arkansas River	790	1200	RO with ZLD	$4.66
Blue Mesa	150	240	Conventional	$1.90
Flaming Gorge Reservoir	150	400	Conventional	$1.90
Green Mountain	140	190	Conventional	$1.90
Yampa River	0	90	Conventional	$1.90

3.1.5 Reuse

It is difficult to assess the true costs of reuse as studies need to be completed on a municipality-by-municipality basis. The location and timing of available reusable effluent has to be coordinated with the location and timing of direct non-potable and indirect potable demands. Both direct non-potable and indirect potable demands require additional treatment requirements, conveyance infrastructure, and storage. Because water reuse will be required in the future to meet projected demands conservative unit costs were assigned, which were not escalated. It is important to note also that the levels of reuse are the same for all projects discussed in this technical memorandum. Therefore, the reuse costing component will not help determine, which projects are more economically viable, but instead provides a planning level cost to reuse the legally available water to its physical extinction.

For direct non-potable reuse a unit cost of $7,000/AF was used for costing and was based on a range of costs-of-services reported in the 2004-2005 Recycled Water System Master Plan Update for Denver Water (Denver Water 2005). The Master Plan Update looked at the required infrastructure to convey reused water to various non-potable demands within their system. The report indicated, "[t]hese costs-of-service are relative, rather than absolute, and provide a benchmark by which to evaluate the economics of serving each customer" (Denver Water 2005).

For indirect potable reuse a unit cost of $13,500/AF was used for costing and was based on a range of estimated provider costs for treating South Platte River supplies near the Brighton area and transporting the treated water to the South Metropolitan Denver area (South Metro Water Supply Authority [SMWSA] 2008). For this technical memorandum is assumed that municipalities will discharge wastewater effluent in Front Range rivers and will build new large regional infrastructure to divert, retreat, and convey reusable supplies to municipalities. The SMWSA Mid-Term Water Delivery Project Plan (SMWSA 2008) costs included diversion, retreatment (RO with ZLD) and regional conveyance. As noted in Section 2, for the Green

Mountain concept, only the volume delivered to the Front Range (53,000 AFY) was assumed to be reused.

3.2 Operation and Maintenance Cost Assumptions

O&M costs were developed for each of the facility types described above. For some of the facilities—such as water rights and firming storage—annual lump sum amounts were estimated, where other facilities like treatment and reuse had unit costs per AF. In the case of the transmission facilities separate O&M costs were developed to differentiate the impacts of the cost of pumping.

3.2.1 Water Rights

For the transfer of agricultural rights to municipal use it was assumed that 25,000 acres would be dried up for every 50,000 AF of consumptive use. It was also assumed that two technicians would be required to oversee ELA compliance of the agricultural dry-up and would earn $50,000/year. For new water right filings, it was assumed similar ELA costs would be required each year as for the transfer of agricultural rights. Thus for Option 1 and Phase 1 of Option 3 an annual O&M cost of $400,000/year was used and for Option 2 and Phase 2 of Option 3 an annual O&M cost of $1,000,000/year was assessed. The O&M costs for Green Mountain were estimated at $300,000/year.

3.2.2 Firming Storage

For new supply development and agricultural transfer concepts it was assumed that an annual O&M cost of $100,000/year would be incurred by each reservoir for general maintenance, reporting, and contributing annually to a general future improvements fund. Therefore, projects with both diversion and delivery reservoirs were assessed an annual O&M cost of $200,000/year.

3.2.3 Transmission Facilities

Estimates of O&M costs were developed for the transmission facilities. Based on experience, pipeline, tunnel, and diversion structure maintenance was estimated at 0.5 percent of pipeline capital costs annually, applied to the overall project capital costs excluding pump stations. Pump station maintenance was estimated at 3 percent of capital costs annually, including only the capital cost of the pump stations. Maintenance costs include the same 30 percent escalation factor for general contingencies used for capital costs, but do not include the 20 percent ELA cost.

Pump station operations cost was based on the brake horsepower calculations presented in Section 2, assuming a flat electric rate of 8 cents per kilowatt-hour (kwhr). This value of 8 cents/kwhr may be considered high for a typical flat billing rate; however, with many variable demand charges options during different times of the day and seasons of the year a slightly high flat hourly billing rate was intended to account for the highly variable demand and schedule charges, which are unknown at this time for larger commercial users.

3.2.4 Water Treatment

Planning level treatment technology O&M costs were developed based on knowledge of recently constructed and operating water treatment plants in Colorado. The unit costs include membrane replacement, power, chemicals, labor, overhead, insurance, lab work, and building utilities. Table 3-9 shows the base unit costs for the various levels of treatment.

Table 3-9 Treatment Technology Base Unit Costs

Treatment Technology	Cost ($/Kgal)	Cost ($/AF)
Conventional Treatment	$0.30	$100
Reverse Osmosis	$0.70	$230
Zero Liquid Discharge	$4.00	$1,300
Disinfection of bypass water	$0.05	$16

For each water source, blended water supplies with TDS less than 500 mg/L were assigned the conventional treatment unit cost. For water sources with blended water supply TDS greater than 500 mg/L the percentages of water treated with RO and disinfected bypass were evaluated with a final treated TDS of 300 mg/L. It was assumed that only 15 percent of the RO volume would be concentrate treated with ZLD. Therefore, for each water supply an adjusted overall unit cost was calculated, specific to the raw water TDS concentrations. Higher TDS concentrations require more RO and consequentially more ZLD treatment. Table 3-10 shows the final treatment unit cost per project; these are considered conservative and were not escalated.

Table 3-10 Final Treatment O&M Unit Cost per Concept

Concept	Raw Water TDS (mg/L)	Pre-treated Blended TDS(mg/L)	Type of Treatment	Treatment Unit Cost ($/Kgal)	Treatment Unit Cost ($/AF)
South Platte	1,200	1000	RO with ZLD	$0.88	$285
Arkansas River	790	1200	RO with ZLD	$0.94	$305
Blue Mesa Reservoir	150	240	Conventional	$0.30	$100
Flaming Gorge Reservoir	150	400	Conventional	$0.30	$100
Green Mountain	140	190	Conventional	$0.30	$100
Yampa River	0	90	Conventional	$0.30	$100

3.2.5 Reuse

Reuse costs in general are difficult to assess as described in Section 2.6, and without specific understanding of how direct non-potable and indirect potable supplies will be used it is impossible to accurately assess projected costs. However, the retreatment of indirect potable supplies will be required; therefore, the indirect potable supply volumes were multiplied by the South Platte concept treatment annual O&M unit costs. While this methodology is a major simplification and does not assess pumping O&M costs, which may be large, the planning level costs for indirect potable supplies included retreatment.

3.3 Reconnaissance Level Costs

Costs are presented for each of these concepts for each of the three options outlined in Section 2:

- Option 1: delivery of 100,000 AFY constructed in a single phase, or 68,600 AFY delivered in a single phase for the Green Mountain concept
- Option 2: delivery of 250,000 AFY constructed in a single phase
- Option 3: delivery of 250,000 AFY constructed with the first phase delivering 100,000 AFY and the second phase delivering the remaining 150,000 AFY

All costs are presented in 2009 dollars. Diversions, appurtenances, and easements are included in overall pipeline costs. All costs for Option 3 are the total combined cost of both phases. Appendix A contains detailed information for each component of the cost estimate discussed throughout the remainder of this section.

3.3.1 Capital Costs

The total capital costs were estimated for all water supply concepts and options based on the methodology described above. The summary of the capital costs is shown in Figure 3-1 below. The figure shows that total capital costs are relatively similar for the concepts discussed in this analysis, except that Green Mountain is lower due to being a shorter pipeline conveying a smaller volume. Although the South Platte and Arkansas concepts require less length of pipeline and less pumping than the other concepts, the expense of purchasing and transferring senior water rights make the total capital costs comparable.

Figure 3-2 below shows the unit capital costs (cost/AFY) of each concept. The per-AFY costs show the same trends between concepts as the capital costs, but highlight that cost differences on a per-AFY basis are minimal between all three Options. The Yampa project shows a greater difference in per-AFY capital costs. This is because tunneling costs do not change between options, and are therefore a bigger driver of cost in Option 1, which has a lower flow and thus lower costs for most of the associated infrastructure; the Yampa concept has significantly more tunneling than other concepts.

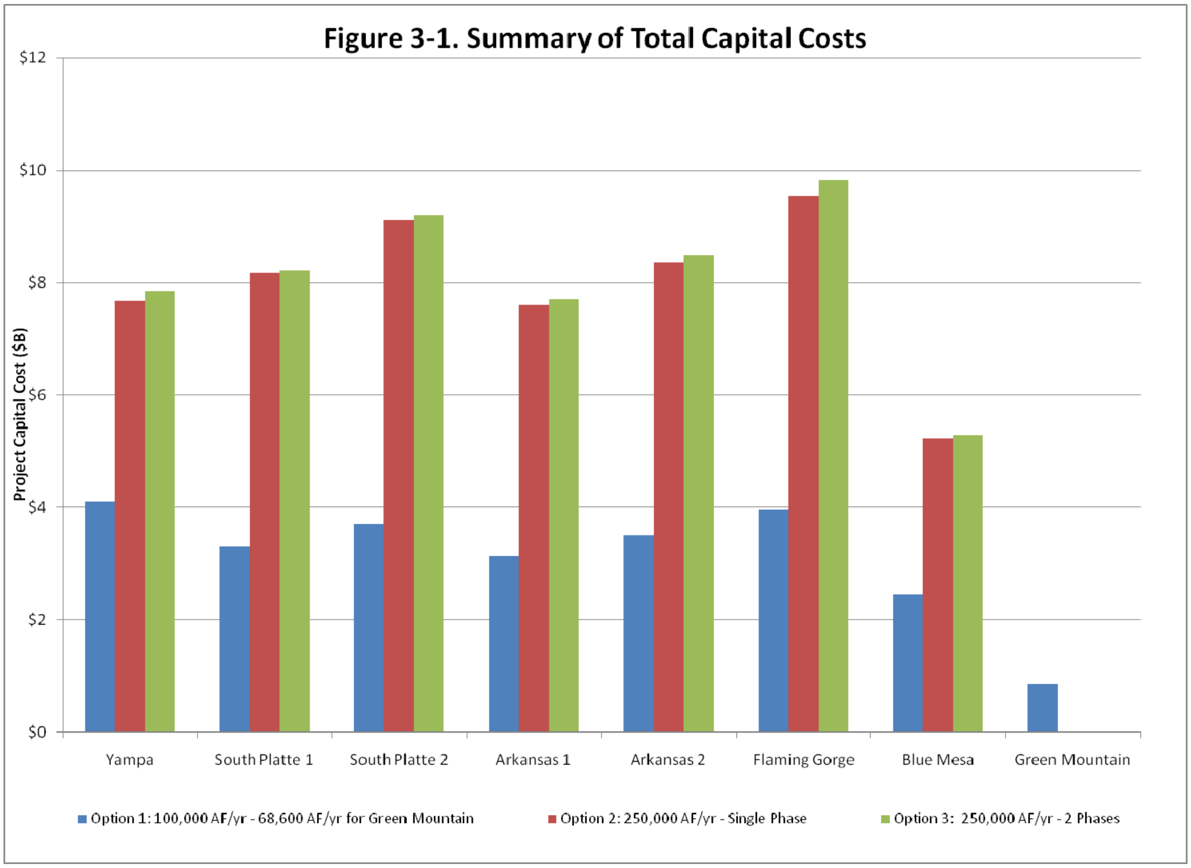


Figure 3-1. Summary of Total Capital Costs
Project Capital Cost ($B)
$12
$10
$8
$6
$4
$2
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

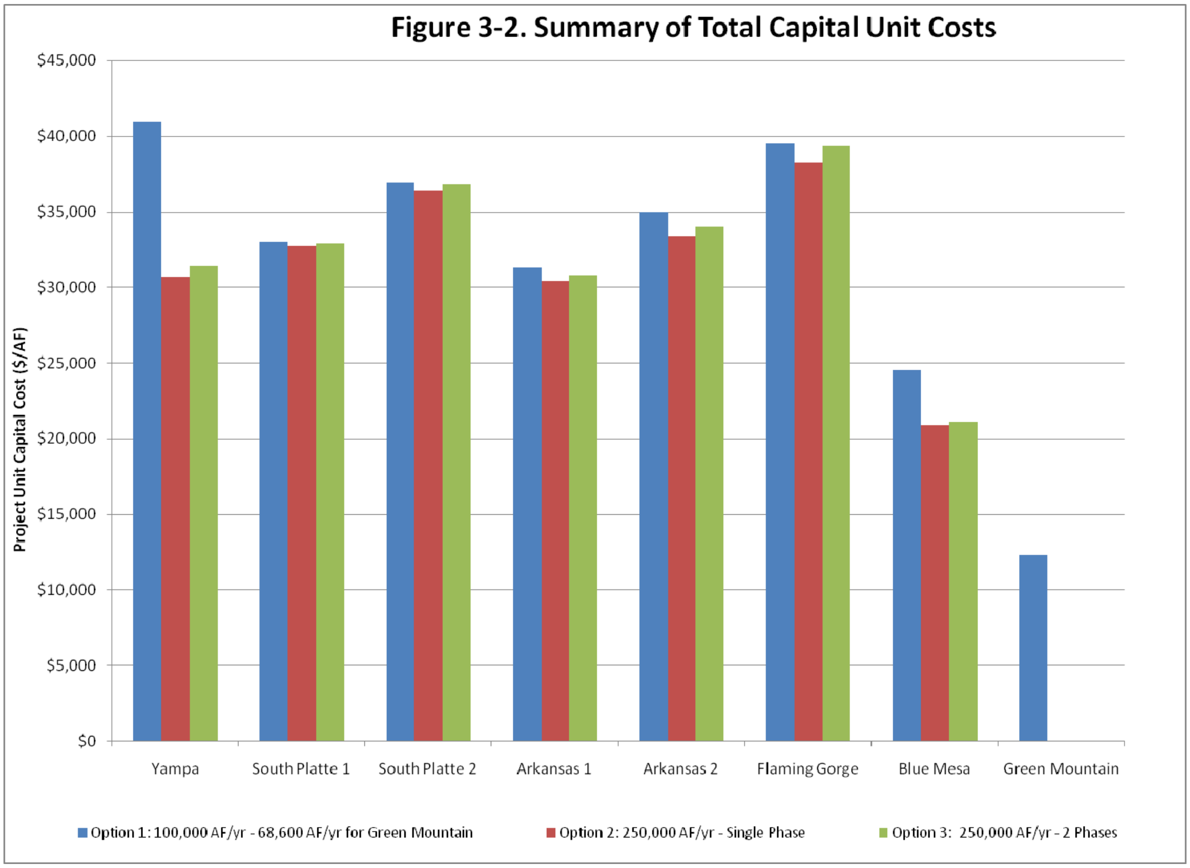


Figure 3-2. Summary of Total Capital Unit Costs
Project Unit Capital Cost ($/AF)
$45,000
$40,000
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

As depicted in Figures 3-1 and 3-2, the most expensive project to build for either 250,000 AFY option would be Flaming Gorge, costing about 25 percent more than Yampa, the least costly. For both total capital and unit capital costs, Yampa has a higher cost for Option 1 (100,000 AF) relative to Options 2 and 3 when compared with the other concepts. This is due to the Yampa concept having significantly more tunneling than other concepts, the cost for which does not vary based on annual delivery capacity.

