RECLAMATION
Managing Water in the West

Draft

Technical Evaluation Report
Fort Cobb Reservoir Supply/Demand Study

FORT COBB DIVISION, Washita Basin Project
Oklahoma

U.S. Department of the Interior
Bureau of Reclamation
Oklahoma-Texas Area Office August

March 2012

Mission Statements

The mission of the *Department of the Interior* is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the *Bureau of Reclamation* is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

U.S. Department of the Interior
Bureau of Reclamation
Oklahoma-Texas Area Office
Austin, Texas

March 2012

Contents

Page

Executive Summary

Fort Cobb Reservoir, part of the Bureau of Reclamation's Washita Basin Project in central Oklahoma, provides water to the City of Anadarko, Western Farmers Electric Cooperative, the Public Service Company of Oklahoma, and the City of Chickasha. The Project is operated and maintained by the Fort Cobb Reservoir Master Conservancy District (District). The purpose of this report is to review the available water supply relative to existing and future demands for the District's customers, identify potential water supply gaps, and document conveyance losses.

The Bureau of Reclamation (Reclamation) re-evaluated the firm yield of Fort Cobb Reservoir (Appendix A) using current data to determine the supply available to the District's customers. Based on this analysis, the reservoir will provide a firm supply of 17,700 acre-feet per year (ac-ft/yr) through 2060. This estimate considers future sediment conditions, evaporation, and possible depletions to the base flow. Because the firm yield might be sensitive to changes in future climate conditions, a "sensitivity analysis" was conducted to predict a range of possible effects of climate change based on four scenarios ranging from wetter and cooler to warmer and drier. This resulted in upper and lower reservoir yield results bounding the firm yield and representing the range of potential climate change effects. An additional scenario was developed representing the middle tendency of the climate change models and produced yield results for Fort Cobb Reservoir that were essentially equivalent to the non-climate change adjusted yield.[1]

The current water demands for the City of Anadarko and the City of Chickasha were determined to be 175 and 200 gallons per capita per day (GPCD), respectively. These numbers were determined by metering into the respective treatment plants and do not include raw water conveyance losses. The 2060 demand was estimated by indexing the existing usage using projected population growth data presented in the final 2012 Oklahoma Comprehensive Water Plan. The 2060 demand projections for the Western Farmers Electric Cooperative power plant near Anadarko and the Public Service Company of Oklahoma power plant west of Anadarko were provided by the utility companies.[2] Based on this information, the 2060 water demand estimate excluding conveyance losses of the customers serviced by the District is 17,256 ac-ft/yr. Overall, these results indicate that the 17,700 ac-ft/yr firm yield of Fort Cobb Reservoir should be sufficient to meet the long-term 2060 water supply needs of the District's customers, provided the District works with the Oklahoma Water Resources Board to ensure future permitting of surface water and/or groundwater does not impact the base flow in Cobb Creek, the primary tributary of Fort Cobb Reservoir.

When reviewing current water usage records, significant conveyance losses have been documented based on a comparison of metered flows from the reservoir into the Anadarko and Chickasha Aqueducts with metered flows out of the aqueducts and into each city's respective treatment plant. These conveyance losses could be due to a variety of reasons, including line breaks, unmetered uses, evaporation, and/or other unknown causes. Further study is recommended to identify the best option for addressing conveyance issues with the existing aqueducts. In addition, further study is recommended to assess the capacity of the existing aqueducts relative to current and future peak-day demands. Problems meeting peak-day demands were documented in a Reclamation Appraisal Report dated December 2006, which concluded that future expansion of the conveyance system would be necessary, but deferred recommending

[1] Fort Cobb Reservoir Firm Yield Analysis, February 2012
[2] Meeting with Project Stakeholders, 2008

a more detailed conveyance system analysis until an evaluation of supply and demand could be completed.[3]

[3] Concluding Appraisal Report, Conveyance System Expansion, Bureau of Reclamation, December 2006

Introduction

The District is concerned with its capability to provide water to its member entities (City of Anadarko and Western Farmers Electric Cooperative), and to the City of Chickasha through the 2060 planning horizon. As such, the District requested Reclamation's assistance in evaluating the available water supply and demand. The District has also experienced difficulty in delivering sufficient water through the Anadarko Aqueduct to meet the peak-day demands of its service population, and wanted to update supply and demand numbers before any expansion to the Aqueduct is planned.

Purpose

The purpose of this Technical Evaluation Report is to:

- Document the water supply projections for the District through 2060.
- Document the average long-term water demands for the District through 2060.
- Document losses occurring in the raw water conveyance pipelines.

The Washita Basin Project

The Washita Basin Project is a water supply project constructed by Reclamation. It is comprised of two divisions (Foss and Fort Cobb), both of which are located in the Washita River Basin in southwestern Oklahoma (Figure 1).

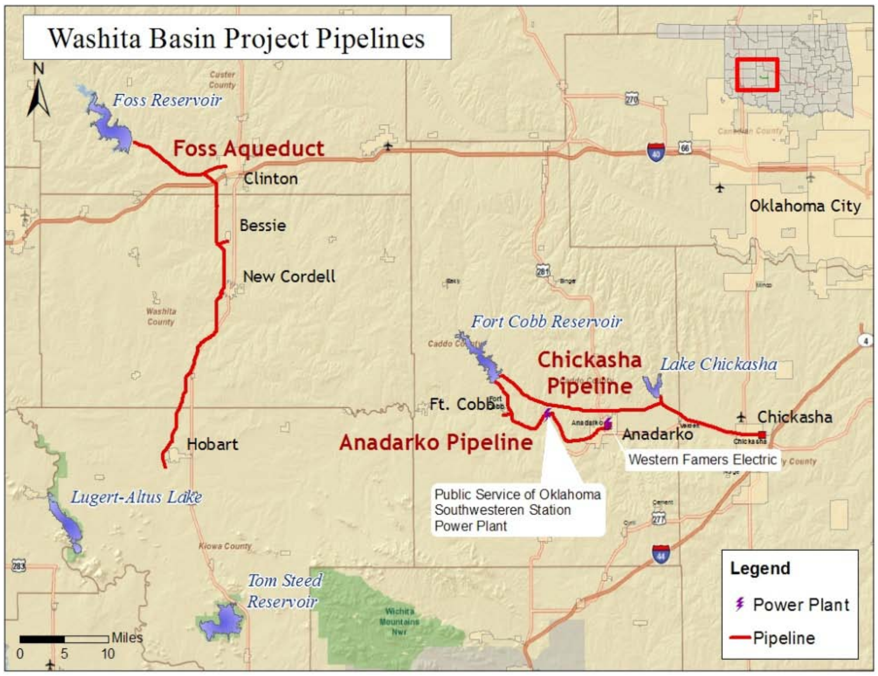


Figure 1 - Washita Basin Project Location Map

Foss Division

The Foss Division includes Foss Dam and Reservoir and the Foss Aqueduct, and is operated by the Foss Reservoir Master Conservancy District under contact with Reclamation. This division provides municipal and industrial (M&I) water to the communities of Clinton, Bessie, Cordell and Hobart. Foss Dam is located on the Washita River about 95 miles west of Oklahoma City, Oklahoma.

Fort Cobb Division

The Fort Cobb Division, which is the subject of this study, includes Fort Cobb Dam and Reservoir and the Anadarko Aqueduct. Reclamation completed construction of these two project features in 1959 and 1961, respectively. Fort Cobb Dam is located on Cobb Creek approximately five miles upstream of its confluence with the Washita River in Caddo County, approximately 60 miles southwest of Oklahoma City, Oklahoma. The Fort Cobb Reservoir Master Conservancy District operates and maintains Fort Cobb Dam and the 20.9-mile long, gravity-flow Anadarko Aqueduct.

Fort Cobb Dam and Reservoir.

The Fort Cobb Division was originally planned to provide M&I water to the cities of Fort Cobb, Anadarko, and Chickasha, as well as water for irrigation of approximately 9,000 acres of land. However, just prior to the organization of the District in 1956 the City of Chickasha withdrew from the project. The proposed project was then revised to include delivery of industrial water to Western Farmers Electric Cooperative (WFEC).

The City of Fort Cobb was released from its contractual obligations with the District in 1964, and in 1966 and a contract to sell surplus water to the City of Chickasha was developed. The City of Chickasha constructed the Chickasha Aqueduct and the first delivery of water occurred in 1969 (Figure 2).

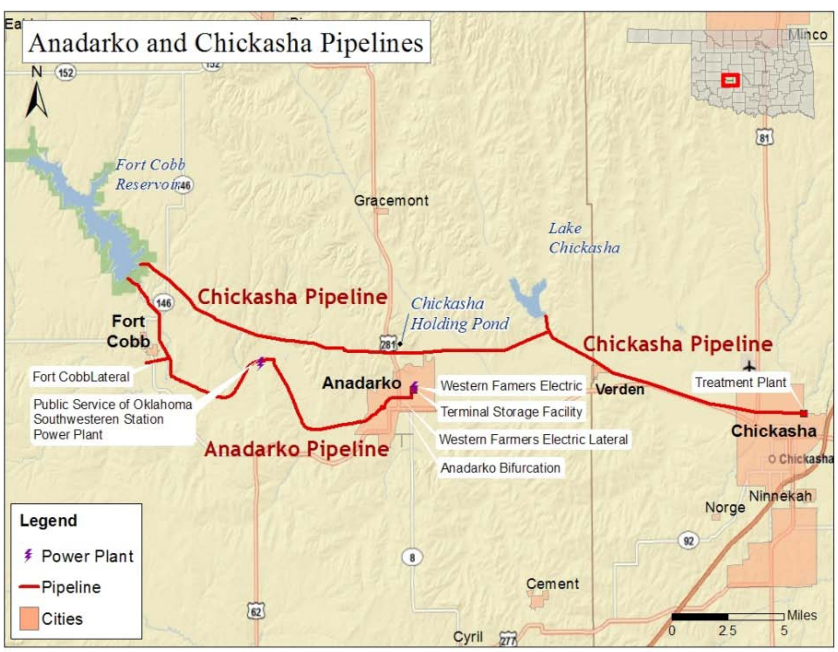


Figure 2 - Anadarko and Chickasha Pipelines

Today, Fort Cobb Reservoir provides M&I water to the Public Service Company of Oklahoma (PSO), Western Farmers Electric Cooperative (WFEC), the City of Anadarko, and the City of Chickasha. Although irrigation was originally envisioned as a benefit of the Fort Cobb Division, this component was never developed and the water rights were later converted to M&I.

Existing Delivery Systems

Water deliveries from Fort Cobb Reservoir are made through the Anadarko and Chickasha Aqueducts. The Anadarko Aqueduct was constructed as part of the Washita Basin Project and is operated and maintained by the District. This aqueduct is a gravity-flow pre-cast reinforced concrete pressure pipeline that begins just below Fort Cobb Dam and terminates at the Anadarko bifurcation structure on the west side of the City of Anadarko. At the bifurcation, three separate diversions are made. The first is a 250-foot pipeline (Anadarko Lateral) to the Anadarko water treatment plant; the second is a 2-mile pipeline that continues east to the WFEC power generating plant; and the third is a 25-foot long pipeline to a one million gallon, concrete storage tank. An overflow at the bifurcation structure conveys water to the Anadarko holding pond in Randlett park.

The City of Chickasha's pumping plant on Fort Cobb Reservoir at the beginning of the Chickasha Aqueduct.

Deliveries to PSO are made from a private pipeline connecting the Anadarko Aqueduct to a holding pond.

The Anadarko Aqueduct was sized to deliver the original M&I allocation of the reservoir firm yield (8,964 acre-feet per year). This amount did not include the 4,336 acre-feet per year irrigation allocation, which was converted to M&I use at a later date. Accordingly, the maximum design capacity of the Anadarko Aqueduct is 16 cubic feet per second (cfs) from Fort Cobb Dam to the Fort Cobb Lateral turnout, and 14 cfs from the Fort Cobb Lateral turnout to the Anadarko bifurcation (Bureau of Reclamation 1962). From the bifurcation, existing pipeline capacities allow Anadarko and WFEC to receive a maximum of 8.4 cfs and 5.6 cfs respectively.

The Chickasha Aqueduct was constructed and is operated and maintained by the City of Chickasha. This aqueduct was completed in 1969 and delivers water to the City of Chickasha. The Chickasha Aqueduct consists of a pressurized 24-inch asbestos cement pipeline and includes a separate intake and pumping plant located near the left abutment of Fort Cobb Dam. The aqueduct transports raw water from Fort Cobb Reservoir to the Chickasha holding pond, a small regulating reservoir located directly north of Anadarko. Water flows by gravity pipeline from the Chickasha holding pond to the City of Chickasha's treatment plant.

Other authorized purposes of Fort Cobb Dam and Reservoir include flood control, conservation of fish and wildlife resources, and enhancement of recreational opportunities. Fishing and hunting opportunities at Fort Cobb Reservoir are managed by the Oklahoma Department of Wildlife Conservation, and recreational facilities are managed by the Oklahoma Tourism and Recreation Department. Fort Cobb Lake State Park is a 1,900-acre park on the shores of Fort Cobb Reservoir featuring camping areas, playgrounds, marina, nature center, golf course, and gift shop.

Water Supply

The water demands for the District and its customers are projected to increase, and there has been some uncertainty in the firm yield water supply projections for Fort Cobb Reservoir. Therefore, Reclamation updated the firm yield estimate for Fort Cobb Reservoir to facilitate a review of projected water supply and demand through the 2060 planning horizon.

Projected Supply - Reservoir Firm Yield

Reclamation defines firm yield as the maximum amount of water that can be consistently withdrawn from a reservoir on an annual basis without completely depleting the reservoir during a drought period equivalent to the historical drought of record. The firm yield for Fort Cobb Reservoir was calculated using a monthly reservoir operations model for a defined period of record that simulates the lake volume/elevation based on sedimentation; historic inflow records; precipitation; estimated losses from evaporation, spills, and seepage; and M&I releases from the reservoir. The model also considers additional base flow reductions that may be expected to result from groundwater pumping and/or other upstream depletions.

The 1958 ***Definite Planning Report*** (DPR) for Fort Cobb Reservoir calculated the firm yield to be 15,400 acre-feet per year based on a period of record of 1926 to 1956. In 1964, the firm yield estimate was reduced to 13,300 acre-feet per year to account for lower inflow conditions that occurred between 1956 and 1963. The updated firm yield for Fort Cobb Reservoir is **17,700 acre-feet per year** as presented in Reclamation's 2012 report titled ***Fort Cobb Reservoir Firm Yield Analysis*** (Appendix A). This evaluation used an updated hydrologic period of record extending from 1926 to 2008**,** and considered the expected sediment accumulation in the reservoir through year 2060. The year 2060 sediment accumulation was projected based on findings from a reservoir sediment survey completed in 2007. The 17,700 acre-feet firm yield is considered a "year 2060" firm yield because it is based on projected reservoir sediment accumulation through year 2060. Table 1 shows how the firm yield is expected to decrease over time as sediment accumulates in the reservoir from 2010 to 2060. The Oklahoma Water Resources Board has issued a surface water permit (No. 51-128) of 18,000 acre-feet per year to the District which is generally consistent with the year 2060 firm yield estimate of 17,700 acre-feet per year.

Year	Firm Yield (acre-feet per year)
2010	18,400
2020	18,300
2030	18,100
2040	18,000
2050	17,800
2060	17,700

Table 1 - Firm Yield of Fort Cobb Reservoir (Reclamation, 2012)

Additionally, the firm yield may be affected by changes in future climate conditions. Therefore, a "sensitivity analysis" was conducted to predict a range of possible effects of climate change on the firm yield of Fort Cobb Reservoir. A study performed by Reclamation's Technical Service Center (TSC) produced four climate change scenarios ranging from wetter and cooler to warmer and drier. An additional scenario was developed representing the middle tendency of the climate change models and produced yield results for Fort Cobb Reservoir that were essentially equivalent to the non-climate change adjusted yield (i.e. minimal change). A detailed description on this climate analysis is included in the firm yield analysis report.

The firm yield of Fort Cobb Reservoir is highly dependent on preservation of the base flow in Cobb Creek. Based on the water demands discussed in the following paragraphs, it is imperative that the firm yield of Fort Cobb Reservoir be protected in order to meet the future needs of the citizens and industry served by the reservoir. To protect the yield, it is critically important that the District work with the Oklahoma Water Resources Board to ensure future permitting of surface water and/or groundwater in the basin upstream of Fort Cobb Reservoir does not impact the base flow in Cobb Creek.

Water Demands

Existing Demands

The District is a major water supplier for Caddo and Grady Counties, and provides water to the cities of Anadarko and Chickasha, as well as to PSO and WFEC. The City of Chickasha has purchased water from the District since 1969 and is a major part of the demand in this area.

At present, the District has executed water supply contracts to provide 15,214 acre-feet per year to its customers. Of this amount, 8,964 acre-feet are permanently contracted to Anadarko and WFEC through the life of the project, and 6,250 acre-feet are contracted to Chickasha on a limited term (10-year) basis. The needs of the Public Service Company of Oklahoma, now part of American Electric Power (AEP), are met from Anadarko's contracted water and AEP is considered a customer of Anadarko. The City of Chickasha's contract with the District expires in 2021 and includes an option to renew.

The historic water deliveries from Fort Cobb Reservoir from 2001 to 2009 as metered by the District are shown in Table 2. The water deliveries are divided between the Anadarko and the Chickasha Aqueducts. The total average annual water delivered into these two aqueducts from the reservoir from 2001 to 2006 was 11,978 acre-feet. The City of Chickasha's usage rate declined in 2007 with the closure of Delta Faucet plant (1 MGD estimated), and a reduction at the Arvin Meritor plant (0.3 mgd current usage reduced from 0.5 mgd)[4]. As a result, from 2007 to 2009 the average water delivered from the reservoir dropped to 9,891 acre-feet per year.

While the values shown in Table 2 reflect total water delivered from the reservoir into the two aqueducts, actual water delivered to the two cities is lower due to line losses and unmetered taps along the Chickasha Aqueduct. Flow into the Anadarko treatment plant is metered at the Anadarko Aqueduct bifurcation in Randlett Park. Flow into the Anadarko Holding Pond, a raw water diversion primarily maintained for an emergency water supply for the City of Anadarko should a failure or interruption in delivery through the Anadarko Aqueduct occur, is also metered[5]. A secondary use of this metered diversion is for recreation and wildlife habitat for the City Park.

[4] Conversation with Larry Shelton, Chickasha City Manager (10/2010)
[5] Conversation with Quintin Opitz, Superintendent, Fort Cobb Reservoir Master Conservancy District

Flow into the Chickasha treatment plant is measured at the treatment plant in Chickasha. Tables 3 and 4 present actual water usage by year for the cities of Anadarko and Chickasha, and the unmetered usage and/or line losses for each aqueduct. Note that the usage for each city as metered at their water treatment plants is substantially less than the amount of water measured/pumped at Fort Cobb Reservoir and is shown in Table 2.

Year	Anadarko Aqueduct	Chickasha Aqueduct (Acre-Feet/Year)	Total Water From Reservoir (Acre-Feet/Year)
	Metered at Fort Cobb Dam	Metered in Chickasha Pumping Plant at Fort Cobb Reservoir	
2001	7,779	4,847	**12,626**
2002	8,052	4,853	**12,905**
2003	7,211	5,240	**12,451**
2004	5,789	4,815	**10,604**
2005	6,333	4,939	**11,272**
2006	6,656	5,353	**12,009**
2007	5,114	4,344	**9,458**
2008	5,174	4,633	**9,807**
2009	5,421	4,988	**10,409**
Average *2001-2009*	6,392	4,890	**11,282**

Table 2 - Water Delivered from Fort Cobb Reservoir, 2001 to 2009

Year	Anadarko Aqueduct Unmetered Use/Loss (Acre-Feet/Year)					
	Metered at Fort Cobb Dam	Metered Delivery Locations			Total Metered Delivery	Anadarko Aqueduct Unmetered Use /Loss
		*Anadarko Meters**	*Anadarko Holding Pond***	*WFEC Terminal 1*		
2001	7,779	*3,277*	*1,533*	*2,159*	6,969	**810**
2002	8,052	*3,521*	*1,513*	*1,575*	6,609	**1,443**
2003	7,211	*3,843*	*1,168*	*1,979*	6,990	**221**
2004	5,789	*2,941*	*1,228*	*1,379*	5,548	**241**
2005	6,333	*3,700*	*1,158*	*1,245*	6,103	**230**
2006	6,656	*3,521*	*,1199*	*1,728*	6,448	**208**
2007	5,114	*1,960*	*928*	*2,066*	4,954	**160**
2008	5,174	*2,652*	*696*	*1,825*	5,173	**1**
2009	5,421	*2,907*	*1,100*	*1,414*	5,421	**0**
Average	**6,392**	***3,147***	***1,169***	***1,708***	**6,024**	**368**

**Includes PSO, Anadarko Bifurcation (Treatment plant), and Hollytex*
*** Randlett Holding Pond is considered a nonconsumptive use of water*

Table 3 - Anadarko Conveyance System Unmetered Use/Loss

Chickasha Aqueduct Unmetered Use/Loss (Acre-Feet/Year)					
Year	Metered at Fort Cobb Reservoir Pumping Plant	Metered Delivery Locations		Total Metered Delivery	Chickasha Aqueduct Unmetered Use / Loss
		WFEC Terminal 2	*Inflow to Treatment Plant*		
2001	4,847	*50*	*3,807*	3,857	**990**
2002	4,853	*21*	*3,708*	3,729	**1,124**
2003	5,240	*13*	*3,704*	3,717	**1,523**
2004	4,815	*9*	*3,589*	3,598	**1,217**
2005	4,939	*0*	*3,432*	3,432	**1,507**
2006	5,353	*41*	*3,798*	3,839	**1,514**
2007	4,344	*9*	*3,069*	3,078	**1,266**
2008	4,633	*26*	*3,352****	3,378	**1,255**
2009	4,988	*552*	*3,251*	3,803	**1,185**
Average	**4,890**	***80***	***3,523***	**3,603**	**1,287**
*Estimated Value					

Table 4 - Chickasha Conveyance System Unmetered Use/Loss

Future Demands

Future water demands for the cities of Anadarko and Chickasha were calculated by indexing the existing water usage as metered at the water treatment plants using the population growth projections shown in Table 5. The population growth projections were developed by the Oklahoma Department of Commerce[6], and indicate the populations of Anadarko and Chickasha should increase by 13 percent and 40 percent, respectively, from 2000 to 2060.

	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Anadarko	6,399	6,663	6,880	7,087	7,295	7,483
Chickasha	17,450	18,073	19,782	20,747	21,712	22,719

Table 5 - Population Projection for Anadarko and Chickasha

The following assumptions were made in forecasting the future water demand:

- Population will increase as projected by Oklahoma Department of Commerce.
- Industrial use by WFEC and PSO, as indicated by the entities, will increase.
- Residential water use in Anadarko and Chickasha will maintain the current average rate of water use per capita.
- Water use among significant large users will increase from the current rate of use at the same rate of growth as for the general population.

[6] Oklahoma Depart of Commerce 10/2008

Water demand projections for the cities of Anadarko and Chickasha were derived using the past consumption and the projected population trend. The consumption was taken from the measured flows at the respective water treatment plants. The average consumption of Anadarko and Chickasha, based on their treatment plant deliveries, was 175 and 200 gallons per capita per day (GPCD) respectively as shown in Table 6.

The diversion into the Anadarko holding pond was not included in the Anadarko average usage because this diversion is a nonconsumptive use. The holding pond is primarily a backup supply for the City of Anadarko to use if the Anadarko Aqueduct is inoperable.

Also note that the water demand data from 2007 to 2009 was not included in the Chickasha average because the drop in industrial user demand (Delta Faucet and Arvin Meritor) during that period is considered to be the result of a short-term economic slowdown. Also note that the per capita use does not separate industrial, agricultural, or oil and gas related uses or post-treatment distribution system losses that occur.

WFEC (5,500 acre-feet per year) and PSO (5,200 acre-feet per year) water use projections of 10,700 acre-feet per year were derived from conversations with the power plant managers. The increases in future water use shown for WFEC and PSO are consistent with the State of Oklahoma's projections for anticipated construction of new power plants or enlargements of existing plants.

Table 7 presents the future water demand projections for Anadarko, WFEC, and Chickasha. The total projected 2060 water demand for the District's customers is 17,256 acre-feet/year.

Year	**Anadarko**			**Chickasha**		
	Population	Water Demand Acre-Ft/Year	Gallons Per Capita Per Day Usage	Population	Water Demand Acre-Ft/Year	Gallons Per Capita Per Day Usage
2001	6,560	1,422	**193**	15,909	3,807	**214**
2002	6,517	1,322	**181**	16,125	3,708	**205**
2003	6,509	1,410	**193**	16,214	3,704	**204**
2004	6,495	1,356	**186**	16,467	3,589	**194**
2005	6,451	1,347	**186**	16,732	3,432	**183**
2006	6,423	1,320	**183**	16,935	3,798	**200**
2007	6,337	1,035	**146**	17,068	3,069	**161***
2008	6,318	1,104	**156**	17,065	3,352*	**175***
2009	6,380	1,065	**149**	17,191	3,251	**169***
Average *2001-2006*	6,443	**1,264**	**175**	16,397	**3,673**	**200**
**Gallons per capita per day usage from 2007 to 2009 were not used for projection purposes*						

Table 6 - Existing Water Consumption of Anadarko and Chickasha (GPCD)

Year	Anadarko			WFEC	Chickasha	Total
	Anadarko	PSO	Subtotal			
2001-2009	*1,264*	*1,883*	***3,147***	*1,788*	***3,673***	***8,608***
2020	1,306	3,130	***4,436***	3,930	**4,049**	***12,415***
2030	1,349	3,850	***5,199***	4,300	**4,432**	***13,931***
2040	1,390	4,740	***6,130***	4,700	**4,648**	***15,478***
2050	1,430	5,000	***6,430***	5,100	**4,864**	***16,394***
2060	1,467	5,200	***6,667***	5,500	**5,089**	***17,256***
Demand projections calculated using 175 and 200 gallons per capita per day for Anadarko and Chickasha, respectively						

Table 7 - Future Demand Projections for Fort Cobb Reservoir

It should be noted that other water demand projections for the City of Chickasha exist:

- The Regional Raw Water Supply Study[7] predicts a 2060 total average annual water demand of 6.4 mgd (7,169 ac-ft/yr), which assumes an average annual growth rate of 0.3 percent over 50 years. This number was provided by the City of Chickasha for the purpose of the Regional Raw Water Supply Study. It appears that this projection was based on usage data, which included the existing raw water conveyance system losses.
- The Draft Oklahoma Comprehensive Water Plan Report on the Lower Washita Basin Watershed Planning Region listed Chickasha's 2060 water demand as 4,028 ac-ft/yr. This demand was defined as the amount of water used by residential and nonresidential customers, and was calculated using the population projection and the 2008 GPCD rate. The 2008 GPCD rate did not capture the industrial customers that were lost in 2007. These industrial customers were accounted for in the water demand projections presented in this report.

Conclusions

Water Supply Issues

The projected 2060 water demand of the District's customers is estimated to be 17,256 acre-feet per year, and the projected 2060 supply from Fort Cobb Reservoir is estimated to be 17,700 ac-ft per year. Therefore, the water supply from Fort Cobb Reservoir should be sufficient to meet the long-term 2060 water demand of the District's customers, provided the District works with the Oklahoma Water Resources Board to ensure future permitting of surface water and/or groundwater does not impact the base flow in Cobb Creek, the primary tributary to Fort Cobb Reservoir, and provided that existing conveyance losses are addressed.

