Chapter 7

Conclusions

This study addressed three questions of interest to the Los Angeles District regarding re-operation of Alamo Reservoir. These questions were:

- Can Alamo reservoir be operated to protect against bald eagle nest inundation, and if so, can impacts on the riparian habitat and other listed species be approximated?
- Can different draw-down schemes for required maintenance improve reservoir performance based on evaluation criteria used in the BWRCTC study?
- Can improvements to the operation plan recommended by the Bill Williams River Corridor Technical Committee be made based on results from an HEC-PRM model of the Alamo Reservoir system?

Addressing these questions led to the following conclusions:

1. Results from a combined approach using an optimization (HEC-PRM) and simulation model of the Alamo Reservoir system confirmed that the operating rule proposed by the Bill Williams River Corridor Technical Committee performs very well.

2. The HEC-PRM model results agree with the BWRCTC findings that 1,125 feet is a good target elevation to meet operational objectives.

3. Slight modifications to the BWRCTC rule form can increase the number of pulse flow events (desirable for riparian habitat) over the simulation period.

4. A flexible draw-down scheme that schedules draw-down events based on the condition of the reservoir instead of on a rigid schedule significantly improves reservoir performance according to the evaluation criteria.

5. Based on the historical record of inflows and the physical characteristics of Alamo Reservoir, it is impossible to prevent eagle nest inundation 100% of the time without structural modifications to the outlet works.

6. Probabilistic simulation of eagle nesting behavior shows that if a modified version of the BWRCTC proposed rule is implemented, there exists an 0.18 probability that an eagle nest will be inundated during a year.

7. The chance of eagle nest inundation can be reduced to 5% per year by implementing an operating policy that responds to the nesting behavior of the eagles, but this reduction in inundation risk causes significant reductions in

performance for other objectives including protecting other species listed under the Endangered Species Act, and even maintenance of forage area for the bald eagles.

8. Provisions in the Endangered Species Act, such as the federal consultation process and multi species recovery plans provide a legal method for the USACE to help formulate a comprehensive long-term approach to manage conflicting interests between listed species impacted by operation of Alamo Reservoir.

Appendix A

References

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Appendix B

AlamoSim Model Configuration

The Bill Williams River system modeled includes pumping from Planet Ranch, simplified stream and aquifer interactions, and channel flows. The following tables present details extracted from the HEC-5 model and used in the AlamoSim model.

Table B1: Evaporation Rates for Alamo Reservoir (Inches / Month) over Area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(in/mo)	1.70	2.08	3.68	5.55	7.42	9.69	9.43	8.52	6.35	4.35	2.42	1.5

Table B2: Alamo Reservoir Physical Characteristics

Storage Capacity (ac-ft)	Outlet Capacity (cfs)	Surface Elevation (feet)	Surface Area (acres)
0	0	990	0
1,282	3,515	1,030	170
8,168	4,314	1,050	542
24,372	4,974	1,070	1,151
38,058	5,274	1,080	1,596
56,619	5,571	1,090	2,139
80,411	5,834	1,100	2,600
108,699	6,095	1,110	3,086
142,224	6,351	1,120	3,606
179,730	6,594	1,130	4,075
221,453	6,732	1,140	4,574
260,399	7,000	1,148	5,063
321,716	7,000	1,160	5,881
386,931	7,000	1,171	6,743
445,866	7,000	1,180	7,519
521,170	7,000	1,190	8,488

Storage Capacity (ac-ft)	Outlet Capacity (cfs)	Surface Elevation (feet)	Surface Area (acres)
605,774	7,000	1,200	9,436
700,080	7,000	1,210	10,390
809,220	7,000	1,220	11,520
930,210	7,000	1,230	12,740
995,300	7,000	1,235	13,300
1,063,500	11,295	1,240	14,000
1,209,100	24,603	1,250	15,200
1,367,400	51,934	1,260	16,500
1,451,300	65,197	1,265	17,100

Table B3: Muskingum Routing Parameters for Stream Reaches

Upstream End	Downstream End	Subreaches	Routing Coef. (X)	Travel Time (K)
ALMO	PRCH	2	0.15	14.5 hrs
BWRNWR	LKHAVASU	2	0.1	13.5 hrs

Table B4: Monthly Diversions Along Stream (cfs)