Although the agricultural transfer concepts and the new supply development concepts are similar in total capital costs, the relative percentages of subcomponent capital costs vary significantly between the two concepts. Figure 3-3 below shows pie charts of the subcomponent capital costs for both the Middle South Platte concept (agricultural transfer) and the Yampa concept (new supply development) at 100,000 AF and 250,000 AF increments. Figure 3-3 shows that for agricultural transfer concepts the majority of the capital cost (regardless of project size) is comprised of water rights acquisition costs. Figure 3-3 also shows that the majority of new supply development concepts capital costs is associated with the transmission costs (pipelines and pump stations). Further detail on the components of capital costs is described in Appendix A.

3.3.2 Operations and Maintenance Costs

In order to evaluate the long-term costs of a regional water supply project, it is important to evaluate the estimated O&M costs. Figure 3-4 shows the expected total annual O&M costs of each concept. The significant variability between projects is due primarily to conveyance costs. Differences in water treatment requirements between conventional treatment (Yampa River, Blue Mesa Reservoir, Green Mountain Reservoir, and Flaming Gorge Reservoir supplies) and RO treatment with ZLD (South Platte River and Arkansas River supplies) also contributes to this variation.

In order to better understand the differences between the annual costs, unit O&M costs in cost per AFY were analyzed, as shown in Figure 3-5 below. The annual O&M unit costs generally do not vary between options, showing a minimal economy-of-scale savings. Slight increases in annual O&M unit cost between Options 2 and 3 are due to the maintenance of twice the distance of pipeline. The Arkansas project is the most expensive concept due mainly to the costs of advanced treatment. Although economy of scale is seen when comparing costs between options, the Green Mountain concept has the least expensive O&M unit costs for Option 1 despite having the lowest annual delivery volume. This is because conveyance, including pumping, which has a high O&M cost, is a relatively small proportion of the total capital cost for the Green Mountain concept. Further detail on O&M costs are described in Appendix A.

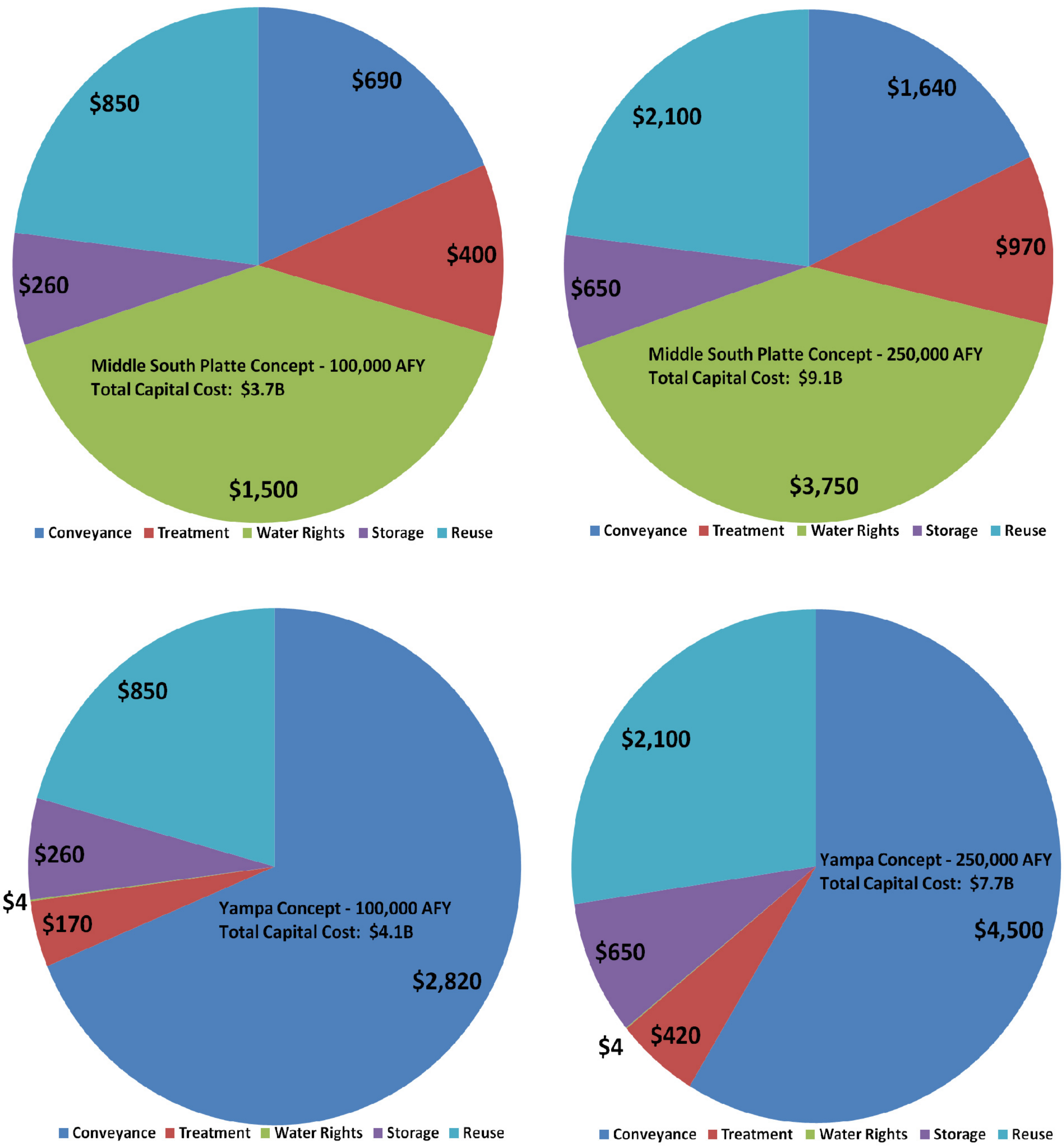


Figure 3-3. Comparison of Agricultural Transfer and New Supply Development Concepts Subcomponent Capital Costs

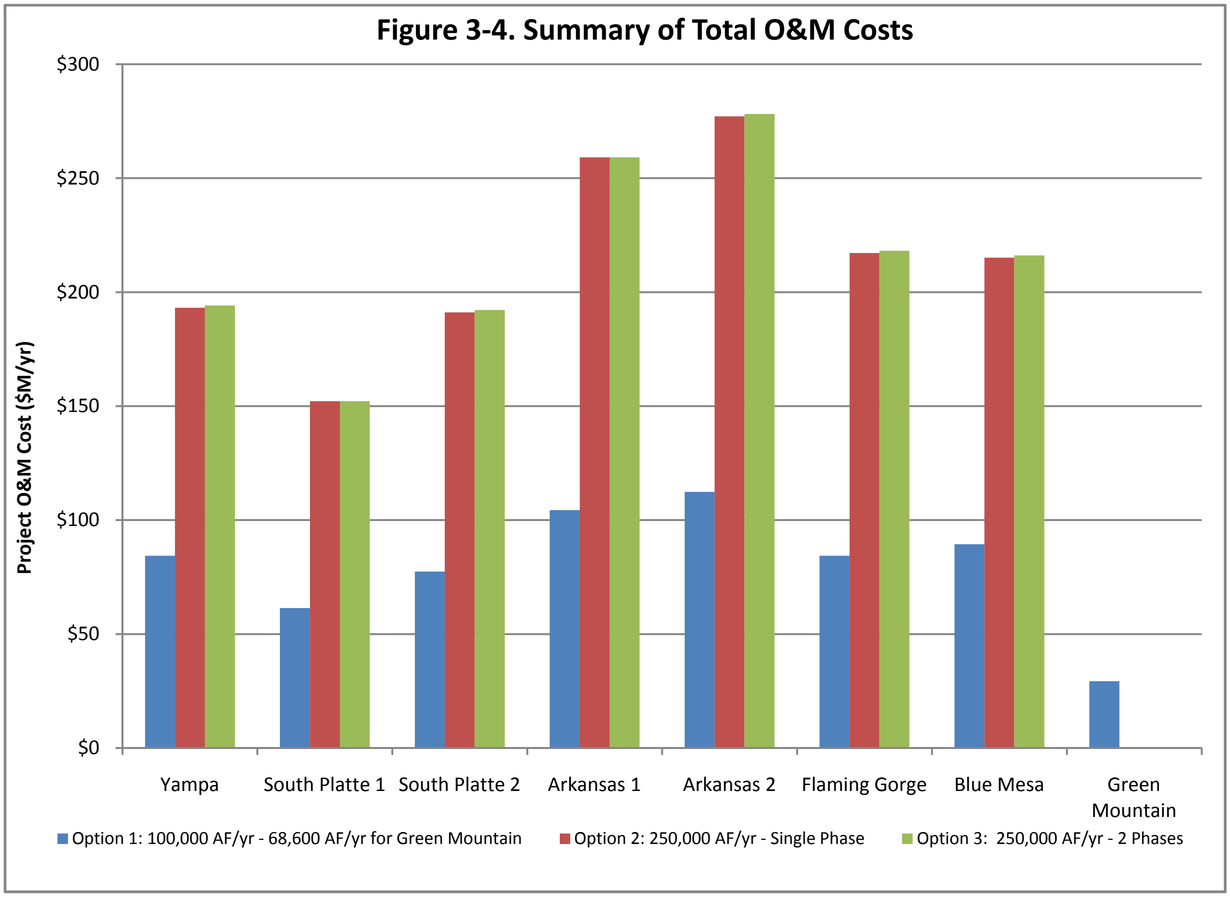


Figure 3-4. Summary of Total O&M Costs
$300
$250
$200
$150
$100
$50
$0
Project O&M Cost ($M/yr)
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

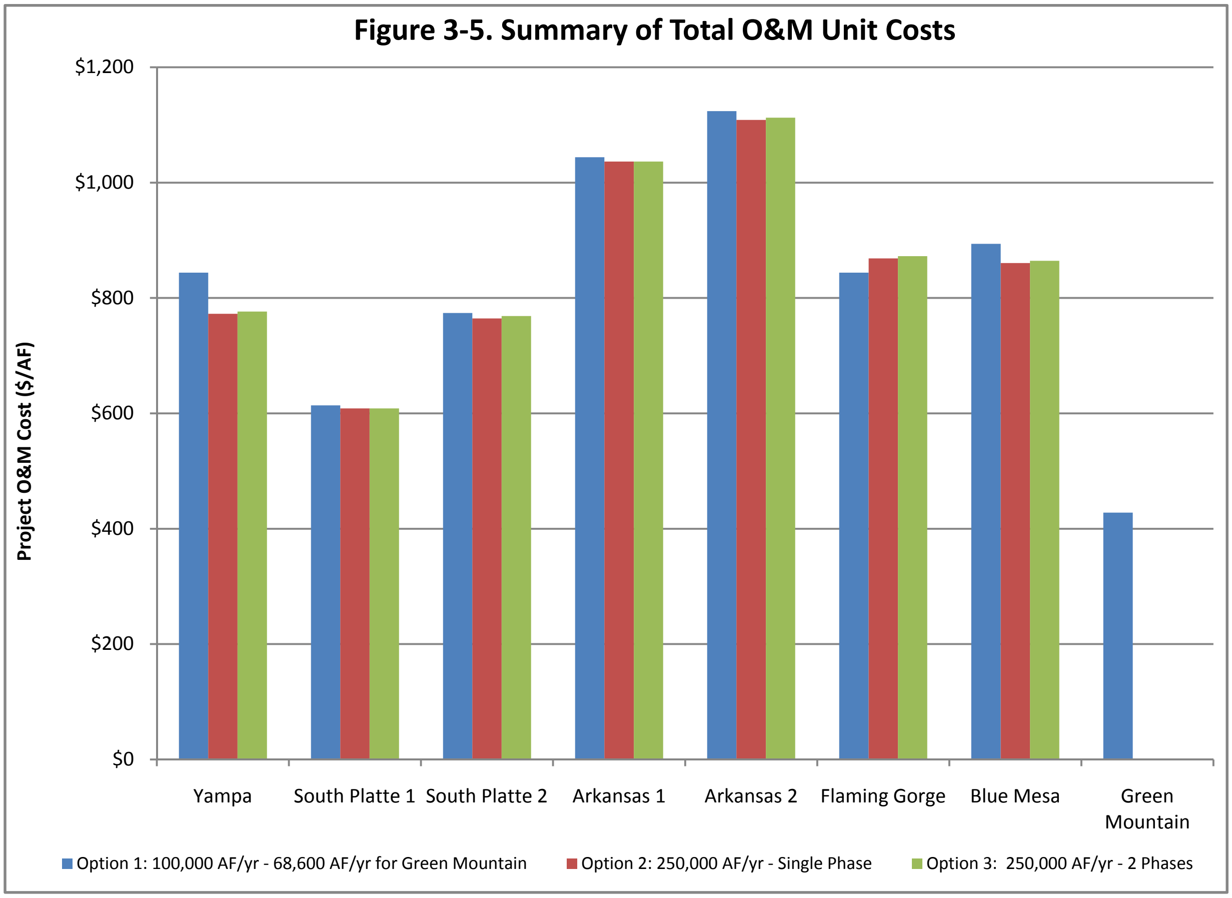


Figure 3-5. Summary of Total O&M Unit Costs
Project O&M Cost ($/AF)
$1,200
$1,000
$800
$600
$400
$200
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

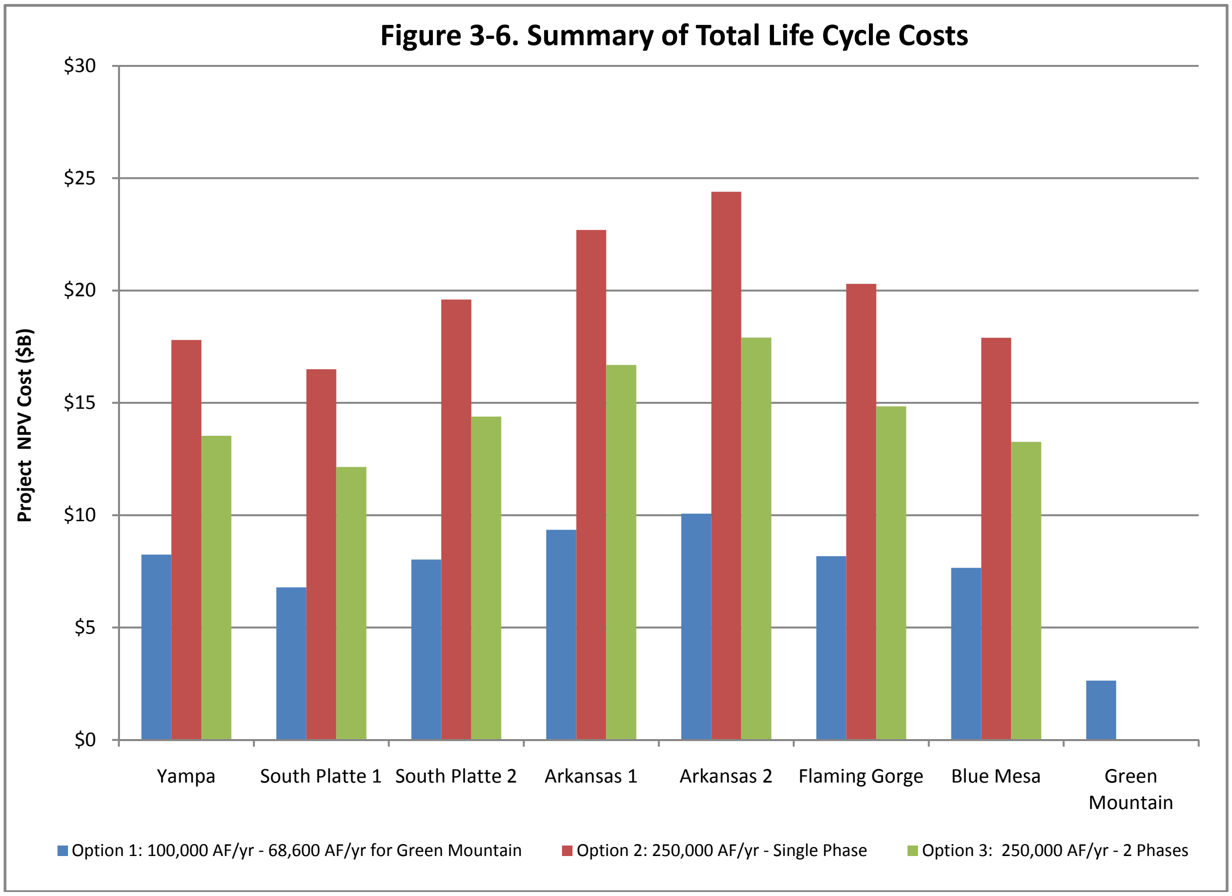
3.3.3 Life Cycle Costs

In addition to the development of capital, operations, and maintenance costs, life cycle costs for comparison of the options and concepts have also been developed. The life cycle costs allow comparison of not only the capital costs, but the operational costs associated with the alternatives, all brought back to a present worth value in order to evaluate the long range economic feasibility of each concept. The following key assumptions associated with life cycle cost development have been used for this analysis:

- Planning period – 50 years after completion of construction
- Present Worth – capital and operating costs brought back to 2009
- Capital costs expended in 2020, with O&M starting in 2021 for Options 1 and 2
- Capital costs expended in 2020, with O&M starting in 2021 for Phase 1 of Option 3 and 2040, with O&M starting in 2041 for Phase 2 of Option 3
- Discount rate, or cost of money – 6 percent
- Escalation
  - Capital items – 3 percent
  - Annual O&M – 3 percent
  - Energy – 5 percent
- 2009 Energy cost ($/kwhr) - $0.08

In addition to initial capital costs and annual operating cost, replacement costs were developed for the constructed facilities if the replacement was required during the 50 year planning period. The pipeline and pump station facilities (which included intake structures, pipelines, pump station structures, and surge structures) are primarily concrete and steel, which could have a useful life of 50 years. However, both the electrical and mechanical components of the pump stations would need to be replaced every 20 years (35 percent of the total capital cost), and it was assumed that this portion of the capital cost would be replaced twice in the 50-year planning period. Similarly the water treatment facilities have structures that are primarily concrete and steel and could have a useful life of 50 years. However, for water treatment facilities the electrical and mechanical equipment would need to be replaced every 25 years (50 percent of the total capital cost), and that portion of the capital cost was assumed to be replaced once in the 50 year planning period.

Based on total life cycle costs depicted in Figure 3-6 below, the least expensive alternative for Option 1 is Green Mountain. However, the most economically feasible alternative with the full 100,000 AFY delivery volume is the South Platte River Alternative 1 concept and the most expensive alternative is the Arkansas River Alternative 2 concept regardless of Option. It should be noted that, except for the smaller Green Mountain concept, the water supply concepts generally have similar life cycle costs.



In the life cycle cost comparison, Option 3 (building a 250,000 AFY project in two phases) consistently has a lower present-day value than building the project in a single phase. This may seem counter-intuitive, but shows that if the entire present-day value for Scenario 3 was invested now and made an annual 5 percent return until the first phase was constructed and the remaining capital continued to receive an annual 5 percent return until the second phase was constructed, a smaller investment would have to be made now, than if the entire present-day value for Scenario 2 was invested. This illustration shows the power of investing money now and deferring the payment of large projects to a later date. However, in practice stakeholders would not likely invest the present-day capital values shown in Figure 3-7 below to construct a project in 2020 or 2040. Present capital would likely be used to fund immediate water resource needs.

The life cycle unit costs also show the Green Mountain concept being the most economically feasible, with the South Platte River Concept Alternative 1 being the most economically feasible of the 100,000 AFY concepts, and the Arkansas River Alternative 2 concept being the most expensive. As with capital and O&M costs, the Green Mountain project is less expensive on a unit life cycle cost basis due primarily to relatively small conveyance cost, due to the short length of pipeline and relatively small lift requirements. With the exception of the Green Mountain Reservoir Concept the Option 1 life cycle unit costs fall between $65,000/AF and $95,000/AF and the Option 3 life cycle unit costs are between $45,000/AF and $65,000/AF; the Green Mountain unit life cycle cost is just below $40,000/AF. Further detail on life cycle costs are provided in Appendix A.

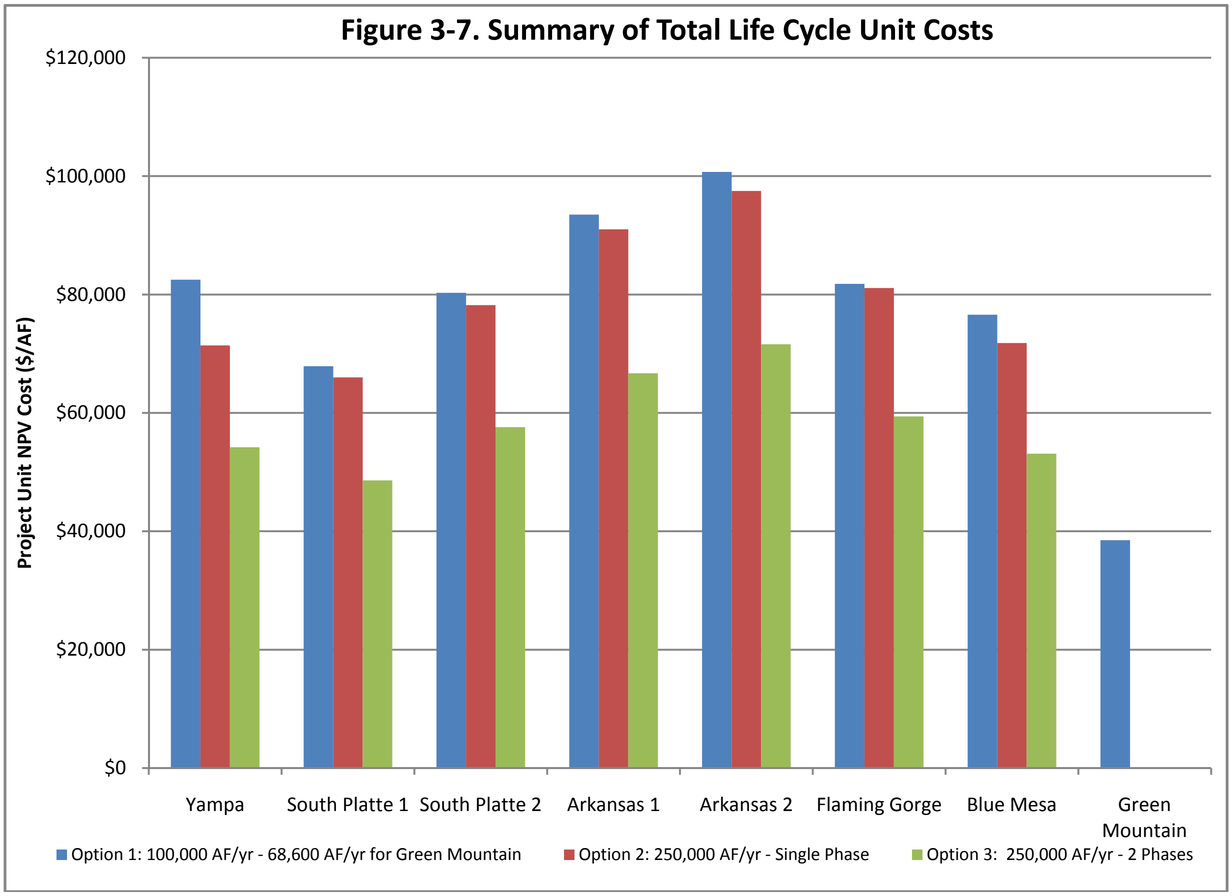


Figure 3-7. Summary of Total Life Cycle Unit Costs
Project Unit NPV Cost ($/AF)
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

Section 4 – References

Cech, Tom. 2009. Personal Communication.

Colorado River Water Conservation District, Clinton Ditch and Reservoir Company, Denver Water, Eagle County Board of County Commissioners, Grand County Board of County Commissioners, Middle Park Water Conservancy District, Northern Colorado Water Conservation District, and Summit County Board of County Commissioners. 2007. Reconnaissance Study: Blue River Pumpbacks & Wolcott Reservoir Alternatives. Denver, Colorado; Boyle Engineering Corporation.

CWCB (Colorado Water Conservation Board). 2008. Part Two of the South Platte Basin Roundtable Consumptive Needs Assessment. Denver, Colorado: CDM

CWCB. 2007. Statewide Water Supply Initiative Phase 2. Denver, Colorado: CDM.

CWCB. 2004. Statewide Water Supply Initiative. Denver, Colorado: CDM.

Colorado Water Resources and Power Development Authority, 1989. Upper Gunnison-Uncompahgre Basin Phase 1 Feasibility Study. Denver, Colorado: HDR Engineering.

Denver Water. 2005. 2004-2005 Recycled Water System Master Plan Updated. Denver, Colorado: Boyle Engineering Corporation.

Frank, Joe. 2009. Personal Communication.

Helton, Duane. 2009. Personal Communication.

Lower Arkansas Valley Water Conservancy District. 2007. Rotational Land Fallowing-Water Leasing Program Engineering Feasibility Analysis Final Report. Denver, Colorado: HDR Engineering, Inc.

Northern Colorado Water Conservancy District. 2006. Multi-Basin Water Supply Investigation. Centennial, Colorado: Black & Veatch.

Peter, Chandler. 2009. Personal Communication.

Pikes Peak Regional Water Authority. 2008. Arkansas River Renewable Water Economic Feasibility Study. Denver, Colorado: Boyle | AECOM.

SMWSA (South Metro Water Supply Authority). 2008. South Metro Water Supply Authority Mid-Term Water Delivery Project Plan. Denver, Colorado: CDM

SMWSA. 2007. Regional Water Master Plan. Denver, Colorado: CDM.

Town of Castle Rock, Castle Pines Metropolitan District, and Castle Pines North Metropolitan District. 2008. Water Resources Implementation Plan Final Report. Denver, Colorado: CDM.

USACE (U.S. Army Corps of Engineers). 2009. Public Scoping Meetings. https://www.nwo.usace.army.mil/html/od-tl/eis/RWSP-EIS.html

USEPA (U.S. Environmental Protection Agency). 2010. STORET. http://www.epa.gov/storet

Ward, Alan. 2009. Personal Communication.

Williamsen, Tom. 2009. Personal Communication.

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Jordan Dimick | CDM

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Appendix A
Detailed Reconnaissance Level Costs

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Appendix A
Detailed Reconnaissance Level Costs

Detailed final capital, operations and maintenance (O&M), and life cycle costs follow. For details on how these costs were developed, please see Section 3.

A.1 Capital Costs

Total capital costs for each concept and option are presented in Figure A-1 at the end of this appendix and Table A-1; these costs are given on a per-AFY basis on Figure A-2 at the end of this appendix and Table A-2. As noted in Section 3.3.1, there is no significant difference in the cost of projects between the total capital costs or the unit capital costs, except that Green Mountain and Blue Mesa are lower due to shorter pipelines and, in the case of Green Mountain, conveying a smaller volume. For all other options, the most expensive concept is 25 to 30 percent more expensive than the least costly. Yampa has a higher relative cost for Option 1 because tunneling costs do not change between options, and are therefore a bigger driver of cost in the lower-flow Option 1; the Yampa concept has significantly more tunneling than other concepts.

The total capital costs for each option are presented in more detail in Figures A-3, A-4, and A-5 at the end of this appendix and Table A-3 and the total unit capital costs for each option are presented in more detail in Figure A-6, A-7, and A-8 at the end of this appendix and Table A-4. These figures and tables show each component of overall capital costs: conveyance, treatment, water rights, storage, and reuse. The treatment costs shown include pipeline and tunnel construction, including diversion, appurtenance, and easement costs. These tables and figures show that the expense of transferring senior water rights for the South Platte and Arkansas concepts makes the total capital costs comparable to the longer and more pumping-intensive new water supply projects; the two agricultural transfer concepts are more expensive than the shorter Blue Mesa and Green Mountain projects.

Table A-1: Summary of Total Concept Capital Costs

		Option 1: 100,000 AFY (M$)*	Option 2: 250,000 AFY, single-phase (M$)	Option 3: 250,000 AFY dual-phase (M$)
Arkansas	Alignment 1	$3,130	$7,600	$7,600
	Alignment 2	$3,500	$8,350	$8,350
Blue Mesa		$2,454	$5,214	$5,214
Flaming Gorge		$3,954	$9,544	$9,544
Green Mountain		$841	N/A	N/A
South Platte	Alignment 1	$3,300	$8,180	$8,180
	Alignment 2	$3,690	$9,110	$9,110
Yampa		$4,094	$7,674	$7,674

* Option 1 for Green Mountain: 68,600 AFY

Table A-2: Summary of Total Concept Unit Capital Costs

		Option 1: 100,000 AFY (M$)*	Option 2: 250,000 AFY, single-phase ($/AFY)	Option 3: 250,000 AFY dual-phase ($/AFY)
Arkansas	Alignment 1	$31,300	$30,400	$30,400
	Alignment 2	$35,000	$33,400	$33,400
Blue Mesa		**$24,500**	**$20,900**	**$20,900**
Flaming Gorge		**$39,500**	**$38,200**	**$38,200**
Green Mountain		**$12,300**	**N/A**	**N/A**
South Platte	Alignment 1	$33,000	$32,700	$32,700
	Alignment 2	$36,900	$36,400	$36,400
Yampa		$40,900	$30,700	$30,700

* Option 1 for Green Mountain: 68,600 AFY

Table A-3: Total Concept Capital Cost Breakdowns

Option	Basin	Alignment	Conveyance* (M$)	Treatment (M$)	Water Rights (M$)	Storage (M$)	Reuse (M$)	Conveyance & Treatment Total (M$)	Total (M$)
Option 1	Arkansas	Alignment 1	$910	$420	$700	$260	$840	$1,330	$3,130
		Alignment 2	$1,280	$420	$700	$260	$840	$1,700	$3,500
	Blue Mesa		$1,180	$170	$4	$260	$840	$1,350	$2,454
	Flaming Gorge		$2,680	$170	$4	$260	$840	$2,850	$3,954
	Green Mountain		$160	$110	$4	$117	$450	$270	$841
	South Platte	Alignment 1	$300	$400	$1,500	$260	$840	$700	$3,300
		Alignment 2	$690	$400	$1,500	$260	$840	$1,090	$3,690
	Yampa		$2,820	$170	$4	$260	$840	$2,990	$4,094
Option 2			Conveyance* (M$)	Treatment (M$)	Water Rights (M$)	Storage (M$)	Reuse (M$)	Conveyance & Treatment Total (M$)	Total (M$)
	Arkansas	Alignment 1	$2,080	$1,020	$1,750	$650	$2,100	$3,100	$7,600
		Alignment 2	$2,830	$1,020	$1,750	$650	$2,100	$3,850	$8,350
	Blue Mesa		$2,040	$420	$4	$650	$2,100	$2,460	$5,214
	Flaming Gorge		$6,670	$420	$4	$350	$2,100	$7,090	$9,544
	Green Mountain		N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Platte	Alignment 1	$710	$970	$3,750	$650	$2,100	$1,680	$8,180
		Alignment 2	$1,640	$970	$3,750	$650	$2,100	$2,610	$9,110
	Yampa		$4,500	$420	$4	$650	$2,100	$4,920	$7,674
Option 3			Conveyance* (M$)	Treatment (M$)	Water Rights (M$)	Storage (M$)	Reuse (M$)	Conveyance & Treatment Total (M$)	Total (M$)
	Arkansas	Alignment 1	$2,180	$1,020	$1,750	$650	$2,100	$3,200	$7,700
		Alignment 2	$2,970	$1,020	$1,750	$650	$2,100	$3,990	$8,490
	Blue Mesa		$2,100	$420	$4	$650	$2,100	$2,520	$5,274
	Flaming Gorge		$6,950	$420	$4	$350	$2,100	$7,370	$9,824
	Green Mountain		N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Platte	Alignment 1	$750	$970	$3,750	$650	$2,100	$1,720	$8,220
		Alignment 2	$1,730	$970	$3,750	$650	$2,100	$2,700	$9,200
	Yampa		$4,680	$420	$4	$650	$2,100	$5,100	$7,854

