M E M O R A N D U M

MWH

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From:	**Jerry Gibbens**	**Reference:**	**1700547.011803**
Subject:	**Yield Analysis for Preliminary Alternatives** **Southern Delivery System Environmental Impact Statement**		

1. Purpose

Estimates of firm and average yield are required for evaluation of Southern Delivery System (SDS) Environmental Impact Statement (EIS) preliminary alternatives. This memorandum summarizes the methods and results of the yield analysis.

2. Methods

The yield analysis for the Colorado Springs Utilities (Utilities) portion of the SDS was analyzed using Colorado Springs Utilities' Operations and Yield Model, as documented in the recent Raw Water Yield Study (MWH 2005a). The Colorado Springs Utilities Operations and Yield Model is a river and reservoir simulation model with a monthly time step that is used to investigate the collection, storage and distribution of Colorado Springs Utilities' raw water supplies. Colorado Springs Utilities (Utilities) uses the Operations and Yield Model as a decision support system for evaluating its water supply system.

In general, the Operations and Yield Model was used as developed in the Raw Water Yield Study. However, because the Raw Water Yield Study did not evaluate alternatives to the SDS Proposed Action, some modifications to the Operations and Yield Model were necessary to adequately simulate the preliminary alternatives. The following subsections document the changes made to the Operations and Yield Model necessary for the EIS analysis.

The City of Fountain (Fountain) and Security Water District (Security) provided yield analyses of their portions of the SDS Proposed Action separately from Utilities. These analyses were based on general analytical information regarding expected yields from existing and proposed supplies, and did not use extensive modeling of their respective systems. Therefore, Fountain and Security's SDS yields for the alternatives were based on their original analytical information, as well as results from the Utilities yield analysis.

[1] Memorandum was revised from original version to address comments on modeling methodologies for the Highway 115 alternatives as discussed in November 21, 2005 letter from Brett Gracely to Pat Mangan. At the same time, a slight modification was made to storage priorities in the model for the Highway 115 alternatives to more closely simulate expected operations.

2.1 Base Colorado Springs Utilities Yield Model

The Operations and Yield Model includes all of the major components of Utilities' local, Arkansas River and transmountain systems. Monthly time-step simulations are performed based on the hydrologic conditions of the study period, projected demand levels, system infrastructure and operational policies. The modeling parameters include the hydrologic condition, legal/institutional aspects, operating priorities and economic criteria. The demand projections used in the model include both spatial and temporal characteristics. The monthly variation and spatial distribution in the demand dictate the overall water allocation patterns in the system as well as the size and schedule of project improvements. The physical layout of the system includes reservoirs, diversions from local streams, wells and numerous raw water pipelines and tunnels.

The Operations and Yield Model uses a combination of the Microsoft Excel spreadsheet program and the MODSIM network flow model. Microsoft Excel is used as the model Graphical User Interface (GUI) and data pre-processor, as well as the data post-processor. MODSIM is used as the model engine. MODSIM was developed by Dr. John Labadie at Colorado State University and is a generalized network flow program developed specifically to simulate river basins and reservoir operations that are operated on a priority-based system (Labadie, et al. 2000). MODSIM was used in the original Operations and Yield Model (MW 1998), the updated Raw Water Yield Study (MWH 2005a), the SDS EIS Daily Model (MWH 2004), and numerous other modeling efforts in the Arkansas River Basin (MW 2001, MWH 2002).

The Operations and Yield Model uses 1950 through 2003 historical hydrology, resulting in a 54-year study period. This study period covers three major droughts that occurred in both the Colorado River and Arkansas River Basins: the early 1950's drought, the mid-to-late 1970's drought and the early 2000's drought.

2.3 Simulation of Preliminary Alternatives for Colorado Springs Utilities

Each of the preliminary alternatives is made up of 7 components, with up to 5 different options for each component. Because the sizes of the options for each component have been standardized, the site characteristics among alternatives is assumed to be relatively equal at this stage, and some of the components do not vary among alternatives, the number of preliminary alternatives requiring simulation in the Operations and Yield Model was substantially less than the total number of alternatives. The only differences among the alternatives simulated were:

- the location of the raw water intake, which affects how water is delivered to the intake location (either by exchange or direct diversion);
- whether the full Pueblo Flow Management Program (City of Pueblo 2004a, 2004b) was assumed to be implemented or not implemented;
- whether the Upper Arkansas Voluntary Flow Management Program (Walcher, 2003) was assumed to be implemented or not implemented;

- location and size of a potential exchange/reusable return flow pipeline.

