RECLAMATION
Managing Water in the West

Anderson Ranch Dam Raise

Preliminary Hydrologic Evaluation

Technical Memorandum

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Regional Office

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U.S. Department of the Interior

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Bureau of Reclamation

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EXECUTIVE SUMMARY

This study evaluated the potential storage benefit associated with a six-foot raise of Anderson Ranch Dam, corresponding to an estimated 28,954 acre-feet of additional storage. The evaluation was conducted using the Boise Planning Model to estimate frequency of fill of the expanded storage space given historical hydrology and future 2080s climate change flows. The results of this study suggest: 1) the probability of filling the expanded storage space is roughly equivalent to the probability of filling the existing storage space under both hydrology scenarios, and 2) larger and earlier runoff peaks in the 2080s Median scenario increases the probability of fill in both storage scenarios (current "baseline" conditions and proposed six-foot dam raise conditions).

Table 0.1 summarizes the results of this analysis in terms of the percent of years that a particular storage volume is equaled or exceeded over the 28-year simulation period. As shown in the table, the new storage space fills completely in 46% of years (13 out of 28 years) given historical hydrologic conditions and in 68% of years (19 out of 28 years) given future 2080s Median Climate Change hydrologic conditions. Results also suggest that the increased operational flexibility provided by the expanded space increases the probability of filling the older, or current, system space. This is shown in Table 0.2, where complete fill of the previously existing space increased from 46% of years to 50% of years under historical hydrologic conditions and from 64% of years to 79% of years under 2080s Median Climate Change conditions.

Table 0.1. Summary of simulated fill to the new six-foot dam raise storage space in terms of the percent (or number of years) a particular fill volume (or fill percent) is equaled or exceeded over the 28-year simulation period (1982 through 2009).

		Historical Hydrology		2080s Median Climate Change Hydrology	
% of Years	No. of Years	Volume (AF)	% Fill	Volume (AF)	% Fill
4%	1	28,954	100.0%	28,954	100.0%
7%	2	28,954	100.0%	28,954	100.0%
11%	3	28,954	100.0%	28,954	100.0%
14%	4	28,954	100.0%	28,954	100.0%
18%	5	28,954	100.0%	28,954	100.0%
21%	6	28,954	100.0%	28,954	100.0%
25%	7	28,954	100.0%	28,954	100.0%
29%	8	28,954	100.0%	28,954	100.0%
32%	9	28,954	100.0%	28,954	100.0%
36%	10	28,954	100.0%	28,954	100.0%
39%	11	28,954	100.0%	28,954	100.0%
43%	12	28,954	100.0%	28,954	100.0%
46%	13	28,954	100.0%	28,954	100.0%
50%	14	15,851	54.7%	28,954	100.0%
54%	15	0	0.0%	28,954	100.0%
57%	16	0	0.0%	28,954	100.0%
61%	17	0	0.0%	28,954	100.0%
64%	18	0	0.0%	28,954	100.0%
68%	19	0	0.0%	28,954	100.0%
71%	20	0	0.0%	25,772	89.0%
75%	21	0	0.0%	17,284	59.7%
79%	22	0	0.0%	15,391	53.2%
82%	23	0	0.0%	0	0.0%
86%	24	0	0.0%	0	0.0%
89%	25	0	0.0%	0	0.0%
93%	26	0	0.0%	0	0.0%
96%	27	0	0.0%	0	0.0%
100%	28	0	0.0%	0	0.0%

Table 0.2. Summary of simulated fill of the previously existing, or current, system space under both the baseline scenario and the new six-foot dam raise scenario in terms of the percent (or number of years) a particular fill volume (or fill percent) is equaled or exceeded over the 28-year simulation period (1982 through 2009).

	Historical Hydrology				2080s Median Climate Change Hydrology			
	Baseline Scenario		6ft Dam Raise		Baseline Scenario		6ft Dam Raise	
% of Years	Volume (AF)	% Fill*	Volume (AF)	% Fill*	Volume (AF)	% Fill*	Volume (AF)	% Fill*
4%	944,860	104.0%	976,392	107.5%	946,839	104.2%	1,003,524	110.4%
7%	944,814	104.0%	973,814	107.2%	946,308	104.1%	1,000,957	110.2%
11%	944,669	104.0%	973,625	107.2%	945,467	104.1%	999,483	110.0%
14%	941,917	103.7%	970,869	106.9%	944,341	103.9%	998,045	109.8%
18%	940,852	103.5%	969,813	106.7%	943,750	103.9%	996,768	109.7%
21%	939,709	103.4%	968,666	106.6%	942,541	103.7%	995,665	109.6%
25%	938,220	103.3%	967,179	106.4%	942,460	103.7%	995,103	109.5%
29%	932,096	102.6%	961,022	105.8%	942,185	103.7%	994,464	109.4%
32%	929,472	102.3%	955,805	105.2%	942,136	103.7%	993,849	109.4%
36%	926,848	102.0%	952,233	104.8%	942,037	103.7%	991,517	109.1%
39%	922,425	101.5%	947,089	104.2%	941,784	103.7%	991,000	109.1%
43%	921,940	101.5%	945,561	104.1%	941,514	103.6%	988,757	108.8%
46%	917,675	101.0%	944,318	103.9%	941,415	103.6%	987,630	108.7%
50%	903,380	99.4%	935,767	103.0%	938,964	103.3%	984,615	108.4%
54%	867,099	95.4%	889,662	97.9%	938,187	103.3%	984,472	108.3%
57%	865,424	95.2%	868,041	95.5%	937,294	103.2%	983,700	108.3%
61%	818,165	90.0%	837,264	92.1%	936,988	103.1%	983,452	108.2%
64%	814,941	89.7%	824,941	90.8%	912,921	100.5%	976,105	107.4%
68%	808,303	89.0%	819,724	90.2%	903,068	99.4%	955,554	105.2%
71%	747,170	82.2%	748,803	82.4%	894,626	98.5%	934,382	102.8%
75%	724,176	79.7%	741,986	81.7%	893,185	98.3%	925,894	101.9%
79%	713,034	78.5%	731,604	80.5%	885,225	97.4%	924,000	101.7%
82%	622,925	68.6%	651,883	71.7%	821,906	90.5%	862,560	94.9%
86%	611,920	67.3%	628,158	69.1%	753,989	83.0%	772,696	85.0%
89%	545,313	60.0%	548,637	60.4%	711,705	78.3%	716,304	78.8%
93%	468,966	51.6%	472,807	52.0%	681,586	75.0%	703,554	77.4%
96%	392,270	43.2%	391,712	43.1%	667,636	73.5%	692,211	76.2%
100%	336,592	37.0%	340,310	37.5%	634,667	69.9%	646,695	71.2%