* Includes costs for construction of tunnels, diversions, and pipelines including diversions and appurtenances

Table A-4: Total Concept Capital Unit Cost Breakdowns

Option	Source	Alignment	Conveyance* ($/AFY)	Treatment ($/AFY)	Water Rights ($/AFY)	Storage ($/AFY)	Reuse ($/AFY)	Conveyance & Treatment Total ($/AFY)	Total ($/AFY)
Option 1	Arkansas	Alignment 1	$9,100	$4,200	$7,000	$2,600	$13,000	$13,300	$31,300
		Alignment 2	$12,800	$4,200	$7,000	$2,600	$13,000	$17,000	$35,000
	Blue Mesa		$11,800	$1,700	$40	$2,600	$13,000	$13,500	$24,500
	Flaming Gorge		$26,800	$1,700	$40	$2,600	$13,000	$28,500	$39,500
	Green Mountain		$2,300	$1,600	$58	$1,706	$10,000	$3,900	$12,300
	South Platte	Alignment 1	$3,000	$4,000	$15,000	$2,600	$13,000	$7,000	$33,000
		Alignment 2	$6,900	$4,000	$15,000	$2,600	$13,000	$10,900	$36,900
	Yampa		$28,200	$1,700	$40	$2,600	$13,000	$29,900	$40,900
Option 2			Conveyance* ($/AFY)	Treatment ($/AFY)	Water Rights ($/AFY)	Storage ($/AFY)	Reuse ($/AFY)	Conveyance & Treatment Total ($/AFY)	Total ($/AFY)
	Arkansas	Alignment 1	$8,300	$4,080	$7,000	$2,600	$13,000	$12,400	$30,400
		Alignment 2	$11,300	$4,080	$7,000	$2,600	$13,000	$15,400	$33,400
	Blue Mesa		$8,200	$1,680	$16	$2,600	$13,000	$9,800	$20,900
	Flaming Gorge		$26,700	$1,680	$16	$1,400	$13,000	$28,400	$38,200
	Green Mountain		N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Platte	Alignment 1	$2,800	$3,880	$15,000	$2,600	$13,000	$6,700	$32,700
		Alignment 2	$6,600	$3,880	$15,000	$2,600	$13,000	$10,400	$36,400
	Yampa		$18,000	$1,680	$16	$2,600	$13,000	$19,700	$30,700
Option 3			Conveyance* ($/AFY)	Treatment ($/AFY)	Water Rights ($/AFY)	Storage ($/AFY)	Reuse ($/AFY)	Conveyance & Treatment Total ($/AFY)	Total ($/AFY)
	Arkansas	Alignment 1	$8,700	$4,080	$7,000	$2,600	$13,000	$12,800	$30,800
		Alignment 2	$11,900	$4,080	$7,000	$2,600	$13,000	$16,000	$34,000
	Blue Mesa		$8,400	$1,680	$16	$2,600	$13,000	$10,100	$21,100
	Flaming Gorge		$27,800	$1,680	$16	$1,400	$13,000	$29,500	$39,300
	Green Mountain		N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Platte	Alignment 1	$3,000	$3,880	$15,000	$2,600	$13,000	$6,900	$32,900
		Alignment 2	$6,900	$3,880	$15,000	$2,600	$13,000	$10,800	$36,800
	Yampa		$18,700	$1,680	$16	$2,600	$13,000	$20,400	$31,400

* Includes costs for construction of tunnels, diversions, and pipelines including diversions and appurtenances

A.2 Operations and Maintenance Costs

Total annual O&M costs for each concept and option are presented in Figure A-9 at the end of this appendix and Table A-5; these costs are given on a per-AFY basis on Figure A-10 at the end of this appendix and Table A-6. The total annual O&M costs for each option are presented in more detail in Figures A-11, A-12, and A-13 at the end of this appendix and Table A-7 and the total unit capital costs for each option are presented in more detail in Figure A-14, A-15, and A-16 at the end of this appendix and Table A-8. These figures and tables show each component of overall capital costs: conveyance, treatment, water rights, storage, and reuse. Annual O&M costs vary widely. The significant variability between projects is due primarily to conveyance costs. Differences in water treatment requirements between conventional treatment (Yampa River, Blue Mesa Reservoir, Green Mountain Reservoir, and Flaming Gorge Reservoir supplies) and RO treatment with ZLD (South Platte River and Arkansas River supplies) also contributes to this variation.

Table A-5: Summary of Total Concept Annual O&M Costs

		Option 1: 100,000 AFY (M$)*	Option 2: 250,000 AFY, single-phase (M$)	Option 3: 250,000 AFY dual-phase (M$)
Arkansas	Alignment 1	$104	$259	$259
	Alignment 2	$112	$277	$277
Blue Mesa		$89	$215	$215
Flaming Gorge		$84	$217	$217
Green Mountain		$29	N/A	N/A
South Platte	Alignment 1	$61	$152	$152
	Alignment 2	$77	$191	$191
Yampa		$84	$193	$193

* Option 1 for Green Mountain: 68,600 AFY

Table A-6: Summary of Total Concept Unit O&M Costs

		Option 1: 100,000 AFY (M$)*	Option 2: 250,000 AFY, single-phase ($/AFY)	Option 3: 250,000 AFY dual-phase ($/AFY)
Arkansas	Alignment 1	$1,044	$1,037	$1,037
	Alignment 2	$1,124	$1,109	$1,109
Blue Mesa		$894	$861	$861
Flaming Gorge		$844	$869	$869
Green Mountain		$428	N/A	N/A
South Platte	Alignment 1	$614	$609	$609
	Alignment 2	$774	$769	$765
Yampa		$844	$773	$773

* Option 1 for Green Mountain: 68,600 AFY

Table A-7: O&M Total Annual Cost Breakdowns

Option	Site	Alignment	Conveyance (M$/yr)	Treatment (M$/yr)	Water Rights (M$/yr)	Storage (M$/yr)	Reuse (M$/yr)	Conveyance & Treatment Total (M$/yr)	Total (M$/yr)
Option 1	Arkansas	Alignment 1	$54	$31	$0.4	$0.2	$19	$85	$104
		Alignment 2	$62	$31	$0.4	$0.2	$19	$93	$112
	Blue Mesa		$60	$10	$0.4	$0.2	$19	$70	$89
	Flaming Gorge		$55	$10	$0.4	$0.2	$19	$65	$84
	Green Mountain		$9	$7	$0.3	$0.2	$13	$16	$29
	South Platte	Alignment 1	$13	$29	$0.4	$0.2	$19	$42	$61
		Alignment 2	$29	$29	$0.4	$0.2	$19	$58	$77
	Yampa		$55	$10	$0.4	$0.2	$19	$65	$84
Option 2			Conveyance (M$/yr)	Treatment (M$/yr)	Water Rights (M$/yr)	Storage (M$/yr)	Reuse (M$/yr)	Conveyance & Treatment Total (M$/yr)	Total (M$/yr)
	Arkansas	Alignment 1	$135	$76	$1.0	$0.2	$47	$211	$259
		Alignment 2	$153	$76	$1.0	$0.2	$47	$229	$277
	Blue Mesa		$143	$24	$1.0	$0.2	$47	$167	$215
	Flaming Gorge		$145	$24	$1.0	$0.2	$47	$169	$217
	Green Mountain		N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Platte	Alignment 1	$33	$71	$1.0	$0.2	$47	$104	$152
		Alignment 2	$72	$71	$1.0	$0.2	$47	$143	$191
	Yampa		$121	$24	$1.0	$0.2	$47	$145	$193
Option 3			Conveyance (M$/yr)	Treatment (M$/yr)	Water Rights (M$/yr)	Storage (M$/yr)	Reuse (M$/yr)	Conveyance & Treatment Total (M$/yr)	Total (M$/yr)
	Arkansas	Alignment 1	$135	$76	$1.0	$0.2	$47	$211	$259
		Alignment 2	$154	$76	$1.0	$0.2	$47	$230	$278
	Blue Mesa		$144	$24	$1.0	$0.2	$47	$168	$216
	Flaming Gorge		$146	$24	$1.0	$0.2	$47	$170	$218
	Green Mountain		N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Platte	Alignment 1	$33	$71	$1.0	$0.2	$47	$104	$152
		Alignment 2	$73	$71	$1.0	$0.2	$47	$144	$192
	Yampa		$122	$24	$1.0	$0.2	$47	$146	$194

Table A-8: O&M Total Annual Unit Cost Breakdowns

			Conveyance ($/AFY/yr)	Treatment ($/AFY/yr)	Water Rights ($/AFY/yr)	Storage ($/AFY/yr)	Reuse ($/AFY/yr)	Conveyance & Treatment Total ($/AFY/yr)	Total ($/AFY/yr)
Option 1	Arkansas	Alignment 1	$540	$310	$4.0	$2.0	$290	$850	$1.044
		Alignment 2	$620	$310	$4.0	$2.0	$290	$930	$1,124
	Blue Mesa		$600	$100	$4.0	$2.0	$290	$700	$834
	Flaming Gorge		$550	$100	$4.0	$2.0	$290	$650	$844
	Green Mountain		$130	$100	$4.0	$2.9	$290	$233	$428
	South Platte	Alignment 1	$130	$290	$4.0	$2.0	$290	$420	$614
		Alignment 2	$290	$290	$4.0	$2.0	$290	$580	$774
	Yampa		$550	$100	$4.0	$2.0	$290	$650	$844
Option 2			**Conveyance ($/AFY/yr)**	**Treatment ($/AFY/yr)**	**Water Rights ($/AFY/yr)**	**Storage ($/AFY/yr)**	**Reuse ($/AFY/yr)**	**Conveyance & Treatment Total ($/AFY/yr)**	**Total ($/AFY/yr)**
	Arkansas	Alignment 1	$540	$300	$4.0	$0.8	$290	$844	$1,037
		Alignment 2	$610	$300	$4.0	$0.8	$290	$916	$1,109
	Blue Mesa		$570	$100	$4.0	$0.8	$290	$668	$861
	Flaming Gorge		$580	$100	$4.0	$0.8	$290	$676	$869
	Green Mountain		N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Platte	Alignment 1	$130	$280	$4.0	$0.8	$290	$416	$603
		Alignment 2	$290	$280	$4.0	$0.8	$290	$416	$765
	Yampa		$480	$100	$4.0	$0.8	$290	$580	$773
Option 3			**Conveyance ($/AFY/yr)**	**Treatment ($/AFY/yr)**	**Water Rights ($/AFY/yr)**	**Storage ($/AFY/yr)**	**Reuse ($/AFY/yr)**	**Conveyance & Treatment Total ($/AFY/yr)**	**Total ($/AFY/yr)**
	Arkansas	Alignment 1	$540	$300	$4.0	$0.8	$290	$844	$1,037
		Alignment 2	$620	$300	$4.0	$0.8	$290	$920	$1,113
	Blue Mesa		$580	$100	$4.0	$0.8	$290	$672	$865
	Flaming Gorge		$580	$100	$4.0	$0.8	$290	$680	$873
	Green Mountain		N/A	N/A	N/A	N/A	N/A	N/A	N/A
	South Platte	Alignment 1	$130	$280	$4.0	$0.8	$290	$416	$69
		Alignment 2	$290	$280	$4.0	$0.8	$290	$576	$769
	Yampa		$490	$100	$4.0	$0.8	$290	$584	$777

A.3 Life Cycle Costs

Total life cycle cost for each concept is presented in Figure A-17 at the end of this appendix and Table A-9, and total life cycle unit cost is presented in Figure A-18 at the end of this appendix and Table A-10.

Table A-9: Summary of Total Concept Life Cycle Costs

		Option 1: 100,000 AFY (M$)*	Option 2: 250,000 AFY, single-phase (M$)	Option 3: 250,000 AFY dual-phase (M$)
Arkansas	Alignment 1	$9,350	$22,700	$22,700
	Alignment 2	$10,070	$24,400	$24,400
Blue Mesa		$7,660	$17,900	$17,900
Flaming Gorge		$8,180	$20,300	$20,300
Green Mountain		$2,640	N/A	N/A
South Platte	Alignment 1	$6,790	$16,500	$16,500
	Alignment 2	$8,030	$19,600	$19,600
Yampa		$8,250	$17,800	$17,800

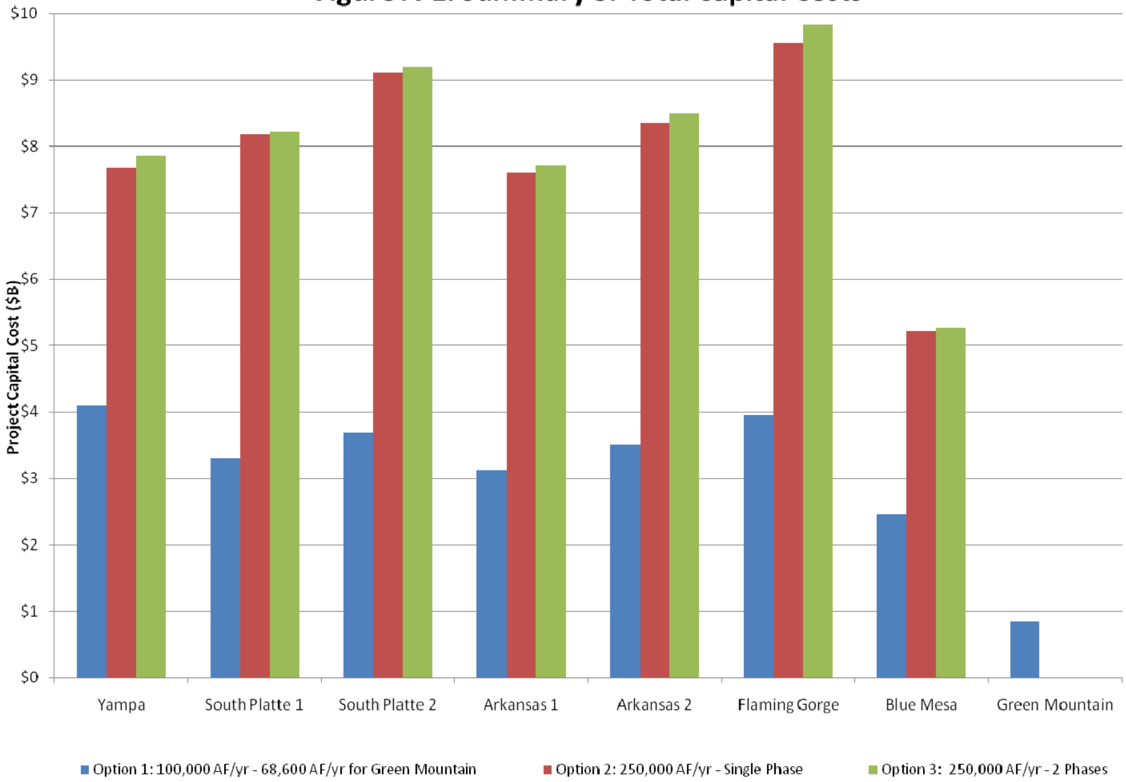
* Option 1 for Green Mountain: 68,600 AFY