The existing condition was also simulated to provide a basis for comparing potential increases in yield. A summary of the standardized modeling components is shown in Table 1, while a summary of the existing condition and alternatives simulated is shown in Table 2.

For all alternatives, it was assumed that exchanges could be made to Pueblo Reservoir under existing decrees (MWH 2005b). For the raw water intake alternative downstream of Fountain Creek (model Run D, K, P and N), reusable return flows could be diverted directly from the Arkansas River without need for a decree as no exchanges are necessary in this scenario. For the alternative with the intake upstream of Fountain Creek (model run C, J, O and M), it was assumed that no exchanges could be made to the raw water intake and all reusable return flows and other consumptive use water must be exchanged to Pueblo Reservoir first then released from Pueblo Reservoir to the intake. For alternatives with the intake at the Lester & Attebery diversion (near Brush Hollow Reservoir), it was also assumed that no junior exchange could be made to the raw water intake and that all water must be exchanged up to Twin and Turquoise Reservoirs or to the Arkansas River at the Otero Pump Station intake and then be released to the intake.

Table 1. Standardized Modeling Components for Colorado Springs Utilities

Components	Options	Assumed Value in Operations and Yield Model
Regulating Storage	Pueblo Reservoir	28,000 ac-ft
Raw Water Intake	Pueblo Reservoir	Varies
	Arkansas River upstream of Fountain Creek	
	Arkansas River downstream of Fountain Creek	
	Lester & Attebery diversion near Highway 115	
Raw Water Conveyance	Western Alignment	70.7 mgd (1)
	Eastern Alignment	
	Highway 115 Alignment	
Terminal Storage & Water Treatment Plant	One of Several Reservoir Options within Fountain Creek Basin or One Option with Terminal Storage at Brush Hollow Reservoir and Treatment within Fountain Creek Basin	28,000 ac-ft (2)
Treated Water Conveyance	Participants' Proposed Alignments with Adjustment	(3)
Exchange Storage (for Utilities use only)	One of Several Reservoir Options within Fountain Creek Basin	25,000 ac-ft (2)
Exchange/Return Flow Pipeline (for Utilities use only) (5)	To Pueblo Reservoir	130 cfs for pipeline
	To Arkansas River downstream of Highway 115	
	To Arkansas River at Confluence with Fountain Creek (used in conjunction with exchange storage)	300 cfs for pipeline (4)

Notes:
(1) Colorado Springs Utilities Capacity = 74.45 mgd with 5% assumed down-time.
(2) Value shown is active storage.
(3) Not required for Operations and Yield Model.
(4) Simulated monthly capacity = 150 cfs (based on a peaking factor of 2.0, MWH 2005a)
(5) An exchange pipeline is a pipeline that conveys exchange releases from the exchange reservoir to the Arkansas River. A return flow pipeline conveys reusable return flows from an intake on Fountain Creek near Colorado Springs to the Arkansas River.

Table 2. Simulated Alternatives

Raw Water Intake	Pueblo Flow Management Program (2)	Exchange Storage (3)	Exchange/Return Flow Pipeline	Model Run (1)
None (Existing Conditions)	No Pueblo FMP	None	None	A
Pueblo Reservoir	Full Pueblo FMP	25,000 acre-feet	None	B
			300 cfs to Arkansas River at Fountain Creek Confluence	F
		None	130 cfs to Pueblo Reservoir	E
			130 cfs to Arkansas River downstream of Highway 115	I
Lester & Attebery diversion near Highway 115 (4)	No Pueblo FMP	25,000 acre-feet	None	G
			300 cfs to Arkansas River at Fountain Creek Confluence	L
		None	130 cfs to Pueblo Reservoir	Q
			130 cfs to Arkansas River downstream of Highway 115	H
Arkansas River Upstream of Fountain Creek Confluence (5)	No Pueblo FMP	25,000 acre-feet	None	C
			300 cfs to Arkansas River at Fountain Creek Confluence	J
		None	130 cfs to Pueblo Reservoir	O
			130 cfs to Arkansas River downstream of Highway 115	M
Arkansas River Downstream of Fountain Creek Confluence	No Pueblo FMP	25,000 acre-feet	None	D
			300 cfs to Arkansas River at Fountain Creek Confluence	K
		None	130 cfs to Pueblo Reservoir	P
			130 cfs to Arkansas River downstream of Highway 115	N

Notes:

(1) For all alternatives:
Terminal Storage = 28,000 acre-feet (active storage), Regulating Storage = 28,000 acre-feet
Scenarios were run with and without the Upper Arkansas Voluntary Flow Management Program

(2) Existing condition and all alternatives contain Restoration-of-Yield Storage in Holbrook Reservoir for Colorado Springs Utilities (2,850 ac-ft) and the City of Fountain (310 ac-ft).