1 PROJECT OVERVIEW

The objective of this project is to evaluate the storage benefit associated with a six-foot raise of Anderson Ranch Dam. Such a raise would provide an additional 28,954 acre-feet of storage space. The evaluation was conducted using the Boise Planning Model to simulate the frequency of fill of the expanded storage space given historical hydrology and future 2080s climate change flows.

2 BOISE PLANNING MODEL DESCRIPTION

The Boise Planning Model was developed using RiverWare and includes logic to simulate all of the competing water demands in the system while adhering to legal water right and physical constraints. Competing water demands include irrigation, flood control, minimum-flow requirements, ecological flow releases, and ecological storage constraints. This model runs at a daily time-step (October 1, 1982 through September 30, 2009) and was recently updated with new operational logic and recalibrated during the Boise General Investigation (Reclamation 2015). Figure 2.1 illustrates simulated and observed storage in the Boise Reservoir System. While the model performs well in simulating physical operations of the reservoir system (particularly with respect to the simulation of annual maximum fill), in its current formulation it is not possible to precisely track ownership of water between the three reservoirs. Therefore analysis in this study is based on fill to the system as a whole, rather than for individual reservoirs.

Figure 2.2 illustrates a comparison of simulated and observed storage for Anderson Ranch Reservoir. It is important to note that operational objectives have changed over the course of the simulation period (1982 – 2009) and that the model has been updated from its original calibration in order to more closely simulate current operational objectives. These include 1) maintaining a minimum storage volume in Arrowrock Reservoir of 50,000 acre-feet, 2) keeping Lucky Peak Reservoir above 264,000 acre-feet from May 31st through September 1st , and 3) manage peak flows at Glenwood gage to be less than 7,000 cfs. In order to meet these more stringent objectives (i.e., backfill Arrowrock Reservoir and Lucky Peak Reservoir), Anderson Ranch Reservoir is drafted lower in the simulation than it is in the observed record. As shown in Figure 2.3 and Figure 2.4, these instances often coincide with periods where simulated storage in Arrowrock Reservoir and Lucky Peak Reservoir is higher than historical observations and is more closely meeting minimum storage objectives.

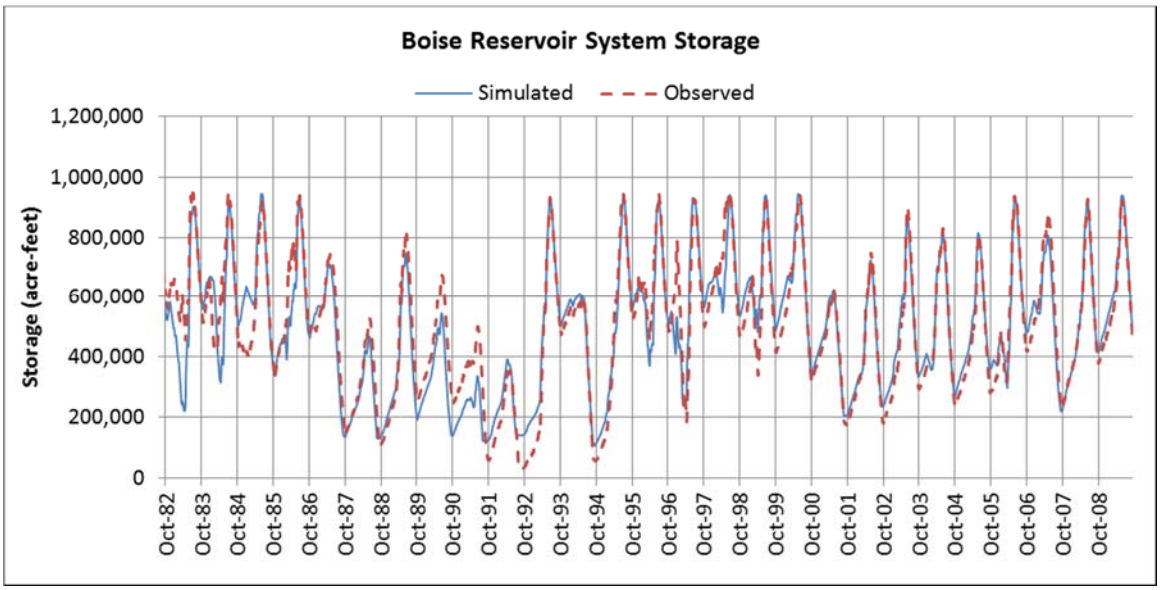

Figure 2.1. Simulated storage (solid blue line) and observed storage (dashed red line) in the Boise Reservoir System for the 1982 through 2009 water years. This figure is adapted from the Boise General Investigation: Modeling the Proposed New Arrowrock Storage Alternatives using the Boise RiverWare Planning Model technical memorandum (Reclamation 2015).