Table A-10: Summary of Total Concept Unit Life Cycle Costs

		Option 1: 100,000 AFY (M$)*	Option 2: 250,000 AFY, single-phase ($/AFY)	Option 3: 250,000 AFY dual-phase ($/AFY)
Arkansas	Alignment 1	$1,044	$1,037	$1,037
	Alignment 2	$1,124	$1,109	$1,109
Blue Mesa		$894	$861	$861
Flaming Gorge		$844	$869	$869
Green Mountain		$428	N/A	N/A
South Platte	Alignment 1	$614	$609	$609
	Alignment 2	$774	$765	$765
Yampa		$844	$773	$773

* Option 1 for Green Mountain: 68,600 AFY

Figure A-1. Summary of Total Capital Costs



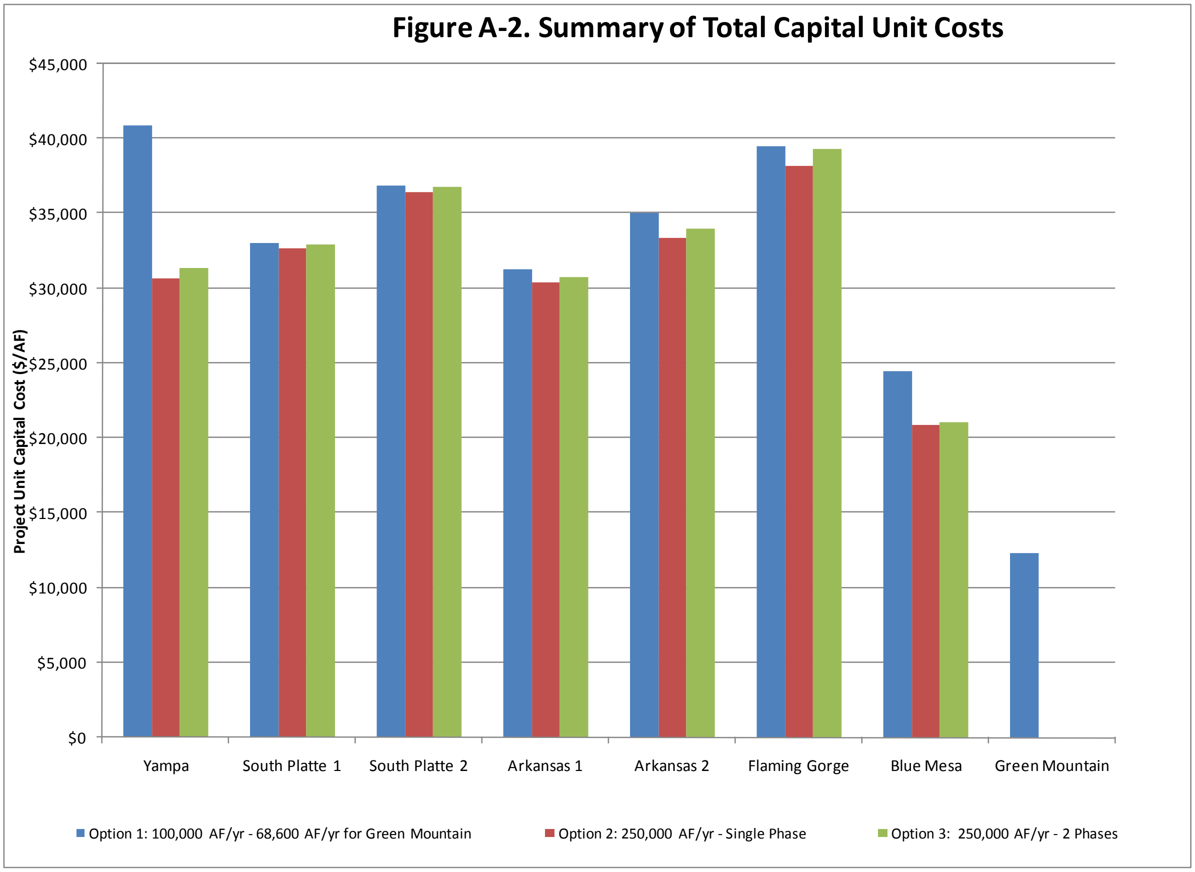


Figure A-2. Summary of Total Capital Unit Costs
Project Unit Capital Cost ($/AF)
$45,000
$40,000
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

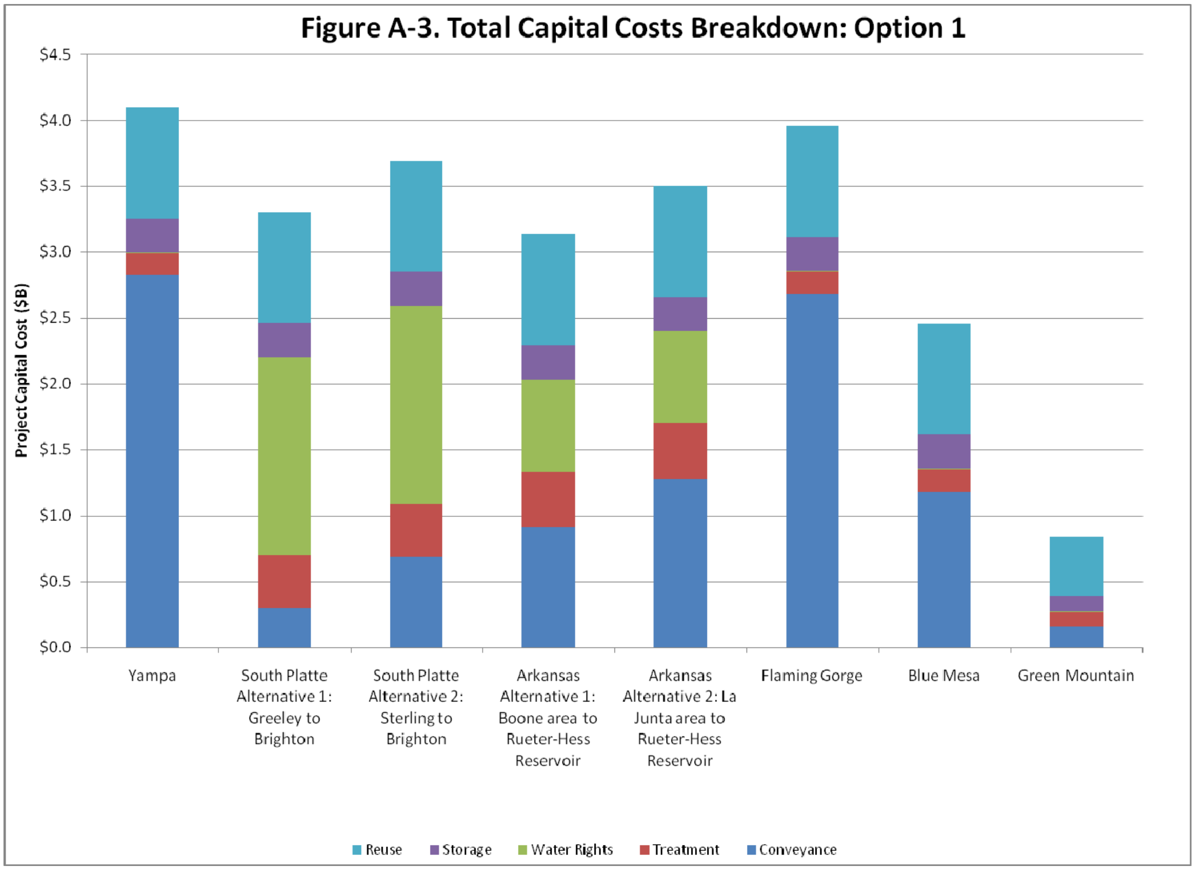


Figure A-3. Total Capital Costs Breakdown: Option 1
Project Capital Cost ($B)
$4.5
$4.0
$3.5
$3.0
$2.5
$2.0
$1.5
$1.0
$0.5
$0.0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Green Mountain
Reuse
Storage
Water Rights
Treatment
Conveyance

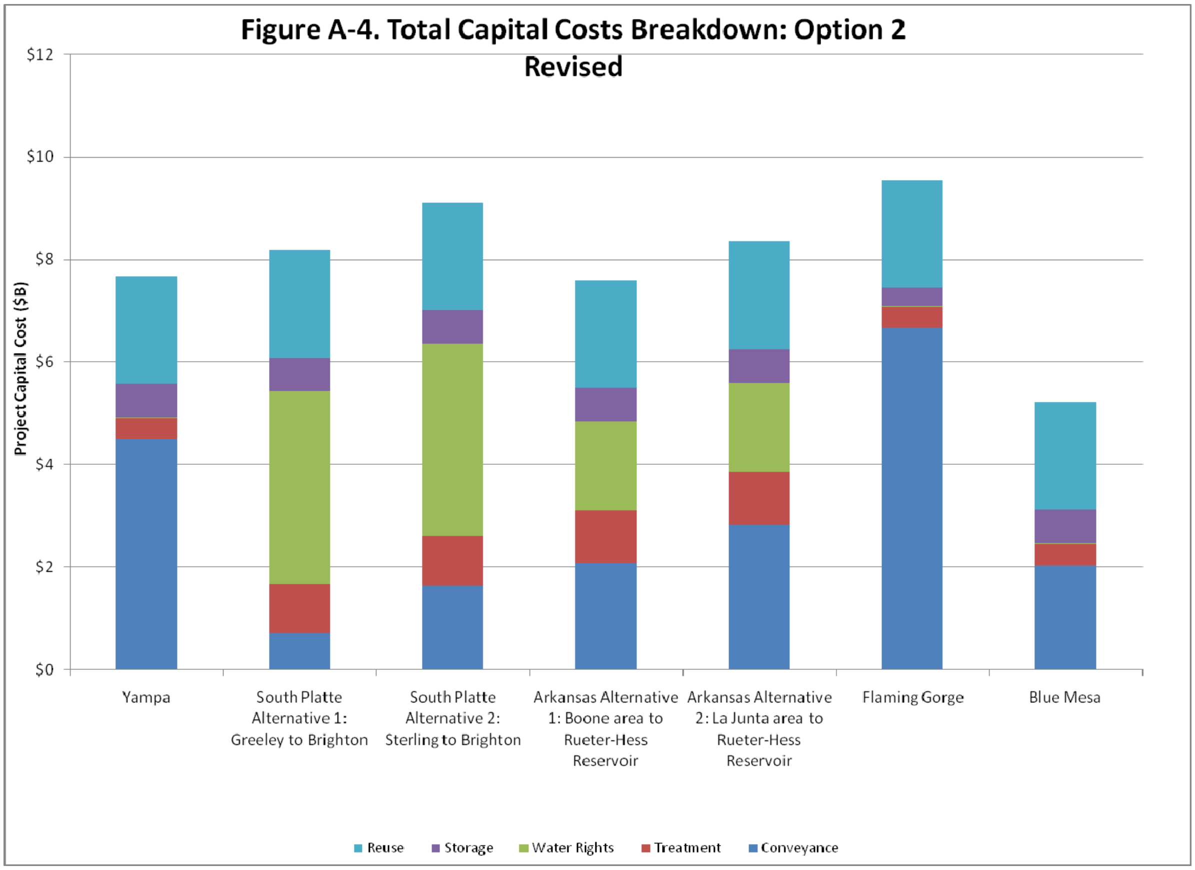


Figure A-4. Total Capital Costs Breakdown: Option 2 Revised
$12
$10
$8
$6
$4
$2
$0
Project Capital Cost ($B)
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Reuse
Storage
Water Rights
Treatment
Conveyance

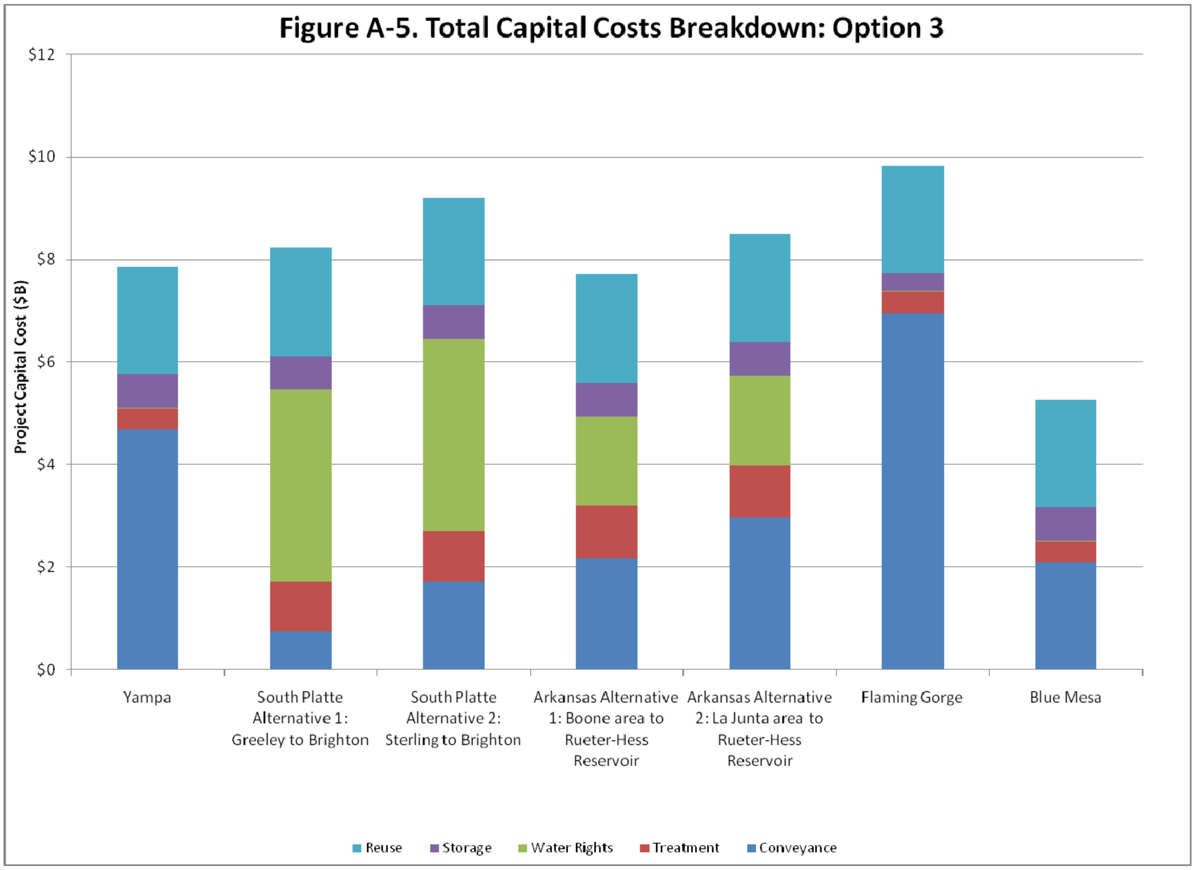


Figure A-5. Total Capital Costs Breakdown: Option 3
Project Capital Cost ($B)
$12
$10
$8
$6
$4
$2
$0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Reuse
Storage
Water Rights
Treatment
Conveyance