---

[7] Regional Raw Water Supply Study for Central Oklahoma, March 2009completed by CDM, for the Oklahoma City Water Utilities Trust

Conveyance Issues

Based on a comparison of metered flows from the reservoir into the Anadarko and Chickasha Aqueducts with metered flows out of the aqueducts and into each city's respective treatment plant, significant conveyance losses have been documented for both aqueducts.
The flow into the Anadarko holding pond is considered a loss because the water diverted is typically lost to evaporation and seepage over time. This water is stored primarily for emergency use by the City of Anadarko in the event that the Anadarko Aqueduct is unable to provide deliveries. Construction of a new conveyance system will allow for redundancy in the delivery system thereby eliminating the need for most diversions into the holding pond.

The Chickasha Aqueduct conveyance losses could be due to a variety of reasons, including line breaks, unmetered uses, and/or other unknown causes. Further study is recommended to identify the best option for addressing conveyance issues with the existing aqueducts. In addition, further study is recommended to assess the capacity of the existing aqueducts relative to current and future peak-day demands. Problems meeting peak-day demands were documented in a Reclamation Appraisal Report dated December 2006, which concluded that future expansion of the conveyance system would be necessary, but deferred recommending a more detailed conveyance system analysis until an evaluation of supply and demand could be completed.

Conveyance options need to be addressed as a separate study. The 2006 Concluding Appraisal Report for the Conveyance System Expansion completed by Reclamation stated that the selection of an alternative is premature until a viable option exists to supplement the water supply. Four conveyance alternatives were explored in that report, each varying depending on the augmentation alternative.

The Chickasha aqueduct was constructed in 1969 by the City of Chickasha and is currently owned and operated by the City of Chickasha. The pipeline is a 24-inch diameter asbestos cement pipe. According to City Staff, repairs and other issues have been commonplace.

Public Works Magazine (Publication Date: 2009-03-01) states that from the 1940's through the late 1970's, asbestos cement pipe became the predominant choice for water transmission and distribution systems, storm drains, and sanitary sewer force mains. The pipe's performance, however, has varied. Failure rates are higher than that of other materials when surrounding soils are acidic or high in sulphates, magnesium salts, or alkaline hydroxides. Performance also suffers when the water supply contains ammonia or is classified as "soft water." In clay soils, the failure rate increases during the summer when the groundwater level reaches the pipe. Absent other factors, rates increase linearly with age. The typical life expectancy is 40 to 60 years. The Chickasha Aqueduct has been in service for 40 years and the 2060 planning horizon far exceeds the expected life of the aqueduct.

For these reasons, a reexamination of alternatives for conveyance system replacement and/or expansion is recommended. The following issues have been noted:

- An additional alternative which was not considered and has the potential of meeting the peak demand is increased storage at the points of delivery
- The Anadarko Aqueduct was constructed in 1961, and by 2060 the aqueduct will be approximately 100 years old and near the end of its life expectancy
- The Chickasha pipeline is an asbestos cement pipe, was constructed in 1969, and has had past maintenance issues. This pipeline will also exceed its life expectancy within the 2060 planning horizon

Recommendations

Based on the preceding assessment of problems, needs, and alternatives, the following recommendations are made:

- The 2060 demand for the service area of Fort Cobb Reservoir Master Conservancy District was estimated to be 17,256 acre-feet per year. The firm yield of the reservoir is estimated to be 17,700 acre-feet per year in 2060. Therefore, it is not recommended that water supply augmentation strategies be evaluated at this time.

- Conveyance losses were documented along both the Anadarko and Chickasha pipelines. In order to meet the 2060 demand, conveyance losses must be eliminated. As well, the District has indicated its inability to meet current peak day demands in the Anadarko Aqueduct. It is recommended that both of these issues be evaluated and potential solutions explored.

- The Fort Cobb Reservoir Master Conservancy District should continue to work with the Oklahoma Water Resources Board to ensure future permitting of surface water and/or groundwater does not impact the base flow in Cobb Creek, the primary tributary to Fort Cobb Reservoir.

References

Bureau of Reclamation. 1960. (Revised) Definite Plan Report, Washita Basin Project, Oklahoma: Volume I, General Plan and Fort Cobb Division (Except Irrigation Features). Bureau of Reclamation, Amarillo, Texas.

Bureau of Reclamation. 1962. Designer's Operating Criteria, Anadarko Aqueduct, Fort Cobb Division, Washita Basin Project, Oklahoma. Bureau of Reclamation, Office of Design and Construction, Denver, Colorado.

Bureau of Reclamation. 1965. Guidelines for Estimating Pumping Plant Operation and Maintenance Costs. John Eyer, U.S. Bureau of Reclamation, Denver, Colorado.

Bureau of Reclamation. 1980. Memorandum from Reclamation to Oklahoma Water Resources Board, Oklahoma City, Oklahoma, dated December 5, 1980.

Bureau of Reclamation. 2001. Fort Cobb Dam; Comprehensive Facility Review. Washita Basin Project, Oklahoma. Great Plains Region. US Department of the Interior. Bureau of Reclamation, Technical Service Center, Denver, CO October 2001. 200 pgs.

Bureau of Reclamation. 2004. Washita Basin Project, Oklahoma, Fort Cobb Division, Appraisal Report. U.S. Bureau of Reclamation, Oklahoma-Texas Area Office, Austin, Texas.

Bureau of Reclamation. 2005a. *Pipeline Appraisal Study Cost Estimate and Design Assumptions, Fort Cobb Division, Washita Basin Project, Oklahoma.* Memorandum from Leon Esparza, Supervisory Program Coordinator, to Area Manager, Austin, Texas, dated December 22, 2005.

Bureau of Reclamation. 2005b. *Pipeline Appraisal Study Peak Flow Analysis, Fort Cobb Division, Washita Basin Project, Oklahoma.* Memorandum from James Allard, Acting Supervisory Program Coordinator, to Area Manager, Austin, Texas, dated September 26, 2005.

Bureau of Reclamation, 2006, Concluding Appraisal Report, Conveyance System Expansion, Fort Cobb Division, Washita Basin Project

City of Chickasha. 2003. Letter to Fort Cobb Reservoir Master Conservancy District dated September 17, 2003. City of Chickasha, Oklahoma.

Linsley, Ray, Joeseph Franzini, David Freyberg, and George Tchobanoglous, 1992. Water Resources Engineering, Fourth Edition. Irwin/McGraw-Hill, New York.

Oklahoma Depart of Commerce,

Oklahoma Water Resources Board. 1976. Report on Application and Monitoring Program for Fort Cobb Reservoir, FY-76. March. Publication No. 68. 65 pgs.

Oklahoma Water Resources Board. 1995. Update of the Oklahoma Comprehensive Water Plan. Oklahoma Department of Water Resources, Oklahoma City, Oklahoma.

Opitz, Quintin. 2009. Personal Communication, Mr. Opitz is the Superintendent of the Fort Cobb Reservoir Master Conservancy District.

Public Works Magazine (Publication Date: 2009-03-01)

Shelton, Larry. 2006. Personal Communication, January 4, 2006. Mr. Shelton is the City Manager of the City of Chickasha.

Appendix A –Fort Cobb Reservoir Firm Yield Analysis (Draft), March 2012

RECLAMATION

Managing Water in the West

Draft

Fort Cobb Reservoir Firm Yield Analysis

Caddo County, Oklahoma

U.S. Department of the Interior
Bureau of Reclamation
Oklahoma-Texas Area Office

March 2012

MISSION STATEMENTS

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Contents

Executive Summary

This report documents a study completed to update the firm yield of Fort Cobb Reservoir; a Bureau of Reclamation (Reclamation) project. The firm yield concept is based on the premise that municipal drinking water supplies are critical water sources, and therefore represents a "dependable" annual yield useful for water supply planning, water management, and water contracts.

The Oklahoma-Texas Area Office (OTAO) of the Bureau of Reclamation reevaluated the firm yield of Fort Cobb Reservoir based on the method used in the Washita Basin Project, Fort Cobb Division Definite Plan Report (DPR, 1957). This original study involved in-depth analysis of the drainage basin characteristics, reservoir site topography, historical hydroclimate for the area, and projected effects from "land treatment measures" and ground water pumping for irrigation uses. Sedimentation analysis was conducted to estimate the 100-year sediment accumulation in the reservoir and a corresponding capacity-elevation table was generated. Gaged inflow records in the Fort Cobb drainage basin were locationally adjusted according to a drainage area ratio to estimate inflows to the reservoir for the pre-construction period. After reducing inflow projections to account for the expected effects of future land treatment measures, and groundwater pumping, the 100-year firm yield determined at the time of the DPR was **15,400** acre-feet per year for the study period 1926 to 1955. Without these inflow reductions, the projected 100-year firm yield would have been about **24,600** acre-feet per year. Therefore, the DPR projected inflow reductions produced an overall *yield* reduction of 37%.

For comparison's sake, the updated 100-year, *non-depleted* firm yield of Fort Cobb Reservoir for the period 1926 to 2008 was estimated to be **21,600** acre-feet per year. This is lower than the DPR undepleted yield estimate of 24,600 for two reasons. First, the updated model used sediment information from a 2007 sediment survey which showed a higher sedimentation rate than originally projected; and second, the additional years of hydrologic data revealed a more severe drought than that of the DPR. The critical drought year of the DPR study was 1955 and the critical drought year of the updated study is 1959.

The original DPR depletions for future "land treatment measures" were also included in the updated yield analysis. In addition, two inflow reduction scenarios were considered during the updated yield analysis to account for potential base flow impacts which may result from nearby groundwater pumping. The first inflow reduction scenario decreased the *base flow* by 25% and resulted in a revised firm yield of **17,700** acre-feet per year. The second scenario decreased the base flow by 50% and resulted in a revised firm yield of **14,800** acre-feet per year.

Additionally, it was recognized that the firm yield might be sensitive to changes in future climate conditions. A change in the regional precipitation aspects of climate would affect water supply through changes in reservoir inflow. Likewise, a change in the regional temperature aspects of climate would affect water supply through changes in reservoir evaporation and watershed evapotranspiration. Therefore, a "sensitivity analysis" was conducted to predict a range of possible effects of climate change on the firm yield of Fort Cobb Reservoir. A study performed by Reclamation's Technical Service Center (TSC) produce four climate change scenarios ranging from wetter and cooler to warmer and drier. This resulted in upper and lower reservoir yield results bounding the 25% base-flow reduced yield and representing the range of potential climate change effects. An additional scenario was developed representing the middle tendency of the climate change models, and produced yield results for Fort Cobb Reservoir which were essentially equivalent to the non-climate change adjusted yield (i.e. minimal change).

Based on this yield study, a 2060 firm yield of **17,700 acre-feet per year** is recommended for water supply planning purposes. This yield is based on year 2060 sediment projections, accounts for "land treatment measures", and assumes a 25% reduction in base-flow to account for possible future groundwater pumping and other factors in the basin that affect inflow.

Reservoir Firm Yield Analysis

Introduction

The Oklahoma-Texas Area Office (OTAO) of the Bureau of Reclamation conducted this analysis in an effort to update the firm yield for Reclamation's Washita Basin Project (Fort Cobb Reservoir). The firm yield methodology is based on the premise that municipal drinking water supplies are critical water sources and a depleted reservoir could be catastrophic to a community. Therefore firm yield represents a "dependable" annual yield useful for water supply planning, water management, and water contracts. The firm yield analysis was conducted based on Reclamation's firm yield methodology.

Project Background and Basin Characteristics

The Bureau of Reclamation built Fort Cobb Dam, a rolled earth-fill structure on Pond (Cobb) Creek located approximately 22 miles northwest of Anadarko, Oklahoma. The dam was constructed between 1958 and 1959, and is a major feature of the Washita Basin Project. The reservoir impounded by the dam has an active conservation capacity of 70,681 acre-feet at reservoir water surface elevation 1342.0 feet. It also has an exclusive flood control capacity of 62,065 acre-feet between reservoir water surface elevations 1342.0 and 1354.8 feet (the spillway crest elevation); and a surcharge capacity of 148,181 acre-feet between reservoir water surface elevations 1354.8 and 1374.4 feet. Fort Cobb Reservoir is usually filled annually to the top of the conservation pool by storing all inflow except when flood releases are required.

Benefits provided by the reservoir include storage of water for municipal and industrial use, flood control, enhancement of fish and wildlife, and recreation. The dam is operated and maintained by the Fort Cobb Reservoir Master Conservancy District (District) under contract with Reclamation. The District contracts for water sales to local users. The OTAO is the Reclamation office with primary responsibility for the facility. When the reservoir surface is in the Flood Pool, reservoir releases are determined by the U. S. Army Corps of Engineers. The Bureau of Reclamation is responsible for releases in the Surcharge Pool.

Pond (Cobb) Creek is a tributary of the Washita River near Fort Cobb, Oklahoma (see Figure 1). Cobb Creek is approximately 41.5 miles long. There are isolated areas in the basin with a combined area of 29.8 square miles that do not contribute to surface run-off. There is considerable base flow entering Cobb Creek in the form of storm interflow and ground water discharge from the Rush Springs Sandstone formation. It was noted in the Fort Cobb Definite Plan Report (DPR) that the base flow amounted to about 18,800 acre-feet per year, or about 49% of the average annual inflow (DPR, 1957).

The Fort Cobb gauging station located downstream of the dam, 2.7 miles north of Fort Cobb, Oklahoma. Fort Cobb gauging station records are available from 1940, and additional stream flow estimates back to 1926 were determined using multiple correlations, as recorded in the DPR. The reservoir is situated in the hydrologic unit structure as described in Table 1. There are 285 square miles of contributing drainage into Fort Cobb Reservoir.

Figure 1. Fort Cobb drainage basin map.

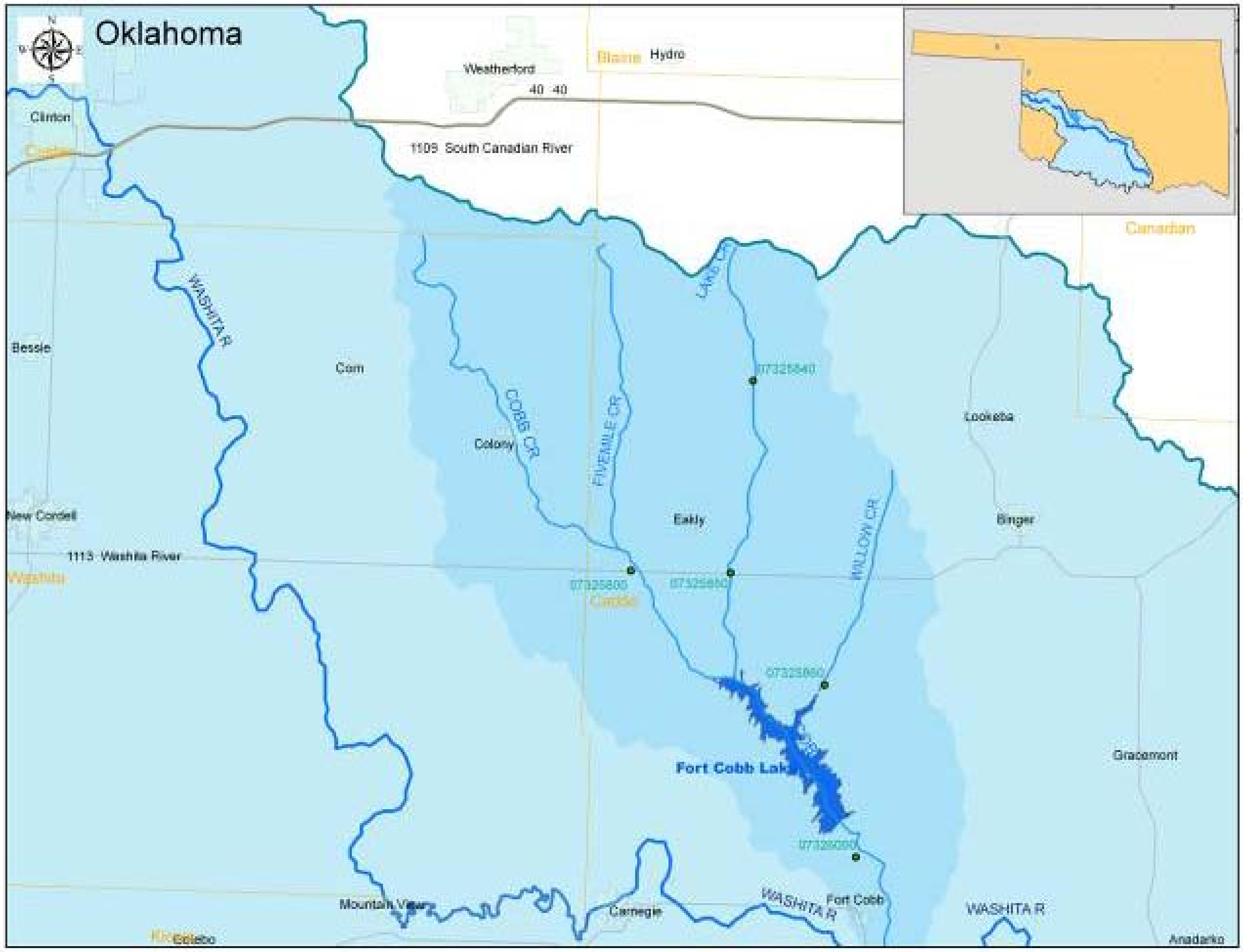


Table 1. Basin information.

	HU number	Name
Region	11	Red River Basin
Sub-region	1113	Washita River
Watershed	11130302160	Cobb-Fast Runner

Previous Studies

Previous firm yield studies have been performed by Reclamation for Fort Cobb Reservoir and are listed below for reference:

1. 1957. Yield$_{100\text{-yr}}$ = 15,400 acre-feet year.
   Definite Plan Report, January 1958, Appendix B

   This firm yield was based on a projected 100-year sediment accumulation of 15,000 acre-feet in the reservoir, and inflow records covering the years 1926-1956. The gaged inflow records were reduced to account for expected future effects of land treatment measures, upstream ground water pumping, and water impoundment structures.

2. ~1964. $Yield_{100\text{-}yr}$ = 13,300 acre-feet year.
   Various Reclamation Correspondence

   The official firm yield was revised to 13,300 acre-feet per year in 1964 (the study included hydrologic data through 1963). Documentation demonstrating this calculation has not been located. This revision was made to capture the lower than average inflow conditions that apparently occurred between 1956 and 1963. Since the study was unavailable for review it is assumed that all other conditions remained the same as the original DPR yield study.

3. 1979. $Yield_{25\text{-}yr}$ = 18,000 acre-feet year.
   Various Reclamation Correspondence

   This yield was calculated for the 1985 sediment conditions (25 years of sediment accumulation) in order to produce a current day yield value for water contracting purposes.

Firm Yield Analysis Methodology

The methodology used herein was adopted from the firm yield concept used during the planning of Reclamation's Oklahoma reservoirs. Firm yield may be defined as *the maximum amount of municipal water that can be consistently withdrawn annually from the reservoir, based on an estimated future sediment accumulation, without completely depleting the reservoir through the historical drought of record.* Most of the firm yield studies conducted for Reclamation reservoirs in Oklahoma were based on the estimated 100-year sediment accumulation in the reservoir and used about 30 years of historical inflow, precipitation and evaporation data. Today, 80 or more years of historical data is generally available for Reclamation's Oklahoma projects.

The firm yield is determined by constructing a monthly reservoir operations model that simulates the lake volume/elevation based on historical inflow to, and predicted losses and releases from the reservoir. The estimated and/or measured reservoir inflow from historical records is used as a predictor of the future flows into the reservoir. The historical evaporation and rainfall rates are used to estimate the monthly combined volumetric loss or gain due to evaporation from, and rainfall onto, the reservoir surface. A constant theoretical *annual municipal water delivery rate* (acre-feet/year) is factored into the total releases from the reservoir. Flood releases are calculated when the modeled reservoir exceeds conservation storage capacity.

Since river fed reservoirs experience sediment accumulation and a subsequent reduction of storage space, the firm yield is calculated based on a future reservoir storage capacity. The model uses a theoretical reservoir capacity vs. elevation curve that is based on the total anticipated sedimentation accumulation for a predetermined year in the future. The 100-year firm yield refers to a yield based on the sediment conditions 100 years after construction of the reservoir. The reservoir storage capacity available for municipal deliveries that was used in the model was determined by reducing the original storage by the volume of sediment expected to accumulate in the reservoir over the 100 year period. The available reservoir capacity can be referred to as the *100-year conservation storage*.

The firm yield of the reservoir is determined by adjusting the *annual municipal water delivery rate* (same each year) until the modeled reservoir nearly reaches the bottom of the available conservation storage but is never completely depleted during the study period. The corresponding annual delivery rate is the firm yield of the reservoir, i.e. the maximum possible annual delivery without completely depleting the reservoir through the historical drought of record.

Yield Analysis Components

To determine the estimated firm yield, a reservoir operations model was created in a spreadsheet using the simple water balance equation:

Starting Reservoir Volume + Inflow – Losses/Releases – Municipal Deliveries = Ending Reservoir Volume

Figure 2 below depicts the typical water balance components used in the operations model.

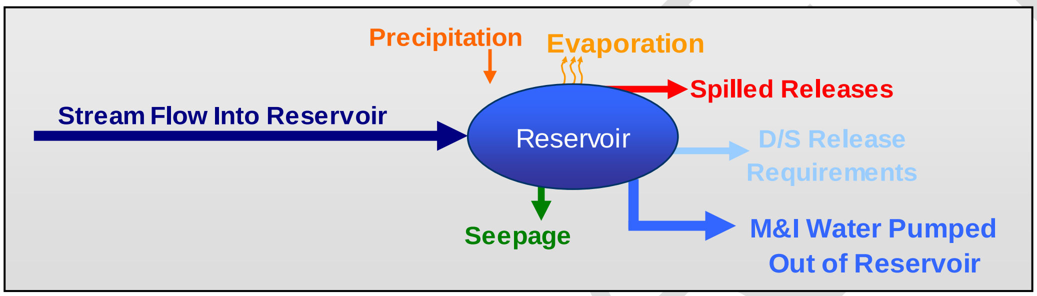


Figure 2. Water balance diagram.

The following sections outline the general concept of each component of the firm yield analysis.

Initial Starting Reservoir Volume

The initial reservoir storage is somewhat arbitrary as long as the modeled reservoir spills before the *critical period* begins. The *critical period* is defined for the purposes of this analysis as the most significant drought during the period of record. It is during this period that the reservoir would go dry if municipal and industrial (M&I) deliveries were set higher than the firm yield. The post-critical period during which the reservoir fills is a recovery period when inflows are significant enough to re-fill the reservoir.

Inflow

Inflow to the reservoir is comprised of river flows, precipitation, and possibly un-quantified gains from groundwater sources.

> ***River Flow***. River flow to the reservoir is the most significant contribution of inflow to the reservoir. River flow gages are desirable sources of flow data. However, gaged data is often not available for long-term historical periods and other methods must be used to construct a time series. These methods may include: estimating river flows with data from stream gages in near-by basins; basin run-off model and rainfall records; or post dam construction reservoir content and release records. The inflow history is used in the model as a predictor

of the future inflows. Of course any expected and quantifiable changes in the basin or climate that would affect reservoir inflow should be accounted for. Increased groundwater pumping along the rivers of a drainage basin, for example, would likely reduce river base-flow and thus the inflow to the reservoir.

The firm yield model processes the streamflow data differently depending on whether the data is pre- or post-construction of the dam because the existing data for each period was estimated differently. Pre-construction data is derived from stream gage records using drainage basin correlations. Post-construction data is calculated from end of month recorded reservoir conditions and operations data, as reported in Reclamation's Water Supply Report. The "computed inflow" in the Water Supply Report is calculated from actual change in reservoir storage, known reservoir releases or withdrawals, and estimated evaporation from the reservoir surface. "Computed inflow" reported in the Water Supply Report is actually the combination of surface water inflow, precipitation on the reservoir, groundwater accretions, and seepage losses. Also, the Water Supply Reports have been found to contain occasional transcription errors which have been corrected with Hydromet elevations and the appropriate capacity-elevation table.

Figure 3 below shows a portion of the "Inflow & Seepage" tab in the firm yield model. The pre-construction section includes two columns; one for river inflow and the other for projected seepage. The projected seepage is subtracted from the inflow each month to determine the "Inflow Offset By Seepage" which is calculated in column K. Seepage is a loss from the reservoir and can be accounted for anywhere in the water balance equation. However, it is accounted for here in this way so that the pre-construction inflow data will match the post-construction data since the post-construction "computed inflow" already accounts for seepage, although the quantity is unknown.

The post-construction section includes three columns; one for "Inflow + Precip +/- Losses" (column H); one for reservoir precipitation (column I); and one for "Reported Seepage" (column J). This section is specifically designed to process the information in the Water Supply Report. In order to match the pre-construction data, the precipitation which falls directly on the reservoir is calculated in column I and subtracted from column H. The calculated inflow from the Water Supply Report already includes all unknown seepage since the change in reservoir storage content accounts for all reservoir gains and losses. Seepage occasionally appears in the Water Supply Reports in the "Other" column as a "code 9". Since these records are sporadic, "Seepage" column (J) is included to put "back in" any attempted estimates of seepage that sporadically appear in the Water Supply Report.

Precipitation. Rainfall on the reservoir surface is another source of inflow to the reservoir and is entered in the model on the "Evap and Precip" tab. Rainfall rates are taken from the recorded values in the Water Supply Report. The reservoir precipitation information on the "Inflow and Seepage" tab is only used to remove precipitation from the post-construction computed inflow data so that it is consistent with the pre-construction inflow data. Missing precipitation data in the monthly Water Supply Report was estimated with Oklahoma "Mesonet" data from a nearby station.

Inflow and Seepage

Reservoir: Ft Cobb

Yr Begin	Yr End		
1926	2008	83	years

Inflow and Seepage Records

Row	Year	Month	Pre-Construction (1965): Historic Inflow x1000 ac-ft	Pre-Construction (1965): Seepage x1000 ac-ft	Post-Construction (1965 to 2006): Inflow + Precip +/- losses x1000 ac-ft	Post-Construction (1965 to 2006): Res Precip x1000 ac-ft	Post-Construction (1965 to 2006): Reported Seepage x1000 ac-ft	Inflow Offset By Seepage x1000 ac-ft
404	1958	June	5.983	0.000				5.983
405		July	0.826	0.000				0.826
406		August	0.232	0.000				0.232
407		September	0.261	0.000				0.261
408		October	0.345	0.000				0.345
409		November	0.650	0.000				0.650
410		December	0.912	0.000				0.912
411		January	1.224	0.000				1.224
412		February	1.145	0.000				1.145
413		March	1.283	0.000				1.283
414		April			1.000	0.105		0.895
415		May			4.506	0.276		4.230
416		June			1.798	0.282		1.516

Figure 3. "Inflow & Seepage" tab. Pre- and post-construction data is entered on this page in the spreadsheet.

Other Inflow. No attempt is made to quantify groundwater accretions to the reservoir but such losses/gains are included to the extent they are accounted for in post-construction inflow calculations.

Losses & Releases

Losses to the reservoir include evaporation, spills, seepage, and releases such as downstream mitigation requirements. These items are discussed further below:

Evaporation. The evaporation rates used from pre-construction records are available from the reservoir planning studies (Definite Plan Report). These rates are presented in the planning studies as *net evaporation* rates defined as being offset by rainfall (i.e., including the effects of rainfall), and are *free-surface* rates appropriate for calculating the effective volumetric loss from the modeled reservoir water surface.

The evaporation rates used from post-construction records are available from Reclamation's Water Supply Report or from the Corps of Engineer's website in the form of *pure pan evaporation* rates. These values must be multiplied by a free-surface correction coefficient (0.7 based on NOAA Technical Report NWS 33, Evaporation Atlas of the Contiguous 48 United States, June 1982) and then reduced by the measured rainfall in order to obtain rates consistent with the pre-construction data as described above.