(3) Values shown are active storage.

(4) No exchanges can be made to the raw water intake. All reusable return flows and other consumptive use water must be exchanged either to Twin Reservoir or Turquoise Reservoir or to the Arkansas River at the Otero Pump Station intake first, then released from the reservoir to the raw water intake.

(5) No exchanges can be made to the raw water intake. All reusable return flows and other consumptive use water must be exchanged to Pueblo Reservoir first then released from Pueblo Reservoir to the intake.

Because the scenarios simulated by the Operations and Yield Model involved exchanges and other operations that were not originally incorporated into the Operations and Yield Model, the following data and modifications were added to the Operations and Yield Model to simulate the alternatives.

- Transit Losses: The alternatives with intakes upstream of Fountain Creek divert water at locations other than what was originally constructed in the Operations and Yield Model. Transit losses were added to the Operations and Yield Model to account for losses that occur from Pueblo Reservoir to each of the intake locations. Transit losses were taken from those developed for the ArkExcel Model (as described in the Raw Water Yield Study) and are identified in Table 3.

Table 3. Transit Losses Added to Operations and Yield Model.

Upstream Node	Downstream Node	Transit Loss
Pueblo Reservoir	Fountain Creek Confluence	0.58%
Colorado Springs	Holbrook Reservoir	17.2% (1)

Notes:

(1) Arkansas River Loss (12.2%) plus Holbrook Canal Loss (5% from Simpson, 2005)

(2) The Temporary Substitute Water Supply Plan (TSWSP) allows ROY participants to take credit for canal seepage that returns to the Arkansas River (Wolfe, 2005). However, for this analysis, it was assumed that all canal seepage is "lost" from the system.

- Exchanges: Additional exchange potential calculations were required from the ROY storage outlet to the Lake Meredith outlet. Exchange potential was calculated using the Full Exchange Impact Model (as described in the Raw Water Yield Study) assuming that these exchanges would be junior to all existing exchange decrees and pending exchange applications, including those by Aurora (Rocky Ford II, 99CW169), Fountain (01CW146), the Southeastern Colorado Water Conservancy District (01CW151) and Pueblo West (01CW152). Additionally, exchange potential to the Otero Pump Station river intake was calculated for use in the Highway 115 (Lester-Attebery) alternatives. Exchanges to the Otero Pump Station were capped at the Colorado Springs Utilities' existing Otero Pump Station physical capacity (68 mgd) consistent with existing exchange decrees and recommendation regarding interpretation of decree language from Colorado Springs Utilities (Gracely 2005).

- Exchange/Return Flow Pipeline: An option was added to the Operations and Yield Model for a exchange/return flow pipeline. The option has three potential configurations: a pipeline that would convey reusable return flows (Return Flow Pipeline) from the Utilities wastewater treatment facilities to Pueblo Reservoir or (2) the Arkansas River downstream of Highway 115 and, (3) a pipeline that would convey exchange releases (Exchange Pipeline) from an exchange reservoir within the Fountain Creek Basin to the Arkansas River at the Fountain Creek confluence. The Pueblo Reservoir and the Highway 115 pipelines were sized at the same capacity as the proposed exchange reservoir inflow facilities of 130 cfs. The Arkansas River pipeline was sized at the same capacity as the proposed exchange reservoir outlet required for exchange releases of 300 cfs. Using a 2.0 peaking factor outlined in Raw Water Yield Study (MWH 2005a), the monthly capacity used in the simulation model is 150 cfs.

2.4 Fountain and Security Analysis

Based upon information supplied by Fountain and Security, the SDS Purpose and Need Statement contains the yields shown in Table 4 for the Proposed Action. These yields are based on information supplied by the entities through their own planning and yield analyses.

Table 4. Fountain and Security Reported Firm and Average Yields for the Proposed Action

Entity	Firm Yield (ac-ft)			Average Yield (ac-ft)		
	Existing Supplies	SDS Project Yield	Supplies with SDS Project	Existing Supplies	SDS Project Yield	Supplies with SDS Project
Fountain	5,600	2,500	8,100	6,600	2,500	9,100
Security	4,000	1,400	5,400	4,000	1,500	5,500

The yield studies performed by Fountain and Security are much more general in nature than those performed by Utilities. Neither entity has documented the use of an exchange model or other type of operations model to analyze different exchange scenarios and Pueblo Flow Management Program scenarios and their impact on yields of the SDS Proposed Action or alternatives. Therefore, this section describes a more general approach to determine the impacts of alternatives on the yields for Fountain and Security. This approach was developed based upon a review of the water rights proposed by each entity to fill the proposed SDS regulating storage space and the SDS pipeline.