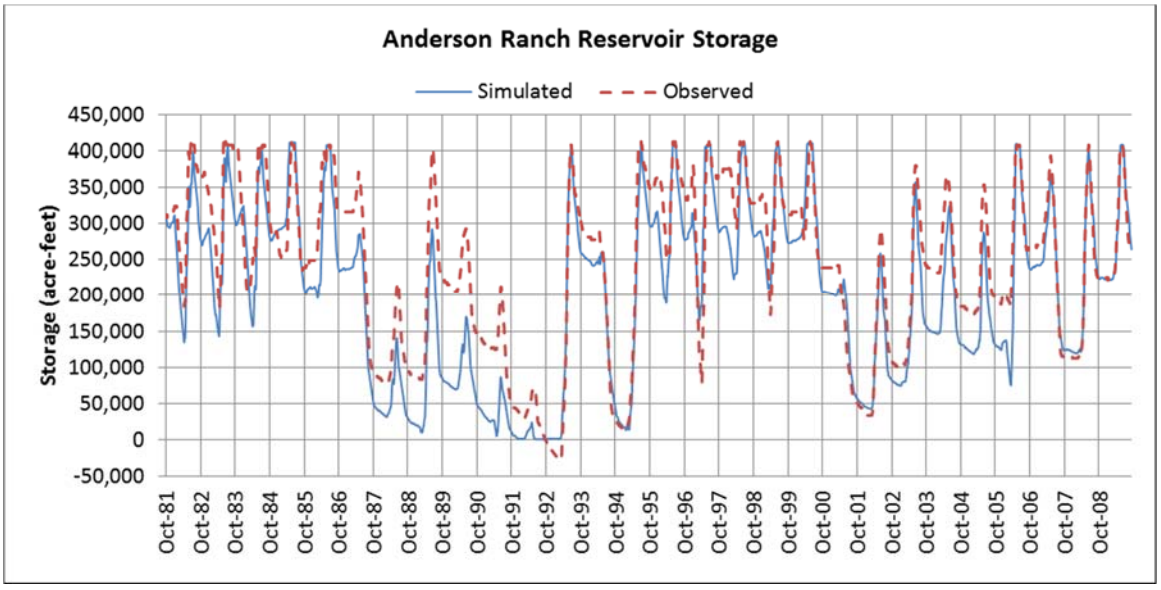

Figure 2.2. Simulated storage (solid blue line) and observed storage (dashed red line) in Anderson Ranch Reservoir for the 1982 through 2009 water years. This figure is adapted from the Boise General Investigation: Modeling the Proposed New Arrowrock Storage Alternatives using the Boise RiverWare Planning Model technical memorandum (Reclamation 2015).

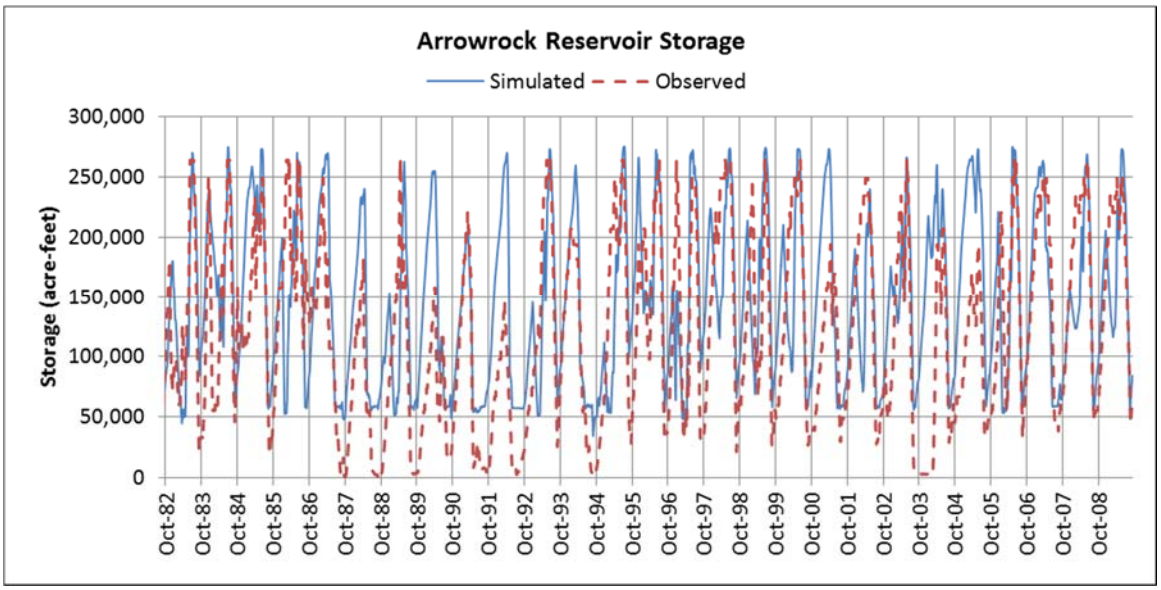

Figure 2.3. Simulated storage (solid blue line) and observed storage (dashed red line) in Arrowrock Reservoir for the 1982 through 2009 water years. This figure is adapted from the Boise General Investigation: Modeling the Proposed New Arrowrock Storage Alternatives using the Boise RiverWare Planning Model technical memorandum (Reclamation 2015).