Figure 4 below shows a portion of the "Evap & Precip" tab in the firm yield model. For each monthly time step, the model multiplies the evaporation rate, "Evap (reservoir) Offset by Precipitation" (column O) converted to feet, by the modeled reservoir area from the end of the previous month, to determine the "Total Evaporation Loss Offset By Precipitation". A positive (+) evaporation loss in the model indicates a month in which the evaporation exceeds the precipitation. A negative (-) evaporation loss is a month where precipitation is higher than evaporation. The pre-construction evaporation records from the planning studies do not include negative values even though they are *net evaporation* rates, thus it appears that the planning study data was "clipped" to include only positive numbers. This is further evidenced by the high frequency of zeros recorded for total monthly evaporation in the pre-construction data set.

Evaporation & Precipitation

Reservoir: Ft Cobb

Pure Evap (pan) = observed pan reading + observed precip. gage reading
*Pure Evap (reservoir) = Pure Evap (pan) * FS correction (.7)*

Yr Begin	Yr End	
1926	2008	83 years

Free-Surface Correction Coeficient: 0.70

	Evaporation & Precipitation Rates							Evaporation & Precipitation Total Volumes — For firm yield period only (Currently set for 1926 to 2008)					To Model
			Pre-Constr.			Calculated							
			Pure Evap (reservoir) Offset by Precip (in)	Precip (in)	Pure Evap (pan) (in)	Pure Evap (reservoir) Offset by Precip (in)	**Pure Evap (reservoir) Offset by Precip (ft)**	Year	Month	Pure Evap (reservoir) Offset by Precip (ft)	Current Model Elev (ft)	Water Surface Area - previous period (acres)	Total Evap Loss Offset by Precip x1000 (ac-ft)
16											1323.51		
378	1956	Feb	1.550	4.23	7.65	2.84	**0.24**		February	0.24	1322.04	1745	0.4
379		March	6.310	1.14	10.48	7.00	**0.58**		March	0.58	1321.31	1752	1.0
380		April	6.890	0.37	10.32	7.38	**0.62**		April	0.62	1320.44	1683	1.0
381		May	4.920	3.29	11.26	5.59	**0.47**		May	0.47	1319.91	1601	0.7
382		June	9.380	3.18	17.49	10.74	**0.89**		June	0.89	1318.46	1552	1.4
383		July	9.620	5.9	21.33	12.24	**1.02**		July	1.02	1316.50	1440	1.5
384		Aug	10.550	2.9	18.80	11.62	**0.97**		August	0.97	1314.38	1290	1.2
385		Sept	8.880	1.28	14.33	10.55	**0.88**		September	0.88	1312.30	1136	1.0
386		Oct		3.91	5.53	1.28	**0.11**		October	0.11	1311.29	1010	0.1
387		Nov		0.76	3.24	1.81	**0.15**		November	0.15	1310.36	949	0.1
388		Dec		1.82	1.86	-0.25	**-0.02**		December	-0.02	1309.58	893	0.0
389		Jan		0.61	1.78	0.71	**0.06**	1957	January	0.06	1308.87	845	0.0
390		Feb		1.1	2.45	1.03	**0.09**		February	0.09	1308.34	801	0.1

Figure 4. "Evap & Precip" tab. Pre- and post- construction data is entered on this page in the spreadsheet.

Seepage. Seepage for pre-construction data was estimated in the planning studies. Seepage for post-construction data is, by virtue of the method of data collection, already accounted for in the computed inflow from the Water Supply Report. Measured seepage data is sporadically recorded in the Water Supply Report, but is removed in the model to keep the data set consistent. Seepage is accounted for on the "Inflow & Seepage" tab.

Spills. When the net inflow fills the reservoir to above the top of the *conservation pool*, the "excess" volume above the conservation pool is defined as a "spill" or release of water from the reservoir. In any month where a spill occurs, the end-of-month reservoir content will be equal to the content at the top of the *conservation pool*. In a month where no spilling occurs, the model will show the spill to be zero. The spills are calculated on the "MODEL" tab.)

Downstream Releases. If there are downstream release requirement, a fixed amount will be counted as a consistent outflow each month. If no releases are required there will be no such adjustment made in the model.

Municipal Deliveries

The model uses a constant annual M&I water delivery rate for the entire period of study. The monthly M&I withdrawals used at each time-step are calculated in the model according to a monthly percent distribution of the annual M&I water delivery. The annual M&I delivery volume is adjusted by the user in the model to determine the value that corresponds to a fully utilized reservoir, as discussed below.

End-of-Month Reservoir Volume

The summation of the starting reservoir volume, the inflow, and the losses, results in the ending reservoir volume for each monthly time step. The ending volume at each month then becomes the starting volume for the subsequent month. Repeating this process for the chosen study period results in simulated monthly reservoir storage as shown below in Figure 5 (see Appendix A for a graph of the model results).

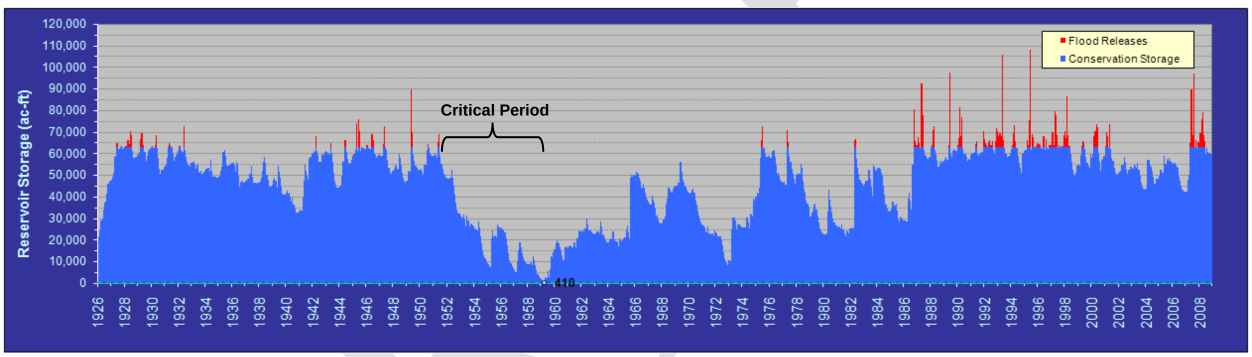


Figure 5. Fort Cobb Reservoir 2060 firm yield analysis graph. (Red indicates monthly spill.)

Firm Yield

The firm yield of the reservoir is determined by adjusting the annual M&I delivery rate until the model demonstrates that the reservoir volume nearly reaches the bottom of the conservation pool but never completely goes dry during the study period. The corresponding delivery rate is the firm yield of the reservoir, or the maximum delivery rate possible without empting the reservoir through the critical drought of record.

Other Factors

Period of Study. While the firm yield period of study can be adjusted to evaluate any specific period of time, typically the entire period of available historical data is used in order to utilize as long a period as possible. Fifty or more years of historical data is preferred.

Defining the Conservation Pool. The bottom of the *conservation pool* is usually defined by the lowest elevation at which the M&I delivery system is physically capable of delivering M&I

water. The model establishes the lowest volume of the reservoir based on the sediment distribution as discussed below.

Sediment Deposition. Siltation of the reservoir is predicted for a future year based on the most recent sediment survey. If the delivery system intake is expected to silt in over time, in such a way as to impede the delivery of M&I water at the lowest elevations of the *conservation pool*, the pipeline intake would have to be kept open and free of sediment so M&I deliveries could continue. This was assumed to be the case for this study. Figure 6 below illustrates this concept.

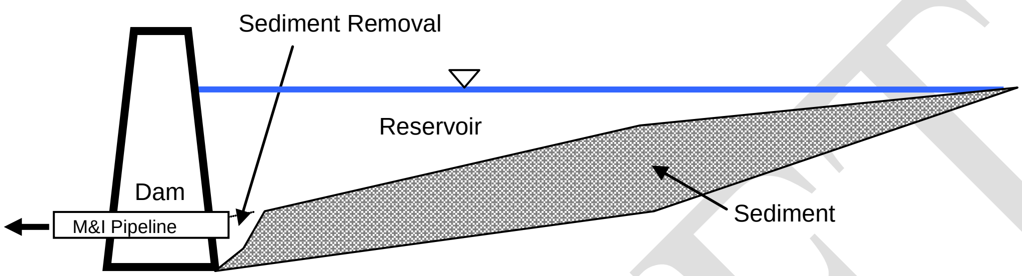


Figure 6. The M&I pipeline intake must be kept free of sediment plugging.

Area-Capacity Tables. The *sediment adjusted capacity* vs. elevation information from the DPR is used to define the *conservation pool*. The estimated sediment rate is used to reduce the base capacity table to reflect the estimated future sediment conditions at a predetermined year in the future. The original *surface area* vs. elevation information from the DPR reservoir survey is used in the model to determine the surface area that corresponds to the end-of-month reservoir volume. The original surface area vs. elevation table is used for evaporation calculations rather than a future sediment reduced area. This is done because reservoir surface area lost to river sediment will sustain significant plant and tree growth, and the evapotranspiration in these areas is likely equivalent to the free surface evaporation rates, i.e. any evaporation reductions resulting from shrinking reservoir surface area due to sedimentation would be offset by evapotranspiration increases from the vegetative growth in the accreting shoreline. The surface area and capacity tables were divided into 100^{ths} of a foot increments using Reclamation's "ACAP" program.

Upstream Basin Usage. It should be understood that any change that has or does occur in the drainage basin that substantially reduces the inflow to the reservoir will likely reduce the firm yield.

Climate Change

Recognizing that a change in the regional precipitation aspects of climate would affect water supply through changes in reservoir inflow, and a change in the regional temperature aspects of climate would affect water supply through changes in reservoir evaporation and watershed evapotranspiration, analysis was performed to determine the corresponding effects on firm yield. A study was performed by Reclamation's Technical Service Center in Denver, Colorado that determined five climate change scenarios and times series adjustment factors for inflow, evaporation, and precipitation. Then this study performed a "sensitivity analysis" to predict the range of possible effects of climate change on the firm yield of Fort Cobb Reservoir.

Yield assessment assumptions were developed for a range of future climates through 2060 in support of the state water plan target year of 2060, where the future climate definitions are based on current climate change science. The merit of doing this analysis is that a sense of yield uncertainty and, thus, a more robust characterization of yield would be conveyed to subsequent water planning efforts.

Definition of future climate change scenarios, in part, is motivated by awareness of recent climate observations but is ultimately rooted in contemporary climate projection (or climate simulation) information. Recent observations suggest that the global climate system has been warming and is likely to continue warming during the 21st century. Evidence also suggests that warming has been experienced over much of the United States during the 20th century. Climate simulation models have been developed and applied to reproduce global and continental temperature trends during the 20th century. Successes in these efforts have built confidence in use of these models to project future climate conditions. The climate change study bases climate change definitions on the results of these global climate simulations, spatially downscaled over the Oklahoma/Texas region. See the section on Climate Change for more details of the effects of this analysis on reservoir yield.

The climate change study is included in this report as Appendix H. The objectives of the climate change study were to (1) define climate change scenarios (i.e., changes in monthly climate from a historical period to a future period), (2) assess changes in reservoir inflow, precipitation, and evaporation associated with each scenario, and then (3) use those changes to generate "alternative historical" data series for reservoir inflow, precipitation, and evaporation for use in conducting alternative yield assessments (i.e., one for each climate change scenario). One theme within these objectives is that priority was placed on retaining our sense of the region's historical hydroclimate variability observed from 1926–2008 (e.g., envelope of monthly and annual possibilities, interarrival of drought and surplus periods) but shifted to represent a scenario change in monthly hydroclimate.

Contemporary climate projections over Oklahoma and North Texas all suggest a warmer future to lesser or greater degrees. For precipitation, they suggest a future ranging from drier to wetter. To represent these possibilities, this task involves defining climate change scenarios that bracket uncertainty. Namely four scenarios were selected varying from less to more warming, and drier to wetter conditions, with a fifth climate change scenario selected to represent the middle tendency of this information. See the complete report, Appendix H, for further details on how the climate change scenarios were developed. The five climate change projections considered for determining firm yield are:

1. Drier-less warming
2. Drier-more warming
3. Wetter-more warming
4. Wetter-less warming
5. Middle

The product of the Oklahoma climate change study was a series of monthly hydroclimate adjustment factors corresponding to each scenario. Each climate change scenario included 12 (monthly) adjustment factors for inflow, precipitation, and evaporation (Appendix G). The base historical hydrologic records already stored in the yield model were adjusted by these factors for each of the five climate change scenarios to determine a resulting firm yield. However, pre-construction net reservoir evaporation required the additional step of separating each monthly record into components of pan evaporation and precipitation so the climate change factors could be appropriately applied. This was done by back-calculating a pan evaporation rate with recorded precipitation rates and the free-surface correction coefficient. The adjusted precipitation and evaporation records were then combined into a net reservoir evaporation rate that was reflective of climate change factors for each scenario.

The model was sequentially adjusted for each climate change scenario to produce a corresponding firm yield. After determining a firm yield for each of the five scenarios, the minimum and maximum yield results were used to frame a range of yield variation due to expected climate change effects. This range reflects the uncertainties in climate change assumptions but is useful in estimating its potential effects on hydroclimate and reservoir yield. Therefore the range of expected reservoir yields due to climate change can be used by water managers to be better prepared for the worst case scenario.

Fort Cobb Firm Yield Analysis

The general methodology described above was used to determine the firm yield of Fort Cobb Reservoir. The updated yield was determined by reducing the historic flows for the pre-construction period by the monthly values given in the DPR for reductions due to the expected effects of future planned "land treatment measures". The DPR states that these reductions resulted in a overall reduction of "8.4% of the undepleted flow of Cobb Creek at the Fort Cobb gaging station". Only the pre-construction period was reduced for land treatment measures since these measures are reported to have been functioning ever since the time period that the dam was constructed in, and are therefore considered to be mostly accounted for in post-construction inflow records.

In addition, historic inflow data was reduced to account for the potential future effects of groundwater pumping, additional surface water use, and any other upstream depletions. The average base flow of Cobb Creek at the Ft Cobb gage for the period from 1926 through 1956 as found in the DPR is 1,443 acre-feet per month. This value was used as the base flow for the inflow reduction analysis. Two base flow reduction scenarios were selected to approximate the range of expected possibilities and provide a point of reference for extrapolated estimates. The first scenario reduced the reference base flow by 25% and the second scenario by 50%. The results are shown below in the Results section. These results can be used by water managers to better understand the effects of continued or increasing groundwater pumping in the drainage basin, issuance of additional stream water rights, changes in land use, and construction of additional impoundment storage upstream of the reservoir.

Various hydroclimate and modeling details used in the determination of the firm yield are presented in Table 2.

Table 2 – Fort Cobb Hydrologic Data.

description	*data*
Inflow	
The inflow into Fort Cobb Reservoir is primarily from Cobb Creek. Varying monthly "land treatment measures" depletions taken from DPR and applied to period from 1/1926 to 9/1956. See Appendix F.	Completed inflow history: 1926-2008 • Pre-construction dates: **1/1926 to 9/1956** (*DPR, 1978*) **10/1956 to 3/1959** (equal to 95.4% of Cobb Creek near Ft Cobb gaging station per 1957 Definite Plan Report--RO Study) • Post-construction dates: **4/1959 to 12/2008** (*Water Supply Report*) *DPR* – Definite Plan Report, May 1957, Appendix A
Evaporation & Precipitation	
Evaporation information is taken from different sources as available. Data is modified as needed to produce "reservoir evaporation offset (reduced) by precipitation". This data then includes the effects of precipitation and is appropriate for calculating the net evaporation loss from a reservoir. (Negative evaporation rates are reported when monthly rainfall exceeds evaporation.) See Appendices C & D.	Completed evap. & precip. history: 1926-2008 • Pre-construction data: **1/1926 to 9/1956** (*DPR, 1957*) • Post-construction data: *Evaporation* **10/1956 to 12/1961** (monthly average calculated from *Water Supply Report*) **1/1962 to 12/2008** (from *Water Supply Report*) *Precipitation* **10/1956 to 3/1959** (Internet source: climate.mesonet.org) **4/1959 to 12/2008 (from Water Supply Report)**
Sedimentation	
DPR predicted sedimentation	Predicted 100-yr (2060) sediment Accumulation at Top of Conservation: **14,264** ac-ft Predicted average annual rate of sediment: **143** ac-ft/yr
2007 Sediment Survey (Top of Conservation)	Predicted 100-yr (2060) sediment Accumulation at Top of Conservation: **16,485** ac-ft Predicted average annual rate of sediment: **165** ac-ft/yr
Sediment distribution	Distribution modeled according to distribution of

description	*data*
	2007 sediment survey
Seepage	
Seepage from the dam is estimated in the DPR and was applied to the pre-construction period. . Actual seepage is unknown but is accounted for in the post-construction data (includes all net "seepage" from dam and groundwater interactions).	• <u>Pre-construction data:</u> **1/1926 to 3/1959** (DPR) 0 ac-ft/m • <u>Post-construction data:</u> **4/1959 to 12/2008** (*Water Supply Report*) Actual seepage is unknown but is accounted for in the inflow calculations (from reservoir storage changes)
Municipal Demand Annual Distribution	
The annual municipal demand is constant each year of the study but the monthly values are set according to a percent distribution of the annual amount. The percent distribution was calculated as the average of deliveries from the Water Supply Report.	Average monthly M&I demand distribution: Jan: 7.6% Feb: 6.9% Mar: 7.4% Apr: 7.4% May: 7.8% Jun: 8.4% Jul: 10.5% Aug: 10.2% Sep: 9.1% Oct: 8.6% Nov: 7.7% Dec: 8.3%
Downstream Release Requirements	
Environmental mitigation	None
Senior downstream water rights	None

Firm Yield - Climate Change Scenarios

Five climate change scenarios were identified during the independent climate change study associated with this effort to determine potential impacts to the firm yield of Fort Cobb Reservoir. Climate change factors were developed and applied to Fort Cobb Reservoir hydroclimate time series for each scenario. The climate change adjustment factors are listed in Appendix G.

Results

After reducing inflow projections to account for the expected effects of developing land treatment measures, groundwater pumping, and upstream water impoundment structures, the 100-year firm yield determined at the time of the DPR was **15,400** acre-feet per year for the study period 1926 to 1955. Without these inflow reductions, the projected 100-year firm yield would be **24,600** acre-feet per year. Therefore, the DPR inflow reductions produced an overall *yield* reduction of 37%.

Based on the described input data and assumptions, the 2060 (100-year) non-depleted firm yield for Fort Cobb Reservoir was estimated to be **21,600** acre-feet per year. This yield was based on 83 years of historical inflow, evaporation, and precipitation data from 1926 to 2008, and the estimated sediment accumulation after 100 years, but does not include any adjustments for "land treatment measures" or base flow reductions.

The critical period of the study occurred between 1951 and 1959, with about 424 acre-feet of storage remaining in the *conservation pool* in March 1959. The reservoir never fully recovered until 1975 resulting in a severely lowered reservoir for a period of nearly 24 years. Additional severe droughts also affected the modeled reservoir from 1977 through 1986.

Because future groundwater pumping in the Rush Springs Aquifer could result in depletions to the base flow of Cobb Creek, inflow reduction estimates were made for two theoretical scenarios. The first depletion scenario assumed a 25% decrease in the Cobb Creek base flow and resulted in a firm yield of **17,700** acre-feet per year. The second scenario assumed a 50% decrease in the Cobb Creek base flow and resulted in a firm yield of **14,800** acre-feet per year. Therefore, the 25% reduction in base flow resulted in a 14% reduction of yield, and a 50% reduction in base flow resulted in a 28% reduction of yield (see Table 3). This reveals that there is roughly a 2:1 relationship between percentage base flow reduction and the corresponding percentage yield reduction.

Table 3 – Inflow Reduction Scenario Summary.

Base-Flow Reduction	*Resulting Yield*	*Yield Reduction Percent (from 20,600 ac-ft/yr)*
25%	17,700 ac-ft/yr	14%
50%	14,800 ac-ft/yr	28%

Climate change analysis resulted in upper and lower reservoir yield results bounding the 25% base-flow reduced yield and represents the range of potential climate change effects on reservoir yield. Five scenarios where analyzed, but the "middle tendency" scenario which resulted in a revised firm yield of **17,800** acre-feet per year was selected for primary focus due to the uncertainty in selecting any other scenario. This result is nearly equivalent to the non climate change adjusted yield which means there is essentially no expected effect due to climate change for Fort Cobb Reservoir. Also notable are the minimum and maximum climate change adjusted yields of 11,700 and 21,000 acre-feet per year, respectively, which are used to define the outer bounds of potential results. These climate change analysis results are presented in Table 4, and Table 5 presents a summary of the study variables and results.

Table 4. Climate Change Scenario Summary.

Fort Cobb Yield	Firm Yield (ac-ft)	Climate Change Adjusted Firm Yield (ac-ft)
25% Base Flow Reduced Firm Yield:	**17,700**	
Climate Change Scenario:		
Scenario 1: Drier-Less Warming		15,900
Scenario 2: Drier-More Warming		11,700
Scenario 3: Wetter-More Warming		21,000
Scenario 4: Wetter-Less Warming		20,800
Scenario 5: Middle	100.6%	17,800
Max:	119%	21,000
Min:	**66%**	**11,700**

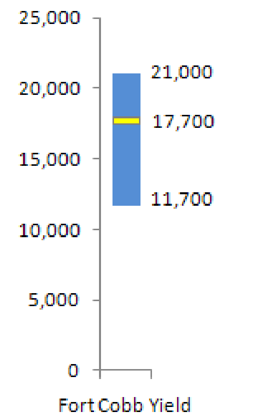


Table 5. Summary of study variables and results.

Period of Record			
Inflow Record	1926-2008	from Reclamation records	
Evaporation Record	1926-2008	from Reclamation records	
Precipitation Record	1926-2008	from Recl. records and Mesonet	
Yield Study	1926-2008	for entire period of record	
Reservoir Statistics			
Reservoir built	1960	started impounding water	
Top of Conservation Pool	1342.0	feet	
Bottom of Conservation Pool	1300.0	feet	
	1960	**2060**	
Top of Cons. Volume (ac-ft)	79,592	62,946	
Top of Cons. Area (acres)	3,584	-	
Sediment Information			
Sediment Accumulation (ac-ft)	0	16,485**	
Sediment Rate (ac-ft/yr)	143*	165**	
	* DPR estimate	** 2007 Survey	
Yield Results			
	Inflow Depletion		
	0%	*25%*	*50%*
No Climate Change	Base Yield 20,600	**17, 700**	14,800
Climate Change Scenarios:			
Scenario 1: Drier-Less Warming		15,900	
Scenario 2: Drier-More Warming		11,700	
Scenario 3: Wetter-More Warming		21,000	
Scenario 4: Wetter-Less Warming		20,800	
Scenario 5: Middle		17,800	

Conclusion

As presented in Table 5, yield estimates range from11,700 acre-feet per year, for the 25% depletion with the drier-more warming climate change scenario, to 21,000 acre-feet per year for the 25% depletion with the wetter-more warming climate change scenario.

Based on this yield study, a firm yield of **17,700** acre-feet per year is recommended for water supply planning purposes. This yield is based on year 2060 sediment projections, and a 25% reduction in base-flow due to future expected groundwater pumping and other factors in the basin that affect inflow.

Limitations and Proper Use of Results

It is important to understand the limitations and assumptions of this analysis in order to properly apply the firm yield in water planning decisions. While efforts are made to accurately quantify the input variables to the model, some amount of uncertainty exists. First, the inflow record is compiled from different sources and may not be as consistent as if one data source had been available for the entire period of record. Also, seepage rates for the pre-construction period are estimates. The evaporation and rainfall rates were based on manually entered records that may contain human error. Also, the pan evaporation rates were converted to reservoir rates by an average correction coefficient. Higher evaporation, seepage, or other unaccounted recurring losses from the reservoir would all reduce the firm yield. Likewise, any groundwater interactions such as natural springs or aquifer exchanges that are not accounted for in the pre-construction period may influence the yield.

The reservoir storage is defined in the model by the elevations of the top and bottom of the *conservation pool*. In reality, the *conservation pool* may only be limited to the district/water utility's practical ability to take water from the reservoir. For example, the reservoir operator may have the ability to pump water from the inactive/dead pool, thereby utilizing more storage. Or, the flood pool may frequently be used for temporary storage. Such practices would increase the available storage capacity and thereby slightly increase the firm yield.

Significant changes upstream of the reservoir that would cause a reduction in the stream flow such as issuance of additional stream water diversion permits, land treatment measures, ground water pumping near the river, etc., would reduce the firm yield of the reservoir. No field study was performed to assess the conditions of the basin due to the extent of effort that would be required. Use of the basin streams is more likely during the worst drought periods, and its during the most severe drought in which any taking of water will reduce the yield of the reservoir.

This analysis assumes that all modeled spills can be physically evacuated each month. This may or may not be the case for this project. A more accurate assessment may be made of the firm yield if the spillway capacity was found to be insufficient to release the maximum spills calculated in the model. If so, the appropriate spillway capacity release curve could be factored into the model. This would likely result in monthly carry-over of storage above the *conservation pool* and thereby could increase the firm yield. However, this study is more conservative since it does not consider this factor.

Author and Peer Review of Model

The firm yield model for this analysis was created by Reclamation's Oklahoma-Texas Area Office. The basic spreadsheet was internally peer reviewed by other OTAO technical staff as well as being formally peer reviewed by Reclamation's Technical Service Center (TSC). The TSC found the model to be conceptually appropriate and made suggestions related to the user interface. These suggestions were incorporated into the final version of the model. Reclamation's Great Plains Regional Office reviewed and approved the technical concept and general approach of this analysis. The model was also verified for operability and accuracy by inputting the DPR yield calculation parameters and reproducing the DPR yield study results.

Photos

Photo 1 – Fort Cobb Dam and Reservoir

Photo 2 – Fort Cobb uncontrolled glory-hole spillway. Releases when elevation is above flood pool.

Photo 3 – Downstream side of Fort Cobb Dam looking down on River Outlet Works chute and M&I sleeve-valve at start of pipeline delivery system.