Month	ET from PRCH	ET from LKHAVASU	Pumping from PLANET RANCH GROUNDWATER
Jan	2.90	5.27	0.217
Feb	3.55	6.45	0.217
Mar	6.27	11.41	13.429
Apr	9.46	17.21	28.21
May	12.65	23.01	42.25
Jun	16.52	30.05	42.25
Jul	16.08	29.24	42.25
Aug	14.53	26.42	42.25
Sep	10.83	19.69	21.19
Oct	7.42	13.49	14.08
Nov	4.13	7.50	0.217
Dec	2.65	4.65	0.217

Table B5: Dry Bed Infiltration to Planet Ranch Aquifer

Flow in Stream (cfs) at PLANET RANCH IN	Flow to Aquifer (cfs) PLANET RANCH GROUNDWATER
0	0
296	236
466	425
1360	638
3200	1010

Table B6: Planet Ranch Groundwater Physical Characteristics

Storage Capacity (ac-ft)	Release Capacity (cfs)	Ground Water Elevation (feet)
1	20	463
365,800	20	563
368,458	103	564
371,116	333	565
373,774	669	566
376,432	1,106	567
379,090	1,643	568
381,748	2,279	569
384,406	3,018	570
387,064	3,862	571
501,146	87,750	600

Table B7: Elevation Discharge Relation for Aquifer

Groundwater Table Elevation (ft)	Channel Capacity (cfs)	Interpolate
463	0.01	Yes
550	9	Yes
555	12	Yes
560	15	Yes
563	19	Yes
600	87,750	No

Appendix C

Hydrologic Record Missing Values

Five missing values (-901) were found in the updated hydrologic record supplied by the Los Angeles District. The following values were inserted into the record based on the values surrounding the missing data.

Date	Value in Record	Changed to
July 1, 1981	-901	0.0
July 2, 1981	-901	0.0
August 30, 1983	-901	5.0
August 31, 1983	-901	5.0
August 31, 1984	-901	28.0

Appendix D

Release Rules

Optimization Based Alternative (OBA) 2A

A simulation rule based on HEC-PRM results for all interests weighted equally. The rule was designed to set releases to maintain a target storage level. The release decision is based on a deviation from the target storage and the inflow. The rule can be written as:

Storage Condition	Criteria	Release (Subject to Release Capacity)
If Storage Deviation	>= 0	Maximum of: Good Release, 0.95 * Net Inflow, or 0.90 * Storage Deviation
ElseIf Storage Deviation	>= -500	Maximum of: Good Release, or 0.95 * (Net Inflow + Storage Deviation)
ElseIf Storage Deviation	> Dry Deviation	Maximum of: Mid Release, or 0.95 * (Net Inflow + Storage Deviation)
Else		Maximum of: Low Release, or 0.95 * (Net Inflow + Storage Deviation)

Where:

Storage Deviation = Current Storage - Target Storage
Net Inflow = Inflow - Evaporation

Month	Target Storage (KAF)	Dry Deviation (KAF)	Good Release (cfs)	Mid Release (cfs)	Low Release (cfs)
Jan	158.1	-9.1	25	10	10
Feb	159.4	-7.0	40	25	10
Mar	160.3	-0.4	40	25	10
Apr	159.4	-1.7	40	25	10
May	156.7	-2.2	40	25	10
Jun	156.1	-2.5	50	25	10
Jul	157.0	-3.8	50	25	10
Aug	156.1	-5.4	50	25	10
Sep	155.2	-5.3	50	25	10
Oct	155.2	-6.5	40	15	10
Nov	154.5	-7.5	25	10	10
Dec	156.7	-12.7	25	10	10

Optimization Based Alternative (OBA) 3A

OBA 2A modified to relax emphasis on maintaining target storage. (Changes from OBA 2A are underlined.) The rule can be written as:

Storage Condition	Criteria	Release (Subject to Release Capacity)
If Storage Deviation	>= 0	Maximum of: Good Release, 0.95 * Net Inflow, or 0.90 * Storage Deviation
ElseIf Storage Deviation	>= -1,500	Maximum of: Good Release, 0.85 * Net Inflow, or 0.95 * (Net Inflow + Storage Deviation)
ElseIf Storage Deviation	> Dry Deviation	Maximum of: Mid Release, 0.50 * Net Inflow, or 0.95 * (Net Inflow + Storage Deviation)
Else		Maximum of: Low Release, or 0.95 * (Net Inflow + Storage Deviation)