Fountain

Fountain's Long-Term Excess Capacity request (regulating storage) is 2,500 acre-feet. Through information supplied to MWH by Fountain, Fountain's primary source of water for SDS is Fry-Ark reusable return flows. Based on an annual allocation of 2,000 acre-feet (Reclamation 1979), 5 percent downtime for delivery of FVA water, a 60 percent return flow ratio (B&V 2004) and a 6 percent Fountain Creek transit loss (MWH 2005a), reusable return flows could supply approximately 2,500 acre-feet per year to SDS. Additionally, Fountain has purchased the Miller Ditch water right (expected yield 300 acre-feet on average), which is currently under review in water court. The source water supply exceeds the storage request to account for reservoir evaporation and losses due to inadequate exchange potential.

Fountain's sewered Fry-Ark reusable return flows in Fountain Creek can be exchanged into Pueblo Reservoir under the SECWCD 1939 Decree priority, which is senior to all other exchanges on the river. Any new water rights would be exchanged under Fountain's currently pending exchange applications (01CW108, 01CW146), which would be junior exchanges. Fountain has the same general agreements as Utilities regarding the Pueblo FMP and typically, due to the diverse water rights portfolio, would be impacted by the Pueblo FMP similarly to Utilities.

Security

Currently, Security plans on filling regulating storage in Pueblo Reservoir (1,500 acre-feet) and the SDS pipeline "using Fry-Ark sewered return flows and additional water rights it will acquire in the future" (W.W. Wheeler 2005). It is likely that Fry-Ark sewered return flows could fill the storage space. Using Security's maximum annual Fry-Ark allocation of 1,646 acre-feet, a 5 percent "downtime" for FVA pipeline deliveries, sewered return flow ratios approximately equal to those of Utilities (approximately 58% of total deliveries; MWH 2005a), and a 6 percent Fountain Creek transit loss (MWH 2005a), reusable return flows could supply approximately 1,900 acre-feet per year to SDS. The source water supply exceeds the storage request to account for reservoir evaporation and losses due to inadequate exchange potential. Security's sewered Fry-Ark reusable return flows could be exchanged into Pueblo Reservoir under the SECWCD 1939 Decree priority, which is senior to all other exchanges on the river.

Fountain plans on using a water rights portfolio that is similar to that proposed for use by Utilities and would be affected by the Pueblo Flow Management Program in a similar way (especially considering the use of ROY storage). Security plans on using a combination of very senior and very junior water rights that bracket those proposed for use by Utilities. Because both Fountain and Security would fill the regulating storage using exchanges in the Arkansas River Basin in which the net yield would likely be affected by exchange priority and Pueblo Flow Management Program operations similar to Utilities, the yields for alternatives are assumed to be impacted at an equal percentage to those found using the modeling approach for Utilities.

Because operations of the SDS Proposed Action and alternatives for both Fountain and Security are similar to those of Utilities, the ratio of the Utilities' alternative average yield to their Proposed Action average yield was multiplied by Fountain and Security's Proposed Action average yield to estimate the average yield of the alternative. This can be represented by the following equation:

$$FAY_{alt} = FAY_{PA} * (CAY_{alt}/CAY_{PA})$$

where:

CAY_{PA} = Colorado Springs Utilities Average Yield, Proposed Action
CAY_{alt} = Colorado Springs Utilities Average Yield, Alternative
FAY_{PA} = Fountain/Security Average Yield, Proposed Action
FAY_{alt} = Fountain/Security Average Yield, Alternative

For the firm yield, the ratio of firm yield to average yield for the Proposed Action was multiplied by the average yield for the alternative. This can be represented by the following equation:

$$FFY_{alt} = FAY_{alt} * (FFY_{PA}/FAY_{PA})$$

where:

FFY_{PA} = Fountain/Security Firm Yield, Proposed Action

FFY_{alt} = Fountain/Security Firm Yield, Alternative

This is a more realistic approach than using the firm yield ratios because the documentation for both Fountain and Security indicates that they will only find enough water supply to meet average yield. Because Fountain and Security will take full delivery of the average yield each year, their systems will likely behave much more like Utilities' average yield rather than firm yield.

By definition, the average and firm yields for Fountain and Security cannot exceed their annual participation rate in SDS of 2,500 acre-feet and 1,500 acre-feet, respectively. These maximum values were used to cap all calculated yields using the method described above.

3. Results

3.1 Colorado Springs Utilities

Results for the specific Operations and Yield Model runs made as part of the Utilities yield analysis without the Upper Arkansas Voluntary Flow Management Program are shown in Table 5. Results with the Upper Arkansas Voluntary flow Management Program are shown in Table 6.