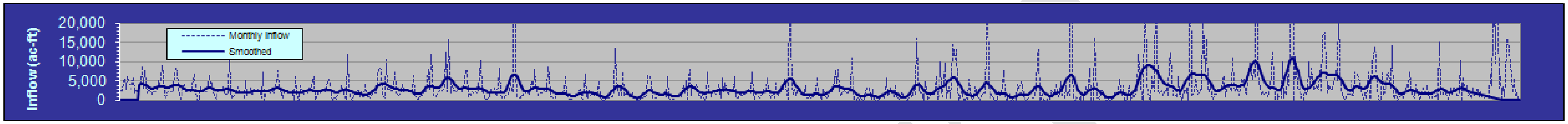
Appendices

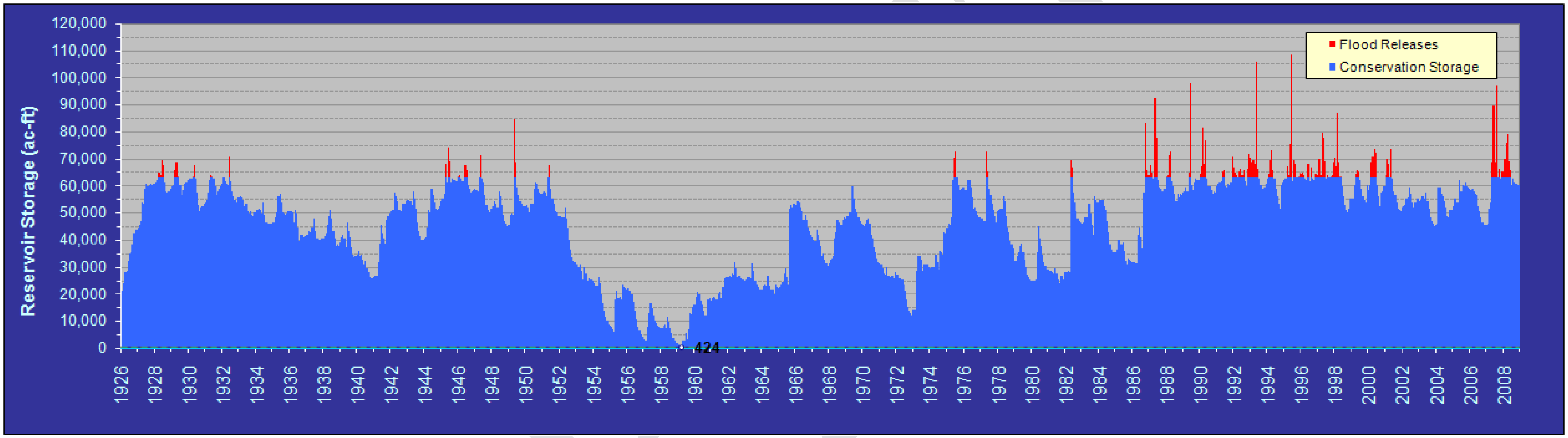
Appendix A	Inflow and Yield Analysis Graphs (2060 Yield)
Appendix B	Firm Yield Model Monthly Iteration Table (2060 Yield)
Appendix C	Evaporation Rates
Appendix D	Precipitation Rates
Appendix E	Area & Capacity Curves
Appendix F	Inflow Records
Appendix G	Climate Change Adjustment Factors
Appendix H	Technical Memorandum: *Climate Change and Hydrology Scenarios for Oklahoma Yield Studies*, Reclamation Technical Service Center, April 2010

Appendix A – Inflow and Yield Analysis Graphs (2060 Yield)

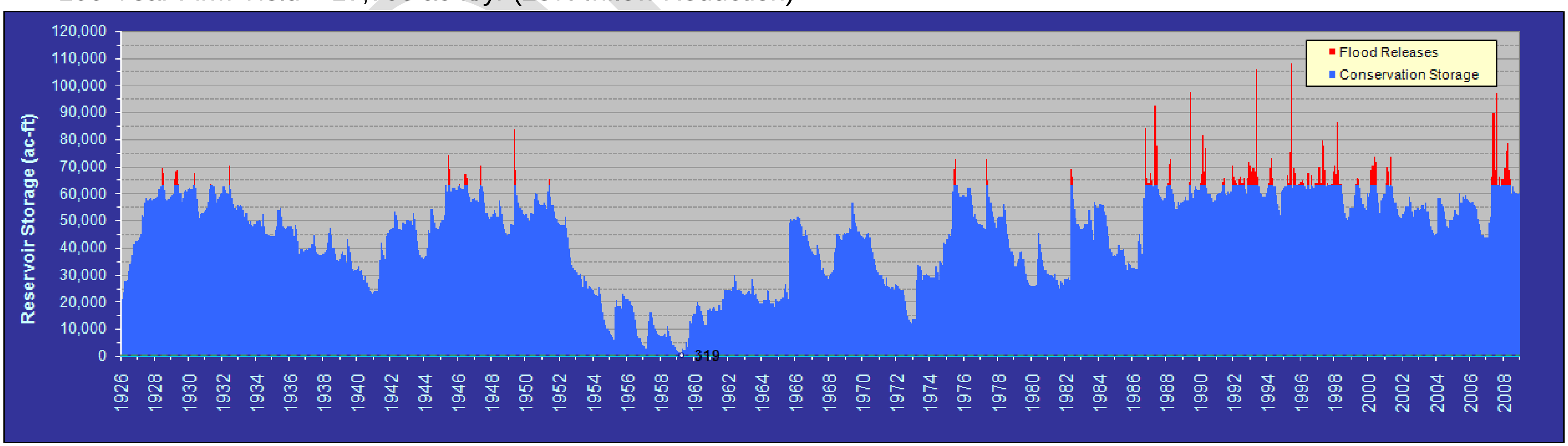
Fort Cobb Reservoir

100-Year Base Yield = 20,600 ac-ft/yr





100-Year Firm Yield = 17,700 ac-ft/yr (25% Inflow Reduction)



Appendix B – Firm Yield Model Monthly Iteration Table

100-Year Firm Yield = 17,700 ac-ft/yr (25% Inflow Reduction)

Firm Yield Model: Ft Cobb

1926 to 2008

Year	Month	In: Inflow Offset By Seepage x1000 (ac-ft) / month	In: TOTAL IN --Start of Period-- x1000 (ac-ft/ month)	Out: Evap Loss Offset by Precip x1000 (ac-ft) / m	Out: Municipal Demand x1000 (ac-ft) / m	Out: MD Per Yr x1000 (ac-ft) / year	Out: TOTAL OUT Start of period-- x1000 (ac-ft / m)	Out: Spilled x1000 (ac-ft) / m	Change in Storage	Vol Stored (x1000 ac-ft)	Water Surface Elevation (ft)
										20.0	1323.51
1926	Jan	2.2	2.2	0.1	1.3	17.7	1.4	0.0	0.8	20.8	1323.97
	Feb	2.2	2.2	0.6	1.2	17.7	1.8	0.0	0.4	21.2	1324.24
	March	4.0	4.0	0.2	1.3	17.7	1.5	0.0	2.5	23.7	1325.70
	April	5.5	5.5	0.2	1.3	17.7	1.5	0.0	3.9	27.6	1327.88
	May	2.4	2.4	0.6	1.4	17.7	2.0	0.0	0.4	28.0	1328.10
	June	5.9	5.9	0.9	1.5	17.7	2.4	0.0	3.5	31.5	1329.85
	July	4.6	4.6	0.1	1.9	17.7	2.0	0.0	2.6	34.1	1331.12
	Aug	2.5	2.5	0.3	1.8	17.7	2.1	0.0	0.4	34.5	1331.30
	Sept	4.5	4.5	0.0	1.6	17.7	1.6	0.0	2.9	37.4	1332.63
	Oct	5.7	5.7	0.0	1.5	17.7	1.5	0.0	4.2	41.5	1334.42
	Nov	1.7	1.7	0.5	1.4	17.7	1.9	0.0	-0.2	41.3	1334.33
	Dec	2.5	2.5	0.0	1.5	17.7	1.5	0.0	1.0	42.4	1334.76
1927	Jan	1.9	1.9	0.0	1.3	17.7	1.4	0.0	0.5	42.9	1334.96
	Feb	2.5	2.5	0.4	1.2	17.7	1.6	0.0	0.9	43.8	1335.33
	March	3.3	3.3	0.5	1.3	17.7	1.9	0.0	1.5	45.3	1335.91
	April	8.7	8.7	0.5	1.3	17.7	1.8	0.0	6.9	52.1	1338.44
	May	2.5	2.5	1.7	1.4	17.7	3.0	0.0	-0.5	51.6	1338.26
	June	7.7	7.7	1.0	1.5	17.7	2.5	0.0	5.3	56.9	1340.03
	July	3.7	3.7	0.3	1.9	17.7	2.1	0.0	1.6	58.5	1340.57
	Aug	1.6	1.6	0.8	1.8	17.7	2.6	0.0	-1.0	57.5	1340.23
	Sept	2.2	2.2	0.0	1.6	17.7	1.6	0.0	0.6	58.0	1340.42
	Oct	2.6	2.6	0.6	1.5	17.7	2.1	0.0	0.5	58.6	1340.59
	Nov	1.3	1.3	0.7	1.4	17.7	2.1	0.0	-0.8	57.8	1340.33
	Dec	1.9	1.9	0.1	1.5	17.7	1.6	0.0	0.3	58.1	1340.45
1928	Jan	2.0	2.0	0.6	1.3	17.7	1.9	0.0	0.1	58.2	1340.49
	Feb	1.8	1.8	0.2	1.2	17.7	1.5	0.0	0.3	58.6	1340.60
	March	2.7	2.7	0.8	1.3	17.7	2.2	0.0	0.5	59.1	1340.76
	April	4.8	4.8	0.9	1.3	17.7	2.2	0.0	2.6	61.7	1341.60
	May	3.4	3.4	0.8	1.4	17.7	2.2	0.0	1.1	62.8	1341.95
	June	8.6	8.6	0.6	1.5	17.7	2.1	6.4	0.1	62.9	1341.99
	July	7.0	7.0	0.2	1.9	17.7	2.1	4.9	0.0	62.9	1342.00
	Aug	1.3	1.3	1.3	1.8	17.7	3.1	0.0	-1.8	61.2	1341.44
	Sept	0.1	0.1	1.4	1.6	17.7	3.0	0.0	-2.9	58.3	1340.51
	Oct	1.5	1.5	0.5	1.5	17.7	2.0	0.0	-0.6	57.7	1340.32
	Nov	1.7	1.7	0.0	1.4	17.7	1.4	0.0	0.4	58.1	1340.44
	Dec	2.2	2.2	0.0	1.5	17.7	1.5	0.0	0.8	58.9	1340.70
1929	Jan	2.0	2.0	0.2	1.3	17.7	1.5	0.0	0.5	59.4	1340.86
	Feb	1.9	1.9	0.1	1.2	17.7	1.3	0.0	0.6	60.0	1341.05
	March	6.7	6.7	0.0	1.3	17.7	1.3	2.4	3.0	62.9	1342.00
	April	8.2	8.2	1.4	1.3	17.7	2.7	5.5	0.0	62.9	1342.00
	May	7.1	7.1	0.0	1.4	17.7	1.4	5.7	0.0	62.9	1342.00
	June	3.3	3.3	1.1	1.5	17.7	2.6	0.7	0.0	62.9	1342.00
	July	1.0	1.0	1.6	1.9	17.7	3.5	0.0	-2.4	60.5	1341.23
	Aug	0.2	0.2	1.9	1.8	17.7	3.7	0.0	-3.5	57.0	1340.08
	Sept	3.2	3.2	0.0	1.6	17.7	1.6	0.0	1.5	58.6	1340.59
	Oct	3.8	3.8	0.0	1.5	17.7	1.5	0.0	2.2	60.8	1341.32
	Nov	1.9	1.9	0.0	1.4	17.7	1.4	0.0	0.6	61.4	1341.50
	Dec	1.8	1.8	0.6	1.5	17.7	2.1	0.0	-0.3	61.1	1341.41
1930	Jan	2.2	2.2	0.0	1.3	17.7	1.3	0.0	0.9	61.9	1341.68
	Feb	2.5	2.5	0.8	1.2	17.7	2.1	0.0	0.4	62.3	1341.81
	March	2.0	2.0	1.3	1.3	17.7	2.6	0.0	-0.6	61.8	1341.63
	April	3.4	3.4	0.9	1.3	17.7	2.2	0.0	1.2	62.9	1341.99
	May	6.4	6.4	0.2	1.4	17.7	1.6	4.8	0.0	62.9	1342.00
	June	2.9	2.9	1.9	1.5	17.7	3.4	0.0	-0.5	62.4	1341.84
	July	0.0	0.0	2.7	1.9	17.7	4.6	0.0	-4.6	57.9	1340.36
	Aug	0.0	0.0	2.5	1.8	17.7	4.3	0.0	-4.3	53.6	1338.93
	Sept	0.3	0.3	1.1	1.6	17.7	2.7	0.0	-2.4	51.2	1338.10
	Oct	3.1	3.1	0.0	1.5	17.7	1.5	0.0	1.5	52.7	1338.64
	Nov	1.8	1.8	0.3	1.4	17.7	1.7	0.0	0.1	52.8	1338.68
	Dec	2.3	2.3	0.0	1.5	17.7	1.5	0.0	0.8	53.7	1338.97
1931	Jan	2.0	2.0	0.2	1.3	17.7	1.6	0.0	0.4	54.1	1339.10
	Feb	2.0	2.0	0.1	1.2	17.7	1.3	0.0	0.6	54.7	1339.31
	March	4.0	4.0	0.0	1.3	17.7	1.3	0.0	2.7	57.4	1340.19
	April	6.0	6.0	0.3	1.3	17.7	1.7	0.0	4.3	61.7	1341.60
	May	3.8	3.8	0.7	1.4	17.7	2.1	0.4	1.3	62.9	1341.99
	June	4.0	4.0	2.1	1.5	17.7	3.6	0.4	0.0	62.9	1342.00
	July	2.3	2.3	0.7	1.9	17.7	2.5	0.0	-0.2	62.7	1341.92
	Aug	0.7	0.7	1.5	1.8	17.7	3.3	0.0	-2.6	60.1	1341.11
	Sept	0.3	0.3	2.1	1.6	17.7	3.7	0.0	-3.4	56.7	1339.96
	Oct	3.0	3.0	0.0	1.5	17.7	1.5	0.0	1.4	58.1	1340.45
	Nov	2.3	2.3	0.0	1.4	17.7	1.4	0.0	1.0	59.1	1340.77
	Dec	2.3	2.3	0.1	1.5	17.7	1.5	0.0	0.7	59.8	1341.00

	Jan	2.1	2.1	0.0	1.3	17.7	1.3	0.0	0.7	60.6	1341.24
	Feb	3.5	3.5	0.2	1.2	17.7	1.4	0.0	2.1	62.7	1341.91
	March	1.0	1.0	1.2	1.3	17.7	2.5	0.0	-1.5	61.2	1341.45
	April	1.3	1.3	1.0	1.3	17.7	2.3	0.0	-1.0	60.2	1341.12
	May	1.3	1.3	0.4	1.4	17.7	1.8	0.0	-0.5	59.7	1340.97
1932	June	12.1	12.1	0.0	1.5	17.7	1.5	7.4	3.2	62.9	1342.00
	July	1.7	1.7	1.2	1.9	17.7	3.1	0.0	-1.3	61.6	1341.58
	Aug	0.5	0.5	1.9	1.8	17.7	3.7	0.0	-3.3	58.4	1340.52
	Sept	0.5	0.5	0.9	1.6	17.7	2.5	0.0	-2.0	56.4	1339.87
	Oct	0.9	0.9	0.8	1.5	17.7	2.4	0.0	-1.4	55.0	1339.40
	Nov	1.2	1.2	0.8	1.4	17.7	2.1	0.0	-1.0	54.0	1339.07
	Dec	3.1	3.1	0.0	1.5	17.7	1.5	0.0	1.6	55.6	1339.60
	Jan	1.7	1.7	0.6	1.3	17.7	1.9	0.0	-0.3	55.3	1339.51
	Feb	1.6	1.6	0.1	1.2	17.7	1.3	0.0	0.3	55.6	1339.61
	March	1.8	1.8	1.0	1.3	17.7	2.3	0.0	-0.5	55.1	1339.45
	April	1.4	1.4	1.3	1.3	17.7	2.6	0.0	-1.2	54.0	1339.06
	May	0.3	0.3	1.1	1.4	17.7	2.5	0.0	-2.1	51.8	1338.33
1933	June	4.9	4.9	2.3	1.5	17.7	3.8	0.0	1.0	52.9	1338.69
	July	0.9	0.9	1.9	1.9	17.7	3.7	0.0	-2.8	50.0	1337.70
	Aug	1.6	1.6	0.8	1.8	17.7	2.6	0.0	-1.0	49.1	1337.34
	Sept	2.7	2.7	0.4	1.6	17.7	2.0	0.0	0.7	49.8	1337.60
	Oct	0.9	0.9	0.8	1.5	17.7	2.4	0.0	-1.5	48.3	1337.07
	Nov	1.2	1.2	0.2	1.4	17.7	1.6	0.0	-0.4	47.9	1336.91
	Dec	2.5	2.5	0.0	1.5	17.7	1.5	0.0	1.1	48.9	1337.30
	Jan	1.9	1.9	0.3	1.3	17.7	1.7	0.0	0.2	49.1	1337.37
	Feb	2.2	2.2	0.5	1.2	17.7	1.7	0.0	0.5	49.6	1337.55
	March	2.6	2.6	0.8	1.3	17.7	2.1	0.0	0.5	50.1	1337.73
	April	1.7	1.7	0.9	1.3	17.7	2.2	0.0	-0.5	49.6	1337.55
	May	0.5	0.5	0.7	1.4	17.7	2.1	0.0	-1.6	48.0	1336.96
1934	June	7.1	7.1	1.3	1.5	17.7	2.7	0.0	4.4	52.4	1338.52
	July	0.0	0.0	2.6	1.9	17.7	4.5	0.0	-4.5	47.9	1336.92
	Aug	0.9	0.9	1.7	1.8	17.7	3.5	0.0	-2.6	45.3	1335.95
	Sept	2.4	2.4	0.8	1.6	17.7	2.4	0.0	-0.1	45.3	1335.91
	Oct	2.0	2.0	0.9	1.5	17.7	2.4	0.0	-0.4	44.8	1335.75
	Nov	1.4	1.4	0.6	1.4	17.7	1.9	0.0	-0.5	44.4	1335.56
	Dec	1.8	1.8	0.4	1.5	17.7	1.9	0.0	-0.1	44.3	1335.53
	Jan	2.1	2.1	0.5	1.3	17.7	1.9	0.0	0.2	44.5	1335.63
	Feb	1.7	1.7	0.5	1.2	17.7	1.7	0.0	0.0	44.5	1335.63
	March	4.0	4.0	0.7	1.3	17.7	2.1	0.0	2.0	46.5	1336.39
	April	4.2	4.2	1.5	1.3	17.7	2.8	0.0	1.3	47.8	1336.90
	May	7.5	7.5	0.0	1.4	17.7	1.4	0.0	6.1	54.0	1339.06
1935	June	3.0	3.0	0.7	1.5	17.7	2.1	0.0	0.8	54.8	1339.34
	July	1.3	1.3	2.6	1.9	17.7	4.5	0.0	-3.1	51.6	1338.26
	Aug	0.6	0.6	2.4	1.8	17.7	4.2	0.0	-3.6	48.0	1336.97
	Sept	1.4	1.4	0.5	1.6	17.7	2.1	0.0	-0.6	47.4	1336.73
	Oct	1.8	1.8	0.7	1.5	17.7	2.2	0.0	-0.4	47.0	1336.57
	Nov	1.7	1.7	0.0	1.4	17.7	1.4	0.0	0.4	47.4	1336.72
	Dec	2.2	2.2	0.1	1.5	17.7	1.6	0.0	0.7	48.0	1336.96
	Jan	2.0	2.0	0.5	1.3	17.7	1.9	0.0	0.1	48.1	1337.01
	Feb	1.5	1.5	0.7	1.2	17.7	1.9	0.0	-0.4	47.8	1336.87
	March	2.3	2.3	1.7	1.3	17.7	3.0	0.0	-0.7	47.0	1336.60
	April	0.0	0.0	1.6	1.3	17.7	2.9	0.0	-2.9	44.1	1335.45
	May	5.9	5.9	0.4	1.4	17.7	1.8	0.0	4.1	48.2	1337.04
1936	June	2.3	2.3	2.1	1.5	17.7	3.6	0.0	-1.3	46.9	1336.55
	July	0.0	0.0	2.7	1.9	17.7	4.5	0.0	-4.5	42.4	1334.76
	Aug	0.0	0.0	2.7	1.8	17.7	4.5	0.0	-4.5	37.8	1332.84
	Sept	3.5	3.5	0.0	1.6	17.7	1.6	0.0	1.9	39.8	1333.67
	Oct	2.1	2.1	0.5	1.5	17.7	2.1	0.0	0.1	39.8	1333.70
	Nov	1.1	1.1	0.7	1.4	17.7	2.1	0.0	-0.9	38.9	1333.31
	Dec	1.9	1.9	0.2	1.5	17.7	1.7	0.0	0.2	39.1	1333.38
	Jan	2.1	2.1	0.3	1.3	17.7	1.6	0.0	0.5	39.6	1333.59
	Feb	1.7	1.7	0.7	1.2	17.7	2.0	0.0	-0.3	39.3	1333.47
	March	3.0	3.0	0.6	1.3	17.7	1.9	0.0	1.1	40.3	1333.92
	April	2.2	2.2	1.1	1.3	17.7	2.4	0.0	-0.2	40.2	1333.84
	May	3.5	3.5	0.6	1.4	17.7	2.0	0.0	1.5	41.7	1334.48
1937	June	5.7	5.7	1.1	1.5	17.7	2.6	0.0	3.1	44.8	1335.75
	July	0.0	0.0	2.4	1.9	17.7	4.3	0.0	-4.3	40.6	1334.02
	Aug	0.6	0.6	1.2	1.8	17.7	3.0	0.0	-2.4	38.2	1333.00
	Sept	2.0	2.0	0.7	1.6	17.7	2.3	0.0	-0.3	37.9	1332.85
	Oct	1.8	1.8	0.5	1.5	17.7	2.0	0.0	-0.3	37.6	1332.73
	Nov	1.5	1.5	0.4	1.4	17.7	1.8	0.0	-0.3	37.3	1332.58
	Dec	1.9	1.9	0.2	1.5	17.7	1.7	0.0	0.3	37.5	1332.70
	Jan	2.1	2.1	0.6	1.3	17.7	1.9	0.0	0.1	37.7	1332.76
	Feb	1.8	1.8	0.0	1.2	17.7	1.2	0.0	0.6	38.2	1333.02
	March	3.0	3.0	0.7	1.3	17.7	2.0	0.0	1.0	39.3	1333.46
	April	4.7	4.7	0.6	1.3	17.7	1.9	0.0	2.8	42.1	1334.65
	May	5.0	5.0	0.3	1.4	17.7	1.7	0.0	3.3	45.5	1335.99
1938	June	4.6	4.6	1.1	1.5	17.7	2.6	0.0	2.0	47.4	1336.75
	July	0.8	0.8	1.6	1.9	17.7	3.4	0.0	-2.7	44.7	1335.71
	Aug	0.0	0.0	2.8	1.8	17.7	4.6	0.0	-4.6	40.2	1333.85
	Sept	0.5	0.5	1.0	1.6	17.7	2.6	0.0	-2.2	38.0	1332.91
	Oct	0.2	0.2	1.3	1.5	17.7	2.9	0.0	-2.6	35.4	1331.73
	Nov	1.5	1.5	0.0	1.4	17.7	1.4	0.0	0.1	35.5	1331.78
	Dec	1.8	1.8	0.6	1.5	17.7	2.1	0.0	-0.3	35.2	1331.66

	Jan	2.2	2.2	0.0	1.3	17.7	1.3	0.0	0.9	36.1	1332.05
	Feb	3.6	3.6	0.6	1.2	17.7	1.8	0.0	1.8	37.9	1332.87
	March	2.9	2.9	0.9	1.3	17.7	2.2	0.0	0.7	38.6	1333.18
	April	1.5	1.5	1.4	1.3	17.7	2.7	0.0	-1.3	37.4	1332.63
	May	0.0	0.0	1.4	1.4	17.7	2.8	0.0	-2.8	34.6	1331.36
1939	June	11.6	11.6	1.2	1.5	17.7	2.7	0.0	8.9	43.5	1335.21
	July	2.0	2.0	2.9	1.9	17.7	4.7	0.0	-2.8	40.7	1334.07
	Aug	0.9	0.9	1.3	1.8	17.7	3.1	0.0	-2.3	38.5	1333.11
	Sept	0.3	0.3	2.2	1.6	17.7	3.8	0.0	-3.5	34.9	1331.50
	Oct	0.0	0.0	1.1	1.5	17.7	2.6	0.0	-2.6	32.3	1330.23
	Nov	1.2	1.2	0.4	1.4	17.7	1.8	0.0	-0.7	31.6	1329.91
	Dec	1.9	1.9	0.3	1.5	17.7	1.8	0.0	0.1	31.7	1329.95
	Jan	2.1	2.1	0.2	1.3	17.7	1.5	0.0	0.5	32.3	1330.22
	Feb	2.1	2.1	0.0	1.2	17.7	1.3	0.0	0.8	33.1	1330.63
	March	0.8	0.8	1.0	1.3	17.7	2.3	0.0	-1.5	31.6	1329.90
	April	2.0	2.0	0.6	1.3	17.7	1.9	0.0	0.1	31.8	1329.98
	May	0.8	0.8	0.9	1.4	17.7	2.3	0.0	-1.5	30.2	1329.23
1940	June	0.6	0.6	1.1	1.5	17.7	2.6	0.0	-2.0	28.2	1328.21
	July	4.2	4.2	1.0	1.9	17.7	2.8	0.0	1.4	29.6	1328.91
	Aug	0.6	0.6	1.3	1.8	17.7	3.1	0.0	-2.5	27.1	1327.63
	Sept	0.8	0.8	0.7	1.6	17.7	2.3	0.0	-1.5	25.6	1326.82
	Oct	0.4	0.4	0.6	1.5	17.7	2.1	0.0	-1.7	23.9	1325.84
	Nov	1.1	1.1	0.0	1.4	17.7	1.4	0.0	-0.3	23.6	1325.67
	Dec	1.3	1.3	0.1	1.5	17.7	1.6	0.0	-0.3	23.3	1325.51
	Jan	1.8	1.8	0.0	1.3	17.7	1.3	0.0	0.4	23.8	1325.77
	Feb	1.5	1.5	0.0	1.2	17.7	1.2	0.0	0.3	24.1	1325.95
	March	1.5	1.5	0.4	1.3	17.7	1.7	0.0	-0.2	23.9	1325.84
	April	6.4	6.4	0.0	1.3	17.7	1.3	0.0	5.0	28.9	1328.56
	May	8.2	8.2	0.0	1.4	17.7	1.4	0.0	6.8	35.7	1331.89
1941	June	7.8	7.8	0.0	1.5	17.7	1.5	0.0	6.3	42.1	1334.64
	July	0.9	0.9	1.7	1.9	17.7	3.5	0.0	-2.7	39.4	1333.52
	Aug	0.7	0.7	0.9	1.8	17.7	2.7	0.0	-2.0	37.4	1332.64
	Sept	0.6	0.6	0.5	1.6	17.7	2.1	0.0	-1.5	35.9	1331.97
	Oct	10.1	10.1	0.0	1.5	17.7	1.5	0.0	8.6	44.5	1335.62
	Nov	2.6	2.6	0.3	1.4	17.7	1.7	0.0	0.9	45.5	1335.99
	Dec	2.7	2.7	0.1	1.5	17.7	1.6	0.0	1.1	46.6	1336.43
	Jan	2.2	2.2	0.4	1.3	17.7	1.7	0.0	0.4	47.0	1336.60
	Feb	2.2	2.2	0.3	1.2	17.7	1.5	0.0	0.7	47.7	1336.84
	March	2.1	2.1	1.0	1.3	17.7	2.3	0.0	-0.2	47.5	1336.76
	April	7.5	7.5	0.0	1.3	17.7	1.3	0.0	6.2	53.6	1338.95
	May	1.8	1.8	2.0	1.4	17.7	3.4	0.0	-1.6	52.1	1338.41
1942	June	1.4	1.4	1.6	1.5	17.7	3.1	0.0	-1.7	50.3	1337.80
	July	1.0	1.0	2.3	1.9	17.7	4.1	0.0	-3.2	47.2	1336.65
	Aug	1.7	1.7	0.3	1.8	17.7	2.1	0.0	-0.4	46.8	1336.50
	Sept	4.1	4.1	0.0	1.6	17.7	1.6	0.0	2.4	49.2	1337.40
	Oct	1.8	1.8	0.3	1.5	17.7	1.8	0.0	0.0	49.2	1337.40
	Nov	1.9	1.9	0.7	1.4	17.7	2.0	0.0	-0.1	49.1	1337.35
	Dec	2.6	2.6	0.0	1.5	17.7	1.5	0.0	1.1	50.1	1337.74
	Jan	2.3	2.3	0.6	1.3	17.7	1.9	0.0	0.4	50.5	1337.87
	Feb	1.8	1.8	0.9	1.2	17.7	2.1	0.0	-0.3	50.2	1337.76
	March	2.0	2.0	1.3	1.3	17.7	2.6	0.0	-0.6	49.6	1337.54
	April	1.7	1.7	1.4	1.3	17.7	2.7	0.0	-1.1	48.5	1337.15
	May	6.0	6.0	0.0	1.4	17.7	1.4	0.0	4.6	53.1	1338.77
1943	June	1.2	1.2	2.2	1.5	17.7	3.7	0.0	-2.5	50.6	1337.90
	July	0.7	0.7	2.7	1.9	17.7	4.5	0.0	-3.8	46.8	1336.50
	Aug	0.3	0.3	3.0	1.8	17.7	4.8	0.0	-4.5	42.3	1334.73
	Sept	0.3	0.3	1.7	1.6	17.7	3.3	0.0	-3.0	39.3	1333.48
	Oct	0.7	0.7	1.0	1.5	17.7	2.5	0.0	-1.8	37.5	1332.69
	Nov	0.9	0.9	0.6	1.4	17.7	2.0	0.0	-1.1	36.3	1332.17
	Dec	1.3	1.3	0.0	1.5	17.7	1.5	0.0	-0.2	36.2	1332.09
	Jan	1.8	1.8	0.0	1.3	17.7	1.3	0.0	0.5	36.6	1332.29
	Feb	1.6	1.6	0.1	1.2	17.7	1.3	0.0	0.2	36.9	1332.41
	March	4.7	4.7	0.0	1.3	17.7	1.3	0.0	3.3	40.2	1333.86
	April	7.8	7.8	0.3	1.3	17.7	1.6	0.0	6.2	46.5	1336.38
	May	2.2	2.2	1.5	1.4	17.7	2.9	0.0	-0.6	45.8	1336.14
1944	June	11.7	11.7	1.6	1.5	17.7	3.1	0.0	8.6	54.4	1339.22
	July	1.2	1.2	1.6	1.9	17.7	3.4	0.0	-2.2	52.2	1338.47
	Aug	0.8	0.8	1.9	1.8	17.7	3.7	0.0	-3.0	49.3	1337.42
	Sept	0.6	0.6	0.7	1.6	17.7	2.4	0.0	-1.7	47.5	1336.78
	Oct	1.1	1.1	0.2	1.5	17.7	1.8	0.0	-0.7	46.9	1336.53
	Nov	1.6	1.6	0.1	1.4	17.7	1.5	0.0	0.1	47.0	1336.57
	Dec	2.6	2.6	0.0	1.5	17.7	1.5	0.0	1.1	48.1	1336.98
	Jan	2.6	2.6	0.0	1.3	17.7	1.3	0.0	1.3	49.3	1337.45
	Feb	2.3	2.3	0.0	1.2	17.7	1.3	0.0	1.0	50.4	1337.82
	March	3.2	3.2	0.3	1.3	17.7	1.6	0.0	1.7	52.0	1338.40
	April	12.2	12.2	0.0	1.3	17.7	1.3	0.0	10.9	62.9	1341.99
	May	1.8	1.8	2.3	1.4	17.7	3.7	0.0	-1.9	61.1	1341.41
1945	June	15.3	15.3	0.9	1.5	17.7	2.3	11.1	1.9	62.9	1341.99
	July	8.4	8.4	0.5	1.9	17.7	2.3	6.1	0.0	62.9	1342.00
	Aug	1.3	1.3	1.4	1.8	17.7	3.2	0.0	-1.9	61.1	1341.41
	Sept	3.7	3.7	0.8	1.6	17.7	2.4	0.0	1.3	62.4	1341.82
	Oct	2.2	2.2	0.8	1.5	17.7	2.4	0.0	-0.2	62.2	1341.76
	Nov	1.7	1.7	1.1	1.4	17.7	2.4	0.0	-0.7	61.5	1341.54
	Dec	2.0	2.0	0.6	1.5	17.7	2.0	0.0	0.0	61.4	1341.53