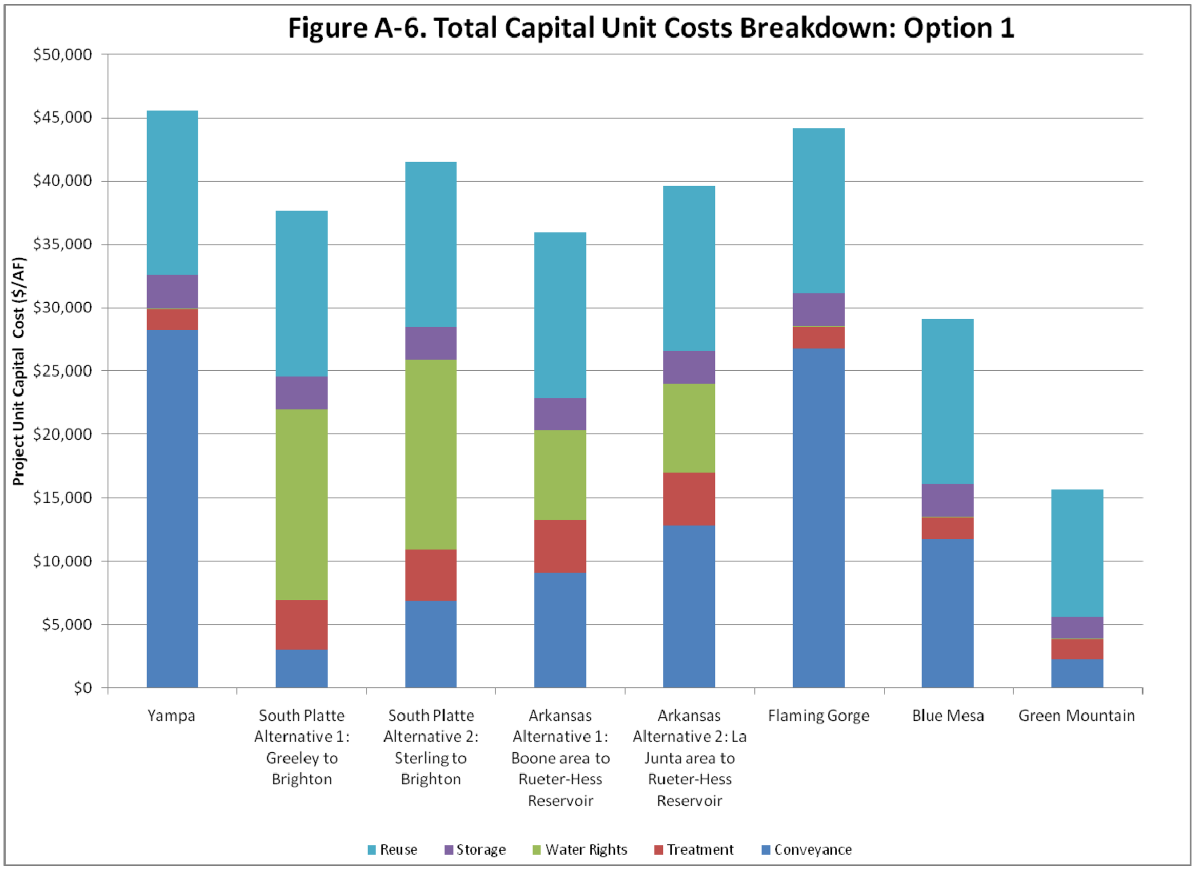


Figure A-6. Total Capital Unit Costs Breakdown: Option 1
Project Unit Capital Cost ($/AF)
$50,000
$45,000
$40,000
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Green Mountain
Reuse
Storage
Water Rights
Treatment
Conveyance

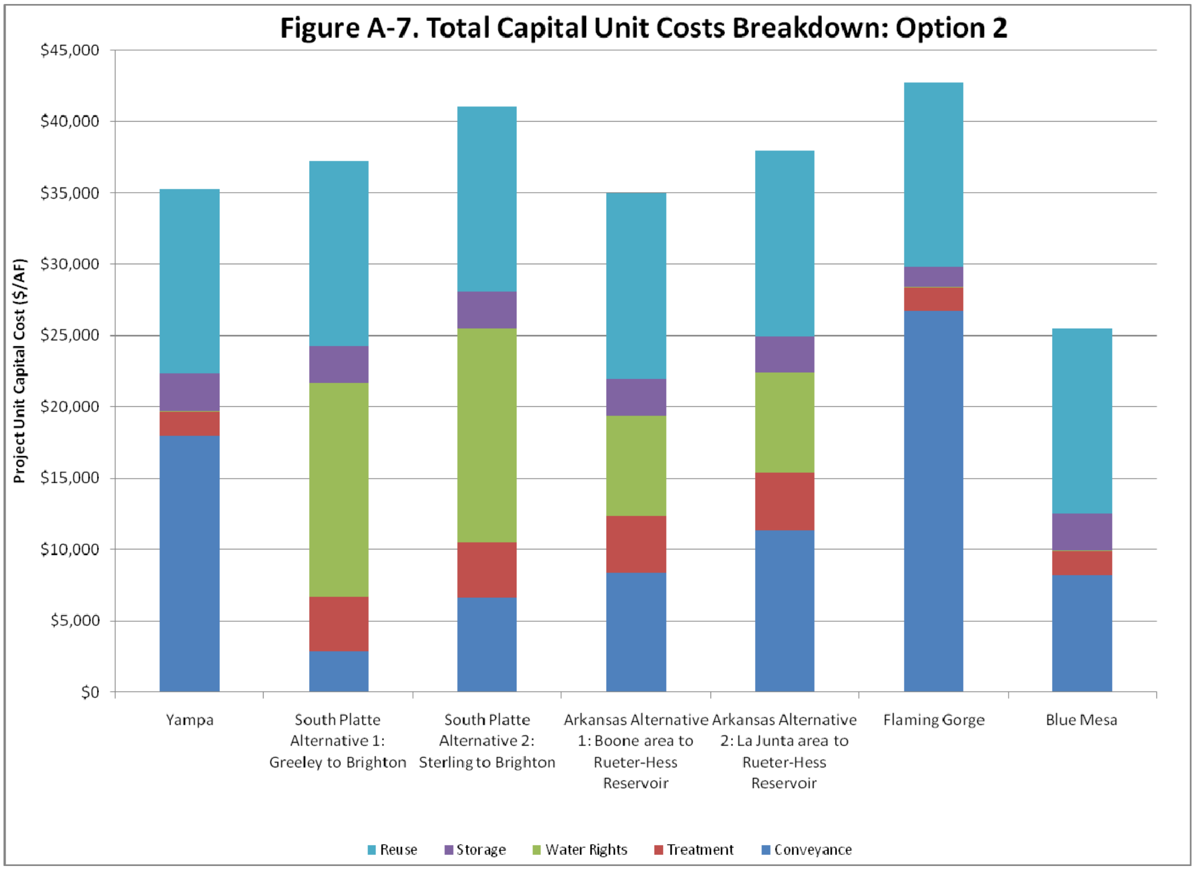


Figure A-7. Total Capital Unit Costs Breakdown: Option 2
Project Unit Capital Cost ($/AF)
$45,000
$40,000
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Reuse
Storage
Water Rights
Treatment
Conveyance

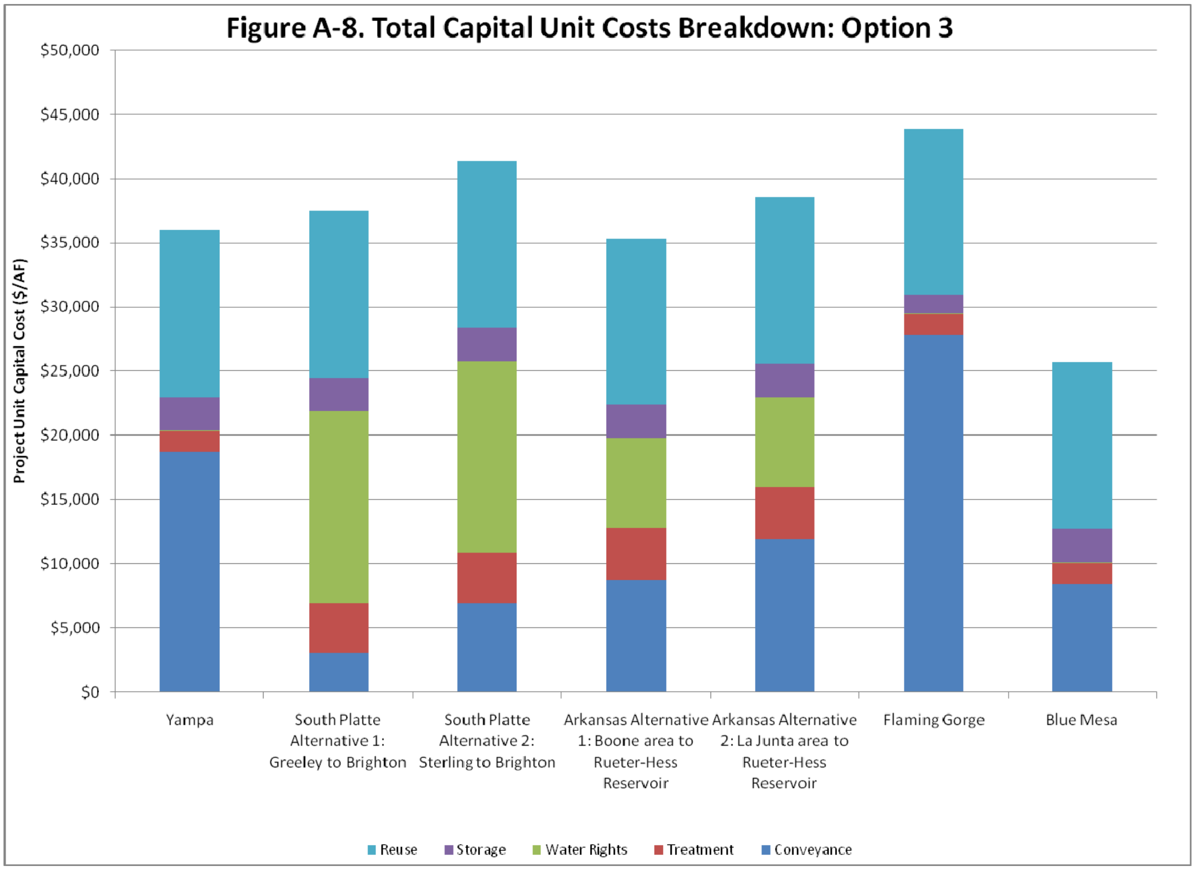


Figure A-8. Total Capital Unit Costs Breakdown: Option 3
Project Unit Capital Cost ($/AF)
$50,000
$45,000
$40,000
$35,000
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Reuse
Storage
Water Rights
Treatment
Conveyance

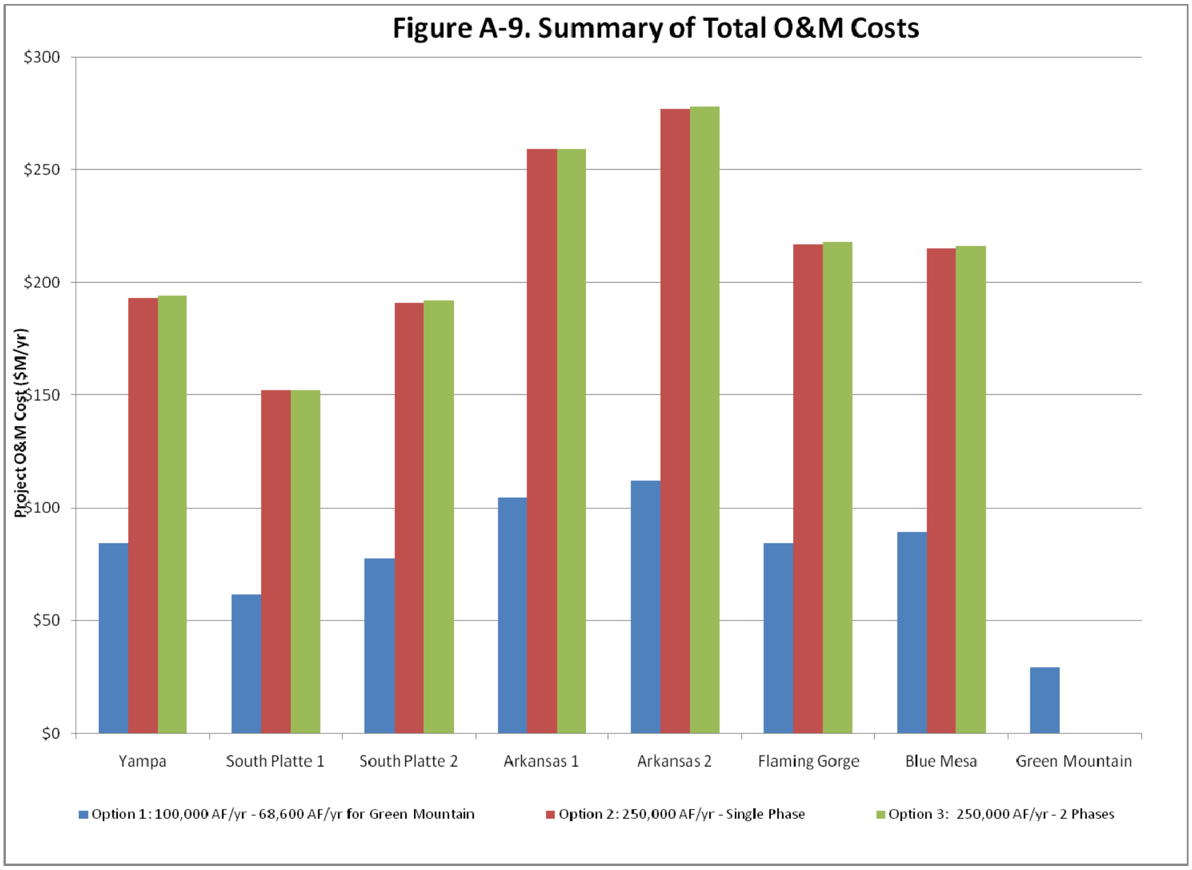


Figure A-9. Summary of Total O&M Costs
Project O&M Cost ($M/yr)
$300
$250
$200
$150
$100
$50
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