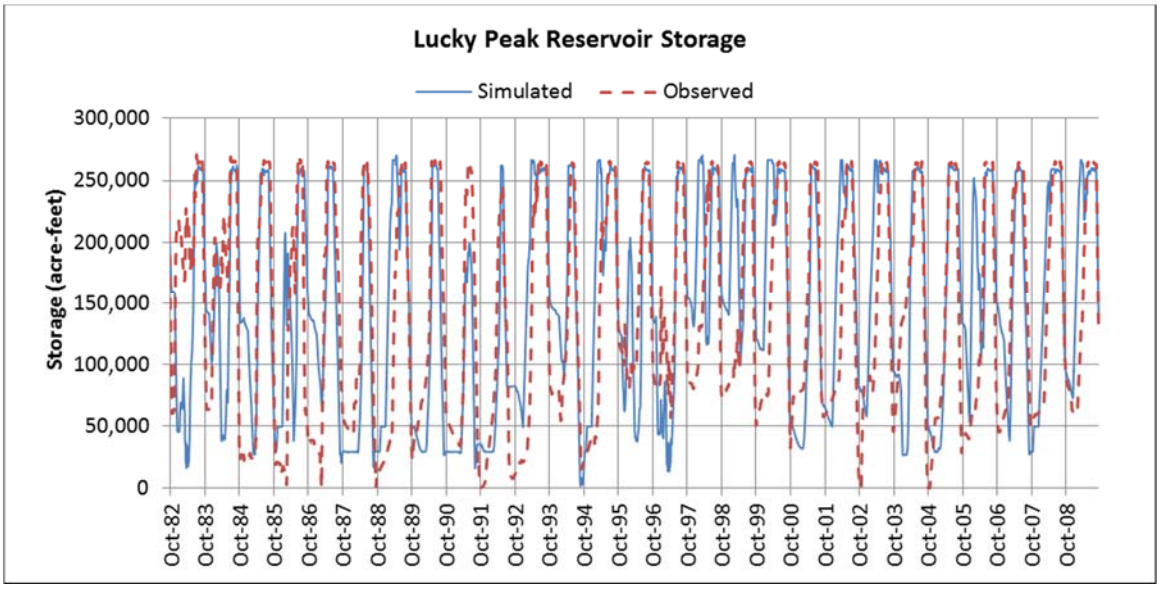

Figure 2.4. Simulated storage (solid blue line) and observed storage (dashed red line) in Lucky Peak Reservoir for the 1982 through 2009 water years. This figure is adapted from the Boise General Investigation: Modeling the Proposed New Arrowrock Storage Alternatives using the Boise RiverWare Planning Model technical memorandum (Reclamation 2015).

3 HISTORICAL REFILL PROBABILITY

Analysis of water right accounting records from the Idaho Department of Water Resources (IDWR), dating back to 1988 and summarized in Appendix Table 9.1, indicates that maximum accrual (excluding accrual to uncontracted space) was achieved in 55% of years for Anderson Ranch Reservoir, 91% of years for Arrowrock Reservoir, and 55% of years for Lucky Peak Reservoir, with all three reservoirs reaching maximum accrual together in only 41% of years. In terms of system fill, IDWR accounting data also suggests that the Boise Reservoir System reached or exceeded the volume of system contracted space (949,668 acre-feet) in 50% of years during the period spanning 1988 through 2009[1]. Simulated results suggest a similar refill probability with the system reaching 949,668 acre-feet in approximately 48% of years for the 1988 through 2009 period and in approximately 46% of years for the full simulation period (1982 through 2009). Results for the full simulation period are summarized in Table 4.1.

4 NEW STORAGE SCENARIO

The Boise Planning Model was used to evaluate the probability of filling an additional 28,954 acre-feet of storage (corresponding to a proposed 6-ft dam raise) in Anderson Ranch Reservoir. This was accomplished by updating the model to include new physical space in Anderson Ranch Reservoir and creating a new storage account with the most junior water right priority date in the basin. In order to evaluate the probability of completely refilling the additional space each year, this evaluation assumed that demand for water is large enough that all water accrued to the new account is used each year, leaving no carryover. This condition was simulated through the addition of a new water user within the model that calls on any water available in the new storage account.

Given the limitations of the current model configuration in tracking ownership or "paper fill" between the reservoirs, fill to the new storage account was calculated as total system fill of the expanded system storage space (978,622 acre-feet) minus the current system storage space (949,668 acre-feet). In other words, fill to the new storage account is assumed to be equivalent to the amount of fill that occurred above and beyond the previously available space. Based on this, simulation results indicate that the new storage account would have similar probability of reaching maximum accrual as the existing

[1] Storage accounting records were not available prior to 1988. Water rights accounting was first implemented in Water District 63 in 1986, however records for 1986 and 1987 did not include values for Anderson Ranch fill. Per conversation with IDWR staff, prior to 1986 allocations were typically based on maximum physical fill of the reservoirs with storage being allocated first to Arrowrock, second to Anderson, and last to Lucky Peak.

reservoir system space, with water available to completely fill the additional 28,954 acre-feet of space in 46% of years over the historical simulation period. These results are summarized in Table 4.1

Table 4.1. Summary of simulated fill in terms of the percent (or number of years) a particular fill volume (or fill percent) is equaled or exceeded over the 28-year simulation period (1982 through 2009).