	Jan	2.7	2.7	0.0	1.3	17.7	1.3	0.0	1.3	62.8	1341.94
	Feb	2.3	2.3	0.3	1.2	17.7	1.5	0.6	0.2	62.9	1342.00
	March	2.1	2.1	1.2	1.3	17.7	2.6	0.0	-0.5	62.4	1341.84
	April	1.9	1.9	1.4	1.3	17.7	2.7	0.0	-0.8	61.7	1341.59
	May	2.7	2.7	1.4	1.4	17.7	2.7	0.0	-0.1	61.6	1341.57
1946	June	7.6	7.6	0.5	1.5	17.7	2.0	4.3	1.4	62.9	1342.00
	July	7.4	7.4	2.5	1.9	17.7	4.4	3.0	0.0	62.9	1342.00
	Aug	0.8	0.8	1.8	1.8	17.7	3.6	0.0	-2.7	60.2	1341.13
	Sept	1.2	1.2	0.9	1.6	17.7	2.5	0.0	-1.4	58.8	1340.69
	Oct	1.0	1.0	1.0	1.5	17.7	2.5	0.0	-1.6	57.3	1340.16
	Nov	2.0	2.0	0.0	1.4	17.7	1.4	0.0	0.7	57.9	1340.39
	Dec	1.7	1.7	0.1	1.5	17.7	1.5	0.0	0.2	58.1	1340.45
	Jan	1.9	1.9	0.2	1.3	17.7	1.6	0.0	0.3	58.5	1340.56
	Feb	1.5	1.5	0.9	1.2	17.7	2.1	0.0	-0.7	57.8	1340.33
	March	1.8	1.8	1.0	1.3	17.7	2.3	0.0	-0.5	57.3	1340.16
	April	6.0	6.0	0.0	1.3	17.7	1.3	0.0	4.7	62.0	1341.70
	May	9.9	9.9	0.0	1.4	17.7	1.4	7.5	1.0	62.9	1341.99
1947	June	1.8	1.8	0.6	1.5	17.7	2.1	0.0	-0.3	62.6	1341.89
	July	2.5	2.5	2.3	1.9	17.7	4.2	0.0	-1.7	60.9	1341.36
	Aug	0.4	0.4	2.8	1.8	17.7	4.6	0.0	-4.2	56.7	1339.98
	Sept	0.3	0.3	2.2	1.6	17.7	3.8	0.0	-3.5	53.2	1338.80
	Oct	0.4	0.4	0.6	1.5	17.7	2.1	0.0	-1.7	51.5	1338.20
	Nov	0.7	0.7	0.0	1.4	17.7	1.4	0.0	-0.8	50.7	1337.94
	Dec	2.6	2.6	0.0	1.5	17.7	1.5	0.0	1.2	51.9	1338.35
	Jan	1.4	1.4	0.3	1.3	17.7	1.6	0.0	-0.2	51.7	1338.29
	Feb	2.0	2.0	0.0	1.2	17.7	1.2	0.0	0.8	52.5	1338.56
	March	3.0	3.0	0.0	1.3	17.7	1.3	0.0	1.7	54.1	1339.12
	April	1.5	1.5	1.1	1.3	17.7	2.4	0.0	-0.9	53.2	1338.80
	May	0.9	0.9	0.9	1.4	17.7	2.2	0.0	-1.4	51.8	1338.33
1948	June	7.9	7.9	0.7	1.5	17.7	2.2	0.0	5.7	57.5	1340.24
	July	1.2	1.2	1.4	1.9	17.7	3.3	0.0	-2.0	55.5	1339.57
	Aug	0.5	0.5	1.8	1.8	17.7	3.6	0.0	-3.1	52.4	1338.52
	Sept	0.4	0.4	2.1	1.6	17.7	3.7	0.0	-3.3	49.1	1337.35
	Oct	0.5	0.5	1.0	1.5	17.7	2.5	0.0	-2.0	47.0	1336.59
	Nov	0.9	0.9	0.8	1.4	17.7	2.1	0.0	-1.2	45.8	1336.12
	Dec	1.1	1.1	0.7	1.5	17.7	2.2	0.0	-1.1	44.7	1335.69
	Jan	1.8	1.8	0.0	1.3	17.7	1.3	0.0	0.4	45.1	1335.85
	Feb	5.1	5.1	0.1	1.2	17.7	1.3	0.0	3.7	48.8	1337.26
	March	2.0	2.0	0.6	1.3	17.7	1.9	0.0	0.1	49.0	1337.31
	April	1.8	1.8	0.9	1.3	17.7	2.2	0.0	-0.4	48.5	1337.15
	May	36.6	36.6	0.0	1.4	17.7	1.4	20.8	14.4	62.9	1342.00
1949	June	7.4	7.4	0.3	1.5	17.7	1.8	5.6	0.0	62.9	1342.00
	July	0.9	0.9	2.7	1.9	17.7	4.5	0.0	-3.6	59.3	1340.85
	Aug	0.6	0.6	1.3	1.8	17.7	3.1	0.0	-2.5	56.8	1340.01
	Sept	0.6	0.6	1.0	1.6	17.7	2.6	0.0	-2.1	54.8	1339.33
	Oct	0.9	0.9	0.3	1.5	17.7	1.8	0.0	-0.9	53.8	1339.02
	Nov	1.0	1.0	0.9	1.4	17.7	2.3	0.0	-1.3	52.6	1338.59
	Dec	1.6	1.6	0.4	1.5	17.7	1.8	0.0	-0.3	52.3	1338.50
	Jan	1.7	1.7	0.2	1.3	17.7	1.5	0.0	0.1	52.5	1338.55
	Feb	1.7	1.7	0.5	1.2	17.7	1.7	0.0	0.0	52.5	1338.57
	March	1.7	1.7	1.5	1.3	17.7	2.8	0.0	-1.1	51.4	1338.18
	April	1.2	1.2	1.6	1.3	17.7	2.9	0.0	-1.6	49.8	1337.60
	May	4.7	4.7	0.2	1.4	17.7	1.6	0.0	3.1	52.9	1338.68
1950	June	2.8	2.8	1.7	1.5	17.7	3.2	0.0	-0.4	52.5	1338.55
	July	7.6	7.6	0.0	1.9	17.7	1.9	0.0	5.7	58.2	1340.46
	Aug	4.5	4.5	0.6	1.8	17.7	2.4	0.0	2.0	60.2	1341.13
	Sept	2.0	2.0	0.8	1.6	17.7	2.4	0.0	-0.4	59.8	1340.99
	Oct	1.0	1.0	1.7	1.5	17.7	3.2	0.0	-2.2	57.6	1340.27
	Nov	1.3	1.3	1.1	1.4	17.7	2.5	0.0	-1.2	56.4	1339.87
	Dec	1.6	1.6	0.6	1.5	17.7	2.0	0.0	-0.5	55.9	1339.71
	Jan	1.7	1.7	0.4	1.3	17.7	1.8	0.0	-0.1	55.9	1339.69
	Feb	2.1	2.1	0.2	1.2	17.7	1.4	0.0	0.7	56.6	1339.93
	March	1.9	1.9	1.3	1.3	17.7	2.6	0.0	-0.6	56.0	1339.72
	April	1.5	1.5	1.8	1.3	17.7	3.2	0.0	-1.7	54.3	1339.17
	May	8.2	8.2	0.2	1.4	17.7	1.6	0.0	6.5	60.8	1341.33
1951	June	7.0	7.0	0.7	1.5	17.7	2.2	2.7	2.1	62.9	1342.00
	July	0.7	0.7	2.6	1.9	17.7	4.4	0.0	-3.7	59.2	1340.81
	Aug	0.4	0.4	2.0	1.8	17.7	3.8	0.0	-3.5	55.8	1339.66
	Sept	0.5	0.5	1.1	1.6	17.7	2.7	0.0	-2.2	53.6	1338.94
	Oct	0.5	0.5	1.2	1.5	17.7	2.7	0.0	-2.3	51.3	1338.16
	Nov	0.9	0.9	0.2	1.4	17.7	1.6	0.0	-0.7	50.6	1337.91
	Dec	1.1	1.1	0.8	1.5	17.7	2.3	0.0	-1.3	49.4	1337.45
	Jan	1.4	1.4	0.5	1.3	17.7	1.8	0.0	-0.4	49.0	1337.31
	Feb	1.4	1.4	0.5	1.2	17.7	1.7	0.0	-0.3	48.7	1337.20
	March	1.7	1.7	0.7	1.3	17.7	2.0	0.0	-0.3	48.3	1337.08
	April	2.1	2.1	0.9	1.3	17.7	2.2	0.0	-0.1	48.3	1337.05
	May	5.7	5.7	1.0	1.4	17.7	2.4	0.0	3.2	51.5	1338.22
1952	June	0.9	0.9	3.5	1.5	17.7	5.0	0.0	-4.1	47.4	1336.74
	July	0.8	0.8	2.3	1.9	17.7	4.2	0.0	-3.4	44.0	1335.43
	Aug	0.3	0.3	2.6	1.8	17.7	4.4	0.0	-4.1	39.9	1333.72
	Sept	0.2	0.2	1.9	1.6	17.7	3.5	0.0	-3.3	36.6	1332.28
	Oct	0.3	0.3	1.5	1.5	17.7	3.0	0.0	-2.7	33.9	1331.02
	Nov	0.6	0.6	0.5	1.4	17.7	1.8	0.0	-1.3	32.6	1330.40
	Dec	0.8	0.8	0.1	1.5	17.7	1.6	0.0	-0.8	31.8	1329.99

	Jan	0.9	0.9	0.5	1.3	17.7	1.9	0.0	-1.0	30.8	1329.52
	Feb	0.9	0.9	0.5	1.2	17.7	1.8	0.0	-0.9	29.9	1329.08
	March	1.8	1.8	0.5	1.3	17.7	1.8	0.0	0.0	30.0	1329.10
	April	2.5	2.5	0.6	1.3	17.7	2.0	0.0	0.6	30.5	1329.38
	May	0.8	0.8	1.5	1.4	17.7	2.9	0.0	-2.1	28.5	1328.34
1953	June	0.3	0.3	2.0	1.5	17.7	3.5	0.0	-3.2	25.3	1326.62
	July	6.8	6.8	0.6	1.9	17.7	2.4	0.0	4.4	29.7	1328.95
	Aug	0.5	0.5	0.8	1.8	17.7	2.6	0.0	-2.0	27.6	1327.91
	Sept	0.4	0.4	1.5	1.6	17.7	3.1	0.0	-2.8	24.9	1326.39
	Oct	2.6	2.6	0.0	1.5	17.7	1.5	0.0	1.0	25.9	1326.97
	Nov	1.0	1.0	0.2	1.4	17.7	1.5	0.0	-0.5	25.4	1326.67
	Dec	1.3	1.3	0.2	1.5	17.7	1.7	0.0	-0.5	24.9	1326.41
	Jan	1.2	1.2	0.3	1.3	17.7	1.7	0.0	-0.5	24.4	1326.11
	Feb	1.0	1.0	0.8	1.2	17.7	2.1	0.0	-1.1	23.3	1325.49
	March	1.5	1.5	0.8	1.3	17.7	2.1	0.0	-0.6	22.7	1325.11
	April	1.1	1.1	0.4	1.3	17.7	1.7	0.0	-0.6	22.1	1324.76
	May	4.8	4.8	0.0	1.4	17.7	1.4	0.0	3.4	25.5	1326.75
1954	June	0.8	0.8	1.8	1.5	17.7	3.3	0.0	-2.5	23.0	1325.29
	July	0.2	0.2	2.0	1.9	17.7	3.9	0.0	-3.6	19.3	1323.09
	Aug	0.1	0.1	1.2	1.8	17.7	3.1	0.0	-2.9	16.4	1321.13
	Sept	0.1	0.1	1.2	1.6	17.7	2.8	0.0	-2.7	13.7	1319.17
	Oct	0.2	0.2	0.5	1.5	17.7	2.0	0.0	-1.8	11.9	1317.76
	Nov	0.4	0.4	0.4	1.4	17.7	1.8	0.0	-1.4	10.5	1316.58
	Dec	0.5	0.5	0.3	1.5	17.7	1.8	0.0	-1.2	9.2	1315.46
	Jan	0.7	0.7	0.0	1.3	17.7	1.4	0.0	-0.7	8.5	1314.79
	Feb	0.8	0.8	0.1	1.2	17.7	1.4	0.0	-0.6	7.9	1314.18
	March	0.8	0.8	0.3	1.3	17.7	1.6	0.0	-0.8	7.1	1313.29
	April	1.1	1.1	0.6	1.3	17.7	1.9	0.0	-0.8	6.3	1312.40
	May	13.2	13.2	0.0	1.4	17.7	1.4	0.0	11.8	18.1	1322.30
1955	June	5.2	5.2	0.9	1.5	17.7	2.4	0.0	2.9	21.0	1324.10
	July	0.7	0.7	1.4	1.9	17.7	3.3	0.0	-2.6	18.4	1322.47
	Aug	3.1	3.1	1.0	1.8	17.7	2.8	0.0	0.3	18.7	1322.66
	Sept	0.7	0.7	0.0	1.6	17.7	1.6	0.0	-0.9	17.8	1322.08
	Oct	7.1	7.1	0.1	1.5	17.7	1.6	0.0	5.5	23.2	1325.45
	Nov	1.0	1.0	0.7	1.4	17.7	2.1	0.0	-1.0	22.2	1324.84
	Dec	1.2	1.2	0.4	1.5	17.7	1.9	0.0	-0.7	21.5	1324.45
	Jan	1.2	1.2	0.3	1.3	17.7	1.7	0.0	-0.4	21.1	1324.19
	Feb	1.8	1.8	0.3	1.2	17.7	1.5	0.0	0.4	21.5	1324.40
	March	1.4	1.4	1.0	1.3	17.7	2.3	0.0	-1.0	20.5	1323.80
	April	1.0	1.0	1.1	1.3	17.7	2.4	0.0	-1.4	19.1	1322.91
	May	1.6	1.6	0.8	1.4	17.7	2.1	0.0	-0.5	18.5	1322.58
1956	June	0.6	0.6	1.4	1.5	17.7	2.9	0.0	-2.3	16.2	1321.02
	July	0.2	0.2	1.3	1.9	17.7	3.2	0.0	-2.9	13.3	1318.88
	Aug	0.0	0.0	1.3	1.8	17.7	3.1	0.0	-3.1	10.2	1316.38
	Sept	0.0	0.0	0.9	1.6	17.7	2.6	0.0	-2.5	7.7	1313.91
	Oct	0.2	0.2	0.0	1.5	17.7	1.5	0.0	-1.3	6.4	1312.51
	Nov	0.4	0.4	0.1	1.4	17.7	1.5	0.0	-1.1	5.3	1311.17
	Dec	0.5	0.5	0.0	1.5	17.7	1.4	0.0	-0.9	4.4	1309.98
	Jan	0.6	0.6	0.0	1.3	17.7	1.4	0.0	-0.8	3.7	1308.84
	Feb	0.7	0.7	0.0	1.2	17.7	1.3	0.0	-0.5	3.1	1307.96
	March	1.1	1.1	0.0	1.3	17.7	1.3	0.0	-0.3	2.9	1307.51
	April	6.1	6.1	0.0	1.3	17.7	1.3	0.0	4.8	7.7	1313.94
	May	6.1	6.1	-0.5	1.4	17.7	0.9	0.0	5.2	12.9	1318.57
1957	June	5.2	5.2	0.3	1.5	17.7	1.7	0.0	3.5	16.4	1321.12
	July	0.6	0.6	0.8	1.9	17.7	2.7	0.0	-2.0	14.4	1319.67
	Aug	0.2	0.2	0.9	1.8	17.7	2.7	0.0	-2.5	11.9	1317.76
	Sept	0.5	0.5	0.2	1.6	17.7	1.9	0.0	-1.4	10.5	1316.59
	Oct	0.5	0.5	0.1	1.5	17.7	1.7	0.0	-1.1	9.4	1315.57
	Nov	0.7	0.7	0.1	1.4	17.7	1.4	0.0	-0.7	8.6	1314.85
	Dec	0.8	0.8	0.1	1.5	17.7	1.6	0.0	-0.7	7.9	1314.11
	Jan	1.1	1.1	0.0	1.3	17.7	1.3	0.0	-0.2	7.7	1313.88
	Feb	1.00	1.0	0.1	1.2	17.7	1.3	0.0	-0.3	7.4	1313.58
	March	1.8	1.8	0.0	1.3	17.7	1.3	0.0	0.5	7.9	1314.11
	April	1.9	1.9	0.2	1.3	17.7	1.5	0.0	0.4	8.3	1314.56
	May	0.7	0.7	0.4	1.4	17.7	1.8	0.0	-1.2	7.2	1313.34
1958	June	5.6	5.6	0.2	1.5	17.7	1.7	0.0	4.0	11.1	1317.14
	July	0.6	0.6	0.3	1.9	17.7	2.2	0.0	-1.6	9.5	1315.75
	Aug	0.2	0.2	0.4	1.8	17.7	2.2	0.0	-2.1	7.5	1313.70
	Sept	0.2	0.2	0.3	1.6	17.7	1.9	0.0	-1.7	5.8	1311.73
	Oct	0.3	0.3	0.3	1.5	17.7	1.8	0.0	-1.6	4.2	1309.62
	Nov	0.5	0.5	0.1	1.4	17.7	1.5	0.0	-1.0	3.2	1308.06
	Dec	0.7	0.7	0.0	1.5	17.7	1.4	0.0	-0.8	2.4	1306.69
	Jan	0.9	0.9	0.1	1.3	17.7	1.4	0.0	-0.5	1.9	1305.65
	Feb	0.9	0.9	0.1	1.2	17.7	1.3	0.0	-0.4	1.5	1304.59
	March	1.0	1.0	0.1	1.3	17.7	1.4	0.0	-0.4	1.1	1303.36
	April	0.7	0.7	0.1	1.3	17.7	1.4	0.0	-0.7	0.3	1300.67
	May	3.9	3.9	-0.1	1.4	17.7	1.3	0.0	2.6	2.9	1307.56
1959	June	1.2	1.2	0.1	1.5	17.7	1.6	0.0	-0.4	2.5	1306.75
	July	4.7	4.7	-0.1	1.9	17.7	1.8	0.0	2.9	5.4	1311.29
	Aug	0.2	0.2	0.4	1.8	17.7	2.2	0.0	-2.0	3.4	1308.36
	Sept	5.3	5.3	0.3	1.6	17.7	2.0	0.0	3.4	6.7	1312.88
	Oct	7.6	7.6	-0.2	1.5	17.7	1.4	0.0	6.2	13.0	1318.63
	Nov	0.9	0.9	0.2	1.4	17.7	1.6	0.0	-0.7	12.3	1318.08
	Dec	3.7	3.7	-0.3	1.5	17.7	1.2	0.0	2.5	14.8	1319.98

	Jan	2.4	2.4	0.0	1.3	17.7	1.4	0.0	1.0	15.8	1320.71
	Feb	3.8	3.8	0.0	1.2	17.7	1.2	0.0	2.6	18.4	1322.48
	March	3.1	3.1	0.3	1.3	17.7	1.7	0.0	1.5	19.8	1323.40
	April	1.0	1.0	0.7	1.3	17.7	2.0	0.0	-1.0	18.9	1322.80
	May	1.3	1.3	0.3	1.4	17.7	1.6	0.0	-0.3	18.6	1322.61
1960	June	0.4	0.4	0.8	1.5	17.7	2.3	0.0	-1.9	16.6	1321.32
	July	1.2	1.2	0.6	1.9	17.7	2.5	0.0	-1.3	15.4	1320.42
	Aug	0.1	0.1	0.4	1.8	17.7	2.2	0.0	-2.1	13.3	1318.88
	Sept	0.4	0.4	0.5	1.6	17.7	2.1	0.0	-1.7	11.6	1317.53
	Oct	7.0	7.0	-0.2	1.5	17.7	1.3	0.0	5.7	17.3	1321.78
	Nov	1.6	1.6	0.3	1.4	17.7	1.7	0.0	0.0	17.3	1321.75
	Dec	1.8	1.8	-0.1	1.5	17.7	1.4	0.0	0.4	17.7	1322.02
	Jan	0.7	0.7	0.2	1.3	17.7	1.5	0.0	-0.8	16.8	1321.45
	Feb	1.9	1.9	0.1	1.2	17.7	1.3	0.0	0.6	17.5	1321.88
	March	2.1	2.1	0.2	1.3	17.7	1.5	0.0	0.6	18.1	1322.27
	April	1.4	1.4	0.7	1.3	17.7	2.0	0.0	-0.6	17.5	1321.87
	May	1.2	1.2	0.5	1.4	17.7	1.8	0.0	-0.7	16.8	1321.42
1961	June	4.0	4.0	0.2	1.5	17.7	1.7	0.0	2.3	19.1	1322.95
	July	2.3	2.3	0.4	1.9	17.7	2.2	0.0	0.1	19.2	1323.04
	Aug	0.5	0.5	0.7	1.8	17.7	2.6	0.0	-2.1	17.2	1321.69
	Sept	5.4	5.4	-0.3	1.6	17.7	1.3	0.0	4.0	21.2	1324.26
	Oct	1.9	1.9	0.3	1.5	17.7	1.8	0.0	0.1	21.3	1324.31
	Nov	4.3	4.3	-0.1	1.4	17.7	1.2	0.0	3.1	24.4	1326.11
	Dec	1.9	1.9	0.1	1.5	17.7	1.6	0.0	0.4	24.7	1326.32
	Jan	1.2	1.2	0.1	1.3	17.7	1.5	0.0	-0.3	24.4	1326.15
	Feb	2.1	2.1	0.6	1.2	17.7	1.9	0.0	0.2	24.7	1326.29
	March	1.7	1.7	0.8	1.3	17.7	2.1	0.0	-0.4	24.2	1326.04
	April	2.8	2.8	0.2	1.3	17.7	1.5	0.0	1.3	25.5	1326.77
	May	2.1	2.1	0.9	1.4	17.7	2.3	0.0	-0.2	25.3	1326.66
1962	June	5.8	5.8	-0.2	1.5	17.7	1.3	0.0	4.5	29.9	1329.04
	July	0.6	0.6	1.1	1.9	17.7	2.9	0.0	-2.3	27.5	1327.85
	Aug	0.6	0.6	1.6	1.8	17.7	3.4	0.0	-2.9	24.7	1326.29
	Sept	1.8	1.8	0.1	1.6	17.7	1.8	0.0	0.0	24.7	1326.31
	Oct	1.1	1.1	0.3	1.5	17.7	1.8	0.0	-0.7	24.0	1325.88
	Nov	1.0	1.0	0.3	1.4	17.7	1.7	0.0	-0.6	23.4	1325.53
	Dec	1.4	1.4	0.0	1.5	17.7	1.5	0.0	-0.1	23.3	1325.49
	Jan	1.0	1.0	0.1	1.3	17.7	1.5	0.0	-0.5	22.8	1325.21
	Feb	1.9	1.9	0.3	1.2	17.7	1.5	0.0	0.3	23.2	1325.42
	March	2.7	2.7	0.7	1.3	17.7	2.0	0.0	0.7	23.8	1325.81
	April	2.3	2.3	0.8	1.3	17.7	2.1	0.0	0.1	24.0	1325.88
	May	1.7	1.7	1.2	1.4	17.7	2.6	0.0	-0.9	23.1	1325.36
1963	June	7.4	7.4	0.4	1.5	17.7	1.9	0.0	5.6	28.6	1328.42
	July	1.1	1.1	1.8	1.9	17.7	3.6	0.0	-2.5	26.1	1327.10
	Aug	0.0	0.0	1.5	1.8	17.7	3.3	0.0	-3.4	22.8	1325.17
	Sept	1.7	1.7	-0.1	1.6	17.7	1.5	0.0	0.2	23.0	1325.30
	Oct	1.0	1.0	1.0	1.5	17.7	2.5	0.0	-1.5	21.5	1324.41
	Nov	0.6	0.6	0.1	1.4	17.7	1.5	0.0	-0.9	20.6	1323.89
	Dec	0.7	0.7	0.2	1.5	17.7	1.6	0.0	-0.9	19.7	1323.31
	Jan	1.4	1.4	0.1	1.3	17.7	1.5	0.0	-0.1	19.6	1323.24
	Feb	2.5	2.5	-0.1	1.2	17.7	1.1	0.0	1.3	20.9	1324.06
	March	2.1	2.1	0.7	1.3	17.7	2.0	0.0	0.1	21.0	1324.11
	April	2.3	2.3	1.2	1.3	17.7	2.6	0.0	-0.3	20.7	1323.95
	May	5.5	5.5	0.4	1.4	17.7	1.8	0.0	3.7	24.4	1326.12
1964	June	2.9	2.9	1.5	1.5	17.7	3.0	0.0	-0.1	24.3	1326.06
	July	0.3	0.3	1.9	1.9	17.7	3.8	0.0	-3.5	20.8	1323.99
	Aug	1.6	1.6	0.9	1.8	17.7	2.7	0.0	-1.1	19.7	1323.30
	Sept	1.3	1.3	-0.1	1.6	17.7	1.5	0.0	-0.2	19.5	1323.18
	Oct	0.5	0.5	0.6	1.5	17.7	2.1	0.0	-1.6	17.9	1322.17
	Nov	4.3	4.3	-0.4	1.4	17.7	1.0	0.0	3.4	21.3	1324.28
	Dec	0.9	0.9	0.1	1.5	17.7	1.6	0.0	-0.7	20.5	1323.84
	Jan	0.9	0.9	0.1	1.3	17.7	1.4	0.0	-0.5	20.0	1323.52
	Feb	1.7	1.7	0.2	1.2	17.7	1.4	0.0	0.3	20.3	1323.67
	March	2.6	2.6	0.3	1.3	17.7	1.6	0.0	0.9	21.2	1324.25
	April	2.2	2.2	0.4	1.3	17.7	1.7	0.0	0.5	21.7	1324.53
	May	5.1	5.1	0.4	1.4	17.7	1.8	0.0	3.3	24.9	1326.43
1965	June	4.2	4.2	0.6	1.5	17.7	2.1	0.0	2.0	27.0	1327.56
	July	0.7	0.7	2.0	1.9	17.7	3.9	0.0	-3.1	23.8	1325.81
	Aug	0.3	0.3	0.7	1.8	17.7	2.6	0.0	-2.3	21.5	1324.45
	Sept	29.2	29.2	-0.2	1.6	17.7	1.4	0.0	27.7	49.3	1337.43
	Oct	3.6	3.6	0.6	1.5	17.7	2.1	0.0	1.5	50.8	1337.96
	Nov	1.3	1.3	1.0	1.4	17.7	2.3	0.0	-1.0	49.7	1337.60
	Dec	2.6	2.6	0.0	1.5	17.7	1.5	0.0	1.1	50.8	1337.98
	Jan	0.9	0.9	0.1	1.3	17.7	1.4	0.0	-0.5	50.3	1337.81
	Feb	2.1	2.1	-0.5	1.2	17.7	0.7	0.0	1.4	51.7	1338.30
	March	2.5	2.5	1.4	1.3	17.7	2.7	0.0	-0.2	51.5	1338.23
	April	1.6	1.6	0.8	1.3	17.7	2.1	0.0	-0.5	51.0	1338.04
	May	1.4	1.4	1.9	1.4	17.7	3.3	0.0	-1.9	49.1	1337.35
1966	June	1.3	1.3	1.1	1.5	17.7	2.6	0.0	-1.3	47.8	1336.87
	July	1.5	1.5	2.9	1.9	17.7	4.8	0.0	-3.3	44.5	1335.62
	Aug	3.6	3.6	-0.1	1.8	17.7	1.7	0.0	1.9	46.4	1336.35
	Sept	0.4	0.4	0.4	1.6	17.7	2.1	0.0	-1.7	44.7	1335.70
	Oct	0.4	0.4	1.3	1.5	17.7	2.8	0.0	-2.4	42.4	1334.76
	Nov	0.7	0.7	1.0	1.4	17.7	2.3	0.0	-1.6	40.7	1334.08
	Dec	0.4	0.4	0.1	1.5	17.7	1.6	0.0	-1.1	39.6	1333.59