Where:

Storage Deviation = Current Storage - Target Storage
Net Inflow = Inflow - Evaporation
<u>Dry Deviation = -31,000</u>

Month	Target Storage (KAF)	Good Release (cfs)	Mid Release (cfs)	Low Release (cfs)
Jan	158.1	25	10	10
Feb	159.4	40	25	10
Mar	160.3	40	25	10
Apr	159.4	40	25	10
May	156.7	40	25	10
Jun	156.1	50	25	10
Jul	157.0	50	25	10
Aug	156.1	50	25	10
Sep	155.2	50	25	10
Oct	155.2	40	15	10
Nov	154.5	25	10	10
Dec	156.7	25	10	10

Optimization Based Alternative (OBA) 3C

OBA 3A modified to relax emphasis on maintaining target storage. (Changes from OBA 3A are underlined.) The rule can be written as:

Storage Condition	Criteria	Release (Subject to Release Capacity)
If Storage Deviation	>= 0	Maximum of: Good Release, 0.50 * Net Inflow, or 0.10 * Storage Deviation
ElseIf Storage Deviation	>= -40,000	Maximum of: Good Release, 0.50 * Net Inflow, or 0.10 * (Net Inflow + Storage Deviation)
ElseIf Storage Deviation	> Dry Deviation	Maximum of: Mid Release, 0.50 * Net Inflow, or 0.10 * (Net Inflow + Storage Deviation)
Else		Maximum of: Low Release, or 0.10 * (Net Inflow + Storage Deviation)

Where:

Storage Deviation = Current Storage - Target Storage
Net Inflow = Inflow - Evaporation
Dry Deviation = -50,000

Month	Target Storage (KAF)	Good Release (cfs)	Mid Release (cfs)	Low Release (cfs)
Jan	158.1	25	10	10
Feb	159.4	40	25	10
Mar	160.3	40	25	10
Apr	159.4	40	25	10
May	156.7	40	25	10
Jun	156.1	50	25	10
Jul	157.0	50	25	10
Aug	156.1	50	25	10
Sep	155.2	50	25	10
Oct	155.2	40	15	10
Nov	154.5	25	10	10
Dec	156.7	25	10	10

Optimization Based Alternative (OBA) 3G

A simplified form of OBA 3A modified to relax emphasis on maintaining target storage. (Changes from OBA 3A are underlined.) An additional component was added so that if a release greater than or equal to 1,000 cfs was made in January through May, the release would be kept at or above 1,000 cfs for at least seven consecutive days. This new component is referred to as a "Pulse Flow Extender" (PFE). The rule can be written as:

Storage Condition	Criteria	Release (Subject to Release Capacity)
If Storage Deviation	>= 0	Maximum of: Good Release, 0.95 * Net Inflow, or 0.90 * (Net Inflow + Storage Deviation)
ElseIf Storage Deviation	>= -80,566	Maximum of: Good Release, or 0.95 * (Net Inflow + Storage Deviation)
Else		Maximum of: Low Release, or 0.95 * (Net Inflow + Storage Deviation)

Where:

Storage Deviation = Current Storage - Target Storage
Net Inflow = Inflow - Evaporation
<u>Target Storage</u> = 160,977

Month	Good Release (cfs)	Mid Release (cfs)	Low Release (cfs)
Jan	25	10	10
Feb	40	25	10
Mar	40	25	10
Apr	40	25	10
May	40	25	10
Jun	50	25	10
Jul	50	25	10
Aug	50	25	10
Sep	50	25	10
Oct	40	15	10
Nov	25	10	10
Dec	25	10	10

Pulse Flows are sustained by:

```
IF Release > 1,000 cfs THEN
    IF Month > 0 and < 6
        Maintain Release >= 1,000 cfs for at least 7 days
    ENDIF
ENDIF
```

Appendix E

Draw-Down Release Rules

Low Level Draw-Down Release Rule

The target storage for September and October are set to provide enough water for base flows. If the storage is higher than the target storage for that month, releases are made to try and meet the target storage by the end of the month. No releases are made from November 1 to November 14.