The following definitions apply to average and firm yield:

- Firm yield is the highest system demand level that can be continuously fulfilled for the hydrologic study period. The firm yield is the demand level achieved just prior to the level that produces system shortages.
- Average yield is the average annual system yield of the raw water collection, storage, and distribution system for any given constant annual demand. For purposes of this analysis, the average yield was calculated at the estimated 2046 demand level of 197,512 acre-feet. This demand level is slightly lower than the analyses contained in the Raw Water Yield Study of approximately 200,147 acre-feet (MWH 2005a).

The Operations and Yield Model only calculates yields of Utilities' system as a whole, or "System Yield" – it cannot be used to directly calculate the yield of an individual alternative. Yields of individual alternatives, or "Project Yield," is defined as the difference in system yield with and without the alternative. All of the yields presented in Tables 5 and 6 are Project Yields, and were calculated using the following Existing System yields as determined by the Operations and Yield Model (model run A). System yields are presented in the Appendix.

Existing System Firm Yield: 119,000 acre-feet
Existing System Average Yield: 132,200 acre-feet

Table 5. Incremental Firm and Average Project Yield for Colorado Springs Utilities *without* the Upper Arkansas Voluntary Flow Management Program

Raw Water Intake	Exchange/Return Flow Pipeline							
	None		Arkansas River at Fountain Creek		Pueblo Reservoir		D/S of Highway 115	
Pueblo Reservoir	B	Firm: 38,000 Average: 48,100	F	Firm: 42,000 Average: 54,400	E	Firm: 71,000 Average: 64,700	I	Firm: 70,500 Average: 64,200
Lester & Attebery near Highway 115	G	Firm: 38,000 Average: 45,700	L	Firm: 39,500 Average: 51,400	Q	Firm: 39,500 Average: 52,200	H	Firm: 39,500 Average: 51,800
Arkansas River Upstream of Fountain Creek	C	Firm: 42,000 Average: 50,200	J	Firm: 45,000 Average: 56,100	O	Firm: 71,000 Average: 64,600	M	Firm: 70,000 Average: 64,100
Arkansas River Downstream of Fountain Creek	D	Firm: 64,500 Average: 61,800	K	Firm: 68,000 Average: 64,700	P	Firm: 71,000 Average: 64,600	N	Firm: 70,000 Average: 64,100

Notes:

(1) All yield values in acre-feet.
(2) Model runs correspond to those scenarios shown in Table 4..
(3) No Exchange Reservoir for Scenarios with Return Flow Pipeline to Pueblo Reservoir or D/S of Highway 115.

Table 6. Incremental Firm and Average Project Yield for Colorado Springs Utilities *with* the Upper Arkansas Voluntary Flow Management Program

Raw Water Intake	Exchange/Return Flow Pipeline							
	None		Arkansas River at Fountain Creek		Pueblo Reservoir		D/S of Highway 115	
Pueblo Reservoir	B	Firm: 38,000 Average: 48,000	F	Firm: 42,000 Average: 54,400	E	Firm: 71,000 Average: 64,600	I	Firm: 70,500 Average: 64,200
Lester & Attebery near Highway 115	G	Firm: 32,500 Average: 42,800	L	Firm: 32,500 Average: 47,400	Q	Firm: 32,000 Average: 47,200	H	Firm: 32,000 Average: 46,700
Arkansas River Upstream of Fountain Creek	C	Firm: 42,000 Average: 50,200	J	Firm: 45,000 Average: 56,100	O	Firm: 71,000 Average: 64,600	M	Firm: 70,500 Average: 64,100
Arkansas River Downstream of Fountain Creek	D	Firm: 64,500 Average: 61,800	K	Firm: 68,000 Average: 64,700	P	Firm: 71,000 Average: 64,600	N	Firm: 70,500 Average: 64,100

Notes:

(1) All yield values in acre-feet.
(2) Model runs correspond to those scenarios shown in Table 4..
(3) No Exchange Reservoir for Scenarios with Return Flow Pipeline to Pueblo Reservoir or D/S of Highway 115.

The following can be noted regarding the yield analysis.

- Most runs that included a diversion from the Lester & Attebery diversion near Highway 115 (model runs G, L, Q and H) had the lowest firm and average yields that were analyzed. This is due, in part to the 190-cfs flow requirement for the Arkansas River above the Florence wastewater treatment facility discharge that limits the amount of water that can be exchanged from Fountain Creek and Pueblo Reservoir to the Upper Basin, then released back down to the Lester & Attebery diversion..
- The Proposed Action (model run B) had the next lowest firm and average yield of the alternatives analyzed.

