CHAPTER FOUR
Environmental Impacts

This chapter analyzes impacts to resources in the Angostura Reservoir area from the alternatives detailed in Chapter Two:

- The *No Action Alternative*, in which no change would occur in the water service contract with the District (Angostura Irrigation District) beyond those required by law, and no change in water management at the reservoir; this alternative serves as a basis of comparison for the other alternatives as required by NEPA (National Environmental Policy Act) regulations
- *Reestablishment of Natural Flows Below the Dam Alternative*, which would reestablish natural flows to the extent possible in the Cheyenne River below Angostura Dam
- *Improved Efficiencies Alternative* (the Preferred Alternative) which would implement measures to save irrigation water and would create a public process to advise how the water saved should be used
- *Reservoir Recreation and Fisheries Alternative*, which would emphasize recreational use and fisheries at the reservoir.

Direct and indirect impacts on surface water quantity; surface water quality; groundwater;

sediment; the stream corridor; wetlands; wildlife; threatened or endangered fish and wildlife species; social and economic conditions; Indian Trust Assets; environmental justice; and cultural and paleontological resources are detailed in this chapter. The period of analysis extended for a minimum of 25 years into the future (the term of the water service contract), except when a longer period of analysis allowed presentation of more representative information.

Cumulative impacts—those resulting from a combination of the effects of the alternatives with past, present, or reasonably foreseeable actions—follow this discussion in a section of its own.

Chapter Four concludes with sections on unavoidable adverse impacts, short-term uses in comparison to long-term productivity, and irreversible and irretrievable commitments of resources.

SURFACE WATER QUANTITY

Water quantity in Angostura Reservoir was predicted by AGRAOP, a surface water computer model (as described in Chapter Three). AGRAOP simulated monthly operation of the reservoir, meeting water demands (if possible) from inflows and storage and reaching EOM (end-of-month) water elevations set for the reservoir. Among other information, AGRAOP used inflows into Angostura (including an allowance for evaporation) for the 1953-1997 period, determined to be representative for the area since it contained a prolonged drought in the 1950-1960s and another in the late 1980s. From this period, AGRAOP projected water available for a 45-year period in the future (1998-2042).

The alternatives would affect:

- Storage in the reservoir (see Appendixes I and K for full details)
- Water releases from the reservoir to the District (Appendixes J, L, M, N, and O)
- Releases from the reservoir to the river below the dam (Appendix P)
- Return flows from irrigation to the river (Appendix J)
- Return flows into groundwater aquifers (Appendix J)
- Flows at the town of Red Shirt (Appendix J).

No alternative would affect inflows into the reservoir or water rights outside the District.

Impacts of the No Action Alternative

The No Action Alternative would irrigate up to 12,218 acres in the District. As Angostura Reservoir lost storage to the buildup of sediment, water available for irrigation would decrease. Water for recreation, fisheries, and flows in the river below the dam would be as in the past in this alternative.

Figure 4.1 is a water budget schematic for the Cheyenne River and Angostura Reservoir downstream to Buffalo Gap, based on the 1955-1997 period of record. The river is depicted as a vertical line, the reservoir as a triangle, the canal as a diagonal line. Average annual additions or depletions to flows are the arrows (where two flows are given, the first is for 12,218 irrigated acres, the second for 10,000 acres).

Reservoir Storage

AGRAOP simulated operation of the active conservation pool in the reservoir, ranging from elevation 3163 feet (the level of the District's canal outlet) to elevation 3187.2 feet (top of the spillway gates). Elevation 3187.2 feet was set in the model for December-October target elevations, 3184 feet for November. This would allow releases of water if the reservoir elevation

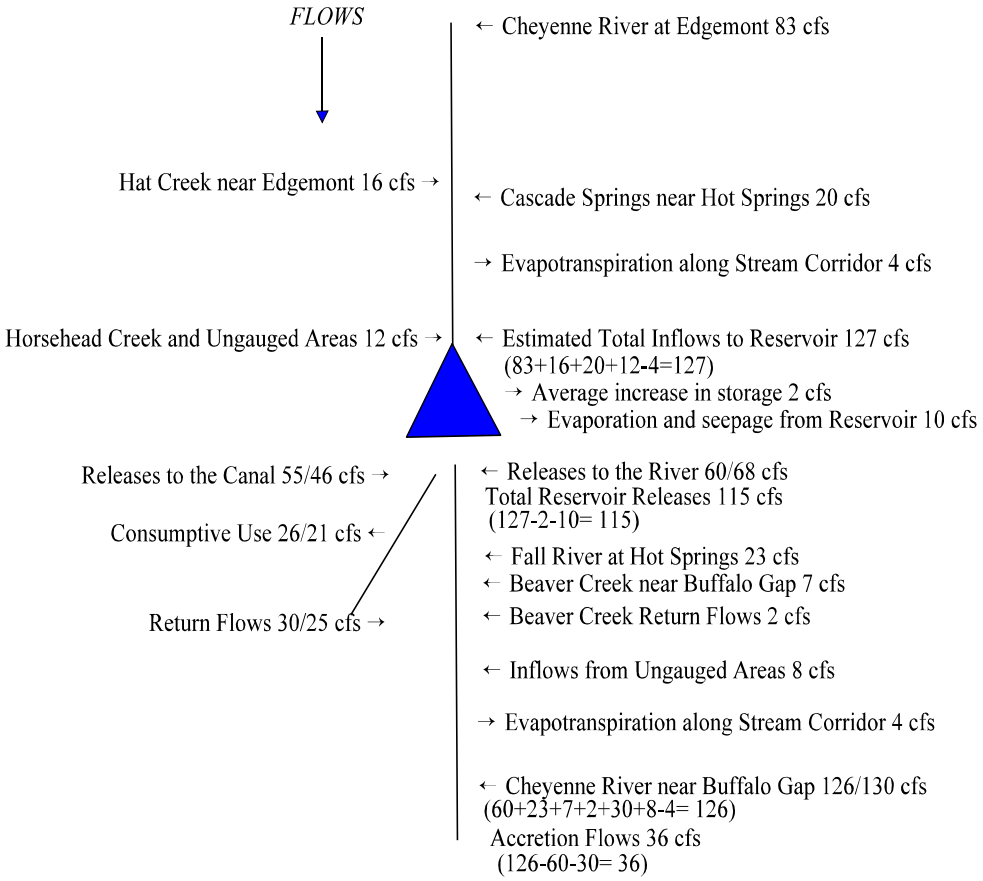


Figure 4.1: Water Budget: No Action Alternative

rose above 3187.2 feet for most of the year but would drop the reservoir back to 3184 feet in November to provide 14,000 AF (acre-feet) of space for winter inflows. The reduction would allow the reservoir to refill in the spring. Reducing storage to elevation 3184 feet would limit winter releases, alleviating freezing problems with radial gate seals and the spillway float wells at the dam, as well as avoiding effects of releases with ice jams in the river.

The 1981 area-capacity table shows active conservation capacity in the reservoir of 82,400 AF, total capacity 130,800 AF (see Chapter Three, Table 3.3). Since capacity is constantly lost to naturally occurring sediment deposition, the DISSED computer program had to estimate area capacities for 1997 and 2042. Table 4.1 shows estimated 1997 active conservation capacity of 79,224 AF (3,243 AF less than the 1981 area-capacity). Estimated 2042 active conservation capacity would be 61,057 AF, 21,400 AF less than 1981.

Historic annual average EOM content was 112,100 AF (at elevation 3179.83 feet), with the highest annual average of 147,600 AF (elevation 3187.61 feet) in 1963, the lowest of

Table 4.1: 1997 and 2042 Area Capacity/Allocations [1]

		Estimated December 1997			Estimated December 2042		
Reservoir Physical Features	**Elevation (Feet)**	**Capacity Allocation**	**Capacity (AF)**	**Area (Acres)**	**Capacity Allocation**	**Capacity (AF)**	**Area (Acres)**
Streambed at Dam Axis	3062.0		0.0	0.0		0.0	0.0
	3125.0		0.0	0.0		0.0	0.0
	3130.0		178.0	126.6		0.0	0.0
	3135.0		1,381.0	353.2		0.0	0.0
Top of Dead/River Outlet Invert	3139.75	3,508.1	3,508.1	539.8	0.0	0.0	0.0
	3140.0		3,620.0	549.6		0.0	0.0
	3145.0		7,171.0	876.0		0.0	0.0
	3150.0		12,232.0	1,148.0		11.0	28.4
	3155.0		18,825.0	1,496.2		1080.0	406.0
Top of Spillway Crest	3157.2		22,528.9	1,661.3		2,430.4	589.2
	3160.0		27,243.0	1,871.5		4,149.0	822.4
Top of Inactive/Canal Outlet	3163.0	29,907.2	33,415.2	2,096.0	7,257.0	7,257.0	1,080.0
	3165.0		37,530.0	2,245.6		9,329.0	1,251.7
Minimum Recreation Pool	3170.0	16,393.8	49,809.0	2,676.1	9,564.0	16,821.0	1,755.6
	3175.0		64,510.0	3,212.5		27,169.0	2,391.5
	3180.0		82,026.0	3,790.7		40,936.0	3,112.3
	3185.0		102,482.0	4,385.8		58,627.0	3,958.3
Top of Active Conservation/Top of Spillway Gates	3187.2	79,223.8	112,639.0	4,841.0	61,057.0	68,314.0	4,841.0
	3190.0		125,705.0	4,959.0		81,720.0	4,959.0
	3195.0		151,645.0	5,417.0		107,660.0	5,417.0
Top of Surcharge/Max. Water Surface	3198.1	56,360.0	168,999.0	5,564.0	56,360.0	124,674.0	5,564.0

[1] Estimated area capacity based on distribution of 985 AF/year of sediment in the reservoir, based on the May 1979 survey.

67,900 AF (elevation 3162.92 feet) in 1989 (Table 4.2). The highest monthly average EOM content of 126,600 AF occurred in May, the lowest of 102,400 AF in September and October. Annual average EOM contents would be 65,900 AF while irrigating 12,218 acres, 71,700 AF while irrigating 10,000 acres. This would be a difference of 46,100 AF and 40,000 AF, respectively, from historic because of sediment buildup and reservoir operation (Table 4.2).

Annual average EOM elevation for 1953-1997 was 3179.81 feet (Table 4.3), the highest average elevation being in May at 3183.42 feet, the lowest in September at 3177.31 feet. The annual average EOM elevation while irrigating 12,218 acres would be 3180.29 feet, 3182.08 feet while irrigating 10,000 acres based on AGRAOP. This is 0.48 and 2.27 feet greater, respectively, than historic EOM elevations due to buildup of sediment (Table 4.3).

Reservoir Releases to the District

Annual average releases into the District's canal were estimated at the CIR (crop irrigation requirement) of 18.74 inches/acre of water based on Modified Blaney-Criddle Method, with 76% canal efficiency and 60% on-farm efficiency (see Chapter Three, "Reservoir Releases to the District"). To irrigate 12,218 acres under these assumptions would require 41,800 AF/year, or 57.8 cfs (cubic feet/second). To irrigate 10,000 acres would require 34,200 AF/year, or 47.3 cfs (Table 4.4).

AGRAOP estimated the District would be able to irrigate 12,218 acres from reservoir releases for all but 3 years during the 1998-2042 period, or 93% of this period (Table 4.4). Water shortages in the 3 years water were short would range from 11,000-32,000 AF. The highest monthly shortage would occur in July and August. To meet the full irrigation need would require an average of 57.8 cfs annually. Annual releases to the canal would average 55.1 cfs.

The District would be able to irrigate 10,000 acres for all but 3 years from 1998-2042, or 93% of this period, the same as with 12,218 acres (Table 4.4). Water shortages in those 3 years would range from 3,000-6,000 AF. The highest monthly shortage would occur in August and September. Annual canal releases would average 46.4 cfs, canal requirements 47.3 cfs.

Reservoir Releases to the River

HYDROMET data showed annual releases to the river for 1953-1997 averaged 59.9 cfs for 1953-1997. The highest annual average was 406.7 cfs, the lowest of less than 3.3 cfs in 12 out of the 45-year period of record, or about 27% of the time.

Releases to the river would be made December-October when reservoir storage were greater than elevation 3187.2 feet. The model estimated annual average releases for 1998-2042 to be 60.2 cfs while irrigating 12,218 acres. The highest annual average was 421.2 cfs, the lowest of 3.3 cfs in 14 out of 45 years, or about 30% of the time. The model included an estimated 200 AF (3.3 cfs) seepage past the dam.

The model estimated annual average river releases for 1998-2042 to be 68.4 cfs, while irrigating 10,000 acres. The highest annual average was 430.0 cfs, the lowest of 3.3 cfs occurring 13 out of 45 years, or about 29% of the time (Table 4.4). Releases would be about 6,100 AF more than in the past.

Annual flows at Buffalo Gap would average 126.0 cfs for 12,218 irrigated acres, 129.5 cfs for 10,000 irrigated acres (Table 4.4 and figure 4.1).

Accretion and Return Flows

Accretion and return flows would remain as at present. Accretion flows would be about 36 cfs,

Table 4.2: No Action Alternative EOM Contents, 1998-2042
(1,000 AF)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average	Annual Minimum	Annual Maximum	Dif.
Historic (1953-1997)[1]	105.9	109.4	117.4	121.7	126.6	126.1	117.4	107.3	102.4	102.4	103.5	104.6	112.1	67.9	147.6	
Irrigating 12,218 acres[2] 1998-2042	61.4	64.9	72.9	76.3	80.2	77.6	68.2	60.0	56.9	57.6	56.9	58.4	65.9	17.5	100.2	-46.1
Irrigating 10,000 acres[3] 1998-2042	67.7	71.2	78.3	80.6	83.8	81.4	73.5	66.6	64.1	64.7	63.2	64.7	71.7	22.5	102.9	-40.4

[1] Actual reservoir operation with an average 10,458 acres irrigated at minimum reservoir elevation of 3163.0 feet; see Appendix K.
[2] 12,218 acres at minimum reservoir elevation of 3163.0 feet, with target elevations December-October of 3187.2 feet and November of 3184.0 feet.
[3] 10,000 acres, with same minimum and target elevations as footnote [2].

Table 4.3: No Action Alternative EOM Contents, 1998-2042
(Feet)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average	Annual Minimum	Annual Maximum	Dif.
Historic (1953-1997)[1]	3,178.3	3,179.2	3,181.2	3,182.2	3,183.4	3,183.3	3,181.2	3,178.6	3,177.3	3,177.4	3,177.7	3,178.1	3,179.8	3,164.9	3,185.6	
Irrigating 12,218 acres[2]	3,179.0	3,180.1	3,182.1	3,183.2	3,184.3	3,183.5	3,181.0	3,178.6	3,177.7	3,177.9	3,177.9	3,178.4	3,180.3	3,165.3	3,185.8	0.48
Irrigating 10,000 acres[3]	3,181.0	3,182.0	3,183.6	3,184.4	3,185.4	3,184.7	3,182.6	3,180.7	3,180.0	3,180.2	3,180.0	3,180.4	3,182.1	3,169.1	3,186.0	2.27

[1] Actual reservoir operation with an average 10,458 acres irrigated at minimum reservoir elevation of 3163.0 feet; see Appendix K.
[2] 12,218 acres at minimum reservoir elevation of 3163.0 feet, with target elevations December-October of 3187.2 feet and November of 3184.0 feet.
[3] 10,000 acres, with same minimum and target elevations as footnote [2].

Table 4.4: Water Availability 1998-2042, No Action Alternative

District Acres at Minimum Elevation	District Irrigation				Annual District Return Flows (cfs)	Annual River Releases from Reservoir (cfs)	Annual River Flows at Buffalo Gap (cfs) [1]
	Average Annual Diversion Requirement (cfs)	Average Annual Releases to Canal (cfs)	Shortage Range (AF)	% of Period Possible			
12,218 acres at 3163 feet [2]	57.8	55.1	11,000-32,000	93	29.8	60.2	126.0
10,000 acres at 3163 feet [3]	47.3	46.4	3,000-6,000	93	25.1	68.4	129.5

[1] Cheyenne River at Buffalo Gap is predicted flow at this gauge based on the Water Budget Analysis (Appendix J).
[2] 12,218 acres at minimum reservoir elevation of 3163 feet, with target elevation December-October of 3187.2 feet and November of elevation 3184 feet; average annual irrigation requirement for 12,218 acres (distribution efficiency = 76%, on-farm efficiency = 60%) = 41,800 AF (57.8 cfs).
[3] 10,000 acres at minimum reservoir elevation of 3163 feet, with target elevation same as for footnote [1] above; average annual irrigation requirement for 10,000 acres (distribution efficiency 76%, on-farm efficiency 60%) = 34,200 AF (47.3 cfs).

return flows 29.8 cfs for 12,218 irrigated acres, for a total of about 66 cfs. Accretion flows would be about 37 cfs, return flows 25.1 cfs for 10,000 irrigated acres, for a total of 62 cfs (Table 4.4 and figure 4.1).