Storage Condition	Criteria	Release (Subject to Release Capacity)
If Storage	> Target Storage	Maximum of: Good Release, or Storage Deviation * (Current Day / 31)
ElseIf Storage	>= 80,411 (1,100 ft)	Good Release
Else		Low Release

Where:

Storage Deviation = Current Storage - Target Storage

Month	Target Storage (acre-feet)	Good Release (cfs)	Low Release (cfs)
Sep	83,911 (1,101.2 ft)	50	10
Oct	80,411 (1,100 ft)	40	10
Nov 1 - 14	80,411	0	0

Forced Draw-Down Release Rule

This release rule is implemented eight years have passed since the last outlet tunnel inspection. The rule is implemented in the Spring to try and release any surplus water as a spring flushing flow with an extended recession as outlined in the *Proposed Water Management Plan For Alamo Lake and the Bill Williams River,* (BWRCTC, 1994). Determining the amount of surplus water is based on a target elevation of 1106 feet at the end of April to provide about 17,800 acre-feet of water make base flow releases until November.

The rule is implemented as follows:

- Determine amount of surplus on April 1.
  Surplus = Storage - 109, 611

- If Surplus > 0 then set a pulse flow strategy.

Condition	Criteria	Pulse Flow Characteristics
If Surplus	> 75,000 ac-ft	Peak Flow = 7,000 cfs; Recession Length = 20 days
ElseIf Surplus	> 50,000 ac-ft	Peak Flow = 5,000 cfs; Recession Length = 20 days
ElseIf Surplus	> 30,000 ac-ft	Peak Flow = 4,000 cfs; Recession Length = 20 days
ElseIf Surplus	> 5,000 ac-ft	Peak Flow = 1,000 cfs; Recession Length = 6 days
Else		No pulse release

- The pulse releases are made starting at 1,000 cfs and increasing by 1,000 cfs per day until the peak is reached.
- The peak release is maintained for as many days as possible according to the available surplus allowing for the volume required for the recession, (always releasing at least 1,000 cfs for at least seven days).
- The recession releases decrease from 500 cfs to 45 cfs over the recession length.

After pulse release make releases as follows. If storage is greater than the target storage for a given month, releases are made to try to meet the target storage by the end of the month.

Storage Condition	Criteria	Release (Subject to Release Capacity)
If Storage	> Target Storage	Maximum of: Good Release, or Storage Deviation * (Current Day / 31)
ElseIf Storage	>= 80,411 ac-ft (1,100 ft)	Good Release
Else		Low Release

Where:

Storage Deviation = Current Storage - Target Storage
and

Month	Target Storage (acre-feet)	Good Release (cfs)	Low Release (cfs)
Apr	109,611	40	10
May	104,611	50	10
Jun	99,211	50	10
Jul	93,811	50	10
Aug	88,411	50	10
Sep	83,911	50	10
Oct	80,411	40	10

Appendix F

Eagle Nest Protection Rule

The following rule is used between November 1 and July 31 if an eagle nest is vulnerable (at least one active nest over the reservoir). The rule can be written as:

Storage Condition	Criteria	Release (Subject to Release Capacity)
If Storage Deviation	>= 0	Maximum of: Good Release, 0.95 * Net Inflow, or 0.90 * (Net Inflow + Storage Deviation)
ElseIf Storage Deviation	>= 80,411 - Storage Target *(Storage between Storage Target and 1,100 ft elevation)*	Maximum of: Good Release, or 0.90 * (Net Inflow + Storage Deviation)
ElseIf Storage Deviation	>= 24,372 - Storage Target *(Storage between 1,100 ft and 1,070 ft elevation)*	Maximum of: Low Release, or 0.50 * (Net Inflow + Storage Deviation)
Else	*(Below 1,070 ft)*	Maximum of: 0 cfs, or 0.50 * (Net Inflow + Storage Deviation)

Where:

Storage Deviation = Current Storage - Target Storage
Net Inflow = Inflow - Evaporation
Target Storage = 101,000 (1,107.3 feet elevation)

Month	Good Release (cfs)	Mid Release (cfs)	Low Release (cfs)
Jan	25	10	10
Feb	40	25	10
Mar	40	25	10
Apr	40	25	10
May	50	25	10
Jun	50	25	10
Jul	50	25	10
Aug	50	25	10
Sep	50	25	10
Oct	40	15	10
Nov	25	10	10
Dec	25	10	10

Pulse Flows are sustained by:

```
IF Release > 1,000 cfs THEN
    IF Month > 0 and < 6
        Maintain Release >= 1,000 cfs for at least 7 days
    ENDIF
ENDIF
```