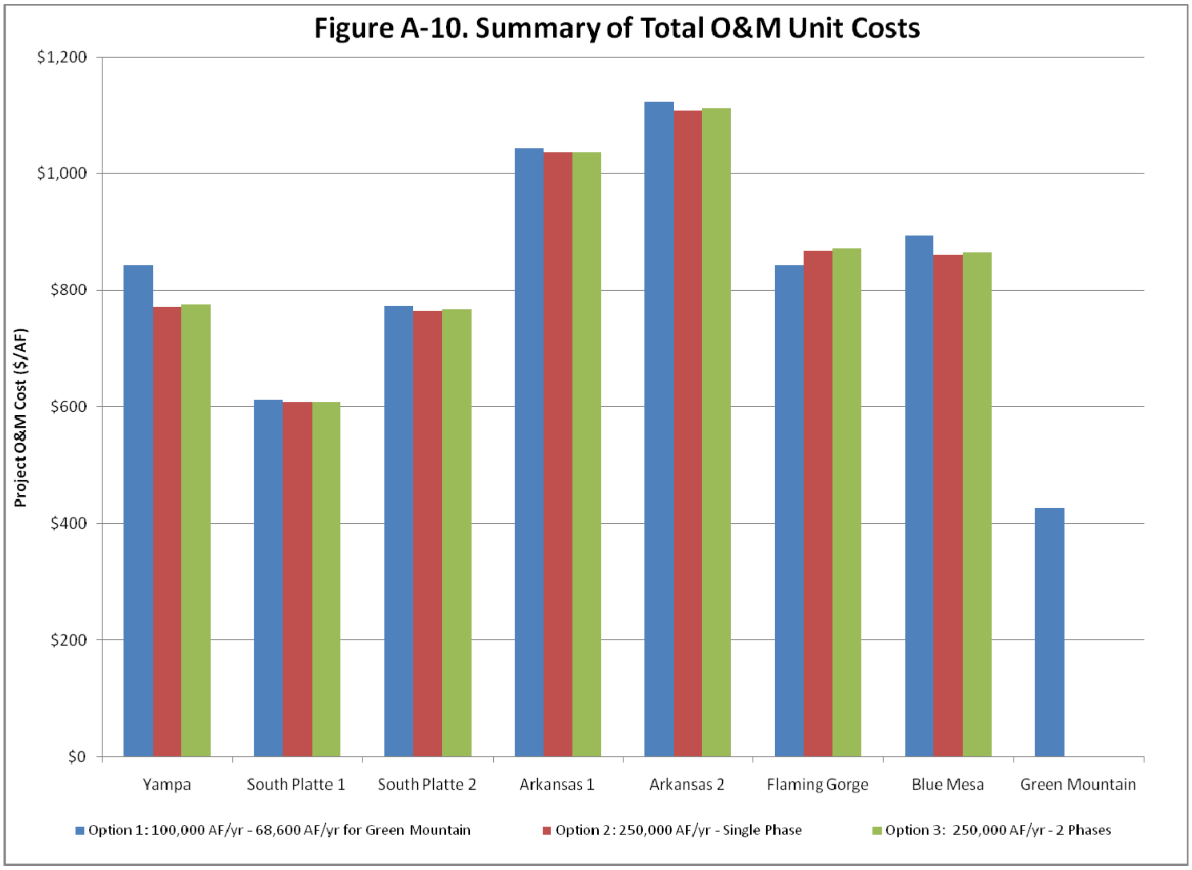


Figure A-10. Summary of Total O&M Unit Costs
Project O&M Cost ($/AF)
$1,200
$1,000
$800
$600
$400
$200
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

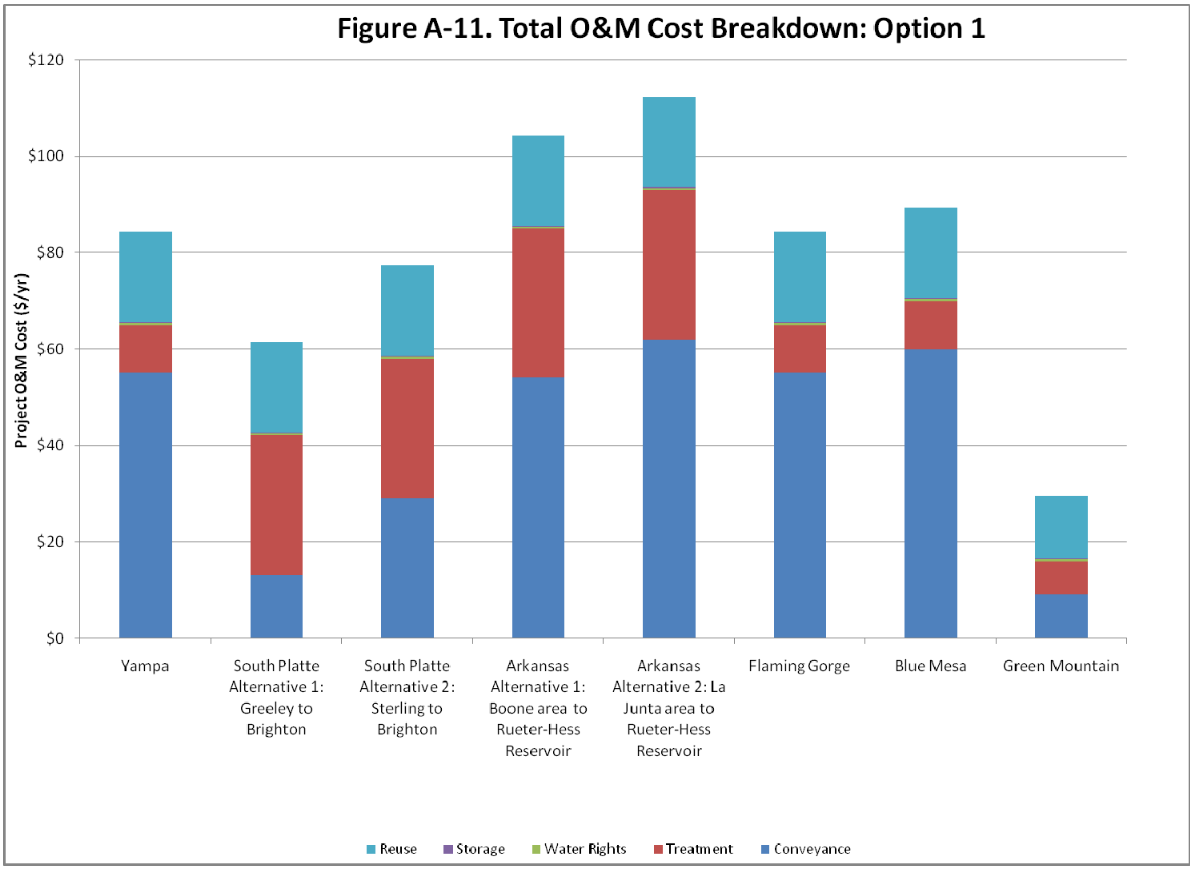


Figure A-11. Total O&M Cost Breakdown: Option 1
$120
$100
$80
$60
$40
$20
$0
Project O&M Cost ($/yr)
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Green Mountain
Reuse
Storage
Water Rights
Treatment
Conveyance

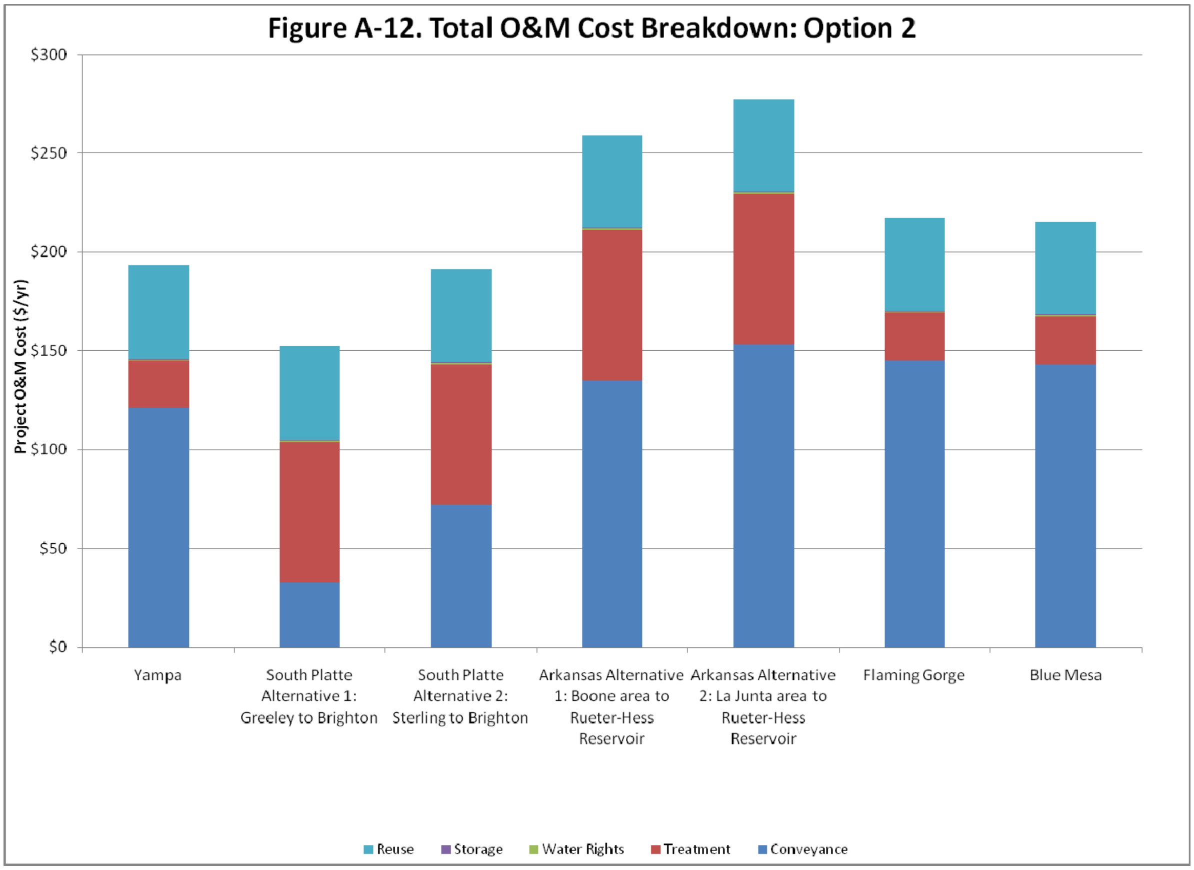
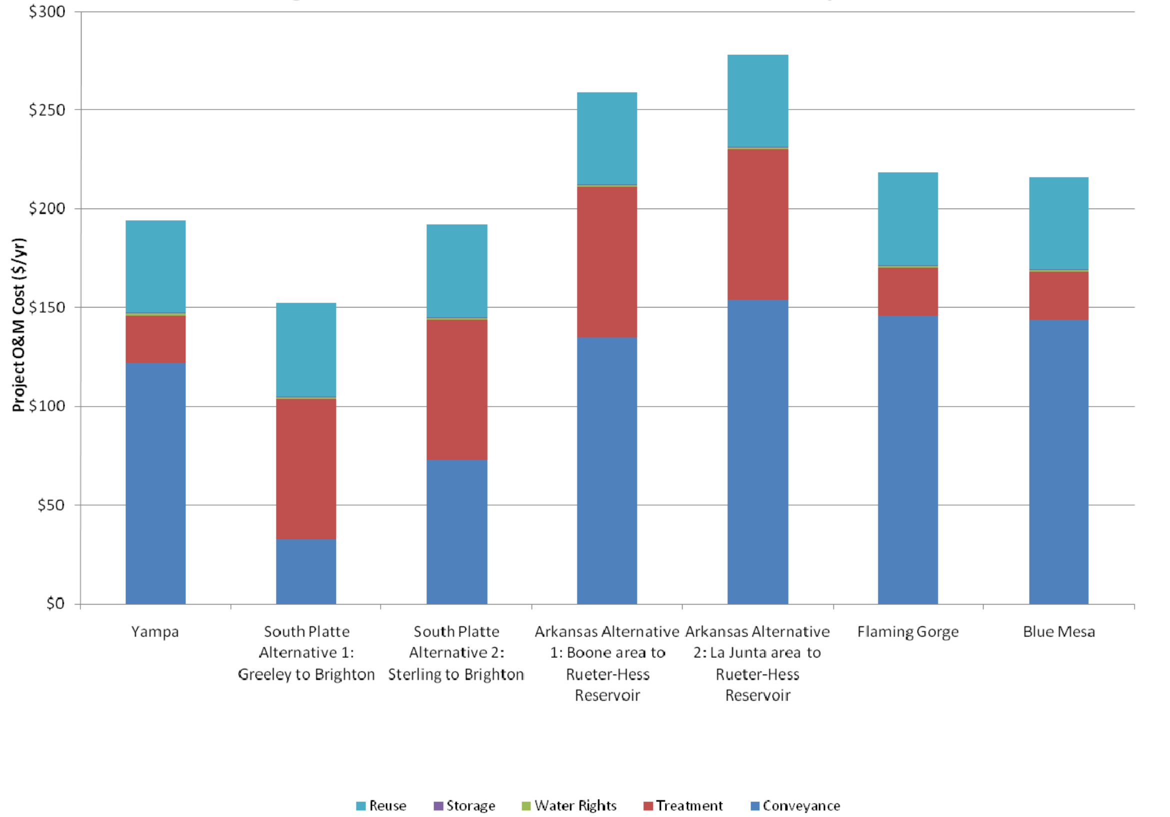


Figure A-12. Total O&M Cost Breakdown: Option 2
Project O&M Cost ($/yr)
$300
$250
$200
$150
$100
$50
$0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Reuse
Storage
Water Rights
Treatment
Conveyance

Figure A-13. Total O&M Cost Breakdown: Option 3



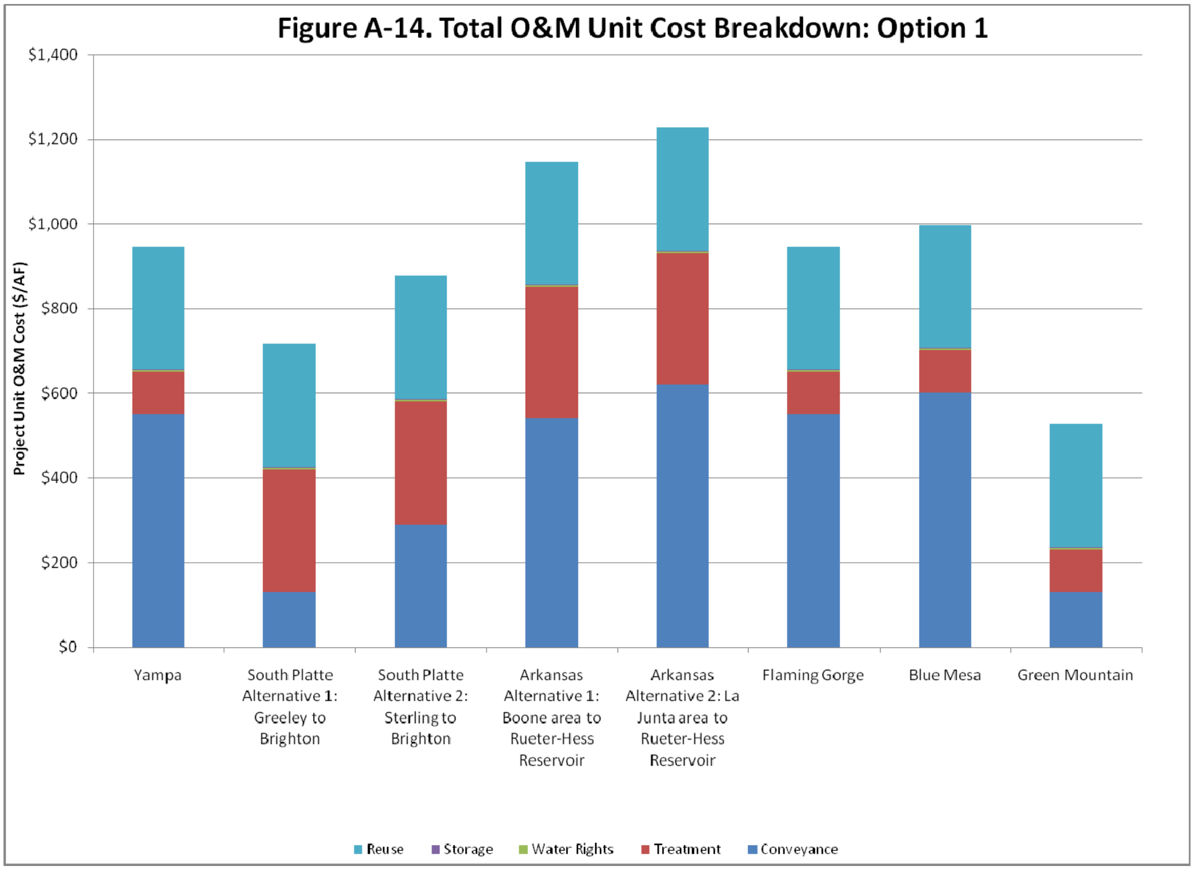


Figure A-14. Total O&M Unit Cost Breakdown: Option 1
Project Unit O&M Cost ($/AF)
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Green Mountain
Reuse
Storage
Water Rights
Treatment
Conveyance