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

This alternative would provide significantly less reservoir storage than the No Action Alternative, resulting in significantly greater flows in the river during most of the year. The river could occasionally dry up in the summer. Inflows to the reservoir would be allowed to pass through, storage would be allowed to fall, and the reservoir would be drawn down to the top of the spillway crest. Spillway gates would remain open. The reservoir's surface area would decrease by about 50% compared to the No Action Alternative. A water budget schematic of the river and reservoir downstream to Buffalo Gap is shown in figure 4.2, based on the 1955-1997 period of record.

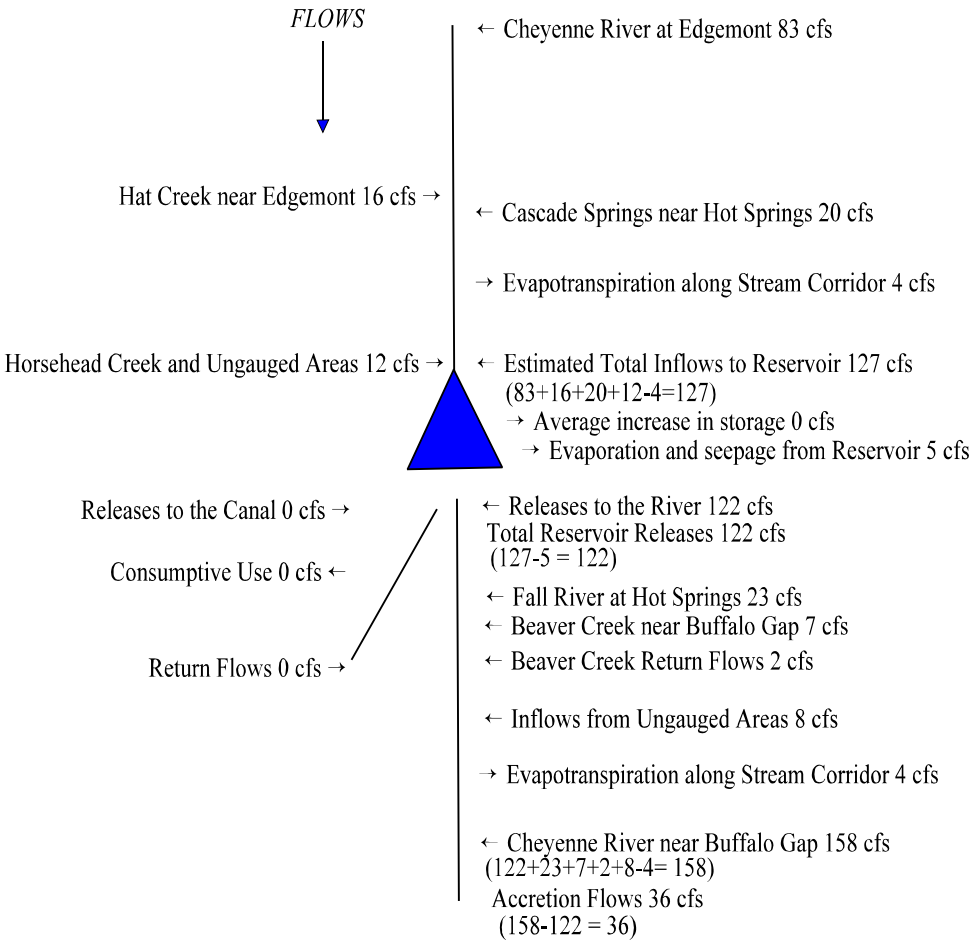


Figure 4.2: Water Budget: Reestablishment Alternative

Reservoir Storage

Maximum water level in the reservoir would be elevation 3159.51 feet, a drop of about 27 feet from the maximum elevation in the No Action Alternative. Storage in 1998-2042 would decrease to an annual average of 13,300 AF, a drop of about 52,600 AF in comparison to No Action (Table 4.5).

Estimated 1997 area-capacity shows a total capacity of about 22,530 AF at elevation 3157.2 feet in this alternative, with a surface area of about 1,661 acres. By 2021, the reservoir would be filled with sediment (assuming 22,000 AF capacity divided by 985 AF of sediment annually). Surface area would be limited except during peak flows, and sediment would pass through the reservoir to the river.

Annual average EOM contents would be 13,300 AF at elevation 3158.92 feet in this alternative, 52,600 AF less than in No Action. The annual average EOM elevation would be 3158.92 feet, 21.4 feet less than in No Action (Table 4.6).

Reservoir Releases to the District

There would be no contract for irrigation in this alternative. Water would be released downstream rather than to the District.

Reservoir Releases to the River

In this alternative, all inflows into the reservoir would become uncontrolled releases to the river (although storage would still exist below the spillway crest of elevation 3157.2 feet until 2021). The model estimated annual average releases to be 120.7 cfs, from 52.3-60.5 cfs more than in No Action.

Maximum floods would not change, but the frequency of mid-range floods (5,000-10,000 cfs) would increase. The river below the dam could occasionally dry up in the summer. Estimated monthly flows in the river at Buffalo Gap are shown in Table 4.7.

Accretion and Return Flows

This alternative would have a minimal effect on accretion flows, which would remain 36 cfs. Since there would be no irrigation, however, there would be no return flows. In low-flow years, minimum flows would be less from May-December, a significant change in comparison to No Action.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

This alternative would provide about 8,000 AF of water to be diverted or used for storage or river flows. Efficiencies of both the District's canal and lateral system and on-farm irrigation would be improved (estimated costs are shown in Chapter 2, Tables 2.1 and 2.2). Irrigation would range from 10,000-12,218 acres per year.

Figure 4.3 shows a water budget schematic for the river and reservoir downstream to Buffalo Gap based on the 1955-1997 period of record. (The first figures are for irrigating 12,218 acres to reservoir elevation 3163 feet, the second set for irrigating 10,000 acres to the same elevation).

Reservoir Storage

AGRAOP simulated operation of the reservoir's active conservation pool as with the No Action Alternative, ranging from the minimum elevation of 3163 feet to the maximum elevation of 3187.2 feet. Target elevations were likewise the same as with No Action: Elevation 3187.2 feet for December-October, 3184 feet for November. Three other minimum elevations were factored into the alternative. Elevation 3170 feet would allow two of the boat ramps to be used, elevation 3175 feet would allow all eight ramps to be used, and elevation 3184 feet would improve recreation and fish spawning. Target elevations for the 3170 feet, 3175 feet, and 3184 feet minimums would be elevation 3187.2 feet for December-May; elevation 3186 feet in June; elevation 3185 feet in July; and elevation 3184 feet for August-November. (Inflows to the reservoir might not allow these elevations to be reached all the time.)

Estimated area capacities would be as described for the No Action Alternative (see Table 4.1). By 2042, sediment would reduce the dead and inactive pool in the reservoir to about 7,000 AF, with active conservation pool capacity about 61,000 AF.

Annual average EOM contents and elevations would vary according to the acres irrigated and the minimum target elevation. Both 12,218 acres and 10,000 acres were modeled at elevations 3163 feet, 3170 feet, 3175 feet, and 3184 feet (Table 4.8). The highest monthly average EOM content with 12,218 irrigated acres would range from 82,400 AF in May to 89,100 AF in April. The lowest monthly average would range from 59,700 AF in September to 75,600 AF in October. This compares to the highest monthly average EOM content of 80,200 AF in May in No Action for 12,218 acres, the lowest monthly average of

Table 4.5: Reestablishment Alternative EOM Contents, 1998-2042
(1,000 AF)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average	Annual Minimum	Annual Maximum	Dif. [1]
No Action (12,218 acres)	61.4	64.9	72.9	76.3	80.2	77.6	68.2	60.0	56.9	57.6	56.9	58.4	65.9	17.5	100.2	-52.6
No Action (10,000 acres)	67.7	71.2	78.3	80.6	83.8	81.4	73.5	66.6	64.1	64.7	63.2	64.7	71.7	22.5	102.9	-58.4
Reestablishment [2]	13.6	13.4	13.5	13.5	13.4	13.3	13.3	13.3	13.1	13.2	13.1	13.2	13.3	3.1	23.7	

Table 4.6: Reestablishment Alternative EOM Elevation, 1998-2042
(Feet)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Aver-age	Annual Mini-mum	Annual Maxi-mum	Diff.[1] (Feet)
No Action (12,218 acres)	3179.0	3180.1	3182.1	3183.2	3184.3	3183.5	3181.0	3178.6	3177.7	3177.9	3177.9	3178.4	3180.3	3165.3	3185.8	+21.4
No Action (10,000 acres)	3181.0	3182.0	3183.6	3184.4	3185.4	3184.7	3182.6	3180.7	3180.0	3180.2	3180.0	3180.4	3182.1	3169.1	3186.0	+23.2
Reestablishment[2]	3159.0	3158.9	3159.0	3159.0	3158.9	3158.9	3158.9	3158.9	3158.8	3158.9	3158.9	3159.0	3158.9	3158.0	3159.5	

[1] Dif. = Difference between annual average Reestablishment contents/elevation minus annual average No Action contents/ elevation.
[2] No irrigation with minimum reservoir elevation 3157.2 feet.

Table 4.7: Reestablishment Alternative Estimated Flows at Buffalo Gap, 1998-2042
(In cfs)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Average	68.9	122.5	241.8	165.8	376.6	424.1	178.2	87.8	54.9	57.3	61.3	62.8	158.5
Minimum	53.8	55.3	61.2	40.1	31.0	20.4	9.2	8.3	18.8	31.4	45.7	52.8	48.6
10 percentile	55.6	61.8	90.5	53.8	41.5	25.1	19.0	12.9	21.4	36.8	49.2	54.4	61.9
Median	61.8	82.3	166.3	128.3	199.5	146.7	62.5	41.0	33.5	44.1	57.5	60.7	124.8
90 percentile	82.7	191.7	525.2	348.9	1,360.6	977.7	354.3	262.4	114.5	73.6	77.7	71.1	302.6
Maximum	196.7	748.7	902.1	916.8	2,596.0	2,916.7	1,406.7	504.3	311.9	246.7	86.2	113.1	595.5

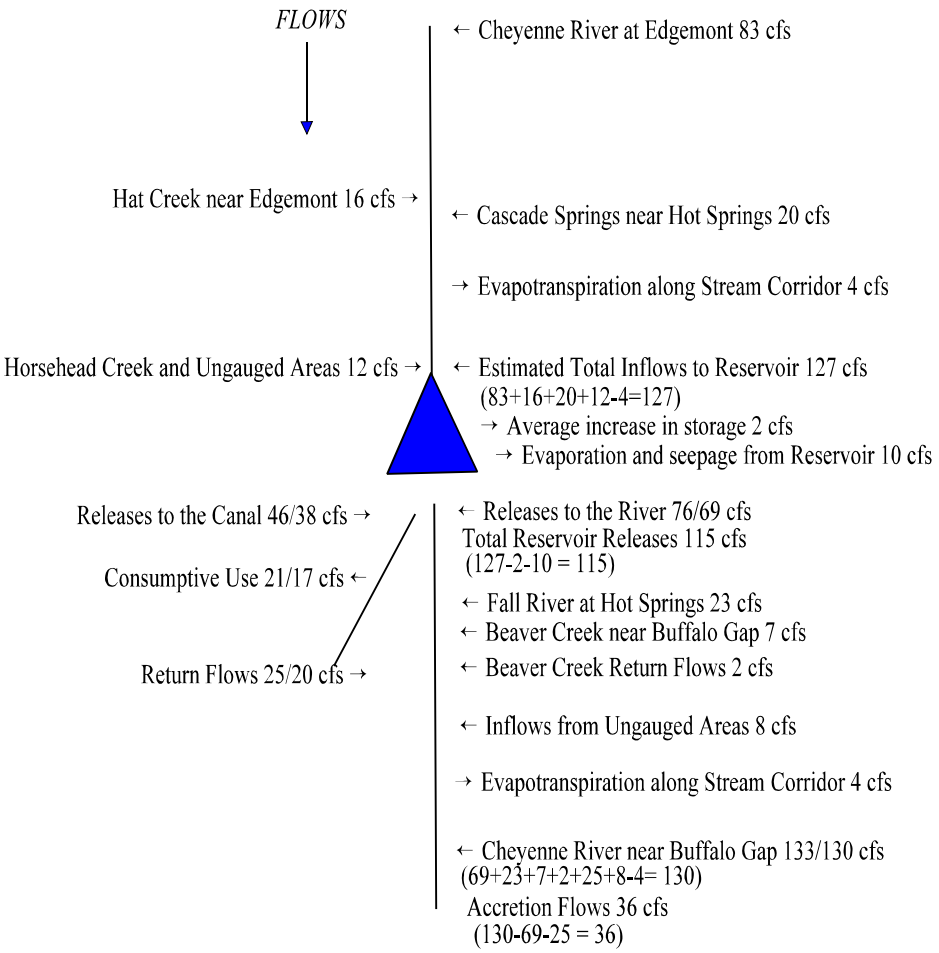


Figure 4.3: Water Budget: Improved Efficiencies Alternative

56,900 AF in September and November. The highest monthly average EOM content with 10,000 irrigated acres would range from 85,300 AF in May to 89,100 AF in April. Lowest monthly average would range 64,400 AF in September to 75,600 AF in October. No Action has a highest monthly average of 83,800 AF in May for irrigating 10,000 acres, the lowest monthly average of 63,200 AF in November.

The highest monthly average EOM elevations with 12,218 irrigated acres would range from elevation 3186.67 feet in April to elevation 3185.14 feet in May (Table 4.9). The lowest monthly average would range from elevations 3179.02-3183.62 feet in October. This compares to the highest monthly average EOM elevation in No Action of 3184.30 feet in May for irrigating 12,218 acres, the lowest monthly average elevation of 3177.63 feet in September. The highest monthly average EOM content with 10,000 irrigated acres would range from elevation 3186.68 feet in April to elevation 3185.66 feet in May. Lowest monthly average would range from elevation 3180.5 in September to elevation 3183.62 in October. No Action has a highest monthly average elevation of 3185.36 feet in May for irrigating 10,000 acres, a lowest monthly average elevation of 3179.98 feet in November.

Table 4.8: Improved Efficiencies EOM Contents, 1998-2042
(1,000 AF)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Aver-age	Annual Mini-mum	Annual Maxi-mum	Dif. [1]
No Action (12,218 acres)	61.4	64.9	72.9	76.3	80.2	77.6	68.2	60.0	56.9	57.6	56.9	58.4	65.9	17.5	100.2	
No Action (10,000 acres)	67.7	71.2	78.3	80.6	83.8	81.4	73.5	66.6	64.1	64.7	63.2	64.7	71.7	22.5	102.9	
12,218 acres at 3163 feet [2]	68.1	71.6	78.2	80.8	84.1	81.7	73.9	67.1	64.6	65.2	63.7	65.1	72.0	22.7	103.1	+6.1
10,000 acres at 3163 feet [3]	73.4	76.9	82.5	84.4	86.5	84.5	78.4	72.9	70.8	71.1	69.0	70.4	76.7	37.0	105.2	+5.0
12,218 acres at 3170 feet [4]	65.6	69.2	76.4	79.5	82.4	78.0	69.6	62.4	59.7	60.0	61.0	62.5	68.9	30.0	100.0	+3.0
10,000 acres at 3170 feet [5]	70.1	73.4	80.0	82.4	85.3	80.3	73.1	66.7	64.4	64.7	65.6	67.1	72.8	35.4	102.1	+1.1
12,218 acres at 3175 feet [6]	66.9	70.5	77.7	80.8	83.6	78.7	70.4	63.5	61.1	61.4	62.4	63.8	70.1	39.6	100.0	+4.2
10,000 acres at 3175 feet [7]	70.9	74.4	80.8	83.4	85.5	80.5	73.5	67.5	65.2	65.4	66.4	67.8	73.4	40.9	102.1	+1.7
12,218 acres at 3184 feet [8]	80.2	83.6	88.4	89.1	88.6	83.1	77.9	76.4	75.9	75.6	75.7	77.2	81.0	61.2	104.3	+15.1
10,000 acres at 3184 feet [9]	80.2	83.6	88.4	89.1	88.9	83.5	78.2	76.4	75.9	75.6	75.7	77.2	81.1	61.2	104.3	+9.4

[1] Dif. = Improved Efficiencies annual average contents minus No Action contents.
[2] 12,218 acres at minimum reservoir elevation of 3163.0 feet, with target elevations December-October 3187.2 feet, November 3184.0 feet.
[3] 10,000 acres at minimum reservoir elevation of 3163.0 feet, with target elevation same as footnote[2].
[4] 12,218 acres at minimum reservoir elevation of 3170.0 feet, with target elevations December- May 3187.2 feet, June 3186 feet, July 3185 feet, and August-November 3184.0 feet.
[5] 10,000 acres at minimum reservoir elevation of 3170.0 feet with target elevation same as footnote[4].
[6] 12,218 acres at minimum reservoir elevation of 3175.0 feet, with target elevation same as footnote[4].
[7] 10,000 acres at minimum reservoir elevation of 3175.0 feet, with target elevation same as footnote[4].
[8] 12,218 acres at minimum reservoir elevation of 3184.0 feet, with target elevation same as footnote[4].
[9] 10,000 acres at minimum reservoir elevation of 3184.0 feet, with target elevation same as footnote[4].