	Observed		Simulated					
			Historical Hydrology					
			Baseline Scenario		6ft Dam Raise Scenario			
	System		System		System		New Space	
% of Years	Volume (AF)	% Fill*	Volume (AF)	% Fill*	Volume (AF)	% Fill*	Volume (AF)	% Fill
4%	952,832	104.9%	944,860	104.0%	976,392	104.2%	28,954	100.0%
7%	948,045	104.3%	944,814	104.0%	973,814	103.9%	28,954	100.0%
11%	946,359	104.2%	944,669	104.0%	973,625	103.9%	28,954	100.0%
14%	942,834	103.8%	941,917	103.7%	970,869	103.6%	28,954	100.0%
18%	942,559	103.7%	940,852	103.5%	969,813	103.5%	28,954	100.0%
21%	942,477	103.7%	939,709	103.4%	968,666	103.4%	28,954	100.0%
25%	941,269	103.6%	938,220	103.3%	967,179	103.2%	28,954	100.0%
29%	938,324	103.3%	932,096	102.6%	961,022	102.6%	28,954	100.0%
32%	937,362	103.2%	929,472	102.3%	955,805	102.0%	28,954	100.0%
36%	934,163	102.8%	926,848	102.0%	952,233	101.6%	28,954	100.0%
39%	932,963	102.7%	922,425	101.5%	947,089	101.1%	28,954	100.0%
43%	927,148	102.0%	921,940	101.5%	945,561	100.9%	28,954	100.0%
46%	926,674	102.0%	917,675	101.0%	944,318	100.8%	28,954	100.0%
50%	923,154	101.6%	903,380	99.4%	935,767	99.9%	15,851	54.7%
54%	922,033	101.5%	867,099	95.4%	889,662	94.9%	0	0.0%
57%	891,577	98.1%	865,424	95.2%	868,041	92.6%	0	0.0%
61%	877,246	96.5%	818,165	90.0%	837,264	89.3%	0	0.0%
64%	828,838	91.2%	814,941	89.7%	824,941	88.0%	0	0.0%
68%	812,842	89.5%	808,303	89.0%	819,724	87.5%	0	0.0%
71%	802,505	88.3%	747,170	82.2%	748,803	79.9%	0	0.0%
75%	751,135	82.7%	724,176	79.7%	741,986	79.2%	0	0.0%
79%	742,698	81.7%	713,034	78.5%	731,604	78.1%	0	0.0%
82%	673,914	74.2%	622,925	68.6%	651,883	69.6%	0	0.0%
86%	621,332	68.4%	611,920	67.3%	628,158	67.0%	0	0.0%
89%	585,613	64.5%	545,313	60.0%	548,637	58.5%	0	0.0%
93%	527,393	58.0%	468,966	51.6%	472,807	50.5%	0	0.0%
96%	499,783	55.0%	392,270	43.2%	391,712	41.8%	0	0.0%
100%	353,276	38.9%	336,592	37.0%	340,310	36.3%	0	0.0%

* The system is considered full in the Baseline scenarios when the volume meets or exceeds 908,610 AF. This represents the total system volume (949,668 AF) less the amount of storage used for annual flow augmentation (41,058 AF). The system is considered full in the 6ft Dam Raise scenarios when the volume meets or exceeds 937,114 AF. This represents the expanded system volume (978,622 AF) less the amount of storage used for annual flow augmentation (41,058 AF).

The simulations also suggest that increased operational flexibility provided by the additional storage may improve the likelihood of filling the previously existing space. Where this space was shown to fill (exceed 908,610 acre-feet) in 46% of years in the baseline scenario, fill probability of the older space increased to 50% of years in the 6ft dam raise scenario.

5 CLIMATE CHANGE SCENARIO

Several climate change scenarios were considered in this evaluation to provide insight into how probability of fill might change in the future. These scenarios were obtained from the recent Columbia River Basin Impact Assessment (Reclamation 2016a) and include a combination of 20th-, 50th-, and 80th-percentile changes in precipitation and temperature (Less Warming/Dry, Less Warming/Wet, Median, More Warming/Dry, and More Warming/Wet) for the 2040 and 2080 periods. More detailed information on the development of these scenarios is available in Reclamation's Columbia River Basin Impact Assessment Technical Memorandum: Climate Change Analysis and Hydrologic Modeling (2016a). Notable changes to Anderson Ranch inflows under these climate change scenarios include

- An increase in annual inflow volumes by the end of the century (across all scenarios),
- Increased inflows during the late-winter and spring and decreased inflows during the summer months (across all scenarios),
- And a shift in peak inflows from May to April by the end of the century (More Warming/Wet, More Warming/Dry, and Median scenarios).

As in the recent Boise General Investigation modeling (Reclamation, 2015), this evaluation focused on storage impacts under the 2080s Median climate change scenario. In order to gain additional insight into the range of potential future outcomes, attempts were made to run the full spectrum of scenarios through the Boise Planning Model. Unfortunately further updates to the model's flood control logic are needed in order to accommodate the large inflows under the wetter scenarios. More information on system storage under these more extreme scenarios is available in the Columbia River Basin Impact Assessment Water Resource Modeling Technical Memorandum (Reclamation, 2016b), which modeled system storage using a monthly time-step MODSIM model.