- The Lester-Attebery alternative with an exchange pipeline to Fountain Creek (model run L) shows a higher yield than the alternatives with a return flow pipeline to Pueblo Reservoir or Highway 115 (model runs Q and H) because of exchange storage in the Fountain Creek basin.
- The Upstream of Fountain Creek alternative (model run C) shows a slightly higher yield than the Proposed Action (model run B) although they are essentially the same operationally (other than their point-of-diversion) because the Diversion Upstream of Fountain Creek (no junior exchange) does not include the Pueblo Flow Management Program.
- The Downstream of Fountain Creek alternative (model run D) yield is higher than the Proposed Action (model run B) and Diversion Upstream of Fountain Creek alternative (model run C) yields because it allows direct diversion of reusable return flows (no decree is required for this diversion).
- The alternatives in which the return flow pipeline returns upstream of or to Pueblo Reservoir and the diversion pipeline is at or downstream of Pueblo Reservoir (model runs E, O and P), show the highest firm and average yields. This is because the reusable return flows are delivered to a storage facility without any exchange losses. Therefore, in times of drought, they can be used despite inadequate exchange potential. Furthermore, because these flows are taken directly from Pueblo Reservoir or released downstream to the points of diversion, the system is virtually a closed system except for a few minor transit losses.
- The Proposed Action with exchange reservoir and exchange pipeline to Arkansas River alternative (model run F) shows a slight increase in firm and average yield over the Proposed Action. The increases in yield are due to a decrease in transit loss incurred by transporting exchange releases in a pipeline rather than Fountain Creek. However, significant increases in yield are not realized by this alternative because exchange potential is not different for this alternative than it is for the Proposed Action.
- The Upper Arkansas Voluntary Flow Management Program does not have a significant impact on firm or average yield except on the alternatives that include a raw water intake at Highway 115. Alternatives with raw water intakes at Highway 115 are affected because all water must be exchanged upstream to the Upper Arkansas River Basin, then released downstream, and thus the yield is directly dependent upon exchange potential through this reach. Those alternatives that include diversions at or below Pueblo Reservoir storage are not as dependent upon the Upper Basin exchange and impacts of the UAVFMP are automatically mitigated by the model using upstream and downstream storage.
- The simulated firm yield for two of the alternatives with a return flow pipeline downstream of Highway 115 (model runs M and N) are higher under the scenario with UAVFMP restrictions than without the restrictions. This occurs because the model always makes exchanges to the Upper Basin as soon as possible to keep Upper Basin storage full. With the UAVFMP restrictions, a small portion of these exchanges are forced to remain in Pueblo Reservoir and transit losses are reduced when they are delivered through the proposed SDS. Therefore, the UAVFMP "forces" the model to be slightly more efficient than without the restrictions. Also, because of the 500 acre-foot increments in firm yield calculations, the results show more difference than there actually is between the simulations. The simulated shortages in the firm yield year for the scenarios without the restrictions is 0.2 percent of the annual demand.
- Firm yield is greater than average yield for alternatives in which the exchange/return flow pipeline is upstream of the diversion location because the alternative is able to recapture a portion of the firm yield that is lost due to exchange potential during existing conditions. Therefore, the impact of these

alternatives are greater for firm yield than for system yield. However, as shown in the appendix, overall system firm yield is always less than average yield in 2046.

3.2 City of Fountain

Results for estimated yield analysis without and with the Upper Arkansas Voluntary Flow Management Program for Fountain are shown in Table 7 and Table 8, respectively. Except for those alternatives with the raw water intake near Highway 115, all of the simulated firm and average yields for Utilities increased from the SDS Proposed Action. For these alternatives, the simulated average and firm yields for Fountain were capped at their annual participation volume to SDS of 2,500 acre-feet. Without the 2,500 acre-foot constraint, firm and average yields for all alternatives would be 100 to 700 acre-feet higher than the Proposed Action firm and average yield. The alternatives that included a raw water diversion near Highway 115 had lower firm and average yields than the Proposed Action and the yields were calculated as described in section 2.4. However, this method does not necessarily account for the junior exchange status of Fountain for exchanges to the Upper Basin, and because Utilities may use nearly all of the exchange potential for its operations, the method may overstate expected yields of the Highway 115 alternatives for Fountain.

Table 7. Incremental Firm and Average Project Yield for the City of Fountain *without* the Upper Arkansas Voluntary Flow Management Program.