Table 4.9: Improved Efficiencies EOM Elevations (Feet)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average	Annual Minimum	Annual Maximum	Diff. (Feet)[1]
No Action (12,218 acres)	3179	3180.1	3182.1	3183.2	3184.3	3183.5	3181	3178.6	3177.7	3177.9	3177.9	3178.4	3180.3	3165.3	3185.8	
No Action (10,000 acres)	3181	3182	3183.6	3184.4	3185.4	3184.7	3182.6	3180.7	3180	3180.2	3180	3180.4	3182.1	3169.1	3186	
12,218 acres at 3163 ft[2]	3181.1	3182.1	3183.8	3184.4	3185.4	3184.8	3182.8	3180.8	3180.2	3180.4	3180.1	3180.6	3182.2	3169.4	3186	1.9
10,000 acres at 3163 ft[3]	3182.7	3183.6	3185	3185.5	3186.1	3185.6	3184.1	3182.6	3182.1	3182.3	3181.8	3182.2	3183.6	3175.2	3186.2	1.6
12,218 acres at 3170 ft[4]	3180.6	3181.6	3183.4	3184.2	3185.1	3183.9	3181.8	3179.1	3179	3179	3179.5	3180	3181.5	3171.2	3184.8	1.2
10,000 acres at 3170 ft[5]	3181.9	3182.8	3184.4	3185	3184.6	3182.8	3181.1	3181.2	3180.5	3180.6	3180.9	3181.3	3182.6	3174	3185.1	0.5
12,218 acres at 3175 ft[6]	3181.1	3182	3183.8	3184.6	3185.4	3184.2	3182.1	3180.2	3179.6	3179.5	3180	3180	3181.9	3175.5	3184.8	1.6
10,000 acres at 3175 ft[7]	3182.1	3183.1	3184.6	3185.2	3185.8	3184.6	3182.9	3181.4	3180.8	3180.9	3181.2	3181.6	3182.9	3179.1	3185.1	0.8
12,218 acres at 3184 ft[8]	3184.6	3185.4	3186.5	3186.7	3186.6	3185.3	3184.1	3183.8	3183.7	3183.6	3183.7	3184.1	3184.8	3183.6	3185.5	4.5
10,000 acres at 3184 ft[9]	3184.6	3185.4	3186.5	3186.7	3186.6	3185.4	3184.2	3183.8	3183.7	3183.6	3183.7	3184.1	3184.9	3183.7	3185.5	2.8

[1] Dif. = Improved Efficiencies annual average elevation minus No Action elevation.
[2] 12,218 acres at minimum reservoir elevation of 3163.0 feet, with target elevations December-October 3187.2 feet, November 3184.0 feet.
[3] 10,000 acres at minimum reservoir elevation of 3163.0 feet, with target elevation same as footnote[2].
[4] 12,218 acres at minimum reservoir elevation of 3170.0 feet, with target elevations December- May 3187.2 feet, June 3186 feet, July 3185 feet, and August-November 3184.0 feet.
[5] 10,000 acres at minimum reservoir elevation of 3170.0 feet with target elevation same as footnote[4].
[6] 12,218 acres at minimum reservoir elevation of 3175.0 feet, with target elevation same as footnote[4].
[7] 10,000 acres at minimum reservoir elevation of 3175.0 feet, with target elevation same as footnote[4].
[8] 12,218 acres at minimum reservoir elevation of 3184.0 feet, with target elevation same as footnote[4].
[9] 10,000 acres at minimum reservoir elevation of 3184.0 feet, with target elevation same as footnote[4].

Reservoir Releases to the District

The District's delivery system efficiency would be increased to 81% in this alternative, and on-farm efficiency to 70%; otherwise, the assumptions would be as described for the No Action Alternative. Irrigating 12,218 acres would require 33,600 AF/year [46.5 cfs], irrigating 10,000 acres would require 27,500 AF/year [38 cfs] (Table 4.10).

According to AGRAOP, irrigating 12,218 acres would be possible while drawing the reservoir down to elevation 3163 feet for all but 3 years until 2042, or 93% of the period. Water shortages would range from 2,000-5,000 AF (Table 4.10). Irrigating 12,218 acres to elevation 3170 feet would also be possible all but 3 years, or 93% of the period. Shortages would range from 3,000-25,000 AF. Irrigating 12,218 acres to elevation 3175 feet would be possible all but 7 years, or 84% of the period. Shortages would range from 2,000-28,000 AF. Irrigating 12,218 acres to elevation 3184 would be possible only 1 year, or 2% of the period. Shortages would range from 1,000-31,000 AF. To meet full irrigation would require 46.5 cfs, while annual average canal releases would range from 27.8-45.7 cfs

Irrigating 10,000 acres drawing the reservoir to elevation 3163 feet would be possible for all years until 2042. No shortages would occur. Irrigating 10,000 acres to 3170 feet would be possible for all but 2 years, or 96% of the period. Shortages would range from 1,000-3,000 AF. Irrigating 10,000 acres to elevation 3175 feet would be possible all but 2 years, or 96% of the period. Shortages would range from 12,000-17,000 AF. Irrigating 10,000 acres to elevation 3184 would be possible for only 1 year, or 2% of the period. Shortages would range from 700-24,000 AF (Table 4.10). To meet full irrigation would require 38.0 cfs, while annual average canal releases would range from 25-37.7 cfs

Reservoir Releases to the River

AGRAOP estimated releases from the reservoir to irrigate 12,218 and 10,000 acres at a minimum elevation of 3163 feet, with target elevations of 3187.2 feet from December-October and elevation 3184 feet for November. This would allow releases to the river from December-October when reservoir elevation were greater than 3187.2 feet and would allow the reservoir to be reduced 3 feet to elevation 3184 in November to provide space for winter inflows.

Annual releases to the river from 1998-2042 would average 68.9 cfs while irrigating 12,218 acres to reservoir elevation 3163 feet (Table 4.10). Irrigating 12,218 acres to 3170 feet would provide an annual release averaging 70.6 cfs; to 3175 feet 71.5 cfs; and to 3184 feet 86.1 cfs. Irrigating 10,000 acres to elevation 3163 feet would provide an annual release averaging 76.3 cfs; to 3170 feet 77.3 cfs; to 3175 feet 78 cfs; and to 3184 feet 88.8 cfs (Table 4.10). This compares to No Action Alternative annual releases ranging from 60.2 cfs (irrigating 12,218 acres to elevation 3163 feet) to 68.4 cfs (irrigating 10,000 acres to elevation 3163 feet)—see Table 4.4.

Annual average flows in the river at Buffalo Gap would range from 129.6-138.3 cfs, depending on the acreage irrigated and the reservoir level (Table. 4.10).

Accretion and Return Flows

Accretion flows would be 36 cfs, the same as for the No Action Alternative. Return flows would range from 15-24.7 cfs for 12,218 acres, depending on the reservoir level (Table 4.10). For 10,000 acres, return flows would range from 13.5-20.4 cfs. Return flows to groundwater would be reduced because of the improved system efficiencies, but the effect would be minimal.

Table 4.10: Water Availability 1998-2042 in the Improved Efficiencies Alternative

District Acres at Minimum Elevation	District Irrigation				Annual District Return Flows (cfs)	Annual River Releases from Reservoir (cfs)	Annual River Flows at Buffalo Gap[9] (cfs)
	Annual Average Diversion Requirements (cfs)	Annual Averages Releases to the District (cfs)	Shortage Range (AF)	% of Period Possible			
12,218 acres at 3163 feet[1]	46.5	45.7	2,000-5,000	93	24.7	68.9	129.6
12,218 acres at 3170 feet[2]	46.5	44.7	3,000-25,000	93	24.1	70.6	130.7
12,218 acres at 3175 feet[3]	46.5	43.6	2,000-28,000	84	23.5	71.5	131.0
12,218 acres at 3184 feet[4]	46.5	27.8	1,000-31,000	2	15.0	86.1	137.1
10,000 acres at 3163 feet[5]	38.0	37.7	0.0	100	20.4	76.3	132.7
10,000 acres at 3170 feet[6]	37.5	38.0	1,000-3,000	96	20.3	77.3	133.6
10,000 acres at 3175 feet[7]	38.0	36.8	12,000-17,000	96	19.9	78.0	133.9
10,000 acres at 3184 feet[8]	38.0	25.0	700-24,000	4	13.5	88.8	138.3

[1] 12,218 acres at minimum reservoir elevation of 3163 feet, with target elevation December-October of 3187.2 feet, November of elevation 3184 feet; average annual irrigation requirement for 12,218 acres (distribution efficiency = 81%, on-farm efficiency = 70%) = 33,600 AF (46.5 cfs).

[2] 12,218 acres at minimum reservoir elevation of 3170 feet; target elevation December-May of elevation 3187.2 feet, June elevation 3186 feet, July elevation 3185 feet, August-November elevation 3184 feet.

[3] 12,218 acres at minimum reservoir elevation of 3175 feet, with target elevations same as footnote [2].

[4] 12,218 acres at minimum reservoir elevation of 3184 feet, with target elevations same as footnote [2].

[5] 10,000 acres at minimum reservoir elevation of 3163 feet, with target elevations same as footnote [1]; average annual irrigation requirement for 10,000 acres (distribution efficiency = 81%, on-farm efficiency = 70%) = 27,500 AF (38.0 cfs).

[6] 10,000 acres at minimum reservoir elevation of 3170 feet, with target elevations same as footnote [2].

[7] 10,000 acres at minimum reservoir elevation of 3170 feet, with target elevations same as footnote [2].

[8] 10,000 acres at minimum reservoir elevation of 3170 feet, with target elevations same as footnote [2].

[9] Cheyenne River at Buffalo Gap is predicted flow at this gauge based on the water budget analysis (Appendix J).

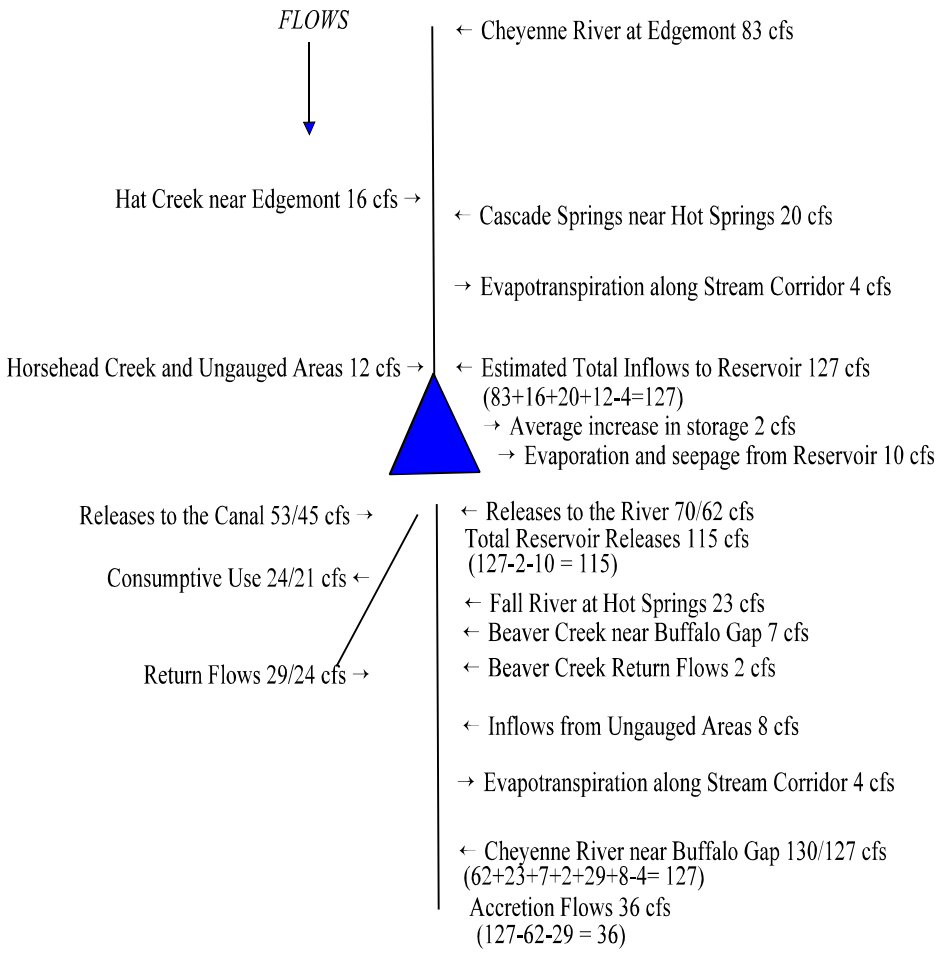


Fig. 4.4: Water Budget: Reservoir Recreation and Fisheries Alternative

Impacts of the Reservoir Recreation and Fisheries Alternative

This alternative would provide more consistent water elevations in the reservoir than No Action, while providing similar flows in the river. Suitable water elevations would be maintained for use of boat ramps and related facilities, for favorable fish spawning, to establish beaches, and to maintain a large reservoir surface area. Irrigation would range from 10,000-12,218 acres/year. The average annual water budget is shown in figure 4.4 showing flows for the river and reservoir downstream to Buffalo Gap based on the 1955-1997 period of record. (The first figures are for 12,218 irrigated acres).

Reservoir Storage

AGRAOP simulated operation of the active conservation pool in the reservoir, ranging from the minimum elevation of 3170 feet to the maximum elevation of 3187.2 feet. Elevation 3170 feet would allow two of the eight boat

ramps to be used, while 3187.2 feet represents the top of the spillway gates. Target elevations in this alternative would be 3187.2 feet from December-May; elevation 3186 feet in June; elevation 3185 feet in July; and elevation 3184 feet in August-November. These targets would allow a foot decrease in elevation in June, July, and August for recreation. Reducing storage from August-November would provide flood protection in the spring and would minimize possibility of releases during winter. (Inflows to the reservoir could limit ability to achieve the target elevations at times.)

Estimated area capacities would be as described for the No Action Alternative (see Table 4.1). By 2042, sediment would reduce the dead and inactive pool in the reservoir to about 7,000 AF, with active conservation pool capacity about 61,000 AF.

Annual average EOM contents and elevations in this alternative would vary according to irrigated acreage and the minimum target elevation. Both 12,218 acres and 10,000 acres were modeled at a minimum elevation of 3170 feet with target elevations of 3187.2 feet, 3186 feet, 3185 feet, and 3184 feet (Table 4.11). Annual average EOM content with 12,218 irrigated acres would be 63,800 AF at elevation 3179.97 feet, 2,100 AF less than in No Action. The highest annual average of 79,300 AF would occur in May, the lowest of 53,600 AF in September. This compares to the highest monthly average EOM content of 80,200 AF in May in No Action for 12,218 acres, the lowest monthly average of 56,900 AF in September and November. The highest monthly average EOM content with 10,000 irrigated acres would be 82,700 AF in May, the lowest 59,200 AF in September. No Action has a highest monthly average of 83,800 AF in May for irrigating 10,000 acres, the lowest monthly average of 63,200 AF in November.

The highest monthly average EOM elevation with 12,218 irrigated acres would be 3184.20 feet in May, while the lowest would be elevation 3177.08 feet in September (Table 4.12). This compares to the highest monthly average EOM elevation in No Action of 3184.30 feet in May for irrigating 12,218 acres, the lowest monthly average elevation of 3177.63 feet in September. The highest monthly average EOM elevation with 10,000 irrigated acres would be elevation 3185.07 feet in May, the lowest elevation 3178.90 in September. No Action has a highest monthly average elevation of 3185.36 feet in May for irrigating 10,000 acres, a lowest monthly average elevation of 3179.98 feet in November.

Reservoir Releases to the District

Distribution system efficiency was estimated at 76% in this alternative, with on-farm efficiency at 60%. Otherwise, assumptions would be as described for the No Action Alternative. Irrigating 12,218 acres would thus require 41,800 AF/year (57.8 cfs), irrigating 10,000 acres would require 34,200 AF/year (47.3 cfs).