Results of the simulations indicate that the probability of filling the new space increases under the 2080s Median climate change scenario, as does the probability of filling the Boise Reservoir System as a whole. Under the climate change scenario the expanded system space fills in 68% of years, compared to 46% under the historical hydrology scenario. These results are summarized in Table 5.1.

Table 5.1. Summary of simulated fill in terms of the percent (or number of years) a particular fill volume (or fill percent) is equaled or exceeded over the 28-year simulation period (1982 through 2009).

	2080s Median Climate Change Hydrology					
	Baseline Scenario		6ft Dam Raise Scenario			
	System		System		New Space	
% of Years	Volume (AF)	% Fill*	Volume (AF)	% Fill*	Volume (AF)	% Fill
4%	946,839	104.2%	1,003,524	107.1%	28,954	100.0%
7%	946,308	104.1%	1,000,957	106.8%	28,954	100.0%
11%	945,467	104.1%	999,483	106.7%	28,954	100.0%
14%	944,341	103.9%	998,045	106.5%	28,954	100.0%
18%	943,750	103.9%	996,768	106.4%	28,954	100.0%
21%	942,541	103.7%	995,665	106.2%	28,954	100.0%
25%	942,460	103.7%	995,103	106.2%	28,954	100.0%
29%	942,185	103.7%	994,464	106.1%	28,954	100.0%
32%	942,136	103.7%	993,849	106.1%	28,954	100.0%
36%	942,037	103.7%	991,517	105.8%	28,954	100.0%
39%	941,784	103.7%	991,000	105.8%	28,954	100.0%
43%	941,514	103.6%	988,757	105.5%	28,954	100.0%
46%	941,415	103.6%	987,630	105.4%	28,954	100.0%
50%	938,964	103.3%	984,615	105.1%	28,954	100.0%
54%	938,187	103.3%	984,472	105.1%	28,954	100.0%
57%	937,294	103.2%	983,700	105.0%	28,954	100.0%
61%	936,988	103.1%	983,452	104.9%	28,954	100.0%
64%	912,921	100.5%	976,105	104.2%	28,954	100.0%
68%	903,068	99.4%	955,554	102.0%	28,954	100.0%
71%	894,626	98.5%	934,382	99.7%	25,772	89.0%
75%	893,185	98.3%	925,894	98.8%	17,284	59.7%
79%	885,225	97.4%	924,000	98.6%	15,391	53.2%
82%	821,906	90.5%	862,560	92.0%	0	0.0%
86%	753,989	83.0%	772,696	82.5%	0	0.0%
89%	711,705	78.3%	716,304	76.4%	0	0.0%
93%	681,586	75.0%	703,554	75.1%	0	0.0%
96%	667,636	73.5%	692,211	73.9%	0	0.0%
100%	634,667	69.9%	646,695	69.0%	0	0.0%

* The system is considered full in the Baseline scenarios when the volume meets or exceeds 908,610 AF. This represents the total system volume (949,668 AF) less the amount of storage used for annual flow augmentation (41,058 AF). The system is considered full in the 6ft Dam Raise scenarios when the volume meets or exceeds 937,114 AF. This represents the expanded system volume (978,622 AF) less the amount of storage used for annual flow augmentation (41,058 AF).

Results of the climate change simulations suggest that increased operational flexibility provided by the additional storage may improve the likelihood of filling the previously existing space. Where this space was shown to fill (exceed 908,610 acre-feet) in 64% of years in the baseline scenario, fill probability of the older space increased to 79% of years in the 6ft dam raise scenario.

6 PREVIOUS STUDY COMPARISON

The refill probabilities estimated by this study are lower than the probabilities suggested by modeling results produced for the 2005 report "Hydrologic Analysis of the Refill Probabilities Associated with Increasing the Storage Capacities of Anderson Ranch and Arrowrock Reservoirs" (Reclamation, 2005). This earlier study reported that the additional storage would fill between 60% and 70% of the time under historical hydrologic conditions, while this study suggests that this space would fill closer to 46% of the time.

While a detailed investigation into the differences between the two modelling efforts was not performed, several differences were noted and likely explain the discrepancy in the reported results. These are summarized in Table 6.1.

Table 6.1. Summary of key model differences between this study (2016) and the earlier 2005 study.

2016 Study	2005 Study
More recent simulation period (1982-2009)	Longer simulation period (1928-2000)
Modeling performed with RiverWare, a rule-based modeling platform for river and reservoir management simulation (www.riverware.org).	Modeling performed with MODSIM, a network flow optimization modeling platform for river and reservoir management simulation (www.modsim.engr.colostate.edu).
System is partitioned into 5 reaches (or river segments)	System is partitioned into 6+ reaches (or river segments)
Reach gains (or local inflow to a particular river segment) obtained from most recent 2010 Modified Flows effort	Reach gains (or local inflow to a particular river segment) obtained from earlier 2000 Modified Flows effort
Demands are represented by historical observed timeseries	Demands are "patterned" (i.e., represented by a 12-month repeating pattern based on historical demands)

7 CONCLUSIONS

The results of this study suggest that the probability of filling an additional 28,954 acre-feet of storage space in Anderson Ranch Reservoir is roughly equivalent to the probability of filling the existing system storage space under both hydrology scenarios (historical and future 2080s Median climate change) and that larger and earlier runoff in the 2080s Median scenario increases the probability of fill in both storage scenarios.