	Jan	0.8	0.8	0.4	1.3	17.7	1.8	0.0	-1.0	38.6	1333.18
	Feb	0.8	0.8	0.5	1.2	17.7	1.8	0.0	-1.0	37.7	1332.76
	March	1.8	1.8	0.9	1.3	17.7	2.2	0.0	-0.4	37.3	1332.59
	April	5.7	5.7	0.4	1.3	17.7	1.7	0.0	4.0	41.3	1334.31
	May	0.7	0.7	1.1	1.4	17.7	2.5	0.0	-1.8	39.5	1333.56
1967	June	1.4	1.4	1.6	1.5	17.7	3.1	0.0	-1.7	37.8	1332.82
	July	0.8	0.8	1.2	1.9	17.7	3.0	0.0	-2.2	35.6	1331.80
	Aug	0.1	0.1	1.8	1.8	17.7	3.6	0.0	-3.5	32.0	1330.10
	Sept	2.4	2.4	0.1	1.6	17.7	1.7	0.0	0.8	32.8	1330.48
	Oct	0.4	0.4	0.9	1.5	17.7	2.5	0.0	-2.1	30.7	1329.47
	Nov	0.5	0.5	0.4	1.4	17.7	1.8	0.0	-1.3	29.4	1328.83
	Dec	0.7	0.7	0.0	1.5	17.7	1.5	0.0	-0.8	28.7	1328.44
	Jan	1.9	1.9	-0.3	1.3	17.7	1.1	0.0	0.8	29.5	1328.83
	Feb	2.5	2.5	0.0	1.2	17.7	1.2	0.0	1.2	30.7	1329.45
	March	2.0	2.0	0.5	1.3	17.7	1.8	0.0	0.2	30.9	1329.56
	April	2.9	2.9	0.4	1.3	17.7	1.7	0.0	1.2	32.1	1330.15
	May	7.5	7.5	0.2	1.4	17.7	1.6	0.0	6.0	38.1	1332.96
1968	June	4.3	4.3	0.6	1.5	17.7	2.1	0.0	2.2	40.3	1333.89
	July	7.6	7.6	0.8	1.9	17.7	2.7	0.0	4.9	45.2	1335.89
	Aug	2.5	2.5	1.7	1.8	17.7	3.5	0.0	-1.0	44.2	1335.48
	Sept	0.8	0.8	0.0	1.6	17.7	1.7	0.0	-0.8	43.3	1335.14
	Oct	1.7	1.7	0.4	1.5	17.7	1.9	0.0	-0.2	43.1	1335.05
	Nov	1.8	1.8	-1.2	1.4	17.7	0.1	0.0	1.6	44.7	1335.71
	Dec	2.3	2.3	0.0	1.5	17.7	1.5	0.0	0.9	45.6	1336.04
	Jan	1.4	1.4	0.3	1.3	17.7	1.6	0.0	-0.2	45.4	1335.97
	Feb	1.7	1.7	-0.1	1.2	17.7	1.2	0.0	0.5	45.9	1336.17
	March	2.8	2.8	0.1	1.3	17.7	1.4	0.0	1.4	47.3	1336.71
	April	2.1	2.1	1.0	1.3	17.7	2.3	0.0	-0.2	47.1	1336.63
	May	10.5	10.5	-0.3	1.4	17.7	1.1	0.0	9.4	56.5	1339.92
1969	June	2.7	2.7	1.1	1.5	17.7	2.6	0.0	0.1	56.6	1339.95
	July	0.3	0.3	2.6	1.9	17.7	4.5	0.0	-4.2	52.4	1338.54
	Aug	-0.5	-0.5	1.0	1.8	17.7	2.8	0.0	-3.3	49.2	1337.38
	Sept	0.7	0.7	0.3	1.6	17.7	1.9	0.0	-1.2	48.0	1336.94
	Oct	-0.1	-0.1	0.2	1.5	17.7	1.7	0.0	-1.8	46.2	1336.28
	Nov	0.7	0.7	0.6	1.4	17.7	2.0	0.0	-1.4	44.9	1335.76
	Dec	0.7	0.7	-0.1	1.5	17.7	1.4	0.0	-0.7	44.2	1335.48
	Jan	-0.3	-0.3	-1.4	1.3	17.7	-0.1	0.0	-0.2	43.9	1335.38
	Feb	0.5	0.5	-0.3	1.2	17.7	1.0	0.0	-0.4	43.5	1335.21
	March	2.2	2.2	0.4	1.3	17.7	1.7	0.0	0.5	44.0	1335.41
	April	3.3	3.3	0.5	1.3	17.7	1.8	0.0	1.5	45.4	1335.98
	May	2.9	2.9	1.3	1.4	17.7	2.7	0.0	0.1	45.6	1336.04
1970	June	1.0	1.0	1.3	1.5	17.7	2.8	0.0	-1.8	43.8	1335.32
	July	0.3	0.3	2.2	1.9	17.7	4.1	0.0	-3.7	40.0	1333.78
	Aug	2.6	2.6	2.3	1.8	17.7	4.1	0.0	-1.5	38.5	1333.13
	Sept	0.3	0.3	1.3	1.6	17.7	2.9	0.0	-2.7	35.9	1331.94
	Oct	0.3	0.3	0.7	1.5	17.7	2.3	0.0	-2.0	33.9	1331.02
	Nov	-0.3	-0.3	0.1	1.4	17.7	1.5	0.0	-1.8	32.1	1330.15
	Dec	0.1	0.1	-0.2	1.5	17.7	1.3	0.0	-1.2	30.9	1329.57
	Jan	0.4	0.4	-0.2	1.3	17.7	1.1	0.0	-0.7	30.2	1329.23
	Feb	0.8	0.8	-0.2	1.2	17.7	1.1	0.0	-0.3	29.9	1329.08
	March	0.8	0.8	0.8	1.3	17.7	2.1	0.0	-1.2	28.7	1328.45
	April	0.6	0.6	1.0	1.3	17.7	2.3	0.0	-1.8	26.9	1327.53
	May	1.7	1.7	1.1	1.4	17.7	2.5	0.0	-0.8	26.1	1327.10
1971	June	5.7	5.7	1.4	1.5	17.7	2.9	0.0	2.8	29.0	1328.59
	July	0.6	0.6	1.8	1.9	17.7	3.7	0.0	-3.0	26.0	1327.00
	Aug	2.8	2.8	1.3	1.8	17.7	3.1	0.0	-0.3	25.7	1326.86
	Sept	2.0	2.0	0.9	1.6	17.7	2.5	0.0	-0.5	25.2	1326.56
	Oct	2.5	2.5	0.4	1.5	17.7	2.0	0.0	0.5	25.7	1326.85
	Nov	0.7	0.7	0.3	1.4	17.7	1.7	0.0	-1.0	24.7	1326.29
	Dec	3.9	3.9	0.1	1.5	17.7	1.6	0.0	2.3	27.0	1327.55
	Jan	0.1	0.1	-0.5	1.3	17.7	0.9	0.0	-0.7	26.2	1327.16
	Feb	0.5	0.5	-0.5	1.2	17.7	0.7	0.0	-0.3	26.0	1327.01
	March	0.3	0.3	0.1	1.3	17.7	1.5	0.0	-1.2	24.8	1326.36
	April	1.6	1.6	0.5	1.3	17.7	1.8	0.0	-0.2	24.6	1326.25
	May	1.3	1.3	0.3	1.4	17.7	1.6	0.0	-0.3	24.3	1326.08
1972	June	0.5	0.5	0.7	1.5	17.7	2.2	0.0	-1.7	22.6	1325.10
	July	0.8	0.8	1.4	1.9	17.7	3.2	0.0	-2.4	20.2	1323.65
	Aug	-0.3	-0.3	0.8	1.8	17.7	2.6	0.0	-2.9	17.3	1321.78
	Sept	0.0	0.0	0.9	1.6	17.7	2.5	0.0	-2.5	14.8	1320.00
	Oct	0.4	0.4	0.1	1.5	17.7	1.6	0.0	-1.2	13.6	1319.09
	Nov	0.9	0.9	0.3	1.4	17.7	1.7	0.0	-0.8	12.8	1318.50
	Dec	0.5	0.5	-0.3	1.5	17.7	1.2	0.0	-0.7	12.1	1317.92
	Jan	3.2	3.2	-0.2	1.3	17.7	1.1	0.0	2.0	14.1	1319.49
	Feb	1.0	1.0	0.1	1.2	17.7	1.3	0.0	-0.3	13.8	1319.24
	March	15.8	15.8	0.1	1.3	17.7	1.4	0.0	14.4	28.1	1328.16
	April	7.2	7.2	0.6	1.3	17.7	1.9	0.0	5.4	33.5	1330.84
	May	2.4	2.4	1.3	1.4	17.7	2.7	0.0	-0.2	33.3	1330.72
1973	June	1.7	1.7	0.4	1.5	17.7	1.9	0.0	-0.1	33.2	1330.67
	July	1.5	1.5	0.9	1.9	17.7	2.8	0.0	-1.3	31.9	1330.04
	Aug	-0.7	-0.7	1.3	1.8	17.7	3.1	0.0	-3.8	28.1	1328.14
	Sept	4.6	4.6	0.8	1.6	17.7	2.4	0.0	2.2	30.3	1329.25
	Oct	2.1	2.1	0.5	1.5	17.7	2.0	0.0	0.0	30.3	1329.28
	Nov	-0.1	-0.1	-1.3	1.4	17.7	0.1	0.0	-0.2	30.1	1329.18
	Dec	0.4	0.4	-0.4	1.5	17.7	1.1	0.0	-0.7	29.4	1328.82

	Jan	0.7	0.7	-0.5	1.3	17.7	0.9	0.0	-0.2	29.2	1328.72
	Feb	1.5	1.5	0.2	1.2	17.7	1.4	0.0	0.1	29.3	1328.75
	March	1.1	1.1	0.0	1.3	17.7	1.3	0.0	-0.2	29.1	1328.64
	April	2.4	2.4	1.2	1.3	17.7	2.5	0.0	-0.1	29.0	1328.60
	May	6.0	6.0	0.2	1.4	17.7	1.5	0.0	4.4	33.4	1330.79
1974	June	0.2	0.2	1.0	1.5	17.7	2.5	0.0	-2.3	31.1	1329.64
	July	1.1	1.1	2.0	1.9	17.7	3.8	0.0	-2.8	28.3	1328.27
	Aug	9.7	9.7	1.1	1.8	17.7	3.0	0.0	6.7	35.1	1331.58
	Sept	1.9	1.9	0.8	1.6	17.7	2.4	0.0	-0.5	34.6	1331.34
	Oct	0.7	0.7	-0.1	1.5	17.7	1.4	0.0	-0.7	33.8	1331.00
	Nov	9.3	9.3	-0.3	1.4	17.7	1.1	0.0	8.2	42.0	1334.61
	Dec	0.5	0.5	-0.6	1.5	17.7	0.9	0.0	-0.5	41.6	1334.43
	Jan	1.8	1.8	-1.2	1.3	17.7	0.1	0.0	1.7	43.2	1335.10
	Feb	3.2	3.2	0.1	1.2	17.7	1.3	0.0	1.9	45.1	1335.86
	March	0.5	0.5	-0.1	1.3	17.7	1.2	0.0	-0.7	44.5	1335.60
	April	4.3	4.3	0.3	1.3	17.7	1.6	0.0	2.7	47.1	1336.63
	May	14.2	14.2	-0.7	1.4	17.7	0.7	0.0	13.5	60.7	1341.28
1975	June	10.4	10.4	0.6	1.5	17.7	2.0	6.1	2.3	62.9	1342.00
	July	12.8	12.8	1.2	1.9	17.7	3.0	9.8	0.0	62.9	1342.00
	Aug	3.5	3.5	1.7	1.8	17.7	3.5	0.0	0.0	62.9	1342.00
	Sept	0.1	0.1	0.9	1.6	17.7	2.5	0.0	-2.4	60.5	1341.23
	Oct	0.6	0.6	0.7	1.5	17.7	2.2	0.0	-1.6	58.9	1340.72
	Nov	1.7	1.7	0.2	1.4	17.7	1.6	0.0	0.1	59.1	1340.76
	Dec	1.9	1.9	0.0	1.5	17.7	1.5	0.0	0.4	59.4	1340.88
	Jan	-0.8	-0.8	-2.2	1.3	17.7	-0.9	0.0	0.1	59.5	1340.90
	Feb	0.7	0.7	0.1	1.2	17.7	1.3	0.0	-0.6	58.9	1340.71
	March	0.3	0.3	-1.0	1.3	17.7	0.4	0.0	0.0	58.9	1340.71
	April	5.0	5.0	0.4	1.3	17.7	1.7	0.0	3.3	62.2	1341.77
	May	2.6	2.6	1.1	1.4	17.7	2.5	0.0	0.1	62.3	1341.80
1976	June	0.8	0.8	2.2	1.5	17.7	3.7	0.0	-2.9	59.4	1340.87
	July	0.3	0.3	1.9	1.9	17.7	3.8	0.0	-3.4	56.0	1339.73
	Aug	0.2	0.2	2.5	1.8	17.7	4.3	0.0	-4.1	51.9	1338.35
	Sept	3.3	3.3	1.2	1.6	17.7	2.8	0.0	0.6	52.4	1338.54
	Oct	1.1	1.1	1.0	1.5	17.7	2.5	0.0	-1.5	50.9	1338.02
	Nov	0.1	0.1	0.1	1.4	17.7	1.5	0.0	-1.4	49.6	1337.53
	Dec	0.0	0.0	-0.8	1.5	17.7	0.7	0.0	-0.7	48.9	1337.28
	Jan	0.6	0.6	-0.4	1.3	17.7	0.9	0.0	-0.3	48.6	1337.17
	Feb	1.6	1.6	0.3	1.2	17.7	1.5	0.0	0.1	48.7	1337.20
	March	1.4	1.4	1.2	1.3	17.7	2.5	0.0	-1.1	47.6	1336.80
	April	1.7	1.7	0.6	1.3	17.7	2.0	0.0	-0.3	47.3	1336.69
	May	26.4	26.4	-0.4	1.4	17.7	1.0	9.7	15.7	62.9	1342.00
1977	June	5.1	5.1	1.3	1.5	17.7	2.8	2.3	0.0	62.9	1342.00
	July	0.6	0.6	2.5	1.9	17.7	4.4	0.0	-3.8	59.1	1340.78
	Aug	1.1	1.1	1.8	1.8	17.7	3.6	0.0	-2.6	56.6	1339.92
	Sept	0.5	0.5	2.0	1.6	17.7	3.6	0.0	-3.1	53.5	1338.90
	Oct	0.5	0.5	1.0	1.5	17.7	2.5	0.0	-2.0	51.5	1338.20
	Nov	0.0	0.0	0.6	1.4	17.7	1.9	0.0	-1.9	49.5	1337.52
	Dec	-0.6	-0.6	0.0	1.5	17.7	1.5	0.0	-2.1	47.5	1336.76
	Jan	1.8	1.8	-3.4	1.3	17.7	-2.0	0.0	3.8	51.2	1338.13
	Feb	0.9	0.9	-0.8	1.2	17.7	0.5	0.0	0.4	51.7	1338.28
	March	2.2	2.2	0.7	1.3	17.7	2.0	0.0	0.1	51.8	1338.33
	April	2.4	2.4	1.3	1.3	17.7	2.6	0.0	-0.2	51.6	1338.25
	May	7.4	7.4	1.4	1.4	17.7	2.7	0.0	4.7	56.2	1339.82
1978	June	1.1	1.1	1.7	1.5	17.7	3.2	0.0	-2.1	54.1	1339.11
	July	-0.6	-0.6	2.8	1.9	17.7	4.6	0.0	-5.2	48.9	1337.29
	Aug	0.4	0.4	2.5	1.8	17.7	4.3	0.0	-3.9	45.0	1335.82
	Sept	1.3	1.3	1.5	1.6	17.7	3.1	0.0	-1.9	43.2	1335.08
	Oct	-0.5	-0.5	1.2	1.5	17.7	2.7	0.0	-3.2	40.0	1333.77
	Nov	0.6	0.6	0.5	1.4	17.7	1.8	0.0	-1.2	38.8	1333.24
	Dec	0.5	0.5	0.4	1.5	17.7	1.9	0.0	-1.3	37.4	1332.65
	Jan	-4.4	-4.4	-1.4	1.3	17.7	-0.1	0.0	-4.4	33.1	1330.61
	Feb	0.6	0.6	-0.7	1.2	17.7	0.6	0.0	0.0	33.1	1330.62
	March	3.8	3.8	0.8	1.3	17.7	2.1	0.0	1.7	34.7	1331.43
	April	3.0	3.0	0.6	1.3	17.7	1.9	0.0	1.1	35.8	1331.94
	May	4.4	4.4	0.5	1.4	17.7	1.9	0.0	2.5	38.3	1333.06
1979	June	3.7	3.7	1.6	1.5	17.7	3.1	0.0	0.6	38.9	1333.31
	July	0.4	0.4	1.3	1.9	17.7	3.1	0.0	-2.8	36.2	1332.08
	Aug	0.6	0.6	1.7	1.8	17.7	3.5	0.0	-3.0	33.2	1330.68
	Sept	0.1	0.1	1.0	1.6	17.7	2.6	0.0	-2.6	30.6	1329.41
	Oct	0.1	0.1	1.0	1.5	17.7	2.5	0.0	-2.5	28.1	1328.15
	Nov	0.5	0.5	-0.2	1.4	17.7	1.2	0.0	-0.7	27.4	1327.78
	Dec	0.3	0.3	-0.3	1.5	17.7	1.1	0.0	-0.8	26.6	1327.34
	Jan	0.6	0.6	-0.3	1.3	17.7	1.0	0.0	-0.5	26.1	1327.09
	Feb	0.6	0.6	-0.5	1.2	17.7	0.7	0.0	-0.2	26.0	1327.01
	March	1.6	1.6	0.5	1.3	17.7	1.8	0.0	-0.2	25.8	1326.89
	April	2.3	2.3	0.6	1.3	17.7	1.9	0.0	0.4	26.2	1327.11
	May	12.0	12.0	0.7	1.4	17.7	2.1	0.0	9.9	36.1	1332.03
1980	June	13.0	13.0	1.7	1.5	17.7	3.2	0.0	9.8	45.9	1336.16
	July	-0.2	-0.2	2.4	1.9	17.7	4.2	0.0	-4.4	41.5	1334.38
	Aug	1.4	1.4	2.7	1.8	17.7	4.5	0.0	-3.1	38.4	1333.09
	Sept	0.1	0.1	1.2	1.6	17.7	2.9	0.0	-2.8	35.6	1331.83
	Oct	-0.2	-0.2	0.8	1.5	17.7	2.4	0.0	-2.5	33.1	1330.63
	Nov	0.1	0.1	0.1	1.4	17.7	1.5	0.0	-1.4	31.7	1329.95
	Dec	0.3	0.3	0.2	1.5	17.7	1.6	0.0	-1.3	30.4	1329.31

	Jan	-0.3	-0.3	-1.8	1.3	17.7	-0.5	0.0	0.1	30.5	1329.38
	Feb	0.5	0.5	-0.3	1.2	17.7	0.9	0.0	-0.4	30.1	1329.17
	March	2.1	2.1	0.8	1.3	17.7	2.1	0.0	0.0	30.1	1329.18
	April	1.5	1.5	0.8	1.3	17.7	2.1	0.0	-0.6	29.5	1328.88
	May	1.9	1.9	1.1	1.4	17.7	2.4	0.0	-0.5	29.0	1328.62
1981	June	4.2	4.2	1.1	1.5	17.7	2.6	0.0	1.7	30.7	1329.44
	July	1.4	1.4	1.8	1.9	17.7	3.7	0.0	-2.2	28.4	1328.32
	Aug	0.8	0.8	1.1	1.8	17.7	2.9	0.0	-2.1	26.3	1327.20
	Sept	1.5	1.5	1.2	1.6	17.7	2.8	0.0	-1.3	25.0	1326.49
	Oct	4.6	4.6	0.5	1.5	17.7	2.1	0.0	2.5	27.6	1327.87
	Nov	0.9	0.9	0.0	1.4	17.7	1.3	0.0	-0.4	27.2	1327.65
	Dec	0.4	0.4	-0.1	1.5	17.7	1.4	0.0	-0.9	26.2	1327.15
	Jan	3.5	3.5	-0.4	1.3	17.7	0.9	0.0	2.6	28.8	1328.51
	Feb	0.9	0.9	-0.3	1.2	17.7	0.9	0.0	-0.1	28.8	1328.48
	March	1.8	1.8	0.2	1.3	17.7	1.5	0.0	0.3	29.0	1328.63
	April	1.0	1.0	0.6	1.3	17.7	1.9	0.0	-0.9	28.2	1328.17
	May	42.3	42.3	-0.2	1.4	17.7	1.1	6.4	34.8	62.9	1341.99
1982	June	5.9	5.9	0.7	1.5	17.7	2.2	3.6	0.0	62.9	1341.99
	July	-1.2	-1.2	1.8	1.9	17.7	3.7	0.0	-4.9	58.1	1340.43
	Aug	0.7	0.7	2.7	1.8	17.7	4.5	0.0	-3.8	54.3	1339.16
	Sept	0.4	0.4	1.7	1.6	17.7	3.3	0.0	-2.9	51.4	1338.17
	Oct	0.3	0.3	1.4	1.5	17.7	2.9	0.0	-2.6	48.8	1337.25
	Nov	0.3	0.3	0.0	1.4	17.7	1.3	0.0	-1.0	47.8	1336.88
	Dec	0.9	0.9	0.0	1.5	17.7	1.5	0.0	-0.6	47.2	1336.66
	Jan	-2.1	-2.1	-3.2	1.3	17.7	-1.8	0.0	-0.3	46.9	1336.55
	Feb	0.7	0.7	-1.2	1.2	17.7	0.1	0.0	0.6	47.6	1336.79
	March	3.1	3.1	0.3	1.3	17.7	1.6	0.0	1.5	49.1	1337.36
	April	2.3	2.3	1.2	1.3	17.7	2.5	0.0	-0.2	48.9	1337.29
	May	2.8	2.8	1.2	1.4	17.7	2.6	0.0	0.1	49.0	1337.33
1983	June	7.9	7.9	1.6	1.5	17.7	3.0	0.0	4.8	53.9	1339.02
	July	0.2	0.2	2.1	1.9	17.7	3.9	0.0	-3.7	50.1	1337.74
	Aug	-1.1	-1.1	0.7	1.8	17.7	2.5	0.0	-3.6	46.6	1336.41
	Sept	-0.4	-0.4	1.7	1.6	17.7	3.4	0.0	-3.7	42.8	1334.94
	Oct	16.0	16.0	0.3	1.5	17.7	1.9	0.0	14.1	56.9	1340.05
	Nov	0.5	0.5	0.1	1.4	17.7	1.4	0.0	-0.9	56.0	1339.74
	Dec	0.4	0.4	-0.1	1.5	17.7	1.4	0.0	-1.0	55.0	1339.42
	Jan	0.2	0.2	-1.0	1.3	17.7	0.3	0.0	-0.1	55.0	1339.40
	Feb	1.8	1.8	-0.5	1.2	17.7	0.7	0.0	1.2	56.1	1339.78
	March	2.4	2.4	1.3	1.3	17.7	2.6	0.0	-0.2	56.0	1339.72
	April	1.9	1.9	1.0	1.3	17.7	2.3	0.0	-0.4	55.6	1339.59
	May	1.0	1.0	1.9	1.4	17.7	3.3	0.0	-2.3	53.3	1338.83
1984	June	-0.3	-0.3	-0.7	1.5	17.7	0.8	0.0	-1.2	52.1	1338.44
	July	0.2	0.2	2.5	1.9	17.7	4.3	0.0	-4.1	48.0	1336.96
	Aug	0.0	0.0	2.1	1.8	17.7	3.9	0.0	-3.9	44.1	1335.46
	Sept	-0.6	-0.6	2.0	1.6	17.7	3.6	0.0	-4.2	39.9	1333.74
	Oct	0.6	0.6	0.8	1.5	17.7	2.3	0.0	-1.7	38.2	1333.01
	Nov	0.2	0.2	0.0	1.4	17.7	1.3	0.0	-1.1	37.1	1332.50
	Dec	1.5	1.5	-0.3	1.5	17.7	1.2	0.0	0.3	37.4	1332.63
	Jan	0.9	0.9	0.1	1.3	17.7	1.4	0.0	-0.5	36.8	1332.39
	Feb	1.7	1.7	-0.7	1.2	17.7	0.5	0.0	1.1	37.9	1332.89
	March	5.2	5.2	0.7	1.3	17.7	2.0	0.0	3.2	41.1	1334.25
	April	2.4	2.4	1.1	1.3	17.7	2.4	0.0	0.0	41.1	1334.25
	May	1.0	1.0	1.6	1.4	17.7	3.0	0.0	-2.0	39.2	1333.41
1985	June	3.4	3.4	1.2	1.5	17.7	2.7	0.0	0.7	39.8	1333.71
	July	0.2	0.2	1.5	1.9	17.7	3.3	0.0	-3.1	36.8	1332.36
	Aug	-0.6	-0.6	0.7	1.8	17.7	2.5	0.0	-3.2	33.6	1330.87
	Sept	0.8	0.8	0.7	1.6	17.7	2.3	0.0	-1.5	32.0	1330.10
	Oct	4.0	4.0	0.0	1.5	17.7	1.5	0.0	2.5	34.5	1331.31
	Nov	0.0	0.0	-0.9	1.4	17.7	0.4	0.0	-0.5	34.0	1331.09
	Dec	0.7	0.7	-0.3	1.5	17.7	1.1	0.0	-0.5	33.6	1330.87
	Jan	1.0	1.0	0.3	1.3	17.7	1.7	0.0	-0.7	32.9	1330.54
	Feb	0.3	0.3	-1.0	1.2	17.7	0.3	0.0	0.1	33.0	1330.57
	March	1.5	1.5	0.9	1.3	17.7	2.2	0.0	-0.7	32.3	1330.22
	April	2.1	2.1	0.7	1.3	17.7	2.1	0.0	0.0	32.3	1330.24
	May	11.7	11.7	0.1	1.4	17.7	1.5	0.0	10.2	42.5	1334.81
1986	June	4.6	4.6	0.2	1.5	17.7	1.6	0.0	2.9	45.4	1335.97
	July	0.6	0.6	2.4	1.9	17.7	4.2	0.0	-3.7	41.7	1334.50
	Aug	-0.3	-0.3	1.9	1.8	17.7	3.7	0.0	-4.0	37.8	1332.81
	Sept	23.2	23.2	0.9	1.6	17.7	2.5	0.0	20.6	58.4	1340.54
	Oct	28.0	28.0	0.8	1.5	17.7	2.3	21.2	4.5	62.9	1342.00
	Nov	4.4	4.4	0.3	1.4	17.7	1.6	2.8	0.0	62.9	1342.00
	Dec	2.0	2.0	-0.5	1.5	17.7	1.0	1.0	0.0	62.9	1342.00
	Jan	-0.7	-0.7	-3.2	1.3	17.7	-1.9	1.2	0.0	62.9	1342.00
	Feb	5.7	5.7	-0.3	1.2	17.7	0.9	4.8	0.0	62.9	1342.00
	March	3.8	3.8	0.6	1.3	17.7	1.9	1.9	0.0	62.9	1342.00
	April	1.9	1.9	1.1	1.3	17.7	2.4	0.0	-0.5	62.5	1341.84
	May	30.4	30.4	-0.9	1.4	17.7	0.5	29.5	0.5	62.9	1342.00
1987	June	15.9	15.9	-0.5	1.5	17.7	1.0	14.9	0.0	62.9	1342.00
	July	2.0	2.0	1.1	1.9	17.7	3.0	0.0	-1.0	62.0	1341.69
	Aug	1.6	1.6	2.3	1.8	17.7	4.1	0.0	-2.6	59.4	1340.87
	Sept	2.2	2.2	1.0	1.6	17.7	2.6	0.0	-0.4	59.0	1340.73
	Oct	0.9	0.9	0.3	1.5	17.7	1.8	0.0	-0.9	58.0	1340.42
	Nov	1.5	1.5	0.4	1.4	17.7	1.8	0.0	-0.3	57.7	1340.31
	Dec	2.7	2.7	0.3	1.5	17.7	1.8	0.0	0.9	58.6	1340.61