AGRAOP predicted that irrigating 12,218 acres would be possible while drawing the reservoir down to elevation 3170 feet for all but 8 years from 1998-2042, or 82% of the period (Table 4.13). Water shortages would range from 3,000-37,000 AF. This compares to being able to irrigate 12,218 acres in the No Action Alternative for all but 3 years, or 93% of the period, with shortages ranging from 11,000-32,000 AF (see Table 4.4). To meet full irrigation would require 57.8 cfs annually, while annual releases would average 53.5 cfs. Irrigating 10,000 acres drawing the reservoir to elevation 3170 feet would be possible for all but 3 years, or 93% of the period. Water shortages would range from 4,000-27,000 AF (Table 4.13). This compares to being able to irrigate 10,000 acres in the No Action Alternative for all but 3 years of the period, with shortages ranging from 3,000-6,000 AF (see

Table 4.11: Reservoir Recreation EOM Contents, 1998-2042
(1,000 AF)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Aver-age	Annual Mini-mum	Annual Maxi-mum	Dif. [1]
No Action (12,218 acres)	61.4	64.9	72.9	76.3	80.2	77.6	68.2	60.0	56.9	57.6	56.9	58.4	65.9	17.5	100.2	
No Action (10,000 acres)	67.7	71.2	78.3	80.6	83.8	81.4	73.5	66.6	64.1	64.7	63.2	64.7	71.7	22.5	102.9	
12,218 acres at 3170 feet[2]	59.8	63.6	71.3	75.8	79.3	74.8	64.6	56.5	53.6	54.2	55.2	56.7	63.8	28.2	97.1	-2.1
10,000 acres at 3170 ft. [3]	65.1	68.8	76.5	79.3	82.7	77.8	69.2	61.9	59.2	59.6	60.6	62.0	68.6	29.5	99.7	-3.1

Table 4.12: Recreation Reservoir EOM Elevations, 1998-2042
(Feet)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Aver-age	Annual Mini-mum	Annual Maxi-mum	Diff. [1] (Feet)
No Action (12,218 acres)	3179.0	3180.1	3182.1	3183.2	3184.3	3183.5	3181.0	3178.6	3177.7	3177.9	3177.9	3178.4	3180.3	3165.3	3185.8	
No Action (10,000 acres)	3181.0	3182.0	3183.6	3184.4	3185.4	3184.7	3182.6	3180.7	3180.0	3180.2	3180.0	3180.4	3182.1	3169.1	3186.0	
12,218 acres at 3170 feet[2]	3178.8	3179.9	3182.1	3183.2	3184.2	3183.0	3180.3	3177.9	3177.1	3177.3	3177.7	3178.2	3180.0	3170.9	3184.3	-0.3
10,000 acres at 3170 feet	3180.4	3181.4	3183.4	3184.2	3185.7	3183.9	3181.7	3179.7	3178.9	3179.1	3179.4	3179.8	3181.4	3171.0	3184.8	-0.7

[1] Dif. = Reservoir Recreation annual average contents/elevation minus No Action contents/average.
[2] 12,218 acres at minimum elevation of 3170.0 feet, with target elevations December-May of 3187.2 feet, June of 3186 feet, July of 3185, and August-November of 3184.0 feet.
[3] 10,000 acres at minimum reservoir elevation of 3170.0 feet, with target elevations same as footnote [1].

Table 4.13: Water Availability 1998-2042 in the Reservoir Recreation and Fisheries Alternative

District Acres at Minimum Elevation	District Irrigation				District Return Flows (cfs)	Annual River Releases from Reservoir (cfs)	Annual River Flows at Buffalo Gap[3] (cfs)
	Annual Average Diversion Requirements (cfs)	Annual Average Releases to the District (cfs)	Shortage Range (AF)	% of Period Possible (Percent)			
12,218 acres at 3170 feet[1]	57.8	53.5	3,000-37,000	82	28.9	62.3	127.2
10,000 acres at 3170 feet[2]	47.3	45.3	4,000-27,000	93	24.5	70.0	130.5

[1] 12,218 acres at minimum reservoir elevation of 3170 feet, with target elevations December-May of 3187.2 feet, June of 3186 feet, July of 3185 feet, and August -November of 3184 feet; average annual irrigation requirement for 12,218 acres (distribution efficiency = 76%, on-farm efficiency = 60%) = 41,800 AF (57.8 cfs).

[2] 10,000 acres at minimum reservoir elevation of 3170 feet, with target elevations same as for footnote [1] above; average annual irrigation requirement for 10,000 acres (distribution efficiency = 76%, on-farm efficiency = 60%) = 34,200 AF (47.3 cfs).

[3] Predicted flow at this gauge based on the Water Budget Analysis (Appendix J).

Table 4.4). Full irrigation would require 47.3 cfs annually, while annual releases to the canal would average 45.3 cfs.

Reservoir Releases to the River

AGRAOP estimated release from the reservoir to irrigate 12,218 and 10,000 acres at a minimum elevation of 3170 feet, with target elevations of 3187.2 feet from December-May, 3186 feet in June, 3185 feet in July, and 3184 feet from August-November.

The model showed annual average release to the river while irrigating 12,218 acres to elevation 3170 feet to be 62.3 cfs until 2042 (Table 4.13). This compares to release of 60.2 cfs in No Action. Irrigating 10,000 acres to elevation 3170 feet would provide an annual release averaging 70.0 cfs until 2042, compared to 68.4 cfs in No Action.

Accretion and Return Flows

Return flows would be as described for the No Action Alternative.

SURFACE WATER QUALITY

This analysis focused on eutrophication and TDS (total dissolved solids—salts dissolved in the water) as indicators of surface water quality. TDS can be used to measure suitability of water for irrigation use and for aquatic species. Measuring the EC (electrical conductivity) of water is one way to estimate TDS. Trace elements, pesticides, and uranium were not found in significant concentrations to be considered in this analysis.

Total phosphorus, a TDS constituent, was considered from the aspect of eutrophication

potential in the reservoir (that is, the potential of excessive productivity to reduce dissolved oxygen to the detriment of fish and other aquatic species), and from the aspect of total phosphorus loading in both the reservoir and in the Cheyenne River downstream of the dam.

Eutrophication potential was projected from an index of areal phosphorus loading to critical phosphorous loading. Reclamation's AGRAOP computer model supplied the water volume of the reservoir, inflows, and outflows. The area was computed by an equation developed from area-capacity data based on the 1997 sediment adjustment. Inflows were the same for all the alternatives. (See Appendix T for a description of the process in greater detail.)

Information for the phosphorus analysis was taken from USGS's (U.S. Geological Survey's) gauge at Edgemont during the early 1970's; later information was available but only for the dissolved fraction. A correlation was made to bridge information to the time when both the dissolved fraction and the total concentration were available, but there was no statistically significant relationship.

There was a significant correlation between total phosphorus and flows, however, indicating that the phosphorus source is erosion, with much of it in particulate form. This could affect applicability of the eutrophication index. If a significant part of total phosphorus were unavailable for algal uptake, the index would overestimate eutrophication potential. Since the index is used only to compare alternatives, it is thought to be valid. In this case, the alternative with the greatest difference from No Action would have the greatest impact.

TDS loading in the reservoir was developed from a *running flow-weighted* average TDS concentration. The running average was based on hydraulic residence time, ranging from 2-11 months. Inflow volumes and TDS were multiplied and summed over the hydraulic residence time and divided by total flows over the period. Monthly averages were also calculated for the AGRAOP simulations from 1998-2042.

TDS loading in the river downstream was based on a basin-wide salt-budget analysis developed from past flows, EC, and TDS data, and the TDS data for the reservoir. Fall River and Beaver Creek, key tributaries below the dam, were included in the analysis. These often contribute most flows between the dam and the lower end of the District. Irrigation return flows were not explicitly estimated but were included in a gain-loss term calculated as the flow difference between the dam and the lower end of the District. This gain-loss term included return flows from the District, as well as tributary groundwater and return flows from irrigation outside the District.

Impacts for the Improved Efficiencies and Reservoir Recreation and Fisheries Alternatives were based on 10,000 irrigated acres, the average irrigated acreage in the District. Impacts for 12,218 irrigated acres would be very similar to those for 10,000 acres.

Impacts of the No Action Alternative

Eutrophication

Eutrophication potential in this alternative is shown in Table 4.14. Total phosphorus concentration of inflows was 0.08 mg/L (milligrams/liter). This is both the median inflow and the geometric mean; the arithmetic mean was 0.24 mg/L. (The arithmetic mean was obviously highly skewed, appearing to be an overestimation rather than an accurate representation of the central tendency of the data. For this reason it was not used.)

As shown in Table 4.14, average depth of the reservoir in the No Action Alternative would

Table 4.14: Eutrophication Index for the Alternatives

	Average Depth of Reservoir (Feet)	Hydraulic Residence Time (% of year)	Hydraulic Loading (Feet/ year)	Critical Spring Phosphorus Concen-tration (µg/L)	Critical Phosphorus Loading (g/m²/year)	Areal Phosphorus Loading (g/m²/year)	Index
No Action (12,218 acres at 3163 feet)	17.29	0.74	23.46	10.00	0.13	0.60	4.539
No Action (10,000 acres at 3163 feet)	17.72	0.80	22.11	10.00	0.13	0.57	4.451
Reestablishment of Natural Flows	7.48	0.15	50.49	10.00	0.21	1.30	6.093
Improved Efficiencies (10,000 acres at 3163 feet)	18.04	0.86	21.00	10.00	0.12	0.54	4.379
Improved Efficiencies (10,000 acres at 3170 feet)	17.68	0.81	21.72	10.00	0.13	0.56	4.434
Improved Efficiencies (10,000 acres at 3175 feet)	17.72	0.82	21.56	10.00	0.13	0.55	4.425
Improved Efficiencies (10,000 acres at 3184 feet)	18.27	0.91	20.18	10.00	0.12	0.52	4.321
Reservoir Recreation and Fisheries (10,000 acres at 3170 feet)	17.32	0.77	22.60	10.00	0.13	0.58	4.498

range from 17.29-17.72 feet, hydraulic residence (retention) time would range from 8.9-9.6 months, hydraulic loading would range from 23.46-22.11 feet/year, critical spring phosphorus concentrations would be 10.00 µg/L (micrograms/liter), critical area loading 0.13 grams/meter²/year, and areal loading 0.60-0.57 grams/meter²/year. The eutrophication index (last column of the table) was above 1, indicating that phosphorus load would be greater than the critical spring phosphorus load.

Normally, reservoirs above critical loading would be expected to be eutrophic, but, in this study the index simply compares alternatives as mentioned.

The reservoir is monitored by the SDDENR (South Dakota Department of Environment and Natural Resources) which consistently classifies it as mesotrophic (Stueven and Stewart 1996).

TDS

Annual average TDS at the reservoir in the No Action Alternative would range from 1,750-1,770 mg/L, depending on whether 10,000 acres or 12,218 acres were irrigated (Table 4.15). This alternative irrigating 10,000 acres would result in lower TDS than when irrigating 12,218 acres since the average reservoir pool would be larger. August would experience the maximum TDS, ranging from 1,937-1,971 mg/L. It should be noted that in all cases TDS in the reservoir would be less than TDS in the inflows into the reservoir.

While minimum TDS in releases to the river would be higher than that of inflows in this alternative, the maximum would be smaller (Table 4.15). The decrease in maximum TDS between inflows and releases would be greater than the increase in the minimum. This reduction in range between minimum and maximum TDS reflects the seasonal mixing of higher and lower TDS inflows in the reservoir, reducing the range of TDS in releases to the river. Thus, the reservoir would serve to reduce overall TDS in the river below the dam in this alternative.

TDS was projected for the river downstream to the junction with Cherry Creek (Table 4.16). It would range from 1,750-1,760 mg/L below the dam, increasing to 1,890 mg/L near Buffalo Gap. TDS would drop farther downstream, reaching 1,340-1,350 mg/L at Cherry Creek.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Eutrophication

The Reestablishment Alternative would have the highest eutrophication potential, highest reservoir TDS, and slightly less TDS at Buffalo Gap and Cherry Creek in comparison to No Action. This alternative would reduce the size of the reservoir as inflows were passed through to the river. Average depth of the reservoir would be less than half that of the other alternatives as shown in Table 4.14.

Because of the reduction, retention time would be about 2 months, and areal loading would increase as the same phosphorus load were applied to a much smaller surface area. This results in this alternative having the greatest eutrophication potential of the alternatives.

TDS

Annual average TDS in the reservoir would be 1,930 mg/L (Table 4.15), compared to 1,750-1,770 mg/L for the No Action Alternative. TDS would be at maximum in September at 2,143 mg/L. TDS in the reservoir still would be less than TDS in the inflows.

As with No Action, the reservoir would reduce overall TDS in the river below the dam in this alternative. TDS would be 1,930 mg/L below the dam, decreasing to 1,280 mg/L at Cherry Creek (Table 4.16). This compares to the No Action range of from 1,750-1,760 mg/L below the dam to 1,340-1,350 mg/L at Cherry Creek.

Table 4.15: Average Monthly TDS at Angostura Reservoir and Summary [1] (mg/L)

	Inflows	No Action (12,218 acres at 3163 feet)	No Action (10,000 acres at 3163 feet)	Reestablish-ment of Natural Flows	Improved Efficiencies (10,000 acres at 3163 feet)	Improved Efficiencies (10,000 acres at 3170 feet)	Improved Efficiencies (10,000 acres at 3175 feet)	Improved Efficiencies (10,000 acres at 3184 feet)	Reservoir Recrea-tion and Fisheries
Jan.	2,526	1,724	1,722	2,189	1,724	1,718	1,716	1707	1,722
Feb.	2,175	1,707	1,694	2,147	1,697	1,693	1,693	1,691	1,708
Mar.	1,764	1,629	1,615	1,941	1,637	1,624	1,625	1,642	1,641
Apr.	2,019	1,675	1,671	1,859	1,688	1,677	1,678	1,674	1,685
May	1,854	1,665	1,659	1,765	1,676	1,664	1,669	1,681	1,668
June	1,830	1,774	1,738	1,705	1,723	1,744	1,745	1,740	1,760
July	2,068	1,909	1,870	1,697	1,812	1,835	1,826	1,780	1,866
Aug.	2,300	1,971	1,937	1,787	1,871	1,891	1,865	1,771	1,916
Sept.	2,807	1,893	1,867	1,891	1,834	1,843	1,830	1,754	1,859
Oct.	2,646	1,779	1,785	2,002	1,776	1,780	1,773	1,744	1,775
Nov.	2,597	1,733	1,753	2,068	1,758	1,734	1,730	1,732	1,724
Dec.	2,578	1,719	1,714	2,143	1,718	1,707	1,705	1,710	1,716

Summary

Avg.	2,260	1,770	1,750	1,930	1,740	1,740	1,740	1,720	1,750
Median	2,340	1,718	1,704	1,968	1,704	1,713	1,713	1,710	1,714
Geo. Mean	2,210	1,710	1,710	1,890	1,700	1,700	1,700	1,680	1,710
No. of Obs.	540	531	530	538	530	530	530	529	531
Min.	810	921	922	858	922	922	922	928	920
Max.	4,470	3,621	3,634	2,790	3,327	3,264	2,839	2,542	3,153

[1] There are 18 months of no inflows in the 1953-1997 period of record.

Table 4.16: Annual Average TDS Downstream[1] (mg/L)

Alternative (District Acres at Minimum Elevation)	River below Dam [2]	Ungauged Gain/Loss	River near Buffalo Gap [3]	River near Wasta	River near Plainview	River at Cherry Creek
No Action (12,218 acres at 3163 feet)	1,760	1,820	1,890	1,220	1,380	1,350
No Action (10,000 acres at 3163 feet)	1,750	1,900	1,890	1,210	1,370	1,340
Reestablish-ment of Natural Flows	1,930	1,810	1,860	1,160	1,320	1,280
Improved Efficiencies (10,000 acres at 3163 feet)	1,740	1,920	1,880	1,200	1,360	1,330
Improved Efficiencies (10,000 acres at 3170 feet)	1,740	1,900	1,890	1,200	1,360	1,330
Improved Efficiencies (10,000 acres at 3175 feet)	1,740	1,910	1,890	1,200	1,360	1,330
Improved Efficiencies (10,000 acres at 3184 feet)	1,720	1,940	1,880	1,190	1,350	1,320
Res. Rec. and Fisheries (10,000 acres at 3170 feet)	1,750	1,870	1,890	1,210	1,370	1,340

[1] Based on the geometric mean.
[2] Inflows = 1,990 mg/L.
[3] Fall River = 980 mg/L; Beaver Creek = 1,880 mg/L.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Eutrophication

Eutrophication potential would be similar to No Action, as would be TDS in the reservoir and river. Average depth of the reservoir would range from 17.72-18.27 feet in this alternative, retention time would range from 9.72-10.32 months, hydraulic loading would range from 20.18-21.72 feet/year, critical spring concentrations would be 10.00 µ/L, critical phosphorus loading would range from 0.12-0.13 grams/meter²/year, and areal phosphorus loading would range from 0.52-0.56 grams/meter²/year. The

eutrophication index would range from 4.321-4.425, indicating that phosphorus load would be equal to the critical spring phosphorus load. Thus, the Improved Efficiencies Alternative would have a similar potential for eutrophication as No Action.