In addition to providing potential carryover benefits, such space may also increase operational flexibility as a result of larger flood control space and increased storage supply to help meet Arrowrock Reservoir and Lucky Peak Reservoir minimum pool criteria. More detailed investigation is needed to more fully quantify the system benefit provided by the additional space.

It is recommended that future work consider a wider range of climate change projections and that the model logic be further updated to accommodate more extreme conditions (as seen in future climate change scenario flows) and more precisely track ownership of water between the reservoirs.

8 LITERATURE CITED

Parenthetical Reference	Bibliographic Citation
Reclamation 2005	Bureau of Reclamation. 2005. Hydrologic Analysis of the Refill Probabilities Associated with Increasing the Storage capacities of Anderson Ranch and Arrowrock Reservoirs. Prepared by the U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. February 2005.
Reclamation 2015	Bureau of Reclamation. 2015. Boise General Investigation: Modeling the Proposed New Arrowrock Storage Alternatives using the Boise RiverWare Planning Model. Prepared by the U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. December 2015.
Reclamation 2016a	Bureau of Reclamation. 2016. Columbia River Basin Impacts Assessment: Climate Change Analysis and Hydrologic Modeling Technical Memorandum. Prepared by the U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. April 2016.
Reclamation 2016b	Bureau of Reclamation. 2016. Columbia River Basin Impacts Assessment: Water Resources Modeling Technical Memorandum. Prepared by the U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. April 2016.

9 APPENDIX

Table 9.1. Summary of Idaho Department of Water Resources water rights accounting data for storage account fill for each year in the data record. Available space reported excludes uncontracted space. Data for storage fill is not available for years prior to 1988.

	Anderson Ranch			Arrowrock			Lucky Peak			System		
Year	Fill (AF)	Space (AF)*	% Fill	Fill (AF)	Space (AF)	% Fill	Fill (AF)	Space (AF)	% Fill	Fill (AF)	Space (AF)	% Fill
1988	151,088	413,074	36.6%	286,600	286,600	100.0%	119,057	264,250	45.1%	556,744	963,924	57.8%
1989	423,200	413,074	102.5%	286,600	286,600	100.0%	137,777	264,250	52.1%	847,577	963,924	87.9%
1990	285,897	413,074	69.2%	286,600	286,600	100.0%	141,468	264,250	53.5%	713,964	963,924	74.1%
1991	190,943	413,074	46.2%	286,600	286,600	100.0%	63,118	264,250	23.9%	540,661	963,924	56.1%
1992	37,006	413,074	9.0%	286,600	286,600	100.0%	66,531	264,250	25.2%	390,137	963,924	40.5%
1993	464,200	413,074	112.4%	286,600	286,600	100.0%	248,879	264,250	94.2%	999,679	963,924	103.7%
1994	303,978	413,074	73.6%	184,854	286,600	64.5%	203,863	264,250	77.1%	692,696	963,924	71.9%
1995	464,200	413,074	112.4%	286,600	286,600	100.0%	264,250	264,250	100.0%	1,015,050	963,924	105.3%
1996	464,200	413,074	112.4%	286,600	286,600	100.0%	264,250	264,250	100.0%	1,015,050	963,924	105.3%
1997	464,200	413,074	112.4%	286,600	286,600	100.0%	264,250	264,250	100.0%	1,015,050	963,924	105.3%
1998	464,200	413,074	112.4%	286,600	286,600	100.0%	264,250	264,250	100.0%	1,015,050	963,924	105.3%
1999	464,200	413,074	112.4%	286,600	286,600	100.0%	257,402	264,370	97.4%	1,008,202	964,044	104.6%
2000	464,200	413,074	112.4%	286,600	286,600	100.0%	264,370	264,370	100.0%	1,015,170	964,044	105.3%
2001	217,658	413,074	52.7%	272,224	272,224	100.0%	183,619	264,370	69.5%	673,502	949,668	70.9%
2002	345,049	413,074	83.5%	272,224	272,224	100.0%	225,624	264,370	85.3%	842,898	949,668	88.8%
2003	413,292	413,074	100.1%	272,224	272,224	100.0%	264,370	264,370	100.0%	949,886	949,668	100.0%
2004	382,027	413,074	92.5%	252,261	272,224	92.7%	264,370	264,370	100.0%	898,658	949,668	94.6%
2005	328,474	413,074	79.5%	272,224	272,224	100.0%	264,370	264,370	100.0%	865,068	949,668	91.1%
2006	450,030	413,074	108.9%	272,224	272,224	100.0%	264,370	264,370	100.0%	986,624	949,668	103.9%
2007	396,490	413,074	96.0%	272,224	272,224	100.0%	264,370	264,370	100.0%	933,084	949,668	98.3%
2008	450,030	413,074	108.9%	272,224	272,224	100.0%	264,370	264,370	100.0%	986,624	949,668	103.9%
2009	450,030	413,074	108.9%	272,224	272,224	100.0%	264,370	264,370	100.0%	986,624	949,668	103.9%

* Volume of space excludes uncontracted space in Anderson Ranch Reservoir.

Table 9.2. Summary of simulated fill in terms of the percent (or number of years) a particular fill volume (or fill percent) is equaled or exceeded over the 28-year simulation period (1982 through 2009).