	Jan	2.8	2.8	-2.8	1.3	17.7	-1.5	0.0	4.3	62.9	1341.98
	Feb	0.7	0.7	-1.6	1.2	17.7	-0.4	1.0	0.0	62.9	1342.00
	March	10.1	10.1	0.7	1.3	17.7	2.0	8.1	0.0	62.9	1342.00
	April	11.8	11.8	0.8	1.3	17.7	2.1	9.6	0.0	62.9	1342.00
	May	1.0	1.0	1.0	1.4	17.7	2.4	0.0	-1.4	61.5	1341.56
1988	June	1.7	1.7	1.8	1.5	17.7	3.3	0.0	-1.6	59.9	1341.04
	July	0.9	0.9	1.7	1.9	17.7	3.6	0.0	-2.7	57.2	1340.14
	Aug	0.5	0.5	1.7	1.8	17.7	3.5	0.0	-3.0	54.2	1339.15
	Sept	5.7	5.7	1.2	1.6	17.7	2.8	0.0	2.9	57.1	1340.10
	Oct	1.3	1.3	1.1	1.5	17.7	2.7	0.0	-1.4	55.7	1339.65
	Nov	2.0	2.0	-0.5	1.4	17.7	0.9	0.0	1.1	56.8	1340.01
	Dec	-0.4	-0.4	-1.7	1.5	17.7	-0.3	0.0	-0.1	56.7	1339.96
	Jan	2.3	2.3	0.5	1.3	17.7	1.9	0.0	0.4	57.1	1340.11
	Feb	1.8	1.8	-0.1	1.2	17.7	1.1	0.0	0.7	57.8	1340.33
	March	2.9	2.9	0.4	1.3	17.7	1.7	0.0	1.2	59.0	1340.72
	April	0.1	0.1	0.0	1.3	17.7	1.3	0.0	-1.2	57.7	1340.31
	May	7.0	7.0	-1.2	1.4	17.7	0.1	1.6	5.2	62.9	1341.99
1989	June	37.3	37.3	1.0	1.5	17.7	2.5	34.8	0.0	62.9	1341.99
	July	0.9	0.9	1.6	1.9	17.7	3.5	0.0	-2.6	60.3	1341.17
	Aug	1.7	1.7	1.6	1.8	17.7	3.4	0.0	-1.7	58.6	1340.61
	Sept	5.5	5.5	1.2	1.6	17.7	2.8	0.0	2.6	61.3	1341.46
	Oct	3.8	3.8	1.0	1.5	17.7	2.6	0.0	1.2	62.5	1341.85
	Nov	1.3	1.3	0.5	1.4	17.7	1.9	0.0	-0.7	61.8	1341.65
	Dec	1.7	1.7	0.6	1.5	17.7	2.0	0.0	-0.3	61.5	1341.55
	Jan	2.4	2.4	-1.4	1.3	17.7	-0.1	1.1	1.4	62.9	1342.00
	Feb	2.2	2.2	-3.3	1.2	17.7	-2.0	4.3	0.0	62.9	1342.00
	March	20.6	20.6	0.7	1.3	17.7	2.0	18.6	0.0	62.9	1342.00
	April	6.8	6.8	0.3	1.3	17.7	1.6	5.2	0.0	62.9	1342.00
	May	15.4	15.4	0.2	1.4	17.7	1.6	13.9	0.0	62.9	1342.00
1990	June	2.6	2.6	1.6	1.5	17.7	3.1	0.0	-0.5	62.4	1341.84
	July	1.8	1.8	2.5	1.9	17.7	4.3	0.0	-2.5	60.0	1341.06
	Aug	3.7	3.7	2.1	1.8	17.7	3.9	0.0	-0.2	59.8	1341.00
	Sept	1.3	1.3	1.1	1.6	17.7	2.7	0.0	-1.4	58.4	1340.54
	Oct	-0.1	-0.1	-0.2	1.5	17.7	1.3	0.0	-1.4	57.0	1340.06
	Nov	1.3	1.3	-0.9	1.4	17.7	0.4	0.0	0.8	57.8	1340.34
	Dec	1.1	1.1	0.0	1.5	17.7	1.4	0.0	-0.3	57.5	1340.23
	Jan	2.8	2.8	-0.6	1.3	17.7	0.7	0.0	2.1	59.6	1340.92
	Feb	2.4	2.4	0.7	1.2	17.7	1.9	0.0	0.5	60.1	1341.09
	March	2.3	2.3	0.5	1.3	17.7	1.8	0.0	0.4	60.5	1341.23
	April	2.4	2.4	0.7	1.3	17.7	2.1	0.0	0.4	60.9	1341.35
	May	5.1	5.1	0.1	1.4	17.7	1.5	1.6	2.1	62.9	1342.00
1991	June	6.0	6.0	1.7	1.5	17.7	3.2	2.8	0.0	62.9	1342.00
	July	0.7	0.7	1.8	1.9	17.7	3.6	0.0	-2.9	60.0	1341.07
	Aug	3.1	3.1	2.0	1.8	17.7	3.8	0.0	-0.7	59.3	1340.83
	Sept	3.8	3.8	0.7	1.6	17.7	2.3	0.0	1.5	60.8	1341.32
	Oct	2.2	2.2	1.5	1.5	17.7	3.0	0.0	-0.8	60.0	1341.06
	Nov	2.2	2.2	-0.2	1.4	17.7	1.2	0.0	1.0	61.0	1341.38
	Dec	10.8	10.8	-0.2	1.5	17.7	1.3	7.6	2.0	62.9	1342.00
	Jan	3.1	3.1	-1.9	1.3	17.7	-0.6	3.6	0.0	62.9	1341.99
	Feb	2.1	2.1	-1.0	1.2	17.7	0.2	1.9	0.0	62.9	1342.00
	March	3.3	3.3	0.9	1.3	17.7	2.2	1.1	0.0	62.9	1342.00
	April	1.0	1.0	-0.6	1.3	17.7	0.7	0.3	0.0	62.9	1342.00
	May	3.1	3.1	-0.8	1.4	17.7	0.6	2.4	0.0	62.9	1342.00
1992	June	5.3	5.3	0.3	1.5	17.7	1.8	3.5	0.0	62.9	1341.99
	July	4.4	4.4	1.6	1.9	17.7	3.4	1.0	0.0	62.9	1342.00
	Aug	5.2	5.2	0.3	1.8	17.7	2.1	3.1	0.0	62.9	1342.00
	Sept	1.5	1.5	1.3	1.6	17.7	2.9	0.0	-1.4	61.6	1341.56
	Oct	1.3	1.3	1.4	1.5	17.7	2.9	0.0	-1.6	59.9	1341.05
	Nov	7.4	7.4	0.2	1.4	17.7	1.5	2.9	3.0	62.9	1342.00
	Dec	9.7	9.7	-0.7	1.5	17.7	0.8	8.9	0.0	62.9	1341.99
	Jan	6.6	6.6	-2.3	1.3	17.7	-1.0	7.5	0.0	62.9	1342.00
	Feb	4.8	4.8	-1.8	1.2	17.7	-0.6	5.3	0.0	62.9	1342.00
	March	7.6	7.6	-0.3	1.3	17.7	1.0	6.5	0.0	62.9	1342.00
	April	5.5	5.5	-1.0	1.3	17.7	0.3	5.2	0.0	62.9	1342.00
	May	45.3	45.3	0.9	1.4	17.7	2.3	43.0	0.0	62.9	1342.00
1993	June	7.2	7.2	2.2	1.5	17.7	3.7	3.5	0.0	62.9	1342.00
	July	2.6	2.6	0.8	1.9	17.7	2.7	0.0	-0.1	62.8	1341.96
	Aug	1.0	1.0	1.7	1.8	17.7	3.5	0.0	-2.4	60.4	1341.19
	Sept	2.3	2.3	1.0	1.6	17.7	2.6	0.0	-0.3	60.1	1341.09
	Oct	0.9	0.9	0.6	1.5	17.7	2.1	0.0	-1.2	58.9	1340.69
	Nov	1.7	1.7	0.2	1.4	17.7	1.5	0.0	0.2	59.0	1340.75
	Dec	1.6	1.6	-1.3	1.5	17.7	0.2	0.0	1.4	60.5	1341.22
	Jan	0.7	0.7	-2.2	1.3	17.7	-0.9	0.0	1.6	62.1	1341.73
	Feb	2.4	2.4	-0.6	1.2	17.7	0.6	0.9	0.9	62.9	1342.00
	March	8.1	8.1	0.1	1.3	17.7	1.4	6.7	0.0	62.9	1342.00
	April	12.5	12.5	1.1	1.3	17.7	2.4	10.1	0.0	62.9	1342.00
	May	4.9	4.9	0.5	1.4	17.7	1.9	3.0	0.0	62.9	1342.00
1994	June	1.1	1.1	-0.1	1.5	17.7	1.4	0.0	-0.2	62.7	1341.92
	July	-1.9	-1.9	-0.3	1.9	17.7	1.5	0.0	-3.4	59.3	1340.83
	Aug	1.2	1.2	2.4	1.8	17.7	4.2	0.0	-3.0	56.2	1339.82
	Sept	0.7	0.7	1.6	1.6	17.7	3.2	0.0	-2.5	53.8	1339.00
	Oct	0.4	0.4	0.7	1.5	17.7	2.2	0.0	-1.8	52.0	1338.38
	Nov	9.9	9.9	-0.1	1.4	17.7	1.2	0.0	8.7	60.7	1341.29
	Dec	0.5	0.5	-1.5	1.5	17.7	0.0	0.0	0.6	61.3	1341.48

	Jan	1.8	1.8	-0.5	1.3	17.7	0.8	0.0	1.0	62.2	1341.78
	Feb	1.1	1.1	-0.3	1.2	17.7	0.9	0.0	0.2	62.5	1341.85
	March	5.8	5.8	0.1	1.3	17.7	1.4	3.9	0.5	62.9	1342.00
	April	3.5	3.5	1.3	1.3	17.7	2.6	1.0	0.0	62.9	1342.00
	May	15.1	15.1	1.0	1.4	17.7	2.4	12.7	0.0	62.9	1342.00
1995	June	48.4	48.4	1.5	1.5	17.7	3.0	45.4	0.0	62.9	1342.00
	July	-0.7	-0.7	-1.8	1.9	17.7	0.0	0.0	-0.8	62.2	1341.76
	Aug	11.2	11.2	2.0	1.8	17.7	3.8	6.7	0.8	62.9	1341.99
	Sept	7.9	7.9	1.2	1.6	17.7	2.8	5.0	0.0	62.9	1342.00
	Oct	3.4	3.4	1.7	1.5	17.7	3.2	0.2	0.0	62.9	1342.00
	Nov	2.4	2.4	0.3	1.4	17.7	1.7	0.7	0.0	62.9	1342.00
	Dec	2.9	2.9	-0.3	1.5	17.7	1.1	1.8	0.0	62.9	1342.00
	Jan	0.5	0.5	-2.4	1.3	17.7	-1.0	1.5	0.0	62.9	1342.00
	Feb	-0.1	-0.1	-3.3	1.2	17.7	-2.1	2.0	0.0	62.9	1342.00
	March	3.2	3.2	0.7	1.3	17.7	2.1	1.1	0.0	62.9	1342.00
	April	1.2	1.2	0.4	1.3	17.7	1.7	0.0	-0.5	62.5	1341.85
	May	1.5	1.5	0.7	1.4	17.7	2.1	0.0	-0.6	61.9	1341.67
1996	June	9.5	9.5	2.0	1.5	17.7	3.5	5.0	1.1	62.9	1341.99
	July	2.8	2.8	2.2	1.9	17.7	4.1	0.0	-1.3	61.7	1341.60
	Aug	8.2	8.2	1.2	1.8	17.7	3.0	3.9	1.3	62.9	1342.00
	Sept	2.5	2.5	1.2	1.6	17.7	2.8	0.0	-0.3	62.6	1341.89
	Oct	2.4	2.4	1.4	1.5	17.7	2.9	0.0	-0.6	62.0	1341.72
	Nov	3.4	3.4	0.0	1.4	17.7	1.4	1.1	0.9	62.9	1342.00
	Dec	3.2	3.2	0.5	1.5	17.7	2.0	1.3	0.0	62.9	1342.00
	Jan	2.5	2.5	0.0	1.3	17.7	1.3	1.2	0.0	62.9	1342.00
	Feb	7.2	7.2	-1.1	1.2	17.7	0.1	7.1	0.0	62.9	1342.00
	March	2.2	2.2	0.0	1.3	17.7	1.3	1.0	0.0	62.9	1342.00
	April	16.4	16.4	-1.5	1.3	17.7	-0.2	16.6	0.0	62.9	1342.00
	May	17.4	17.4	1.3	1.4	17.7	2.7	14.7	0.0	62.9	1342.00
1997	June	8.9	8.9	1.5	1.5	17.7	3.0	5.9	0.0	62.9	1342.00
	July	1.3	1.3	-0.3	1.9	17.7	1.5	0.0	-0.2	62.7	1341.93
	Aug	3.6	3.6	0.5	1.8	17.7	2.3	1.1	0.2	62.9	1342.00
	Sept	3.4	3.4	1.7	1.6	17.7	3.3	0.1	0.0	62.9	1342.00
	Oct	2.1	2.1	0.0	1.5	17.7	1.5	0.6	0.0	62.9	1342.00
	Nov	2.7	2.7	0.5	1.4	17.7	1.9	0.8	0.0	62.9	1342.00
	Dec	4.3	4.3	-2.7	1.5	17.7	-1.2	5.5	0.0	62.9	1342.00
	Jan	7.5	7.5	-1.3	1.3	17.7	0.0	7.4	0.0	62.9	1341.99
	Feb	4.7	4.7	-0.8	1.2	17.7	0.4	4.3	0.0	62.9	1341.99
	March	24.4	24.4	-0.7	1.3	17.7	0.6	23.8	0.0	62.9	1341.99
	April	7.3	7.3	0.4	1.3	17.7	1.7	5.5	0.0	62.9	1342.00
	May	2.8	2.8	0.7	1.4	17.7	2.1	0.7	0.0	62.9	1342.00
1998	June	0.9	0.9	2.4	1.5	17.7	3.9	0.0	-3.0	59.9	1341.04
	July	1.0	1.0	3.0	1.9	17.7	4.8	0.0	-3.8	56.1	1339.78
	Aug	-0.1	-0.1	1.2	1.8	17.7	3.0	0.0	-3.1	53.0	1338.75
	Sept	1.3	1.3	1.4	1.6	17.7	3.0	0.0	-1.8	51.3	1338.14
	Oct	1.3	1.3	0.6	1.5	17.7	2.1	0.0	-0.9	50.4	1337.84
	Nov	1.4	1.4	-1.0	1.4	17.7	0.3	0.0	1.0	51.5	1338.20
	Dec	4.8	4.8	-0.2	1.5	17.7	1.3	0.0	3.5	55.0	1339.39
	Jan	1.1	1.1	-0.3	1.3	17.7	1.0	0.0	0.0	55.0	1339.40
	Feb	0.9	0.9	-0.2	1.2	17.7	1.0	0.0	-0.1	54.9	1339.37
	March	6.9	6.9	0.9	1.3	17.7	2.3	0.0	4.7	59.5	1340.92
	April	6.4	6.4	1.0	1.3	17.7	2.3	0.7	3.4	62.9	1342.00
	May	5.8	5.8	1.6	1.4	17.7	3.0	2.8	0.0	62.9	1342.00
1999	June	4.2	4.2	0.5	1.5	17.7	2.0	2.3	0.0	62.9	1342.00
	July	2.4	2.4	1.2	1.9	17.7	3.1	0.0	-0.7	62.3	1341.78
	Aug	1.0	1.0	2.7	1.8	17.7	4.5	0.0	-3.5	58.8	1340.66
	Sept	0.3	0.3	1.2	1.6	17.7	2.8	0.0	-2.5	56.3	1339.82
	Oct	1.6	1.6	1.5	1.5	17.7	3.0	0.0	-1.4	54.9	1339.36
	Nov	0.3	0.3	-0.2	1.4	17.7	1.1	0.0	-0.9	54.0	1339.07
	Dec	6.9	6.9	-0.8	1.5	17.7	0.6	0.0	6.3	60.3	1341.15
	Jan	-1.0	-1.0	-1.0	1.3	17.7	0.3	0.0	-1.4	58.9	1340.70
	Feb	1.8	1.8	-0.9	1.2	17.7	0.3	0.0	1.5	60.4	1341.20
	March	9.9	9.9	0.4	1.3	17.7	1.7	5.7	2.5	62.9	1342.00
	April	10.5	10.5	1.5	1.3	17.7	2.8	7.7	0.0	62.9	1342.00
	May	13.6	13.6	1.4	1.4	17.7	2.8	10.8	0.0	62.9	1342.00
2000	June	11.5	11.5	0.9	1.5	17.7	2.4	9.1	0.0	62.9	1342.00
	July	2.0	2.0	2.6	1.9	17.7	4.5	0.0	-2.5	60.4	1341.21
	Aug	-0.4	-0.4	1.7	1.8	17.7	3.5	0.0	-3.9	56.6	1339.92
	Sept	0.2	0.2	2.2	1.6	17.7	3.8	0.0	-3.6	53.0	1338.74
	Oct	6.8	6.8	0.6	1.5	17.7	2.1	0.0	4.7	57.7	1340.31
	Nov	0.9	0.9	-1.2	1.4	17.7	0.2	0.0	0.7	58.4	1340.54
	Dec	2.2	2.2	-0.8	1.5	17.7	0.7	0.0	1.5	59.9	1341.02
	Jan	3.4	3.4	-2.1	1.3	17.7	-0.8	1.1	3.1	62.9	1342.00
	Feb	6.0	6.0	-2.2	1.2	17.7	-0.9	6.9	0.0	62.9	1342.00
	March	6.8	6.8	0.3	1.3	17.7	1.6	5.2	0.0	62.9	1342.00
	April	2.8	2.8	1.6	1.3	17.7	3.0	0.0	-0.1	62.8	1341.96
	May	13.7	13.7	1.5	1.4	17.7	2.9	10.7	0.1	62.9	1342.00
2001	June	0.8	0.8	-0.2	1.5	17.7	1.3	0.0	-0.5	62.5	1341.86
	July	0.3	0.3	2.5	1.9	17.7	4.3	0.0	-4.0	58.4	1340.55
	Aug	2.0	2.0	1.7	1.8	17.7	3.5	0.0	-1.6	56.9	1340.02
	Sept	0.0	0.0	0.9	1.6	17.7	2.6	0.0	-2.5	54.4	1339.19
	Oct	0.2	0.2	0.7	1.5	17.7	2.2	0.0	-2.0	52.3	1338.50
	Nov	0.9	0.9	0.3	1.4	17.7	1.7	0.0	-0.8	51.5	1338.23
	Dec	1.0	1.0	-0.1	1.5	17.7	1.3	0.0	-0.3	51.2	1338.12