TDS

Annual average TDS in the reservoir would range from 1,720-1,740 mg/L (Table 4.15), compared to 1,750-1,770 mg/L for No Action. TDS would be at the maximum in August, ranging from 1,771-1,891 mg/L. TDS in the reservoir would be less than TDS in inflows. As with No Action, the reservoir would reduce overall TDS in the river below the dam in this alternative.

TDS would range from 1,720-1,740 mg/L below the dam to 1,320-1,330 mg/L at Cherry Creek, compared to TDS ranging from 1,750-1,760 mg/L below the dam to 1,340-1,350 mg/L at Cherry Creek in No Action.

Impacts of the Reservoir Recreation and Fisheries Alternative

Eutrophication

This alternative's eutrophication index would be similar to that in No Action, and TDS in the reservoir and river would also be similar. Average depth of the reservoir would be 17.32 feet, retention time 9.24 months, hydraulic loading 22.60 feet/year, critical spring concentrations 10.00 µg/L, critical phosphorus loading 0.13 grams/meter^2/year, and areal phosphorus loading 0.58 grams/meter^2/year. The eutrophication index would be 4.498, indicating that phosphorus load would be greater than the critical spring phosphorus load. This alternative would thus have a similar potential for eutrophication as the No Action Alternative.

TDS

Annual average TDS in the reservoir would be 1,750 mg/L (Table 4.15), compared to 1,750-1,770 mg/L in the No Action Alternative. TDS would be at the maximum in August at 1,916 mg/L. In all cases, TDS in the reservoir would be less than TDS in inflows. As with No Action, the reservoir would reduce overall TDS in the river below the dam in this alternative.

TDS would be 1,750 mg/L below the dam, dropping to 1,340 mg/L at Cherry Creek. This compares to TDS ranging from 1,750-1,760 mg/L below the dam to 1,340-1,350 mg/L at Cherry Creek in the No Action Alternative.

GROUNDWATER

Impacts on groundwater quantity were based on deep percolation to shallow aquifers. Impacts on groundwater quality were estimated from a combination of TDS concentrations and salt loads from both canal losses and deep percolation. The TDS of the canal losses is equal to the TDS of the canal water, assumed to be the same as that of the reservoir. The TDS of deep percolation was based on quality of canal water adjusted for the consumptive use of the crops; that is, a concentration factor was calculated as the ratio of the on-farm delivery to the consumptive use of the crops (the data used to calculate the concentration factor are shown in Table 4.17). The TDS loading to groundwater is the sum of the loading from canal losses and deep percolation.

The TDS of groundwater in the past (1,390-1,670 mg/L) is much lower than TDS of the recharge. This indicates that lateral groundwater flows are important in controlling quality in comparison to recharge from the District. In other words, the TDS of the upgradient groundwater is low enough to dilute the inflowing recharge from the District. Since the rate of lateral groundwater

flows into the aquifer underlying the District is unknown, impacts of the alternatives on groundwater quality was calculated by comparing the recharge TDS concentration and TDS loading to the groundwater to those in the No Action Alternative. The historic condition was based on an average irrigated acreage of 10,500 acres when the groundwater quality data was collected.

Impacts of the No Action Alternative

Quantity

Return flows to groundwater would remain as at present. Thus, there would be no effects on the shallow wells or springs in the Angostura area.

The frequency of river flows greater than 10,000 cfs would be the same as at present (see Table 3.20). No appreciable recharge of shallow aquifers along the river would occur.

Quality

Loss of reservoir storage to sediment buildup would cause further irrigation shortages in the future. However, these were comparatively small during the model period, and differences in TDS between the historic condition and this alternative would be negligible (Table 4.17). TDS of the recharge with 10,000 irrigated acres would be slightly lower than historic.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Quantity

This alternative would significantly reduce groundwater quantities in the area. With no irrigation from the reservoir, return flows to groundwater would be eliminated. Wells and springs could experience significant changes by an unquantified volume.

Frequency of river flows greater than 10,000 cfs would increase in this alternative, recharging shallow aquifers along the river. This could benefit riparian vegetation, depending on current land use practices like grazing.

Quality

Because TDS in groundwater is much lower than in recharge, this upgradient groundwater dilutes it. Eliminating the recharge from irrigation return flows should reduce TDS to that of laterally inflowing groundwater. Although the exact TDS is unknown, it would be something lower than it would be in No Action.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Quantity

Groundwater quantities would be slightly reduced in this alternative compared to No Action. An increase in the efficiencies of the District's delivery system and on-farm operations would reduce return flows. Wells and springs could experience changes by an unquantified volume.

Recharge of shallow aquifers along the river would be as described for No Action.

Quality

The TDS of recharge in this alternative (to all reservoir elevations) would be similar to No Action. The more important measure is recharge TDS loading to groundwater. The Improved Efficiencies Alternative (to all reservoir elevations) would have a much lower recharge TDS load than No Action. The effect

on groundwater quality would be less than that of No Action: Irrigating 10,000 acres to reservoir elevations 3163, 3170, and 3175 feet would be slightly less, while the effect of irrigating 10,000 acres to reservoir elevation 3184 feet would be much less than that of No Action. Groundwater TDS would be less affected in this alternative (to all reservoir elevations) than in No Action.

Impacts of the Reservoir Recreation and Fisheries Alternative

Quantity

This alternative would have similar impacts on quantity as No Action. Return flows to groundwater would be as described for the No Action Alternative.

Recharge of shallow aquifers along the river would be as described for No Action.

Quality

This alternative would have a recharge TDS similar to that of No Action. The recharge TDS loading to groundwater would be about the same as that of No Action and quite a bit less than historic (Table 4.17). Because the loading is lower, groundwater TDS would be lower than in No Action. The effect would be insignificant. The difference in TDS loadings to groundwater would be only slightly outside the range of TDS loading in No Action.

SEDIMENT

Like groundwater, impacts of the alternatives on sediment were analyzed from both the quantity and quality standpoint, also.

Impacts of the No Action Alternative

Quantity

The upper part of the reservoir would fill with sediment in this alternative, but it would be well beyond the 25-year long term. Total sediment volume in the reservoir for 1949-2042 was estimated at 91,605 AF, indicating capacity loss of about 57% from the present. Total capacity at elevation 3187.2 feet in 2042 would be 68,314 AF (159,919 AF original capacity minus 91,605 AF), with active capacity of about 61,000 AF (68,314 AF minus inactive storage of 7,257 AF).

Table 4 17: Farm Delivery Water and Salt Budget

	Irrigated Acres	Reservoir Min. Elev. (Feet)	Canal Loss (cfs)	Canal Loss TDS (Tons)	On-Farm Deep Perc. (cfs)	Deep Perc. TDS (mg/L)	Deep Perc. TDS Load (Tons)	Weighted Recharge TDS (mg/L)	Recharge TDS Load (Tons)
Historic	10,500	3163	12.9	21,730	16.9	2,850	47,460	2,360	69,190
No Action	10,000	3163	10.8	18,200	14.2	2,860	40,010	2,360	58,210
Reestablishment	NA	3157	0	0	0	NA	NA	NA	NA
Imp. Efficiency	10,000	3163	12.9	21,610	7.4	2,440	17,790	1,970	39,400
Imp. Efficiency	10,000	3170	12.9	21,610	7.4	2,420	17,640	1,960	39,250
Imp. Efficiency	10,000	3175	12.6	21,100	7.3	2,430	17,480	1,970	38,580
Imp. Efficiency	10,000	3184	8.6	14,240	4.9	2,400	11,590	1,940	25,830
Res. Rec.	10,000	3170	10.6	17,860	13.9	2,850	39,030	2,360	56,890

Quality

Elements in the sediment—which were within the baseline for western soils except for uranium—would remain as at present. Uranium at the reservoir near the dam was found to be 5.8 mg/L, slightly exceeding the upper confidence level, and was found to be 17.8 mg/L at Topeska's Pond, the off-river site. The source of the uranium is unknown, but it is unlikely it came from the reservoir or the river.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Quantity

This alternative would result in the significant loss of the reservoir as a settling basin, with consequent impacts on sediment quantity and quality in the river downstream. It would allow water to flow through the dam at the spillway crest, so the reservoir would fill with sediment to elevation of 3157.2 feet by 2021. The reservoir would no longer serve as a settling basin, resulting in release of water higher in turbidity.

Quality

Elements in the sediment would remain as at present, but a smaller reservoir would have a lower trap efficiency and would always release more sediment (particularly silt) than in No Action.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Quantity

Sedimentation volume would be as described for the No Action Alternative

Quality

Sedimentation quality would be as described for the No Action Alternative.

Impacts of the Reservoir Recreation and Fisheries Alternative

Quantity

Sediment in this alternative would be as described for the No Action Alternative.

Quality

Sediment quality would be as described for the No Action Alternative.

STREAM CORRIDOR

The Cheyenne River and other streams in the region (like the Belle Fourche River) have been affected by regulation by dams and other structures. The regulated river serves as the standard against which the alternatives were compared. Predictions are qualitative rather than quantitative, and are based on how the river has responded in the past and how other systems respond to similar changes.

Impacts of the No Action Alternative

Annual releases averaged 59.9 cfs for the 1953-1997 period of record, with a high of 406.7 cfs and a low of 3.3 cfs (in 12 of 45 years—see "Surface Water Quantity" in this chapter). In the No Action Alternative, average annual river releases would range from an estimated 60.2 cfs (with 12,218 irrigated acres) to 68.4 cfs (10,000 irrigated acres). The highest average annual river release is estimated to be 430 cfs, the lowest 3.3 cfs.

Selected Channel Characteristics

Annual and peak flows would continue to follow the current pattern. The reservoir would continue to trap sediment, and downstream conditions would mirror current conditions (see Chapter Three, "Stream Corridor"). Flows and sediment have likely attained a post-dam balance; if so, stream length should stabilize in its current condition.

Riparian Vegetation

If flows and sediment have reached a balance, then the area of exposed sediment, area coverage of vegetation, and number of vegetated polygons also have likely stabilized and would not exhibit large changes in the next 25 years. Existing vegetation would continue to age with only limited recruitment to cottonwood communities downstream from the dam (see Chapter Three, "Stream Corridor"). Depending on future land use (that is, fire or grazing), some characteristics of open grasslands or green ash communities might begin to appear by the end of the long term, the 25-year irrigation contract. However, because of the extended time involved in cottonwood community succession, such changes would likely go undetected except to the trained observer.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

This alternative would have significant impacts on the stream corridor. The reservoir would be operated as a flow-through facility, with inflows equaling releases. Annual releases to the river would average an estimated 120.7 cfs. Occasionally, the river could dry up in summer, and could experience flooding up to 25,000 cfs (see"Surface Water Quantity"). Annual releases could double those in the No Action Alternative. The DISSED model shows that reservoir dead storage would fill with sediment in 25 years; flows would carry sediment through the reservoir and into the river downstream thereafter.

Selected Channel Characteristics

This alternative would result in hydrologic conditions similar to those before the dam was built, although the many stock ponds and other impoundments on the tributaries would prevent flows from reaching pre-dam proportions. Increased annual flows, and an increased frequency of flows greater than 5,000 and 10,000 cfs, would likely result in some restructuring of the river channel. Increased flow and increased sediment would cause the river to adjust to a new balance similar—but short of—pre-dam conditions (see Chapter Three, "Stream Corridor"). These conditions include higher flows, additional sediment, and a decrease in stream length in comparison to No Action.

Riparian Vegetation

An increase in flows and sediment would likely result in an increase in the area of exposed sediment and a decrease in the area coverage of vegetation. The number of vegetated polygons would also decline. Relative abundance of canopy closure categories would change. Because 25 years is a short period in development of riparian communities, changes would probably not appear dramatic. Most would occur in the active channel which is the site of most of the post-dam changes. It is likely that much of the current 21-40% canopy category would be reworked into exposed sediment. Depending on future land use, riparian vegetation might return to conditions similar to pre-dam some time beyond the end of the 25-year long term.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Average annual reservoir releases to the river would range from 68.9-88.8 cfs, depending on the acreage irrigated and reservoir elevations (see "Water Quantity" in this chapter). This

would be an increase compared to No Action, ranging from less than 2% (No Action high flows compared to Improved Efficiencies Alternative low flows) to 47.5% (No Action low flows to Improved Efficiencies high flows). Thus, depending on flows, changes could range from as described for the No Action Alternative to changes very different from No Action. Qualitatively, some changes from No Action were assumed, although effects might not be detectable in 25 years.

Selected Channel Characteristics

Annual and peak flows would continue to follow the existing pattern, with some increase likely. The reservoir would continue to trap sediment. Flows and sediment would adjust from the assumed post-dam balance. Increased annual flows and an increased frequency of flows greater than 5,000 and 10,000 cfs would likely result in some minor restructuring of the channel. Increased flows—without an increased sediment supply—would cause the river to adjust to a new balance somewhat different from the No Action Alternative. These new conditions include somewhat higher flows, no additional sediment, and a decrease in stream length.

Riparian Vegetation

An increase in flows without an increase in sediment would likely result in a decrease in the area coverage of vegetation. The number of vegetated polygons would also decline in comparison to No Action. The relative abundance of canopy closure categories would also change, mostly in the active river channel, the area of most of post-dam changes. It is likely that some of the current 21-40% canopy category would be reworked, and the released sediment moved out of the river system by increased flows. At some time beyond the end of the 25-year long term, riparian vegetation would stabilize as channel characteristics reached a new balance.

Existing vegetation would continue to age in this alternative, with limited recruitment to cottonwood communities downstream from the dam (see Chapter Three, "Stream Corridor"). Depending on future land use (fire or grazing), some characteristics of open grasslands or green ash communities might begin to appear by the end of the irrigation contract.

Impacts of the Reservoir Recreation and Fisheries Alternative

Average annual river releases would range from an estimated 61.7 cfs (with 12,218 irrigated acres) to 69.5 cfs (10,000 irrigated acres). This would represent an increase of 1.1-1.5 cfs. Flows in this alternative would be as described for No Action, with sediment and vegetation characteristics likewise.

Selected Channel Characteristics

Annual and peak flows would continue to follow the existing pattern. The reservoir would continue to trap sediment and downstream conditions would likely mirror existing conditions. Because flows and sediment have likely attained a post-dam balance, stream length would not change much from the No Action Alternative.

Riparian Vegetation

If flows and sediment have reached a balance, then the area of exposed sediment, area coverage of vegetation, and number of vegetated polygons have likely stabilized, and thus would not show large changes in the next 25 years in this alternative. Existing vegetation would continue to age with only limited recruitment to cottonwood communities downstream from the dam. Depending on future land use (fire or

grazing), some characteristics of open grasslands or green ash communities might begin to appear by the end of the 25-year long term. Such changes would likely go undetected except to the trained observer.

WETLANDS

Wetlands in the Angostura area were grouped into those in the reservoir, around the reservoir, wetlands in the District, and riparian wetlands. Impacts to wetlands are qualified but not quantified.

Impacts of the No Action Alternative

The No Action Alternative would have no impacts on the 376 acres of wetlands in and around the reservoir, on the 794 acres in the District, or on the 2,085 acres of riparian wetlands.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

This alternative would have the greatest impacts on wetlands. By operating at an elevation of

Riparian area along river near Red Shirt. Note lack of understory.

3157.2 feet, it would cause an immediate reduction in the reservoir surface area to 1,661 acres, with 22,529 AF of water at elevation 3157.2 feet. Sediment would form a delta where the river entered the reservoir, with the reservoir filled by sediment by 2021. Deep-water habitat would give way to shallow-marsh habitat. Upland vegetation—annual weeds, grasses, willow, and cottonwood—would eventually establish on the delta, with the river running through it. Reservoir wetland habitat by 2021 would consist of a river channel meandering through vegetated sediment, cut-off river meanders, and flood plain wetlands similar to that currently found both above and below the reservoir.

The shallow-marsh wetlands along the shore would change to upland habitat. Wetlands that rely on precipitation would remain as at present.

Most of the wetlands along the canals and laterals in the District would be lost, as they would no longer receive irrigation water. Others maintained by return flows would be lost, while some would change from permanent to seasonal.

Wetlands along the river would be improved by the greater frequency of 5,000-10,000 cfs floods in this alternative. These floods would scour wetland vegetation and deposit sediment. The river would begin to mimic pre-dam conditions, causing the loss of an oxbow in one locale only to create one in another.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Wetlands in the reservoir and around the reservoir might increase slightly, if the saved water were retained in the reservoir. If saved water were released to the river, riparian wetlands would benefit from increased inundation.

District wetlands would be reduced because of the increased efficiencies of the delivery system and on-farm practices, making less water available in return flows. Saved water could be released to the canal to maintain these wetlands.

Impacts of the Reservoir Recreation and Fisheries Alternative

Impacts would be as described for the No Action Alternative.

FISHERIES

The fisheries analysis was divided into three segments: Angostura Reservoir; the river from below the dam to the confluence with the Belle Fourche River (Middle Cheyenne River); and the river from its confluence with the Belle Fourche to Lake Oahe (Lower Cheyenne River).