	Exchange/Return Flow Pipeline							
Raw Water Intake		**None**		**Arkansas River at Fountain Creek**		**Pueblo Reservoir**		**D/S of Highway 115**
Pueblo Reservoir	**B**	Firm: 2,500 Average: 2,500	**F**	Firm: 2,500 Average: 2,500	**E**	Firm: 2,500 Average: 2,500	**I**	Firm: 2,500 Average: 2,500
Lester & Attebery near Highway 115	**G**	Firm: 2,400 Average: 2,400	**L**	Firm: 2,500 Average: 2,500	**Q**	Firm: 2,500 Average: 2,500	**H**	Firm: 2,500 Average: 2,500
Arkansas River Upstream of Fountain Creek	**C**	Firm: 2,500 Average: 2,500	**J**	Firm: 2,500 Average: 2,500	**O**	Firm: 2,500 Average: 2,500	**M**	Firm: 2,500 Average: 2,500
Arkansas River Downstream of Fountain Creek	**D**	Firm: 2,500 Average: 2,500	**K**	Firm: 2,500 Average: 2,500	**P**	Firm: 2,500 Average: 2,500	**N**	Firm: 2,500 Average: 2,500

Table 8. Incremental Firm and Average Project Yield for the City of Fountain *with* the Upper Arkansas Voluntary Flow Management Program.

	Exchange/Return Flow Pipeline							
Raw Water Intake		**None**		**Arkansas River at Fountain Creek**		**Pueblo Reservoir**		**D/S of Highway 115**
Pueblo Reservoir	**B**	Firm: 2,500 Average: 2,500	**F**	Firm: 2,500 Average: 2,500	**E**	Firm: 2,500 Average: 2,500	**I**	Firm: 2,500 Average: 2,500
Lester & Attebery near Highway 115	**G**	Firm: 2,200 Average: 2,200	**L**	Firm: 2,500 Average: 2,500	**Q**	Firm: 2,500 Average: 2,500	**H**	Firm: 2,400 Average: 2,400
Arkansas River Upstream of Fountain Creek	**C**	Firm: 2,500 Average: 2,500	**J**	Firm: 2,500 Average: 2,500	**O**	Firm: 2,500 Average: 2,500	**M**	Firm: 2,500 Average: 2,500
Arkansas River Downstream of Fountain Creek	**D**	Firm: 2,500 Average: 2,500	**K**	Firm: 2,500 Average: 2,500	**P**	Firm: 2,500 Average: 2,500	**N**	Firm: 2,500 Average: 2,500

3.3 Security Water District

Results for estimated yield analysis without and with the Upper Arkansas Voluntary Flow Management Program for Security are shown in Table 9 and Table 10, respectively. As with Fountain, all of the simulated firm and average yields for Utilities that increased from the SDS Proposed Action were capped at their annual participation volume to SDS of 1,500 acre-feet. Without the 1,500 acre-foot constraint, firm and average yields for all alternatives that did not include the raw water intake near Highway 115, would be up to 400 acre-feet higher than the Proposed Action firm and average yield. The alternatives that included a raw water intake near Highway 115 had lower firm and average yields than the Proposed Action and the yields were calculated as described in section 2.4. However, this method does not necessarily account for the junior exchange status of Fountain and Security for exchanges to the Upper Basin, and because Colorado Springs Utilities may use nearly all of the exchange potential for its operations, the method may overstate expected yields of the Highway 115 alternatives for Security.

Table 9. Incremental Firm and Average Project Yield for Security Water District *without* the Upper Arkansas Voluntary Flow Management Program.

	Exchange/Return Flow Pipeline							
Raw Water Intake	**None**		**Arkansas River at Fountain Creek**		**Pueblo Reservoir**		**D/S of Highway 115**	
Pueblo Reservoir	**B**	Firm: 1,400 Average: 1,500	**F**	Firm: 1,400 Average: 1,500	**E**	Firm: 1,400 Average: 1,500	**I**	Firm: 1,400 Average: 1,500
Lester & Attebery near Highway 115	**G**	Firm: 1,300 Average: 1,400	**L**	Firm: 1,400 Average: 1,500	**Q**	Firm: 1,400 Average: 1,500	**H**	Firm: 1,400 Average: 1,500
Arkansas River Upstream of Fountain Creek	**C**	Firm: 1,400 Average: 1,500	**J**	Firm: 1,400 Average: 1,500	**O**	Firm: 1,400 Average: 1,500	**M**	Firm: 1,400 Average: 1,500
Arkansas River Downstream of Fountain Creek	**D**	Firm: 1,400 Average: 1,500	**K**	Firm: 1,400 Average: 1,500	**P**	Firm: 1,400 Average: 1,500	**N**	Firm: 1,400 Average: 1,500

Table 10. Incremental Firm and Average Project Yield for Security Water District with the Upper Arkansas Voluntary Flow Management Program.