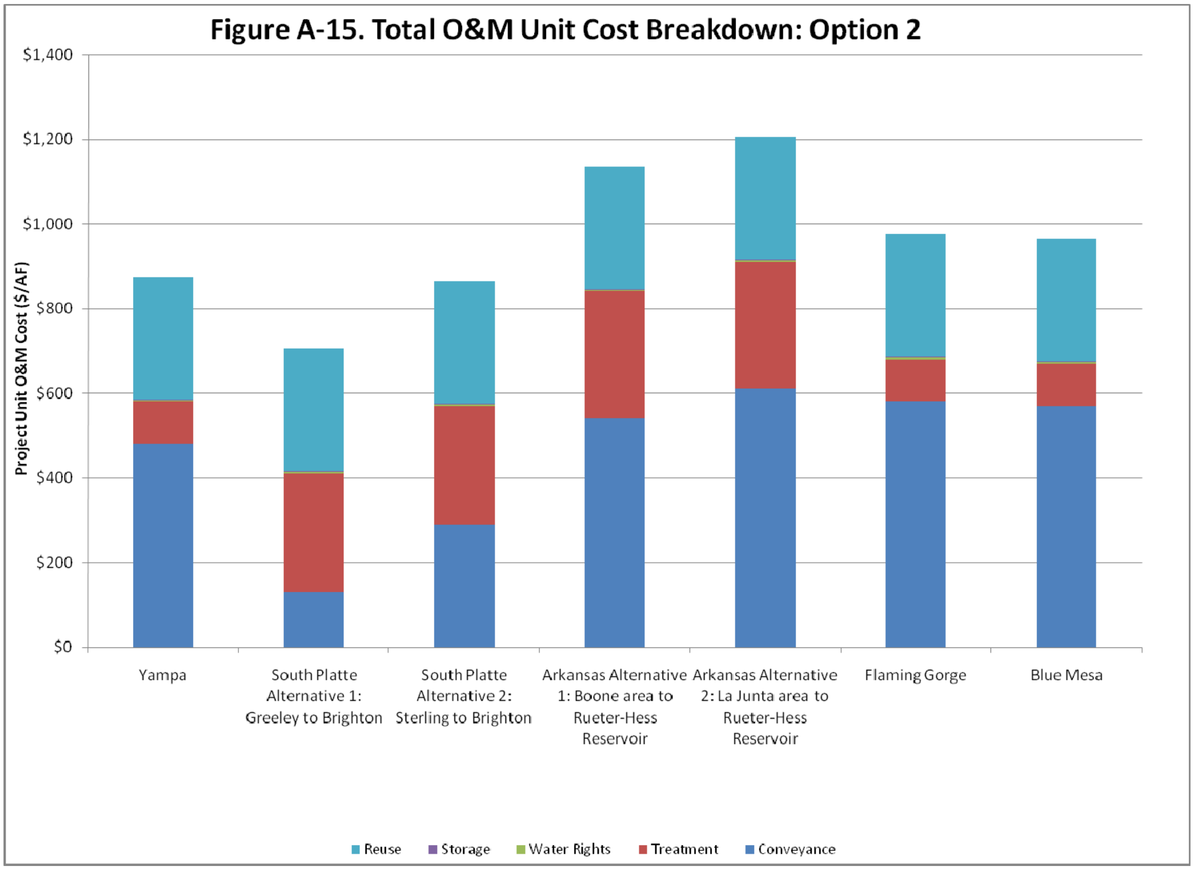


Figure A-15. Total O&M Unit Cost Breakdown: Option 2
Project Unit O&M Cost ($/AF)
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Reuse
Storage
Water Rights
Treatment
Conveyance

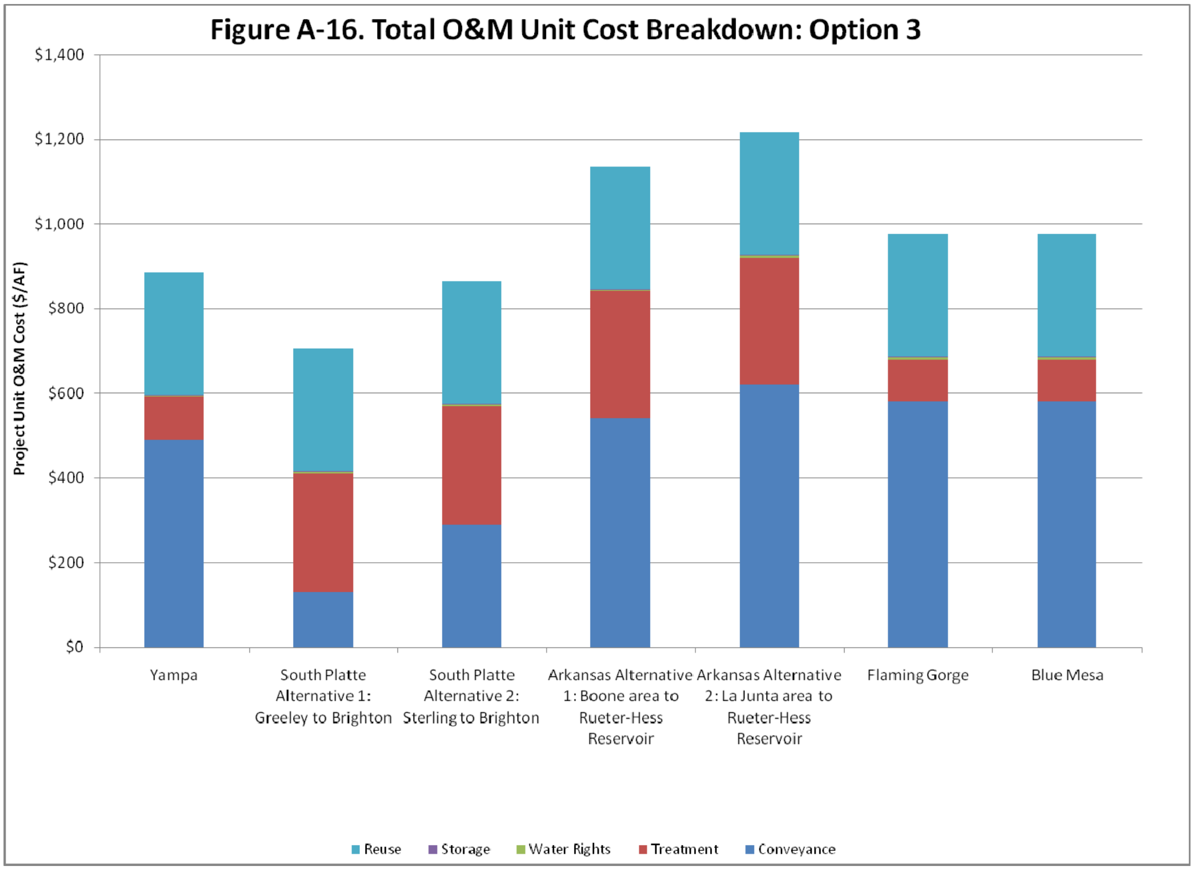


Figure A-16. Total O&M Unit Cost Breakdown: Option 3
Project Unit O&M Cost ($/AF)
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
Yampa
South Platte Alternative 1: Greeley to Brighton
South Platte Alternative 2: Sterling to Brighton
Arkansas Alternative 1: Boone area to Rueter-Hess Reservoir
Arkansas Alternative 2: La Junta area to Rueter-Hess Reservoir
Flaming Gorge
Blue Mesa
Reuse
Storage
Water Rights
Treatment
Conveyance

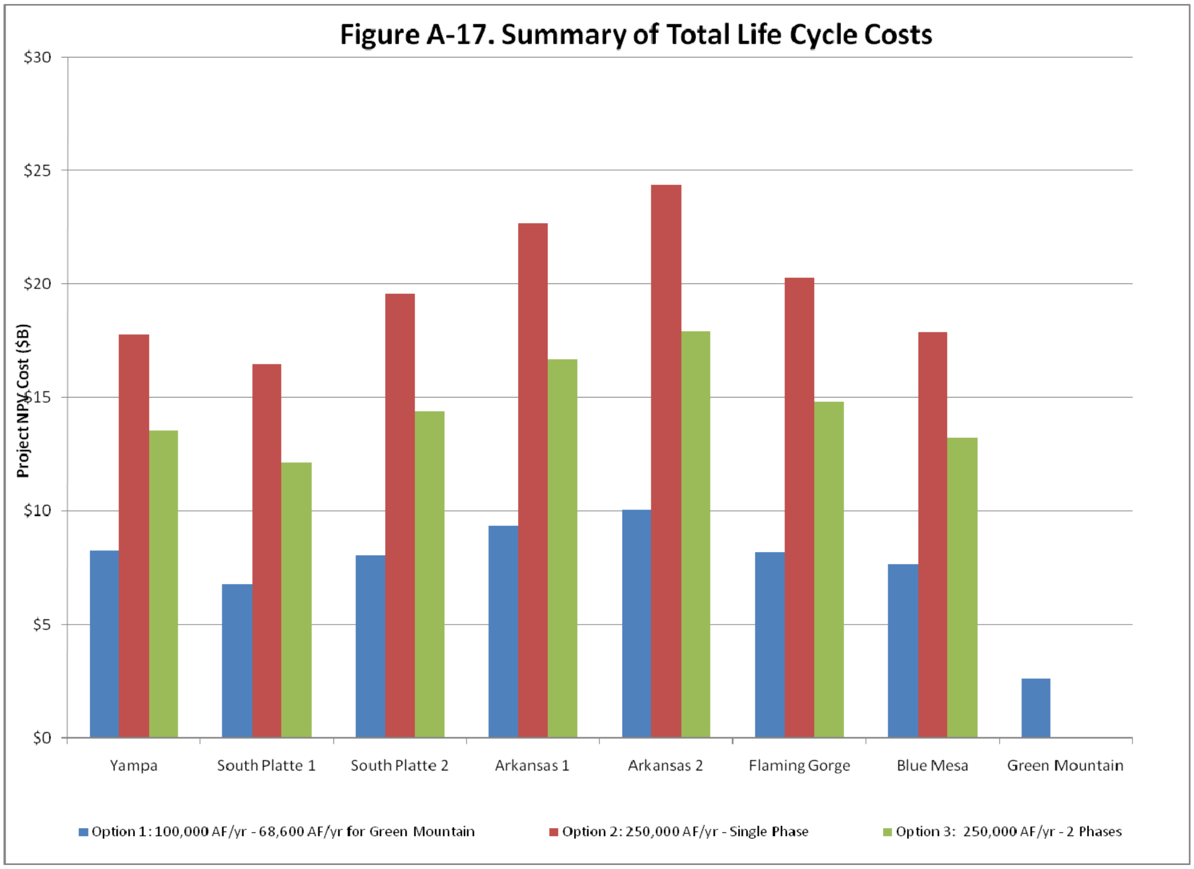


Figure A-17. Summary of Total Life Cycle Costs
Project NPV Cost ($B)
$30
$25
$20
$15
$10
$5
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases

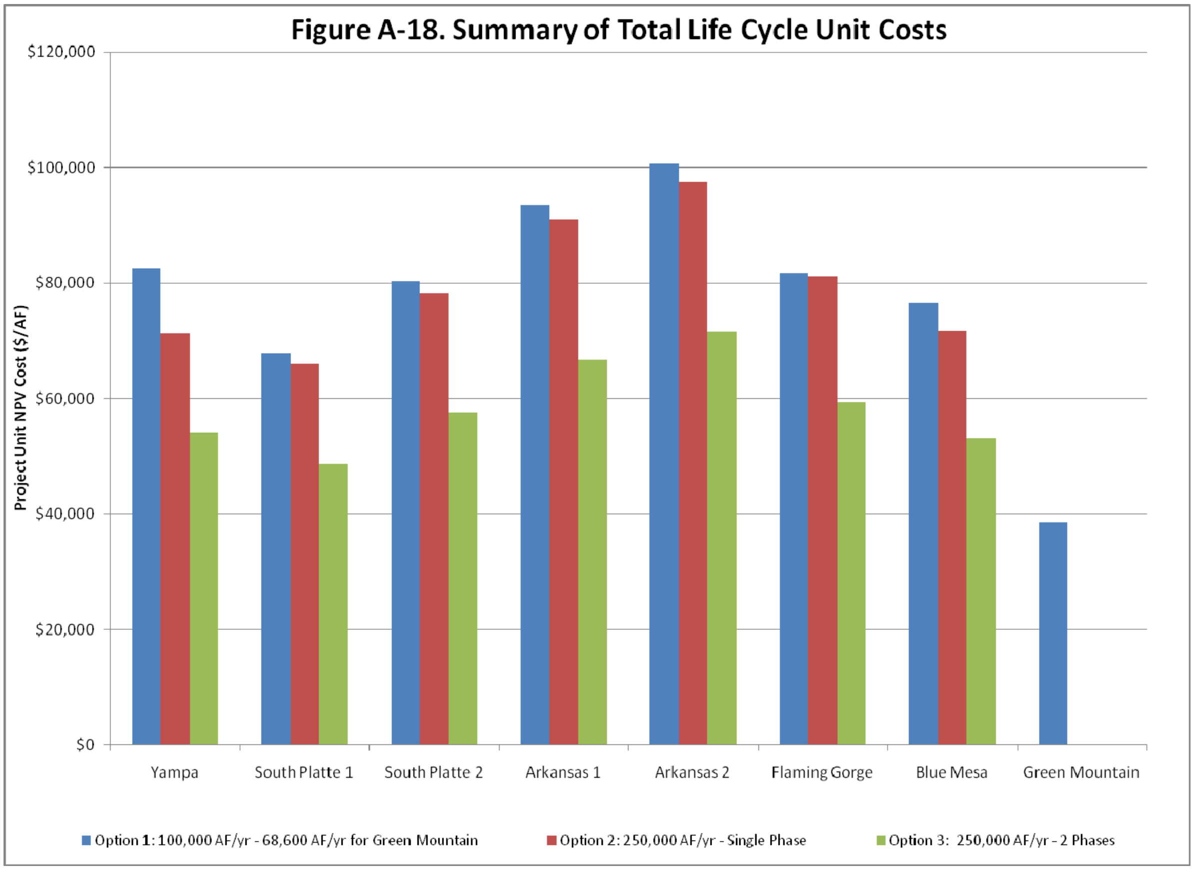


Figure A-18. Summary of Total Life Cycle Unit Costs
Project Unit NPV Cost ($/AF)
$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$0
Yampa
South Platte 1
South Platte 2
Arkansas 1
Arkansas 2
Flaming Gorge
Blue Mesa
Green Mountain
Option 1: 100,000 AF/yr - 68,600 AF/yr for Green Mountain
Option 2: 250,000 AF/yr - Single Phase
Option 3: 250,000 AF/yr - 2 Phases