The fish tissue analysis (see Chapter Three, "Fisheries") concluded there would be no effect on fish health from any of the alternatives.

Impacts of the No Action Alternative

Angostura Reservoir

Currently, water levels fluctuate greatly from month to month and year to year, depending on inflows and irrigation diversions. Fluctuating water levels prevent extensive development of aquatic vegetation, having been identified by SDGF&P (South Dakota Department of Game, Fish and Parks) as the main reason for low reproductive success of game and forage fish in the reservoir. This would continue in the No Action Alternative.

Middle Cheyenne River
No Action would not affect this segment of the river or the fishery it supports. Fish species, including exotics, would continue to inhabit the Middle Cheyenne.

Lower Cheyenne River
Since the reservoir is so far upstream, impacts of No Action would not be felt in the Lower Cheyenne nor by the fishery it supports.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Angostura Reservoir
In the short term, this alternative would have a beneficial impact on reservoir fisheries in comparison to No Action. Stable water levels and the smaller surface and shallower depth of the reservoir would increase aquatic vegetation thus improving fish propagation and recruitment. As the reservoir surface area became smaller and the depth shallower during the 25-year long term, however, species diversity would diminish and would change from a reservoir fisheries to a riverine fisheries.

Middle Cheyenne River
The frequency of 5,000- to 10,000-cfs floods in the river would be greater in this alternative in comparison to No Action, and low flows would be lower. The Cheyenne River between the dam and Fall River would periodically dry up. This would result in localized, short-term effects to the fisheries, with some fish following flows, others marooned in pools to perish when DO (dissolved oxygen) became too low to support life. Downstream, Fall River would maintain flows of the Cheyenne but at a much lower rate, thus reducing fisheries habitat.

Lower Cheyenne River
This alternative would have no effect on the lower Cheyenne.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Angostura Reservoir
The Reservoir fishery could benefit if the saved water were kept in reservoir storage.

Middle Cheyenne River
Impacts to fisheries would be as described for the No Action Alternative.

Lower Cheyenne River
This alternative would have no effect on the lower Cheyenne.

Impacts of the Reservoir Recreation and Fisheries Alternative

Angostura Reservoir
This alternative would improve reservoir fisheries when compared to No Action by managing water elevations to expand the aquatic vegetation vital to reproductive success of fish.

Middle Cheyenne River
Impacts would be as described for the No Action Alternative.

Lower Cheyenne River
Impacts would be as described for the No Action Alternative.

WILDLIFE

The Angostura Unit affects wildlife habitat linked to flows in the Cheyenne River. This section focuses on indicators—*cottonwood* (changes in cottonwood forests or woodlands) and *bird species* (changes in bird species

diversity)—that reflect changes in riparian vegetation resulting from changes in river flows.

Impacts of the No Action Alternative

Cottonwoods

There would be minimal (if not undetectable) changes to riparian vegetation in the next 25 years. Existing vegetation would continue to age with only limited cottonwood recruitment occurring downstream of the dam. It is likely that at least one flood greater than 25,000 cfs would occur in the next 25 years, which would restructure the river channel and allow some cottonwood and willow recruitment. Cottonwoods live for about 100-150 years. Cheyenne River cottonwoods are about 50-60 years old, so in 25 years they will be 75-85 years old. Depending on future land use (such as fire and grazing), some characteristics of open grasslands or green ash communities might begin to appear by the end of the 25-year long term.

Birds Species

There would be no significant impacts to cavity or tree nesting birds that require older cottonwood forests as preferred habitat. By the end of 25 years, cottonwood forests will have lived half of their life span, so an increase in cavities could be expected, providing more habitat for cavity nesting birds. Impacts to tree and shrub nesting birds that require plant-height diversity for preferred habitat would depend on future land use practices. Habitat for ground nesting birds would also depend on future land use practices. Bird species diversity may have been at a peak before the dam was completed, and the combination of river regulation and land use practices may have shifted habitat preference that favor cavity and ground nesting birds.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Cottonwoods

In this alternative, an increase in flows and sediment would likely increase the area of exposed sediment and decrease the area coverage of vegetation (see "Stream Corridor" in this chapter). Most of the change would occur within the active river channel. Annually, 4,000- to 5,000-cfs spring floods would occur, allowing cottonwoods to re-establish next to the stream corridor. It is probable that at least one flood greater than 25,000 cfs would occur within the next 25 years, creating point bars or disturbing the ground surface to recruit cottonwood and willows. Some time beyond the 25 years, cottonwoods might return to conditions similar to pre-dam. Depending on land use, cottonwood recruitment might be limited, and existing cottonwoods would continue to age. Open grasslands or green ash communities might begin to appear by the end of the long-term.

Birds Species

This alternative would have the most beneficial impact on bird species. As cottonwoods and willows established and aged, more habitat would be provided for tree nesters. Existing cottonwoods would age and provide more habitat for cavity nesters. Depending on land use, cottonwood recruitment might be limited, to be replaced beyond the 25-year long term with grassland-shrub habitat more suitable for ground and shrub nesters.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Cottonwoods

Annual flows in the river could increase if the saved water were released from the reservoir,

benefitting cottonwood recruitment. Depending on land use, open grasslands or green ash communities might begin to appear at the end of the long term.

Birds Species

Tree nesting birds could benefit if increased flows in the river resulted in cottonwood recruitment. Otherwise, grassland-shrub habitat more suitable for ground and shrub nesters might replace cottonwoods at some point beyond 25 years.

Impacts of the Reservoir Recreation and Fisheries Alternative

Cottonwoods

Impacts would be as described for the No Action Alternative.

Birds Species

Impacts would be as described for the No Action Alternative.

THREATENED OR ENDANGERED SPECIES

This section (along with "Threatened and Endangered Species," Chapter Three) constitutes the biological assessment required under Section 7c of the Endangered Species Act. Environmental issues and mitigation measures in this EIS (environmental impact statement) were developed through consultation with USFWS (U.S. Fish and Wildlife Service). Reclamation has determined that alternatives in this EIS are not likely to adversely affect species listed under the Endangered Species Act.

Reclamation consulted with SDGF&P on State endangered, threatened, or rare species. Table 4.18 shows the effects on those State species not on the Federal list.

Impacts of the No Action Alternative

Bald Eagle

Bald eagles migrate through the area in spring and fall and roost in the riparian area along the Cheyenne River. Some would remain as long as enough of the river remained ice-free, feeding on waterfowl, fish, rabbits, and carrion. Although there is currently no nesting population along the river, riparian cottonwoods could provide suitable nesting habitat.

Because of regulated river flows and unregulated grazing, the riparian area is expected to change in seral stage (age) and species composition over time. The area would go from one dominated by cottonwoods of several age classes to one of even age classes with green ash, brush, grass understory, and eventually to a green ash forest or brush/grassland community (this change is described in detail in Chapter Three, "Stream Corridor). The number of available roost sites would initially increase as the cottonwoods matured. As the riparian cottonwoods were replaced by grasses and understory shrubs, roost sites would decline. The result would be an eventual loss of roost habitat and potential bald eagle nest sites.

Although this situation will probably take place, it is doubtful that changes would be significant over the 25-year life of the contract. Feeding opportunities for the eagle should remain constant, as there should be no decrease in the fish populations, waterfowl, and carrion. The No Action Alternative would not adversely impact the bald eagle during the 25-year long term.

Whooping Crane

Whooping cranes migrate through the area and might roost or forage in surrounding agricultural fields and prairie. In this alternative, agricultural cropping patterns should remain relatively constant, thereby not adversely affecting incidental use by whooping cranes. Thus, this alternative would not adversely impact the whooping crane.

Piping Plover

While they nest on sandbars in the river below the confluence with the Belle Fourche River, piping plovers have not been recorded along the river above that point, and there was only one recorded sighting for the reservoir. This alternative would not change existing flows, thereby not impacting creation or existence of sand and gravel bars in the river. Thus, this alternative would not adversely impact the piping plover.

Interior Least Tern

Like the plover, the interior least tern nests on sandbars along the river below the confluence with the Belle Fourche River. It forages for small fish and crustaceans further upstream. The river above that point does not provide suitable nesting habitat. This alternative would not change existing flows in the river, thereby not impacting creation or existence of sand and gravel bars in the river, or the habitat of the small fish and crustaceans on which the tern feeds. This alternative would thus not adversely impact the interior least tern.

Black-footed Ferret

The only populations of black-footed ferrets known to occur in South Dakota are experimental ones in the Badlands National Park and Buffalo Gap National Grasslands, initially released in 1992. The ferret is dependent on prairie dog colonies for food and cover. No prairie dog colonies would be impacted in this alternative, as cropping patterns should remain the same. No new ground would be broken for agricultural purposes. Thus, this alternative would not adversely impact the black-footed ferret.

American Burying Beetle

Potential habitat would not be changed in this alternative as land uses should remain constant. Therefore, this alternative would not adversely impact the American burying beetle.

Swift Fox

The swift fox, which occurs in the area only rarely, is a candidate species for listing. This alternative would not result in loss of more prairie habitat or affect prairie dogs, both important to survival of the fox. Thus, it would not adversely affect the swift fox.

Black-tailed Prairie Dog

This alternative would not adversely impact the black-tailed prairie dog as cropping patterns would remain the same.

Sicklefin Chub

The sicklefin chub is a candidate species, too. In South Dakota, the species is only known to occur in the Missouri River, but it may also be found in Missouri River tributaries like the Cheyenne River. This alternative would not change flows in the river; therefore, it would not adversely impact the sicklefin chub.

Sturgeon Chub

The sturgeon chub is also a candidate species for listing, and is known to occur in the Cheyenne River. It has a rather restricted habitat, preferring turbid water over sand or gravel areas where the current is swift. Angostura Reservoir acts as a settling basin for sediment in the river above the dam, so water discharged to the river below is relatively clear,

Table 4.18: Impacts on State Endangered, Threatened, or Rare Plants and Animals (Not on Federal List)

Species	Status	Primary Habitat Use	Impacts			
			No Action Alternative	Reestablishment of Natural Flows Below the Dam Alternative	Improved Efficiencies Alternative	Reservoir Recreation and Fisheries Alternative
finescale dace	Endangered	Aquatic	None	None	None	None
fringe-tailed myotis	Rare	Terrestrial	None	None	None	None
marten	Rare	Terrestrial	None	None	None	None
black bear	Rare	Terrestrial	None	None	None	None
mountain lion	Rare	Terrestrial	None	None	None	None
longnose sucker	Threatened	Aquatic	None	None	None	None
banded killifish	Endangered	Aquatic	None	None	None	None
osprey	Threatened	Terrestrial and Aquatic	None	None	None	None
Baird's sparrow	Rare	Terrestrial	None	Beneficial	None	None
spiny softshell turtle	Threatened	Aquatic and Terrestrial	None	None	None	Beneficial
short-horned lizard	Rare	Terrestrial	None	Beneficial	None	None
regal fritillary butterfly	Rare	Terrestrial	None	None	None	None
Ottoe skipper butterfly	Rare	Terrestrial	None	Beneficial	None	None
great blue heron	Rare	Aquatic and Terrestrial	None	None	None	None

Table 4.18: Impacts on State Endangered, Threatened, or Rare Plants and Animals (Not on Federal List) (Continued)

Species	Status	Primary Habitat Use	Impacts			
			No Action Alternative	Reestablishment of Natural Flows Below the Dam Alternative	Improved Efficiencies Alternative	Reservoir Recreation and Fisheries Alternative
common merganser	Rare	Aquatic and Terrestrial	None	None	None	None
golden eagle	Rare	Terrestrial	None	None	None	None
plains topminnow	Threatened	Aquatic	None	None	None	None
barn owl	Rare	Terrestrial	None	None	None	None
burrowing owl	Rare	Terrestrial	None	Beneficial	None	None
Brewer's sparrow	Rare	Terrestrial	None	Beneficial	None	None
quillback	Rare	Aquatic	None	None	None	None
Plains spotted skunk	Rare	Terrestrial	None	None	None	None
tiger beetle	Rare	Terrestrial	None	None	None	None
largeflower Townsend daisy	Rare	Terrestrial	None	None	None	None
bitter fleabane	Rare	Terrestrial	None	None	None	None
Barr's milkvetch	Rare	Terrestrial	None	None	None	None
Lewis woodpecker	Rare	Terrestrial	None	None	None	None

rather than turbid as the sturgeon chub prefers. Thus, the species is not found in the river until further downstream where it begins to load-up with sediment. This alternative would not change flows in the river or the status of the dam. Available habitat for the chub would thus remain the same, so this alternative would not adversely impact the sturgeon chub.

Mountain Plover

The shortgrass prairie and shrub-steppe habitats used by the mountain plover would not be affected, and cropland acres would remain constant in this alternative. Thus, the mountain plover would not be affected.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Bald Eagle

Reestablishment of natural flows in the Cheyenne River would have two effects on habitat supporting the migrating bald eagles: First, more frequent downstream flooding would aid in regeneration of the riparian cottonwood forests, allowing for a more diverse age-class stand of trees. This would mean that required roost trees would be available far into the foreseeable future, causing an increase in bald eagle roosting habitat in the future. Second would be the impact of the smaller reservoir on the riparian habitat currently surrounding the reservoir. As the reservoir shrank in this alternative, the riparian community would re-establish at a lower level. In fact, the newly established community should be healthier than at present due to the lack of water-elevation fluctuations. Still, because of the smaller perimeter of the reservoir, overall area of the riparian community would be less, meaning a decrease in bald eagle roosting habitat.

From the standpoint of prey, the native river fishery below the dam should improve with return to more natural flows in the river, while the reservoir fishery should decrease as available habitat decreased.

Considering both roosting and feeding, the impact of this alternative should be neutral. Therefore, the Reestablishment of Natural Flows Below the Dam Alternative would not adversely impact the bald eagle.

Whooping Crane

Reestablishment of natural flows in the river would decrease the agriculture in the area, due to the decrease of irrigation. Cultivated fields would be less available for roosting and feeding by the cranes. Even without these fields, however, there should be enough natural habitat in the area as not to impact the nontraditional stopover sites that might be located in the area. This alternative would thus not adversely impact the whooping crane.

Piping Plover

This alternative could result in increased use by piping plovers of the reservoir because it would provide more beaches through gradual drawdown. Depending on timing of the drawdowns in relation to the arrival of migrating piping plovers, the size of substrate sand and gravels, and the degree of slope, some beaches might provide plovers with their nesting requisites. More natural flows in the river—and transport of more sediment as reservoir volume decreased—would also promote establishment of new sand bars downstream of the dam where the plover could nest. Thus, this alternative would not adversely impact the piping plover.

Interior Least Tern

As with the piping plover, the least tern would not be adversely impacted by this alternative because of the increase of sand bar habitat.

This alternative would thus not adversely impact the interior least tern.

Black-footed Ferret

In this alternative, there would be a decline in cropland due to less irrigation. Any prairie dog colonies in the area should not be impacted. There would be a possibility that their habitat could expand if some of the cropland were converted to rangeland. Therefore, this alternative would not adversely impact the black-footed ferret.

American Burying Beetle

Habitat required by the beetle should not be impacted by this alternative. As with the ferret, conversion of cropland to rangeland could expand beetle habitat, so this alternative would not adversely impact the burying beetle.

Swift Fox

Conversion of cropland to rangeland could likewise expand the range of the fox and its prey. Thus, this alternative would not adversely impact the swift fox.

Black-tailed Prairie Dog

There would be a decline in cropland because of less irrigation in this alternative. Any prairie dog colonies in the area should not be impacted. Their habitat could expand if some of the cropland were converted to rangeland. Therefore, this alternative would not adversely impact the black-tailed prairie dog.

Sicklefin Chub

As with the topminnow, a return to more natural flows should improve the chub's habitat. This alternative would not adversely impact the sicklefin chub.

Sturgeon Chub

As with the topminnow and sicklefin chub, a return to a more natural flows and higher turbidity should improve the sturgeon chub's habitat. The chub's requirement for swift water would be met by higher spring flows and by continued flows from tributaries like Rapid Creek. This alternative would thus not adversely impact the sturgeon chub.

Mountain Plover

Impacts to the mountain plover would as described for the No Action Alternative: Habitat would not be affected, and cropland acres would remain constant in this alternative. Thus, it would not affect the mountain plover.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Bald Eagle

Impacts to the bald eagle in the Improved Efficiencies Alternative would be as described for the No Action Alternative. If some of the water saved through improved efficiencies were added to the instream flow in the river, there might be an improvement in cottonwood regeneration and in availability of native fish as prey for the eagle. Thus, this alternative would not adversely impact the bald eagle.

Whooping Crane

Impacts to the whooping crane would be as described for No Action. Irrigated fields would still be available for feeding and roosting, so the alternative would not adversely impact the whooping crane.

Piping Plover

Impacts to the piping plover would be as described for No Action. If some of the saved

water were added to instream flow, the river could form more sandbars, improving plover habitat. This alternative would thus not adversely impact the piping plover.