	Exchange/Return Flow Pipeline							
Raw Water Intake	**None**		**Arkansas River at Fountain Creek**		**Pueblo Reservoir**		**D/S of Highway 115**	
Pueblo Reservoir	**B**	Firm: 1,400 Average: 1,500	**F**	Firm: 1,400 Average: 1,500	**E**	Firm: 1,400 Average: 1,500	**I**	Firm: 1,400 Average: 1,500
Lester & Attebery near Highway 115	**G**	Firm: 1,200 Average: 1,300	**L**	Firm: 1,400 Average: 1,500	**Q**	Firm: 1,400 Average: 1,500	**H**	Firm: 1,400 Average: 1,500
Arkansas River Upstream of Fountain Creek	**C**	Firm: 1,400 Average: 1,500	**J**	Firm: 1,400 Average: 1,500	**O**	Firm: 1,400 Average: 1,500	**M**	Firm: 1,400 Average: 1,500
Arkansas River Downstream of Fountain Creek	**D**	Firm: 1,400 Average: 1,500	**K**	Firm: 1,400 Average: 1,500	**P**	Firm: 1,400 Average: 1,500	**N**	Firm: 1,400 Average: 1,500

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5. Appendix

Table A1. Firm and Average System yield for Existing Conditions used to calculate project yield

Existing Condition System Yields	**A**	Firm: 119,000 Average: 132,200

Table A2. Firm and Average System Yield for Colorado Springs Utilities *without* the Upper Arkansas Voluntary Flow Management Program

Raw Water Intake	Exchange/Return Flow Pipeline: None		Arkansas River at Fountain Creek		Pueblo Reservoir		D/S of Highway 115	
Pueblo Reservoir	**B**	Firm: 157,000 Average: 180,300	**F**	Firm: 161,000 Average: 186,600	**E**	Firm: 190,000 Average: 196,900	**I**	Firm: 189,500 Average: 196,400
Lester & Attebery near Highway 115	**G**	Firm: 157,000 Average: 177,900	**L**	Firm: 158,500 Average: 183,600	**Q**	Firm: 158,500 Average: 184,400	**H**	Firm: 158,500 Average: 184,000
Arkansas River Upstream of Fountain Creek	**C**	Firm: 161,000 Average: 182,400	**J**	Firm: 164,000 Average: 188,300	**O**	Firm: 190,000 Average: 196,800	**M**	Firm: 189,900 Average: 196,300
Arkansas River Downstream of Fountain Creek	**D**	Firm: 183,500 Average: 194,000	**K**	Firm: 187,000 Average: 196,900	**P**	Firm: 190,000 Average: 196,800	**N**	Firm: 189,000 Average: 196,300

Table A3. Firm and Average System Yield for Colorado Springs Utilities *with* the Upper Arkansas Voluntary Flow Management Program

Raw Water Intake	Exchange/Return Flow Pipeline: None		Arkansas River at Fountain Creek		Pueblo Reservoir		D/S of Highway 115	
Pueblo Reservoir	**B**	Firm: 157,000 Average: 180,200	**F**	Firm: 161,000 Average: 186,600	**E**	Firm: 190,000 Average: 196,800	**I**	Firm: 189,500 Average: 196,400
Lester & Attebery near Highway 115	**G**	Firm: 151,500 Average: 175,000	**L**	Firm: 151,500 Average: 179,600	**Q**	Firm: 151,000 Average: 179,400	**H**	Firm: 151,000 Average: 178,900
Arkansas River Upstream of Fountain Creek	**C**	Firm: 161,000 Average: 182,400	**J**	Firm: 164,000 Average: 188,300	**O**	Firm: 190,000 Average: 196,800	**M**	Firm: 189,500 Average: 196,300
Arkansas River Downstream of Fountain Creek	**D**	Firm: 183,500 Average: 194,000	**K**	Firm: 187,000 Average: 196,900	**P**	Firm: 190,000 Average: 196,800	**N**	Firm: 189,500 Average: 196,300

Table A4. Example of Project Yield Calculations for Tables 5 and 6 (Model Run B)

Raw Water Intake		**Exchange/Return Flow Pipeline**
		None
Pueblo Reservoir	**B**	Firm Yield System Firm: 157,000 (From Table A2) - Existing Condition: 119,000 (From Table A1) = Project Firm: 38,000 (Value in Table 5) Average Yield System Average: 180,300 (From Table A2) - Existing Condition: 132,200 (From Table A1) = Project Average: 48,100 (Value in Table 5)