	Observed		Simulated													
			Historical Hydrology						2080s Median Climate Change Hydrology							
			Baseline Scenario		6ft Dam Raise Scenario				Baseline Scenario		6ft Dam Raise Scenario					
	System		System		System		New Space		System		System		New Space			
% of Years	Volume (AF)	% Fill*	Volume (AF)	% Fill*	Volume (AF)	% Fill*	Volume (AF)	% Fill	Volume (AF)	% Fill*	Volume (AF)	% Fill*	Volume (AF)	% Fill		
4%	952,832	104.9%	944,860	104.0%	976,392	104.2%	28,954	100.0%	946,839	104.2%	1,003,524	107.1%	28,954	100.0%		
7%	948,045	104.3%	944,814	104.0%	973,814	103.9%	28,954	100.0%	946,308	104.1%	1,000,957	106.8%	28,954	100.0%		
11%	946,359	104.2%	944,669	104.0%	973,625	103.9%	28,954	100.0%	945,467	104.1%	999,483	106.7%	28,954	100.0%		
14%	942,834	103.8%	941,917	103.7%	970,869	103.6%	28,954	100.0%	944,341	103.9%	998,045	106.5%	28,954	100.0%		
18%	942,559	103.7%	940,852	103.5%	969,813	103.5%	28,954	100.0%	943,750	103.9%	996,768	106.4%	28,954	100.0%		
21%	942,477	103.7%	939,709	103.4%	968,666	103.4%	28,954	100.0%	942,541	103.7%	995,665	106.2%	28,954	100.0%		
25%	941,269	103.6%	938,220	103.3%	967,179	103.2%	28,954	100.0%	942,460	103.7%	995,103	106.2%	28,954	100.0%		
29%	938,324	103.3%	932,096	102.6%	961,022	102.6%	28,954	100.0%	942,185	103.7%	994,464	106.1%	28,954	100.0%		
32%	937,362	103.2%	929,472	102.3%	955,805	102.0%	28,954	100.0%	942,136	103.7%	993,849	106.1%	28,954	100.0%		
36%	934,163	102.8%	926,848	102.0%	952,233	101.6%	28,954	100.0%	942,037	103.7%	991,517	105.8%	28,954	100.0%		
39%	932,963	102.7%	922,425	101.5%	947,089	101.1%	28,954	100.0%	941,784	103.7%	991,000	105.8%	28,954	100.0%		
43%	927,148	102.0%	921,940	101.5%	945,561	100.9%	28,954	100.0%	941,514	103.6%	988,757	105.5%	28,954	100.0%		
46%	926,674	102.0%	917,675	101.0%	944,318	100.8%	28,954	100.0%	941,415	103.6%	987,630	105.4%	28,954	100.0%		
50%	923,154	101.6%	903,380	99.4%	935,767	99.9%	15,851	54.7%	938,964	103.3%	984,615	105.1%	28,954	100.0%		
54%	922,033	101.5%	867,099	95.4%	889,662	94.9%	0	0.0%	938,187	103.3%	984,472	105.1%	28,954	100.0%		
57%	891,577	98.1%	865,424	95.2%	868,041	92.6%	0	0.0%	937,294	103.2%	983,700	105.0%	28,954	100.0%		
61%	877,246	96.5%	818,165	90.0%	837,264	89.3%	0	0.0%	936,988	103.1%	983,452	104.9%	28,954	100.0%		
64%	828,838	91.2%	814,941	89.7%	824,941	88.0%	0	0.0%	912,921	100.5%	976,105	104.2%	28,954	100.0%		
68%	812,842	89.5%	808,303	89.0%	819,724	87.5%	0	0.0%	903,068	99.4%	955,554	102.0%	28,954	100.0%		
71%	802,505	88.3%	747,170	82.2%	748,803	79.9%	0	0.0%	894,626	98.5%	934,382	99.7%	25,772	89.0%		
75%	751,135	82.7%	724,176	79.7%	741,986	79.2%	0	0.0%	893,185	98.3%	925,894	98.8%	17,284	59.7%		
79%	742,698	81.7%	713,034	78.5%	731,604	78.1%	0	0.0%	885,225	97.4%	924,000	98.6%	15,391	53.2%		
82%	673,914	74.2%	622,925	68.6%	651,883	69.6%	0	0.0%	821,906	90.5%	862,560	92.0%	0	0.0%		
86%	621,332	68.4%	611,920	67.3%	628,158	67.0%	0	0.0%	753,989	83.0%	772,696	82.5%	0	0.0%		
89%	585,613	64.5%	545,313	60.0%	548,637	58.5%	0	0.0%	711,705	78.3%	716,304	76.4%	0	0.0%		
93%	527,393	58.0%	468,966	51.6%	472,807	50.5%	0	0.0%	681,586	75.0%	703,554	75.1%	0	0.0%		
96%	499,783	55.0%	392,270	43.2%	391,712	41.8%	0	0.0%	667,636	73.5%	692,211	73.9%	0	0.0%		
100%	353,276	38.9%	336,592	37.0%	340,310	36.3%	0	0.0%	634,667	69.9%	646,695	69.0%	0	0.0%		

* The system is considered full in the Baseline scenarios when the volume meets or exceeds 908,610 AF. This represents the total system volume (949,668 AF) less the amount of storage used for annual flow augmentation (41,058 AF). The system is considered full in the 6ft Dam Raise scenarios when the volume meets or exceeds 937,114 AF. This represents the expanded system volume (978,622 AF) less the amount of storage used for annual flow augmentation (41,058 AF).