Interior Least Tern

Impacts to the least tern would be as described for No Action. If some of the saved water were added to instream flow, the river could form more sandbars, improving tern habitat. Thus, this alternative would not adversely impact the interior least tern.

Black-footed Ferret

Impacts to the ferret would be as described for No Action. Cropping patterns should remain the same, causing no change in the status of any prairie dog colonies in the area. This alternative would thus not adversely impact the black-footed ferret.

American Burying Beetle

Impacts to the beetle would be as described for No Action. Cropping patterns should remain the same, causing no change in the status of any beetle habitat in the area. The alternative would not adversely impact the American burying beetle therefore.

Swift Fox

Impacts to the swift fox in this alternative would be as described for No Action. Cropping patterns should remain the same, causing no change in the status of any swift fox habitat in the area. This alternative would not adversely impact the swift fox.

Black-tailed Prairie Dog

Impacts would be as described for No Action: Cropping patterns should remain the same, causing no change in prairie dog colonies in the area. This alternative thus would not adversely impact the black-tailed prairie dog.

Sicklefin Chub

Impacts to the sicklefin chub would be as described for No Action. If some of the saved water were added to river flows, the habitat of this native fish would perhaps be increased. This alternative would not adversely impact the sicklefin chub.

Sturgeon Chub

Impacts to the sturgeon chub would be as described for No Action. If some of the saved water were added to river flows, the habitat of this native fish would perhaps be increased, so the alternative would not adversely impact the sturgeon chub.

Mountain Plover

Impacts to the mountain plover would be as described for No Action; habitat would not be affected, and cropland acres would remain constant in this alternative. Thus, it would not affect the mountain plover.

Impacts of the Reservoir Recreation and Fisheries Alternative

Bald Eagle

Impacts would be as described for No Action. There might be an increase in forage fish in the reservoir. Therefore, this alternative would not adversely impact the bald eagle.

Whooping Crane

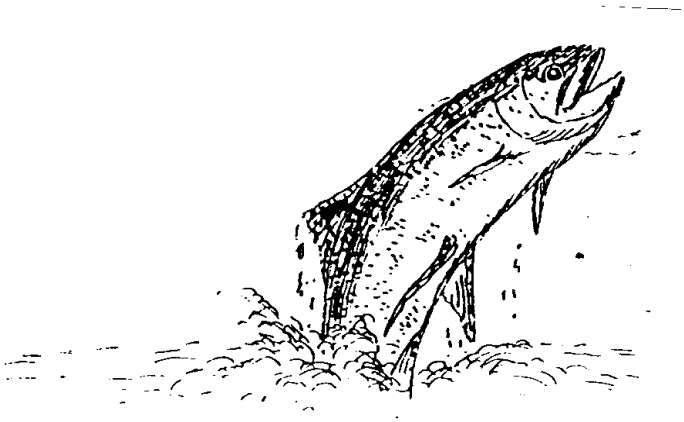
Impacts would be as described for No Action. Cropping patterns should remain similar to the present allowing for feeding and roosting in the fields. Therefore, this alternative would not adversely impact the whooping crane.

Piping Plover
Impacts to the piping plover would be as described for No Action. This alternative would not adversely impact the piping plover.

Interior Least Tern
Impacts to the tern would be as described for No Action. This alternative would thus not adversely impact the interior least tern.

Black-footed Ferret
Impacts to the ferret would be as described for No Action. Prairie dog colonies in the area would not be impacted, so this alternative would not adversely impact the black-footed ferret.

American Burying Beetle
Impacts to the beetle would be as described for No Action. Beetle habitat should remain the same. Thus, this alternative would not adversely impact the American burying beetle.



Swift Fox
Impacts to the swift fox would be as described for No Action. This alternative would not adversely impact the swift fox.

Black-tailed Prairie Dog
Impacts would be as described for No Action. This alternative thus would not adversely impact the black-tailed prairie dog.

Sicklefin Chub
Impacts to the sicklefin chub would be as described for No Action. This species is found in the river, so improvement in the reservoir fishery would not impact it. This alternative would thus not adversely impact the sicklefin chub.

Sturgeon Chub
Impacts to the sturgeon chub would be as described for No Action. This species is found in the river, so improvement in the reservoir fishery would not impact it. This alternative would therefore not adversely impact the sturgeon chub.

Mountain Plover
Impacts to the mountain plover would be as described for No Action: Habitat would not be affected, and cropland acres would remain constant in this alternative. Thus, it would not affect the mountain plover.

State Endangered, Threatened, or Rare Species

Impacts of the alternatives on State species (those not also on the Federal list) are shown in Table 4.18. The Reestablishment of Natural Flows Below the Dam Alternative would have beneficial effects on the Baird's sparrow, short-horned lizard, ottoe skipper butterfly, burrowing

owl, and Brewer's sparrow. The Baird's sparrow would benefit as ungrazed grasslands, preferred habitat of the Baird's sparrow, lizard, butterfly, owl, and Brewer's sparrow would increase in the area with elimination of irrigation.

The Reservoir Recreation and Fisheries Alternative would have a beneficial effect on the spiny softshell turtle by stabilizing water elevations in the reservoir, thereby improving hatching success.

None of the other State species would be affected (Table 4.18).

SOCIAL AND ECONOMIC CONDITIONS

The Angostura Unit generates income and employment to the agricultural and recreational sectors of the economy as explained in Chapter Three. Thus, impacts were divided into those projected for irrigated agriculture and those projected for recreation (including recreational facilities). Changes in water management could affect lifestyles in the area as well, so social impacts were considered in each of these divisions. Impacts to the Pine Ridge Reservation were also considered.

Impacts to the State's endangered, threatened, or rare plants and animals (Table 4.18) was used to estimate ecological benefits and costs.

Impacts of the No Action Alternative

Irrigated Agriculture

No Action would not affect irrigated agriculture since the current average of 10,000 irrigated acres in the District would be maintained.

Annual benefits to the Nation would continue to be $525,000, household income from all sectors of the economy $1,160,000, and agricultural income $540,000. It would continue to provide 47 jobs.

As irrigated acreage would be maintained in this alternative there would be no social effects.

Recreation

Table 4.19 shows camping, day-use, and total visitation estimated for the alternatives based on the recreation computer model discussed in Chapter Three. The table includes the recreation-season average reservoir elevation used in the computer model.

Changes in recreation visitation were used to estimate changes in recreational benefits to the Nation and regional economic impacts. As can be seen in the table, No Action would have no effects on recreation.

The reservoir would stay above elevation 3163 feet in this alternative, so a boat ramp would be available with a large expanse of beach during the recreational season (Table 4.20). At elevation 3170 feet, 97% of the time two boat ramps would be available with a large beach. At elevation 3172 feet, 95.9% of the time twp more boat ramps would become available with a large beach, while, at elevation 3175 feet, 92.2% of the time all eight boat ramps would be available with a large beach. At elevation 3184 feet, 55.2% of the time all eight boat ramps would be available and beaches would begin to be limited. At elevation 3187 feet, 13.7% of the time the reservoir would be full, all boat ramps available, and beaches would be inundated.

Annual recreational visits at the reservoir would continue to be 271,000 visitor days, translating into about $7,080,000 in benefits. Regional economic impacts associated with recreation would continue to be about $1,200,000 in household income and 92 jobs.

Recreation would be unaffected in this alternative, so there would be no effects on social conditions.

Reservation

This alternative would not affect the Pine Ridge Reservation. Economic conditions would not change, remaining at the same relatively high levels of unemployment and low income as at present.

Ecological Benefits/Costs

No Action would have no effect on species listed in Table 4.18. Thus, it would have neither ecological benefits nor costs.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Irrigated Agriculture

Loss of irrigated agriculture would most probably result in dryland farming where possible, affecting feed lot operations and agricultural production. Regional economic impacts in this alternative would be equal to regional impacts from irrigated agriculture in the District minus regional impacts from non-irrigated agricultural production likely to replace irrigation in the region. Regional economic impacts from reduced agricultural production were estimated to be a reduction of $2,020,000 in final demand, reduced total industry output of $2,320,000, a reduction of $1,160,000 in total regional household income from all sectors, a reduction of $540,000 in agricultural income, and loss of 47 jobs.

If most job losses were to occur in Fall River County, population and employment impacts would be about 1% of the 1995 total county population and employment. Social factors (particularly in the town of Oral) such as community lifestyles, cohesion, stability, and family unity might be adversely affected.

Recreation

The reservoir would be drawn down to elevation 3157.2 feet and the surface area would drop, affecting recreation. This alternative would have a significant negative impact on recreation visitation due to drawdown of the reservoir. None of the boat ramps would be useable (Table 4.20). Vegetation would fill in on the exposed beaches. Losses of recreation benefits would total $2,168,000 yearly when compared to the No Action Alternative (Table 4.19). It's possible that recreational benefits downstream of the dam could be generated.

Social effects would be small when compared to the total employment and population in the area, however.

Reservation

This alternative could have a positive impact on the Reservation economy if additional water in the river were applied to beneficial uses like irrigation for subsistence farming or commercial agriculture. Irrigated agriculture and downstream recreation could generate direct employment, income, and overall economic improvements on the Reservation. There might be some lost secondary spending on the Reservation associated with lost agriculture- and recreation-related income. These secondary impacts could include such things as spending at the Tribal casino, expenditures for gas, and sending for other goods and services by people outside the Reservation who work in agricultural-related services or who are going to or have engaged in recreation at Angostura Reservoir. The net impacts of this alternative on the Reservation can't be estimated with certainty.

Table 4. 19: Annual Recreation Visitation (Visitor Days) and Benefits ($), April-September

Irrigated Acres at Minimum Elevation	Average Reservoir Elevation	Camping	Day Use	Total	Change in Visitation from No Action	Change in Recreation Benefits from No Action
No Action (10,000 acres at 3163 feet)	3181.4 ft.	30,300	240,800	271,100		$7,075,000
Reestablishment of Natural Flows (0 acres at 3157 feet)	3158.9 ft.	22,800	165,200	188,000	-83,100	-$2,168,000
Improved Efficiencies (10,000 acres at 3163 feet)	3184.3 ft.	31,400	251,500	282,900	+11,800	+$310,000
Improved Efficiencies (10,000 acres at 3170 feet)	3183.3 ft.	31,000	248,000	279,000	+7,900	+$207,000
Improved Efficiencies (10,000 acres at 3175 feet)	3183.5 ft.	31,100	248,600	279,700	+8,600	+$226,000
Improved Efficiencies (10,000 acres at 3184 feet)	3185.1 ft.	31,600	254,100	285,700	+14,600	+$382,000
Reservoir Recreation and Fisheries (10,000 acres at 3170 feet)	3182.2 ft.	30,700	244,400	275,100	+4,000	+$104,000

Ecological Benefits/Costs

Using Table 4.18 to estimate benefits and costs, it can be seen that this alternative would benefit five of the State's endangered, threatened, or rare plants and animals. This impact is compared to no benefits or costs in No Action.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Irrigated Agriculture

Reservoir releases to the District would result in fewer shortages in this alternative than in No Action (figured on 10,000 irrigated acres to reservoir elevation 3163 feet). Some slight positive social and economic impacts could be felt by the local community, but these are difficult to quantify because of the uncertainty of the effect of reduced shortages on irrigated agriculture.

Recreation

The Improved Efficiencies Alternative irrigating 10,000 acres to elevation 3184 feet would provide the largest beneficial change in recreation benefits compared to the No Action Alternative, $382,000 (Table 4.19). This alternative irrigating the same acreage to elevation 3170 feet would provide the least change at $207,000.

The reservoir would be at elevation 3175 feet a greater percentage of the time in this alternative, and would generally be below elevation 3187 feet a greater percentage of the time also.

Reservation

Impacts would be as described for No Action. Economic conditions would not change, remaining at the same relatively high levels of unemployment and low income as at present.

Table 4.20: Percentage of Time Boat Ramps Would Be Usable April-Sept.[1]

Reservoir Elevation (Feet)	Useable Boat Ramps	No Action at 3163 feet[2]	Re-Establish-ment of Natural Flows at 3157.2 feet[2]	Improved Efficiency at 3163 feet[2]	Improved Efficiency at 3170 feet[2]	Improved Efficiency at 3175 feet[2]	Improved Efficiency at 3184 feet[2]	Reservoir Recreation and Fish at 3170 feet[2]
3163	0	100.0	0.0	100.0	100.0	100.0	100.0	100.0
3170	2	97.0	0.0	100.0	99.3	100.0	100.0	98.5
3172	4	95.9	0.0	98.9	98.5	100.0	100.0	95.6
3175	8	92.2	0.0	97.4	97.0	98.1	100.0	92.2
3184	8	55.2	0.0	65.6	46.3	46.3	60.0	40.7
3187	8	13.7	0.0	13.7	7.0	7.0	8.1	6.7

[1] Based on time EOM elevations equal to or greater than the elevation needed for boat ramp use, 1998-2042.
[2] Minimum reservoir elevation.

Ecological Benefits/Costs

Ecological benefits and costs would be as described for the No Action Alternative.

Impacts of the Reservoir Recreation and Fisheries Alternative

Irrigated Agriculture

Irrigated agriculture could range from 12,218 acres to zero in this alternative. Impacts would be as in No Action for the former acreage. Loss of irrigated agriculture would probably result in dryland farming—where possible—affecting feed-lot operation, and agricultural production. Overall, agricultural production would be reduced $2,020,000 in final demand, industry output reduced $2,320,000, employee compensation $540,000, total income $1,160,000, and an annual reduction of 47 jobs.

Recreation

This alternative would improve recreational opportunities at the reservoir by maintaining high elevations for fish and wildlife in the early part of the season, but lowering the elevation to meet irrigation demand while maintaining accessibility to boat ramps. Recreation benefits would increase by $104,000 yearly (Table 4.19).

The reservoir would be between elevations 3175-3184 feet a greater percentage of the time in comparison to No Action, the best compromise elevations among boat ramps usage, beach creation, and creation of fish habitat.

Reservation

Impacts would be as described for No Action. Economic conditions would not change, remaining at the same relatively high levels of unemployment and low income as at present.

Ecological Benefits/Costs

This alternative would benefit one of the State's threatened, endangered, or rare plants or animals, in comparison to no benefit or cost for No Action.

INDIAN TRUST ASSETS

ITAs (Indian Trust Assets) of concern were determined to be reserved water rights, culturally important plants, and fisheries (see Chapter Three, "Indian Trust Assets").

Impacts of the No Action Alternative

Reserved Water Rights

Irrigation from the Angostura Unit would continue in this alternative. However, a water rights settlement under the Winters Doctrine could complicate operation by decreasing or restricting the volume of water available to the unit.

Culturally Important Plants

Reported declines in local abundance and distribution of the American plum, common chokecherry, and buffaloberry on the Reservation are probably related to land management practices, such as grazing and fire, and not from operation of the Angostura Unit.

Fishery

The fishery in the Cheyenne River would be unaffected, and the Tribes would retain fishing rights as specified in Article 5 of the Fort Laramie Treaty of 1851.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Reserved Water Rights

Irrigation from the Angostura Unit would be eliminated in this alternative, which would possibly simplify any future water rights negotiations under the Winters Doctrine.

Culturally Important Plants

Impacts would be as described for the No Action Alternative.

Fishery

The fishery in the Cheyenne River would revert to a riverine fishery. The Tribes would retain their fishing rights.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Reserved Water Rights

Impacts would be as described for the No Action Alternative.

Culturally Important Plants

Impacts would be as described for the No Action Alternative.

Fishery

Impacts would be as described for the No Action Alternative.

Impacts of the Reservoir Recreation and Fisheries Alternative

Reserved Water Rights

Impacts would be as described for the No Action Alternative.

Culturally Important Plants

Impacts would be as described for the No Action Alternative.

Fishery

Impacts would be as described for the No Action Alternative.

ENVIRONMENTAL JUSTICE

As explained in Chapter Three, environmental justice was evaluated according to three criteria: Whether impacts were significant or above generally accepted norms; whether contract renewal and water management posed a significant environmental hazard to minority or low income populations which appreciably exceeded the risk to the population in general; and whether impacts—when combined with effects of other projects—posed a cumulative environmental hazard to minority or low income populations.

Impacts of the No Action Alternative

The No Action Alternative would not change the present condition. Therefore, it would not place an undue burden on minority or low income populations according to the three criteria listed above.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

This alternative would eliminate irrigation in the District and reduce recreation at the reservoir, thereby adversely affecting the local economy. It could be beneficial to the Ogala Sioux Tribe if water in the river were used to generate income and employment.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Benefits to irrigation would increase slightly and reservoir recreation would increase in this alternative. It would not place an undue burden on minority or low income populations according to the three criteria.

Impacts of the Reservoir Recreation and Fisheries Alternative

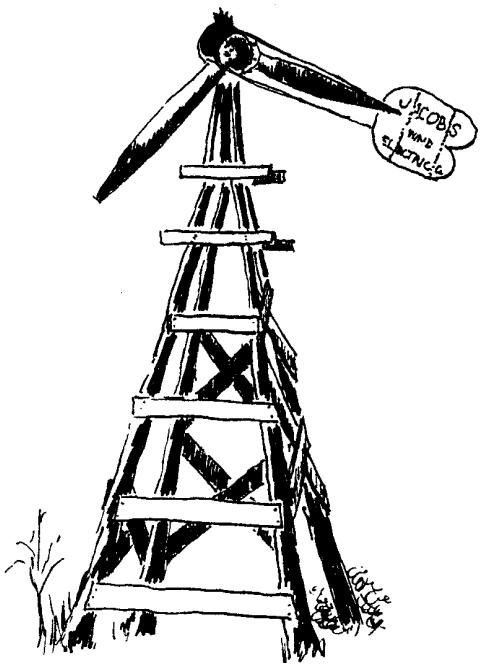
Irrigation would be adversely affected in this alternative, while reservoir recreation would increase. It would not place an undue burden on minority or low income populations according to the three criteria.

CULTURAL RESOURCES

The area analyzed for cultural resources included the reservoir and the surrounding land administered by Reclamation, the District, and the Cheyenne River downstream from the reservoir to the west boundary of the Cheyenne River Sioux Reservation. Particular attention was paid to the shoreline affected by the reservoir's active pool (between elevations 3163-3187 feet) and the T_1 terraces immediately above the Cheyenne River flood plain (see Chapter Three, "Cultural Resources").

Impacts of the No Action Alternative

This alternative would continue current management at the reservoir. The active pool currently covers 28 archaeological sites considered either destroyed or unlocatable. Although Reclamation and SHPO (State Historic Preservation Office) agree these sites probably do not qualify as *historic properties*, Reclamation would attempt to relocate and evaluate these sites if afforded the opportunity. Sites in the 24.2-foot shoreline zone would continue to be affected by inundation and erosion as water elevations fluctuated. Looting and vandalism would occur at sites along shorelines accessible to the public.



Downstream from the dam only sites located immediately next to the active channel would be affected by flows and erosion. However, not all water in the river is released from the gates at the dam; greater flow and even flooding could occur from discharge through the dam spillway, high flow in the tributaries, or from ice dams that impound water behind them. These conditions could also affect sites in the flood plain.

Impacts of Reestablishment of Natural Flows Below the Dam Alternative

Cultural resource sites above elevation 3157 feet would be exposed when the surface area at the reservoir dropped. This would include the 28 sites now underwater. Sites along the shoreline would be subject to erosion. Exposed sites in accessible areas might be looted or vandalized.

Sites in the flood plain would be periodically flooded and exposed as river flows fluctuated. Floods could cause erosion, redeposition, damage, and possibly destruction of sites.

Because there would be no irrigation, District canals and other facilities that might be determined eligible for the National Register could be allowed to decay because their usefulness would be at an end.

Impacts of the Improved Efficiencies Alternative (Preferred Alternative)

Construction to improve efficiency of the District's distribution system would result in ground disturbance. Depending on the nature of the disturbance, unidentified cultural resources might be affected. Otherwise, impacts would be as described for No Action.

Impacts of the Reservoir Recreation and Fisheries Alternative

Impacts would be as described for the No Action Alternative, except the fluctuating shoreline zone would be 17.2 feet wide.

PALEONTOLOGICAL RESOURCES

The area of consideration for paleontological resources was the same as that for cultural resources: Reclamation lands at the reservoir, the District, and 275 miles downstream from the dam to the west boundary of the Cheyenne River Sioux Reservation. The area was further delineated to include the active pool and inundated lands at the reservoir and the T_1 terrace immediately above the flood plain on each side of the Cheyenne River.

Impacts of the No Action Alternative

The reservoir likely covers bedrock containing fossils of paleontological interest. The SI-RBS

(Smithsonian Institute River Basin Survey) did not discover any sites during their paleontological appraisal (Bauxar 1947), but more recent appraisals (Bell 1995a, 1995b, 1997) have documented the presence of vertebrate fossil remains at the reservoir. Although these sites are all above the maximum water level, their presence suggests potential for similar resources within the active 24.2-foot fluctuation zone. Paleontological sites would be subject to erosion due to wave action and fluctuations in the water level, and could be looted or vandalized if exposed by low water levels.

Regulation of the river provides flood control and reduces channel movement and sinuosity in the flood plain. The area of consideration along the Cheyenne probably contains fossil sites. Sites immediately next to the river channel would continue to be affected by flows and formation of ice dams.

Impacts of the Reestablishment of Natural Flows Below the Dam Alternative

Paleontological sites around the reservoir above elevation 3157 feet would be exposed. Sites now along the shoreline would be subject to wave action and erosion. Any sites in areas accessible to the public might be looted or vandalized. Sites in the flood plain and on the T_1 terrace would be subject to periodic flooding and exposure as river flows fluctuated. Floods could cause exposure, redeposition, and damage to sites in the flood plain and on the T_1 terrace.

Impacts of the Improved Efficiencies Alternatives (Preferred Alternative)

Construction to improve efficiency of the District's distribution system would result in ground disturbance. Depending on the type of these operations, unidentified fossil sites might be affected.

Routine operation and maintenance of the District's facilities would often result in ground disturbance. Depending on the type of construction operations, fossil sites might be affected.

Fossil sites around the reservoir within the fluctuating 24.2-foot shoreline zone would be subject to inundation, exposure, and erosion. Those in accessible areas might be exposed to looting and vandalism.

Impacts of the Reservoir Recreation and Fisheries Alternative

Fossil sites within the flood pool would continue to be inundated. Those in the fluctuating 17.2-foot pool level zone would be subject to inundation, exposure, and erosion. Development of beaches and other recreation facilities where sites were located would have potential of destroying fossils or exposing them to looting and vandalism.

CUMULATIVE IMPACTS

Cumulative impacts—impacts of one of the alternatives in this EIS combined with past, present, or reasonably foreseeable actions in the Angostura area—are discussed in this section.

To analyze cumulative effects, EPA recommends determining actions in the area with potential for causing *significant* cumulative impacts, then adding impacts of these actions to those of each of the alternatives. Cumulative impacts thus represent the total effect on a resource, ecosystem, or community of all actions, whether private, Tribal, local, State, or Federal (U.S. Environmental Protection Agency 1998).

Actions with Cumulative Impact Potential

Reclamation determined some actions with cumulative-impact potential, while others were suggested by comment letters (see "Comments/ Responses" in this volume). Unless otherwise specified, actions are considered from the standpoint of their long-term effects (25 years into the future, the period of the new water service contract).

Actions in the Angostura area with potential to contribute to significant cumulative impacts are:

- Stock water and irrigation dams above Angostura Reservoir;
- Development of coalbed methane gas wells in the Cheyenne River drainage;
- Development of housing around the reservoir;
- Construction of the DM&E (Dakota Minnesota and Eastern) Railroad in the Angostura area;
- Reconstruction of State Highway 79 from Rapid City to Nebraska;
- Development of the Fall River Rural Water System;
- Connection of Red Shirt to the Mni Wiconi Rural Water System;
- Development of the hog CFO (confined feeding operation) by the Rosebud Sioux Tribe.

Stock Water and Irrigation Dams above Angostura Reservoir

The National Inventory of Dams lists 251 dams in the Cheyenne River drainage above Angostura Reservoir (U.S. Army Corps of Engineers 2001). Dams—mostly small earth dikes impounding water for livestock or irrigation—have been built on all major tributaries of the Cheyenne in Wyoming, South Dakota, and Nebraska, and on many of the smaller streams in the drainage as well. Effects of these dams was included in the AGRAOP program used to model water available in Angostura Reservoir in the four alternatives (see "Surface Water Quantity in Chapter Three).

Coalbed Methane Wells

Development of coalbed methane wells requires disposal of TDS-laden groundwater pumped out as a byproduct, among other effects. In an EIS they are preparing, the Bureau of Land Management estimated groundwater production through 2018 from coalbed methane wells in the Cheyenne River drainage (which includes the Belle Fourche River). Annual production of groundwater is estimated to peak in 2009 at about 23,000,000 gallons, with 80-90% of this volume expected to be lost to infiltration and evaporation (Paul Beels 2001: personal communication). About 14 AF/year would thus accrue to the drainage, much of which would be impounded behind stock water and irrigation dams.

Housing Around the Reservoir

Housing around Angostura Reservoir has increased greatly in the last five years. On private lands on the west side of the reservoir are housing developments and one trailer park. Preferred housing in the developments is large residential homes. Water's Edge development consists of about 10 home sites. Island Estates, a new development, is selling lots and building some homes. The trailer park contains 30-40 mobile homes. Extensive housing development can be found on private lands on the east side of the reservoir as well, mostly next to Angostura State Recreation Area. Housing there tends to be double-wide trailers or modular homes. There are also 120 sites on public lands around the reservoir, most with trailers. (No new leases are allowed under Reclamation's policy on exclusive use.) A concessionaire at the reservoir has developed cabins to rent: Four have been completed, with another 26 planned.

DM&E Railroad

DM&E Railroad Corporation proposes to build/rebuild about 900 miles of track from Minneapolis to Wyoming's Powder River Basin. The STB (U.S. Surface Transportation Board) completed an EIS for the proposal, signing a Record of Decision in January 2002. The selected alternative includes the WG Divide Segment, which is estimated to affect 437 acres associated with the District, containing both private irrigated land and Reclamation facilities (U.S. Surface Transportation Board 2001).

State Highway 79

State Highway 79 is being widened from two lanes to four and resurfaced from Rapid City to Maverick Junction (where the highway joins State Highway 18, about 2 miles northeast of Angostura Reservoir). Total distance of the construction is about 50 miles. The first section from Rapid City to just south of Hermosa has been completed, with the other three sections scheduled for 2002-2004 (Dale Russell 2001: personal communication).

Fall River Rural Water System

The Fall River Water Users System would supply livestock and domestic water to the eastern third of Fall River County. Water would be drawn from a well drilled into the Madison Formation and distributed by 178 miles of pipeline (U.S. Natural Resources Conservation Service 1996). Other facilities would include 120 miles of conveyance pipeline and 160 livestock tanks. In the *Finding of No Significant Impact* on the project, the U.S. Natural Resources and Conservation Service concluded that improved range management after the project were completed would reduce runoff and sediment into the reservoir and the river downstream.

Connection of Red Shirt with Mni Wiconi

The Mni Wiconi Water Project will pipe treated Missouri River water to Red Shirt by 2003, which could increase per-capita water use in the long term. There would be more wastewater to treat as a consequence. Red Shirt's sewage lagoon has never been sealed and may be undersized (Cal Clifford 2001: personal communication). It is on the Indian Health Service's *Sanitation Deficiency Listing*, but no funding has been proposed to renovate, seal, and perhaps re-size the lagoon.

Hog CFO of the Rosebud Tribe

The Rosebud Sioux Tribe has constructed the first unit of a hog CFO in Mellette County just north of their reservation. The unit consists of 24 barns each producing 4,000 hogs/year (Roy Pulfrey 2001: personal communication). The second unit is under construction, and six more units of similar size planned (along with three other units of 5,000 sows each to supply the piglets). All units would be within 10 miles of each other. The Rosebud Sioux Tribe's operation is nearly 100 miles away from the Cheyenne River at its nearest point, with the White River drainage between the Cheyenne and the CFO.

Impacts

The analyses in this EIS concluded that direct and indirect impacts of the four alternatives would not contribute appreciably to cumulative impacts of the actions discussed above. Consequently, no significant cumulative impacts are anticipated as a result of any of the alternatives. The alternatives interact with the actions in different ways, however. Minor impacts that might result are discussed below by environmental factor.

Surface Water Quality

Development of more housing could increase eutrophication potential of the reservoir in the No Action, Improved Efficiencies, and Reservoir Recreation and Fisheries Alternatives

by increasing the chance of septic/sewer system malfunction. New construction on private lands would have to meet septic/sewer codes. Should these systems begin to fail and increase nutrient loading in the reservoir, Reclamation could take several steps to mitigate the effects: Trailers and cabins on public lands could be encouraged to install septic/sewer systems; livestock could be removed from Reclamation-administered lands around the reservoir; State and Federal Government agencies, private interests, and private landowners could be encouraged to begin a process to reduce nutrient loading upstream of the reservoir.

An increase in eutrophication potential wouldn't be a concern in the Reestablishment of Natural Flows Below the Dam Alternative since the reservoir would be effectively drained and thereby discourage housing development.

Connection of Red Shirt to Mni Wiconi could lead to more seepage from the sewage lagoon into the river in all of the alternatives, affecting the sometimes low DO in the river near the town. Seepage would remain a concern unless the sewage lagoon were renovated, sealed, and re-sized.

Groundwater

Development of more housing around the reservoir in the No Action, Improved Efficiencies, and Reservoir Recreation and Fisheries Alternatives could increase nitrates in shallow aquifers in the area. This would be particularly true in the Improved Efficiencies Alternative as it would reduce irrigation return flows that recharge groundwater. The Reestablishment of Natural Flows Below the Dam Alternative would discourage housing development around the reservoir.

Wetlands

Development of more housing around the reservoir could affect water available to wetlands in and around the reservoir in the No Action, Improved Efficiencies, and Reservoir Recreation and Fisheries Alternatives; this wouldn't be a factor in the Reestablishment of Natural Flows Below the Dam Alternative which would discourage housing. The Fall River Rural Water System will be available to supply water to homes rather than drawing it from the reservoir. Some wetlands in the Angostura area might be affected by construction of the DM&E Railroad. The STB's selected alternative includes the WG Divide Segment through the Angostura area.

Fisheries

Development of more housing could affect fisheries by stimulating eutrophication of the reservoir in the No Action, Improved Efficiencies, and Reservoir Recreation and Fisheries Alternatives. Septic/sewer codes on private lands, encouraging installation of septic/sewer systems on public lands, removing livestock on Reclamation-administered lands at the reservoir, and encouraging reduction of nutrient loading upstream could mitigate this impact. Connection of Red Shirt to Mni Wiconi could lead to more seepage from the sewage lagoon into the river in all of the alternatives, affecting the sometimes low DO in the river near the town, and thus the fisheries. Seepage would remain a concern unless the sewage lagoon were renovated, sealed, and re-sized.

Social and Economic Conditions

Development of more housing around the reservoir in the No Action, Improved Efficiencies, and Reservoir Recreation and Fisheries Alternatives would add to spending in the Angostura area, particularly in the last alternative since it would encourage more visitation. Construction of the WG Divide Segment of the DM&E Railroad would take 437 acres in the District out of production in the No Action, Improved Efficiencies, and Reservoir Recreation and Fisheries Alternatives. This loss could be made up for by irrigating

Cheyenne River near Red Shirt

other parcels of District land. Connection of Red Shirt to Mni Wiconi could encourage development on the Reservation by providing a source of good quality water.

Indian Trust Assets

Connection of Red Shirt to Mni Wiconi could lead to more seepage from the sewage lagoon, affecting the sometimes low DO in the river near the town, and thus the fisheries. This would be less of a concern in the Reestablishment of Natural Flows Below the Dam Alternative since river flows would be seasonally higher than in the other alternatives.

UNAVOIDABLE ADVERSE EFFECTS

Unavoidable adverse effects are environmental impacts of an alternative that can't be avoided, either by changing the nature of the action or through mitigation if the action were undertaken. For the No Action, Improved Efficiencies, and Reservoir Recreation and Fisheries Alternatives, water used for irrigation in the Cheyenne River basin would be unavailable for other uses, such as for aquatic habitat or a municipal water supply. For the Re-establishment of Natural Flows Below the Dam Alternative, water would not be available for irrigation, affecting social and economic conditions of those dependent on irrigation.

SHORT-TERM USES/LONG-TERM PRODUCTIVITY

Short-term negative impacts can be counterbalanced by long-term positive impacts (and vice versa). The short-term negative impacts of diverting water for irrigation in No Action, Improved Efficiencies, and Reservoir Recreation and Fisheries Alternatives would be offset by the long-term beneficial impacts on wetlands and wildlife habitat from irrigation. The short-term negative impacts of the Reestablishment of Natural Flows Below the

Dam Alternative on environmental benefits of irrigation would be balanced by the long-term improvement in riparian habitat along the river below the dam.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Irreversible commitments are decisions affecting renewable resources like soils, wetlands, and waterfowl habitat. Such decisions are considered irreversible because their implementation would affect a resources that has deteriorated to the point that renewal could occur only over a long period of time or at great expense, or because they would cause the resource to be destroyed or removed. Irretrievable commitment of natural resources means loss of production or use as a result of a decision. It represents opportunities foregone for the period that a resource could not be used. The Reestablishment of Natural Flows Below the Dam or Improved Efficiencies Alternatives with more flows in the river downstream of the dam would cause a beneficial impact on resources below the dam. The loss of irrigation in the Reestablishment of Natural Flows Below the Dam Alternative would negatively affect the wetlands found in the District.