2002	Jan	0.4	0.4	-2.2	1.3	17.7	-0.9	0.0	1.2	52.5	1338.55
	Feb	1.4	1.4	-0.2	1.2	17.7	1.1	0.0	0.3	52.8	1338.67
	March	2.1	2.1	0.3	1.3	17.7	1.6	0.0	0.5	53.3	1338.83
	April	3.8	3.8	0.2	1.3	17.7	1.5	0.0	2.3	55.6	1339.59
	May	2.7	2.7	1.4	1.4	17.7	2.8	0.0	0.0	55.5	1339.58
	June	7.2	7.2	2.0	1.5	17.7	3.5	0.0	3.6	59.2	1340.79
	July	1.6	1.6	1.9	1.9	17.7	3.7	0.0	-2.1	57.0	1340.08
	Aug	0.8	0.8	2.5	1.8	17.7	4.3	0.0	-3.5	53.6	1338.93
	Sept	0.5	0.5	0.6	1.6	17.7	2.2	0.0	-1.7	51.8	1338.34
	Oct	4.0	4.0	0.4	1.5	17.7	2.0	0.0	2.0	53.8	1339.02
	Nov	1.4	1.4	0.2	1.4	17.7	1.5	0.0	-0.1	53.7	1338.99
	Dec	1.2	1.2	-1.3	1.5	17.7	0.2	0.0	1.0	54.8	1339.34
2003	Jan	0.1	0.1	-0.6	1.3	17.7	0.8	0.0	-0.7	54.1	1339.11
	Feb	0.4	0.4	-1.4	1.2	17.7	-0.1	0.0	0.5	54.6	1339.28
	March	3.0	3.0	0.4	1.3	17.7	1.7	0.0	1.3	55.9	1339.71
	April	2.4	2.4	1.3	1.3	17.7	2.6	0.0	-0.2	55.7	1339.64
	May	1.4	1.4	1.1	1.4	17.7	2.5	0.0	-1.1	54.6	1339.28
	June	3.6	3.6	0.0	1.5	17.7	1.5	0.0	2.2	56.8	1339.99
	July	0.9	0.9	2.3	1.9	17.7	4.2	0.0	-3.3	53.5	1338.90
	Aug	0.7	0.7	1.5	1.8	17.7	3.3	0.0	-2.6	50.9	1337.99
	Sept	0.2	0.2	1.4	1.6	17.7	3.0	0.0	-2.8	48.1	1336.98
	Oct	0.9	0.9	0.9	1.5	17.7	2.5	0.0	-1.6	46.5	1336.39
	Nov	0.7	0.7	0.3	1.4	17.7	1.6	0.0	-0.9	45.6	1336.03
	Dec	0.7	0.7	0.0	1.5	17.7	1.4	0.0	-0.7	44.9	1335.76
2004	Jan	1.7	1.7	0.0	1.3	17.7	1.3	0.0	0.4	45.2	1335.91
	Feb	0.3	0.3	-1.4	1.2	17.7	-0.2	0.0	0.5	45.8	1336.11
	March	14.9	14.9	0.7	1.3	17.7	2.0	0.0	12.9	58.6	1340.62
	April	1.6	1.6	0.4	1.3	17.7	1.7	0.0	-0.1	58.5	1340.58
	May	1.0	1.0	1.8	1.4	17.7	3.2	0.0	-2.2	56.3	1339.85
	June	2.0	2.0	1.6	1.5	17.7	3.1	0.0	-1.1	55.2	1339.48
	July	1.6	1.6	1.6	1.9	17.7	3.5	0.0	-1.9	53.3	1338.85
	Aug	0.9	0.9	1.5	1.8	17.7	3.3	0.0	-2.4	51.0	1338.03
	Sept	0.3	0.3	1.6	1.6	17.7	3.2	0.0	-2.9	48.1	1336.98
	Oct	1.6	1.6	0.4	1.5	17.7	2.0	0.0	-0.4	47.7	1336.85
	Nov	2.8	2.8	-1.1	1.4	17.7	0.3	0.0	2.5	50.3	1337.78
	Dec	1.1	1.1	-0.1	1.5	17.7	1.3	0.0	-0.2	50.1	1337.70
2005	Jan	3.0	3.0	0.2	1.3	17.7	1.6	0.0	1.4	51.5	1338.20
	Feb	2.8	2.8	-0.8	1.2	17.7	0.4	0.0	2.3	53.8	1339.01
	March	1.0	1.0	-0.3	1.3	17.7	1.1	0.0	0.0	53.8	1339.00
	April	1.0	1.0	1.1	1.3	17.7	2.4	0.0	-1.4	52.4	1338.54
	May	2.2	2.2	1.1	1.4	17.7	2.5	0.0	-0.3	52.2	1338.45
	June	10.0	10.0	0.5	1.5	17.7	2.0	0.0	8.0	60.2	1341.12
	July	-0.8	-0.8	0.8	1.9	17.7	2.6	0.0	-3.4	56.7	1339.98
	Aug	5.7	5.7	1.7	1.8	17.7	3.5	0.0	2.3	59.0	1340.74
	Sept	1.8	1.8	1.0	1.6	17.7	2.7	0.0	-0.8	58.2	1340.46
	Oct	3.4	3.4	0.5	1.5	17.7	2.0	0.0	1.4	59.5	1340.91
	Nov	1.0	1.0	1.0	1.4	17.7	2.4	0.0	-1.4	58.2	1340.46
	Dec	1.2	1.2	0.5	1.5	17.7	1.9	0.0	-0.7	57.4	1340.21
2006	Jan	1.2	1.2	0.2	1.3	17.7	1.6	0.0	-0.4	57.0	1340.08
	Feb	0.3	0.3	-0.5	1.2	17.7	0.7	0.0	-0.4	56.6	1339.95
	March	2.9	2.9	1.3	1.3	17.7	2.6	0.0	0.3	57.0	1340.05
	April	0.9	0.9	0.5	1.3	17.7	1.8	0.0	-1.0	56.0	1339.73
	May	2.2	2.2	1.6	1.4	17.7	3.0	0.0	-0.8	55.2	1339.48
	June	2.8	2.8	1.9	1.5	17.7	3.4	0.0	-0.6	54.6	1339.28
	July	0.7	0.7	2.9	1.9	17.7	4.8	0.0	-4.1	50.6	1337.89
	Aug	2.2	2.2	2.2	1.8	17.7	4.0	0.0	-1.9	48.7	1337.21
	Sept	0.7	0.7	1.3	1.6	17.7	2.9	0.0	-2.3	46.4	1336.36
	Oct	1.0	1.0	1.1	1.5	17.7	2.6	0.0	-1.6	44.8	1335.73
	Nov	0.6	0.6	0.1	1.4	17.7	1.5	0.0	-0.9	43.8	1335.36
	Dec	0.8	0.8	-0.5	1.5	17.7	1.0	0.0	-0.1	43.7	1335.30
2007	Jan	0.8	0.8	-0.7	1.3	17.7	0.6	0.0	0.2	43.9	1335.36
	Feb	0.5	0.5	-0.9	1.2	17.7	0.3	0.0	0.2	44.1	1335.44
	March	6.6	6.6	-0.2	1.3	17.7	1.1	0.0	5.4	49.5	1337.50
	April	3.4	3.4	-0.1	1.3	17.7	1.3	0.0	2.2	51.6	1338.26
	May	16.7	16.7	0.6	1.4	17.7	2.0	3.4	11.3	62.9	1342.00
	June	28.6	28.6	0.4	1.5	17.7	1.9	26.7	0.0	62.9	1342.00
	July	9.3	9.3	1.7	1.9	17.7	3.6	5.8	0.0	62.9	1342.00
	Aug	37.2	37.2	1.4	1.8	17.7	3.2	34.0	0.0	62.9	1342.00
	Sept	3.0	3.0	1.1	1.6	17.7	2.7	0.3	0.0	62.9	1342.00
	Oct	6.1	6.1	1.1	1.5	17.7	2.6	3.5	0.0	62.9	1342.00
	Nov	0.5	0.5	-0.8	1.4	17.7	0.6	0.0	-0.1	62.9	1341.97
	Dec	3.4	3.4	-0.7	1.5	17.7	0.8	2.6	0.1	62.9	1342.00
2008	Jan	0.8	0.8	-3.2	1.3	17.7	-1.9	2.7	0.0	62.9	1342.00
	Feb	4.6	4.6	-3.4	1.2	17.7	-2.2	6.7	0.0	62.9	1342.00
	March	15.2	15.2	0.8	1.3	17.7	2.1	13.1	0.0	62.9	1342.00
	April	15.8	15.8	-1.5	1.3	17.7	-0.2	16.0	0.0	62.9	1342.00
	May	9.3	9.3	2.1	1.4	17.7	3.5	5.9	0.0	62.9	1342.00
	June	5.4	5.4	1.2	1.5	17.7	2.7	2.7	0.0	62.9	1342.00
	July	1.7	1.7	2.6	1.9	17.7	4.4	0.0	-2.8	60.2	1341.11
	Aug	5.6	5.6	1.3	1.8	17.7	3.1	0.0	2.5	62.7	1341.91
	Sept	1.1	1.1	1.1	1.6	17.7	2.7	0.0	-1.6	61.0	1341.39
	Oct	1.5	1.5	0.4	1.5	17.7	1.9	0.0	-0.4	60.6	1341.26
	Nov	0.3	0.3	-0.5	1.4	17.7	0.8	0.0	-0.5	60.1	1341.10
	Dec	0.2	0.2	-1.3	1.5	17.7	0.2	0.0	0.1	60.2	1341.12

Appendix C – Evaporation Rates

Pan Evaporation Rates (Inches/Month)

Fort Cobb Reservoir 2009 Yield Study

Post-Construction Data

- Monthly Averages of Water Supply Report data
- Average of stations at Norman, Mt Park, and Foss Reservoirs
- Water Supply Report data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956										5.53	3.24	1.86	10.63
1957	1.78	2.45	4.87	7.01	7.97	9.11	10.77	10.06	7.72	5.53	3.24	1.86	72.37
1958	1.78	2.45	4.87	7.01	7.97	9.11	10.77	10.06	7.72	5.53	3.24	1.86	72.37
1959	1.78	2.45	4.87	7.01	7.97	9.11	10.77	10.06	7.72	5.53	3.24	1.86	72.37
1960	1.78	2.45	4.87	7.01	7.97	9.11	10.77	10.06	7.72	5.53	3.24	1.86	72.37
1961	1.78	2.45	4.87	7.01	7.97	9.11	10.77	10.06	7.72	5.53	3.24	1.86	72.37
1962	1.44	5.40	6.94	8.36	13.27	9.80	11.61	13.12	6.19	5.54	3.56	2.00	87.22
1963	1.03	3.00	7.86	9.46	11.50	11.54	14.66	13.08	8.68	8.88	4.69	1.75	96.11
1964	2.51	2.25	7.16	11.45	11.69	13.50	15.73	13.25	8.02	6.13	2.74	1.71	96.13
1965	1.40	2.81	4.72	9.44	10.53	11.87	15.81	12.66	9.09	5.70	4.70	4.27	92.95
1966	1.28	1.54	8.25	7.85	10.67	13.56	14.84	10.06	6.65	7.45	5.62	1.55	89.31
1967	2.37	3.08	7.78	8.34	10.23	12.03	11.36	12.43	7.92	8.75	3.01	2.05	89.33
1968	1.43	1.83	4.59	7.58	7.99	8.15	9.12	10.54	7.32	5.06	2.55	1.60	67.75
1969	1.41	2.22	3.77	6.90	7.39	10.36	13.03	9.83	5.85	4.15	3.37	1.64	69.91
1970	1.09	4.01	3.25	7.75	11.50	10.17	11.91	12.91	7.55	5.05	3.77	2.95	81.90
1971	2.49	2.75	7.02	10.33	12.09	12.19	13.58	10.27	7.75	5.00	2.52	1.80	87.79
1972	1.39	2.37	5.36	10.28	8.97	10.64	12.59	10.61	8.52	1.17	3.84	1.47	77.19
1973	2.30	2.74	4.96	4.84	9.56	9.14	10.14	10.15	9.77	4.90	3.27	1.18	72.95
1974	2.55	4.34	5.39	8.89	11.62	10.29	14.85	9.02	5.11	1.26	0.91	0.00	74.24
1975	0.66	0.38	0.22	7.61	1.65	6.57	6.56	8.91	7.00	6.83	3.44	2.21	52.04
1976	3.20	4.81	6.91	6.52	6.74	10.71	10.90	12.71	5.49	5.01	3.60	2.72	79.32
1977	2.26	4.13	7.00	6.98	6.11	10.42	10.77	8.23	9.23	6.60	3.39	3.15	78.27
1978	2.27	1.06	5.01	9.25	8.07	10.59	15.96	12.18	8.39	8.90	3.58	2.70	87.96
1979	2.26	0.80	5.64	5.92	7.93	9.52	10.35	10.51	8.56	8.05	2.72	2.90	75.16
1980	2.32	2.97	5.60	8.19	6.80	11.48	16.20	16.80	9.90	7.55	3.85	3.10	94.76
1981	3.35	3.15	5.53	7.16	8.90	8.83	13.06	9.56	9.29	4.64	3.72	2.58	79.77
1982	2.85	2.54	6.06	7.85	0.59	4.72	10.38	12.38	9.84	6.86	2.02	1.30	67.38
1983	0.70	0.14	3.41	5.89	8.97	7.98	12.93	4.74	9.99	4.57	2.67	1.45	63.44
1984	1.10	5.26	5.71	7.14	10.01	12.46	12.69	11.00	10.47	5.27	3.94	1.85	86.90
1985	1.33	2.29	4.34	6.30	9.30	9.79	11.09	10.58	7.29	3.97	2.39	1.05	69.71
1986	3.33	3.16	6.49	7.45	6.85	7.30	13.95	10.43	5.52	3.47	2.53	1.34	71.82
1987	1.66	2.09	4.13	7.99	8.24	8.34	9.37	10.48	6.35	6.46	3.72	1.59	70.42
1988	2.09	2.96	5.76	5.64	8.79	10.75	10.83	10.50	7.57	5.06	3.57	2.67	76.19
1989	3.25	2.27	5.67	0.82	7.24	6.35	10.03	7.43	7.63	6.60	4.89	2.49	64.67
1990	3.06	2.89	4.17	5.24	8.65	11.48	10.50	9.13	7.35	5.86	4.72	4.11	77.16
1991	3.75	4.99	6.79	6.62	7.31	8.65	10.85	9.77	4.04	6.51	2.06	2.19	73.53
1992	1.62	2.93	5.39	4.83	5.99	5.61	10.54	7.24	7.80	6.79	2.34	0.00	61.08
1993	0.00	1.04	4.33	5.96	6.22	9.40	11.97	11.30	7.37	5.60	4.08	2.51	69.78
1994	2.22	2.16	6.34	7.81	6.52	1.01	1.02	12.16	7.21	5.03	2.75	2.05	56.28
1995	2.00	4.19	4.59	6.44	6.18	8.45	1.18	9.03	6.25	7.38	4.65	2.60	62.94
1996	0.68	2.78	5.65	9.81	12.94	9.66	10.29	6.81	5.18	6.06	2.10	2.97	74.93
1997	1.97	2.79	6.49	5.22	7.98	8.48	1.15	2.36	7.72	5.18	2.49	0.11	51.93
1998	0.00	0.00	0.00	7.24	9.01	14.79	14.24	10.50	9.73	5.54	2.54	1.33	74.92
1999	0.00	0.00	4.52	6.50	7.43	7.22	11.01	12.96	7.77	7.26	4.33	1.86	70.85
2000	1.70	5.32	4.90	6.55	8.88	7.56	11.13	13.85	10.38	4.52	2.17	0.73	77.69
2001	0.70	0.22	3.50	6.99	8.17	10.93	13.46	9.80	6.69	6.69	3.43	0.00	70.57
2002	0.00	0.00	2.43	6.14	7.25	9.54	9.52	11.45	7.30	3.64	3.45	0.39	61.10
2003	0.00	0.00	4.50	7.79	8.93	8.32	11.77	10.24	6.67	5.93	3.00	3.06	70.20
2004	1.70	2.79	5.60	6.55	9.15	8.64	9.35	8.03	9.39	4.12	2.05	2.51	69.89
2005	1.57	2.34	5.56	8.21	6.52	9.42	11.40	8.29	7.72	5.02	4.90	2.80	73.74
2006	4.21	4.46	6.74	10.10	9.61	12.82	13.47	11.04	6.82	5.87	3.78	0.00	88.91
2007	0.00	0.00	0.00	5.52	6.25	6.10	8.25	8.84	6.63	5.77	3.89	1.23	52.48
2008	2.84	2.40	6.39	7.62	9.80	10.66	11.17	8.36	5.37	5.10	4.03	0.00	73.74

Reservoir Evaporation Rates (Feet/Month)

Fort Cobb Reservoir 2009 Yield Study

Pre-Construction

"Monthly Net Evaporation Rates" from Definite Plan Report
Labeled "Pure Evap. (Reservoir) Offset by Precip." in model

Post-Construction

Monthly averages from Water Supply Report data minus precip

Average of stations at Norman, Mt Park, and Foss Reservoirs minus precip

"Total Pan Evap" from Water Supply Report minus precipitation
Labeled "Pure Evap. (Reservoir) Offset by Precip." in model

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1926	0.51	3.53	1.44	1.23	2.94	4.74	0.68	1.21	0.00	0.00	2.02	0.00	18.30
1927	0.10	1.36	2.01	1.87	5.48	3.26	0.89	2.40	0.08	1.80	2.24	0.36	21.85
1928	1.80	0.71	2.61	2.67	2.54	1.73	0.72	3.85	4.18	1.62	0.00	0.00	22.43
1929	0.56	0.16	0.00	4.20	0.00	3.37	4.81	5.61	0.00	0.03	0.00	1.80	20.54
1930	0.00	2.46	3.78	2.68	0.69	5.57	8.07	7.70	3.62	0.00	1.03	0.00	35.60
1931	0.69	0.36	0.00	1.08	2.01	6.21	2.07	4.32	6.36	0.00	0.00	0.23	23.33
1932	0.00	0.59	3.48	3.01	1.22	0.00	3.59	5.74	2.75	2.68	2.51	0.00	25.57
1933	1.88	0.26	3.10	4.19	3.55	7.77	6.12	2.67	1.36	2.89	0.80	0.08	34.67
1934	1.13	1.70	2.76	3.05	2.45	4.38	8.68	5.90	3.02	3.16	2.05	1.53	39.81
1935	1.94	1.78	2.75	5.37	0.00	2.11	8.45	7.93	1.62	2.48	0.00	0.33	34.76
1936	1.87	2.36	5.97	5.79	1.37	7.38	9.48	10.40	0.00	2.18	2.80	1.00	50.60
1937	1.02	3.00	2.50	4.32	2.39	4.23	8.81	4.58	2.79	2.17	1.84	0.82	38.47
1938	2.43	0.00	2.80	2.29	1.17	4.08	5.63	10.12	4.00	5.55	0.00	2.55	40.62
1939	0.00	2.37	3.75	5.69	5.79	5.28	10.75	5.11	9.03	4.87	2.09	1.55	56.28
1940	0.92	0.17	4.36	2.68	4.36	5.43	4.90	6.48	3.66	3.37	0.00	0.58	36.91
1941	0.00	0.00	2.30	0.19	0.00	0.00	6.48	3.63	1.88	0.00	1.23	0.41	16.12
1942	1.41	0.98	3.60	0.00	6.41	5.39	7.77	1.01	0.00	1.09	2.37	0.00	30.03
1943	1.99	3.06	4.38	4.90	0.00	7.15	9.12	10.62	6.34	4.04	2.68	0.00	54.28
1944	0.00	0.49	0.02	1.01	5.30	5.78	5.09	6.37	2.57	0.81	0.46	0.00	27.90
1945	0.00	0.10	0.85	0.00	6.73	2.58	1.43	4.06	2.35	2.50	3.20	1.73	25.53
1946	0.00	0.89	3.70	4.15	4.05	1.47	7.55	5.26	2.81	3.13	0.00	0.19	33.20
1947	0.74	2.84	3.23	0.00	0.00	1.79	6.91	8.36	6.95	2.00	0.16	0.00	32.98
1948	0.93	0.00	0.00	3.58	2.79	2.34	4.38	5.77	7.03	3.50	2.70	2.61	35.63
1949	0.00	0.31	2.06	3.01	0.00	0.94	7.92	3.90	3.19	1.00	3.02	1.18	26.53
1950	0.66	1.53	4.81	5.30	0.77	5.71	0.00	1.86	2.37	5.23	3.50	1.81	33.55
1951	1.41	0.59	3.94	5.84	0.79	2.23	7.64	6.19	3.44	3.91	0.82	2.86	39.66
1952	1.56	1.69	2.39	3.00	3.63	11.70	8.24	9.78	7.42	6.36	2.10	0.67	58.54
1953	2.57	2.57	2.37	3.17	7.18	10.26	3.11	3.81	7.90	0.00	0.86	1.33	45.13
1954	1.93	4.61	4.66	2.08	0.20	9.79	11.73	8.09	8.51	4.07	3.64	2.59	61.90
1955	0.12	1.39	3.21	6.81	0.00	5.88	8.76	6.62	0.00	0.72	4.12	2.36	39.99
1956	1.84	1.55	6.31	6.89	4.92	9.38	9.62	10.55	8.88	0.00	0.13	-0.04	60.02
1957	0.05	0.05	0.01	-0.03	-0.44	0.18	0.48	0.58	0.17	0.10	0.04	0.08	1.28
1958	-0.02	0.05	0.02	0.17	0.38	0.16	0.25	0.35	0.27	0.32	0.15	-0.04	2.05
1959	0.10	0.12	0.18	0.20	-0.25	0.15	-0.08	0.44	0.45	-0.16	0.17	-0.18	1.14
1960	0.02	-0.01	0.19	0.37	0.14	0.47	0.38	0.26	0.33	-0.16	0.18	-0.04	2.13
1961	0.09	0.04	0.09	0.38	0.26	0.11	0.20	0.40	-0.16	0.13	-0.06	0.04	1.53
1962	0.06	0.30	0.36	0.08	0.41	-0.09	0.44	0.71	0.07	0.13	0.14	0.01	2.61
1963	0.05	0.16	0.34	0.39	0.57	0.19	0.75	0.68	-0.07	0.48	0.05	0.08	3.67
1964	0.08	-0.06	0.35	0.64	0.22	0.70	0.90	0.46	-0.04	0.30	-0.21	0.06	3.39
1965	0.03	0.11	0.17	0.20	0.21	0.29	0.89	0.35	-0.09	0.18	0.27	0.01	2.63
1966	0.03	-0.15	0.39	0.22	0.53	0.31	0.86	-0.04	0.13	0.39	0.31	0.04	3.02
1967	0.14	0.18	0.31	0.13	0.37	0.54	0.40	0.65	0.02	0.36	0.16	0.00	3.25
1968	-0.11	0.01	0.19	0.16	0.07	0.22	0.27	0.52	0.01	0.12	-0.38	0.00	1.08
1969	0.08	-0.02	0.03	0.29	-0.08	0.29	0.69	0.28	0.07	0.05	0.19	-0.02	1.86
1970	-0.45	-0.08	0.12	0.16	0.40	0.40	0.69	0.75	0.44	0.27	0.04	-0.06	2.69
1971	-0.08	-0.06	0.31	0.43	0.50	0.62	0.75	0.57	0.39	0.20	0.15	0.05	3.83
1972	-0.21	-0.23	0.07	0.24	0.12	0.32	0.67	0.44	0.50	0.07	0.20	-0.18	2.01
1973	-0.16	0.08	0.05	0.24	0.49	0.14	0.35	0.52	0.35	0.21	-0.51	-0.14	1.61
1974	-0.19	0.09	0.00	0.49	0.07	0.38	0.79	0.49	0.30	-0.05	-0.10	-0.18	2.08
1975	-0.40	0.02	-0.05	0.08	-0.20	0.14	0.29	0.42	0.22	0.17	0.06	0.01	0.77
1976	-0.57	0.02	-0.25	0.10	0.27	0.55	0.49	0.66	0.32	0.28	0.04	-0.23	1.68
1977	-0.11	0.09	0.35	0.19	-0.11	0.33	0.63	0.47	0.52	0.26	0.16	0.00	2.77
1978	-0.99	-0.21	0.20	0.36	0.38	0.46	0.75	0.71	0.46	0.37	0.15	0.13	2.77
1979	-0.49	-0.25	0.30	0.22	0.19	0.55	0.43	0.61	0.39	0.41	-0.07	-0.14	2.16
1980	-0.15	-0.23	0.21	0.27	0.33	0.60	0.71	0.86	0.42	0.30	0.05	0.07	3.46
1981	-0.73	-0.11	0.32	0.33	0.44	0.46	0.74	0.45	0.54	0.24	-0.01	-0.05	2.61
1982	-0.19	-0.12	0.07	0.24	-0.10	0.18	0.45	0.70	0.44	0.38	-0.01	0.00	2.05
1983	-0.93	-0.34	0.08	0.34	0.36	0.45	0.56	0.21	0.52	0.11	0.01	-0.03	1.33
1984	-0.28	-0.14	0.33	0.27	0.50	-0.18	0.68	0.60	0.61	0.25	-0.01	-0.10	2.54
1985	0.02	-0.24	0.23	0.35	0.52	0.40	0.49	0.26	0.27	-0.02	-0.34	-0.12	1.81
1986	0.12	-0.37	0.33	0.29	0.05	0.05	0.72	0.61	0.32	0.20	0.07	-0.11	2.28
1987	-0.80	-0.08	0.15	0.27	-0.23	-0.12	0.27	0.57	0.26	0.07	0.11	0.09	0.56
1988	-0.72	-0.40	0.17	0.21	0.25	0.45	0.44	0.44	0.32	0.30	-0.13	-0.46	0.85
1989	0.14	-0.03	0.11	0.00	-0.32	0.25	0.40	0.41	0.32	0.26	0.14	0.14	1.81
1990	-0.36	-0.81	0.17	0.08	0.04	0.40	0.61	0.53	0.28	-0.06	-0.24	-0.01	0.64
1991	-0.16	0.17	0.13	0.19	0.03	0.43	0.44	0.51	0.17	0.38	-0.04	-0.05	2.20
1992	-0.47	-0.26	0.21	-0.14	-0.19	0.08	0.39	0.08	0.32	0.35	0.04	-0.17	0.24
1993	-0.57	-0.45	-0.07	-0.24	0.23	0.54	0.21	0.41	0.26	0.15	0.05	-0.33	0.18
1994	-0.57	-0.15	0.03	0.27	0.13	-0.03	-0.08	0.62	0.41	0.18	-0.04	-0.38	0.38
1995	-0.14	-0.08	0.02	0.31	0.25	0.37	-0.45	0.49	0.30	0.42	0.08	-0.08	1.49
1996	-0.59	-0.83	0.18	0.09	0.18	0.49	0.55	0.30	0.30	0.35	0.01	0.12	1.17
1997	0.00	-0.27	-0.01	-0.37	0.32	0.37	-0.08	0.11	0.42	-0.01	0.13	-0.66	-0.05
1998	-0.32	-0.19	-0.17	0.10	0.17	0.59	0.75	0.32	0.39	0.17	-0.29	-0.06	1.46
1999	-0.08	-0.06	0.25	0.26	0.40	0.12	0.31	0.68	0.31	0.39	-0.06	-0.23	2.29
2000	-0.26	-0.23	0.09	0.36	0.35	0.22	0.65	0.43	0.57	0.15	-0.31	-0.20	1.83
2001	-0.54	-0.53	0.08	0.41	0.37	-0.05	0.62	0.45	0.25	0.19	0.09	-0.04	1.29
2002	-0.62	-0.05	0.09	0.05	0.36	0.54	0.47	0.64	0.16	0.12	0.05	-0.35	1.48
2003	-0.15	-0.37	0.10	0.34	0.29	0.00	0.61	0.40	0.39	0.27	0.08	-0.01	1.96
2004	0.00	-0.43	0.22	0.11	0.46	0.42	0.44	0.41	0.44	0.13	-0.32	-0.04	1.84
2005	0.07	-0.22	-0.07	0.29	0.30	0.15	0.20	0.44	0.27	0.14	0.26	0.12	1.92
2006	0.05	-0.13	0.34	0.13	0.43	0.51	0.79	0.62	0.38	0.33	0.05	-0.15	3.35
2007	-0.22	-0.29	-0.05	-0.02	0.16	0.10	0.42	0.34	0.27	0.26	-0.19	-0.17	0.61
2008	-0.80	-0.84	0.20	-0.38	0.51	0.30	0.64	0.32	0.27	0.11	-0.13	-0.33	

Notes: Negative values denote a month in which rainfall exceeded evaporation. Pre-construction data does not include this information and only shows a zero in months in which rainfall apparently exceeded evaporation.

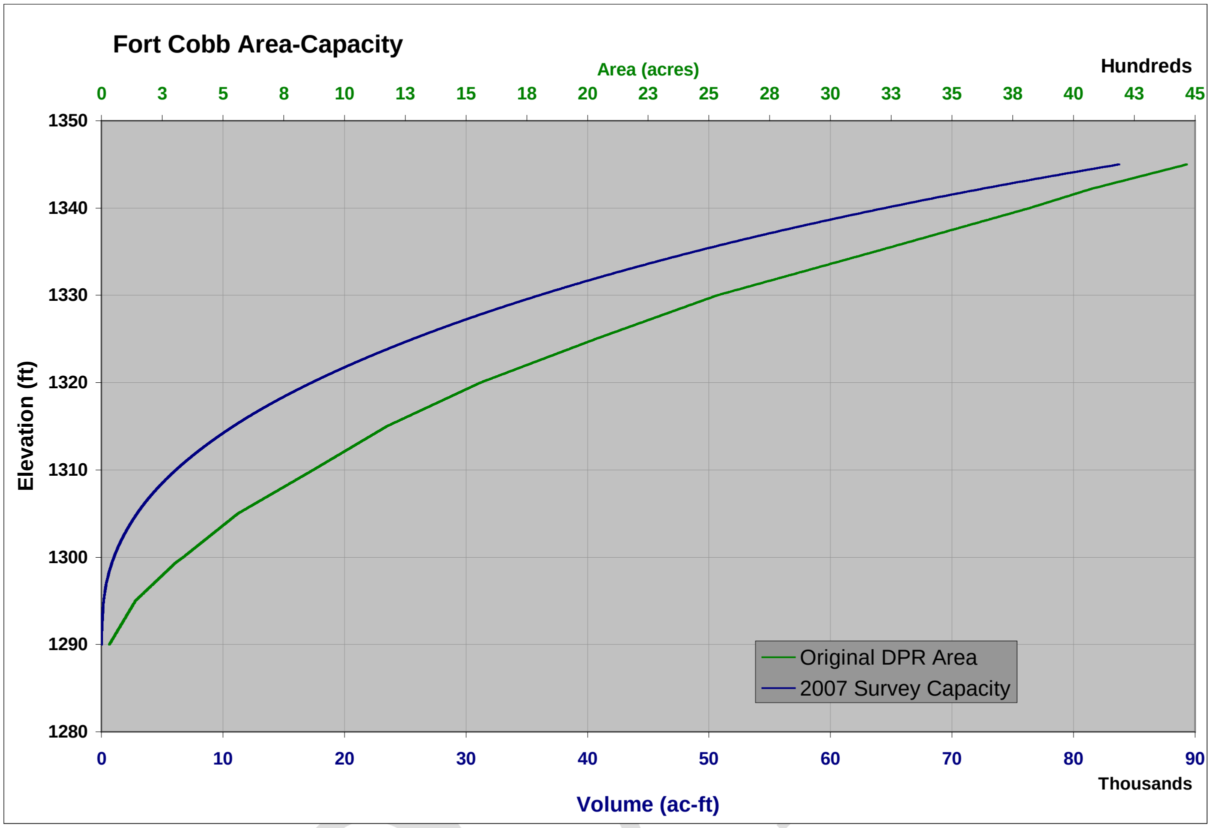
Appendix D – Precipitation Rates

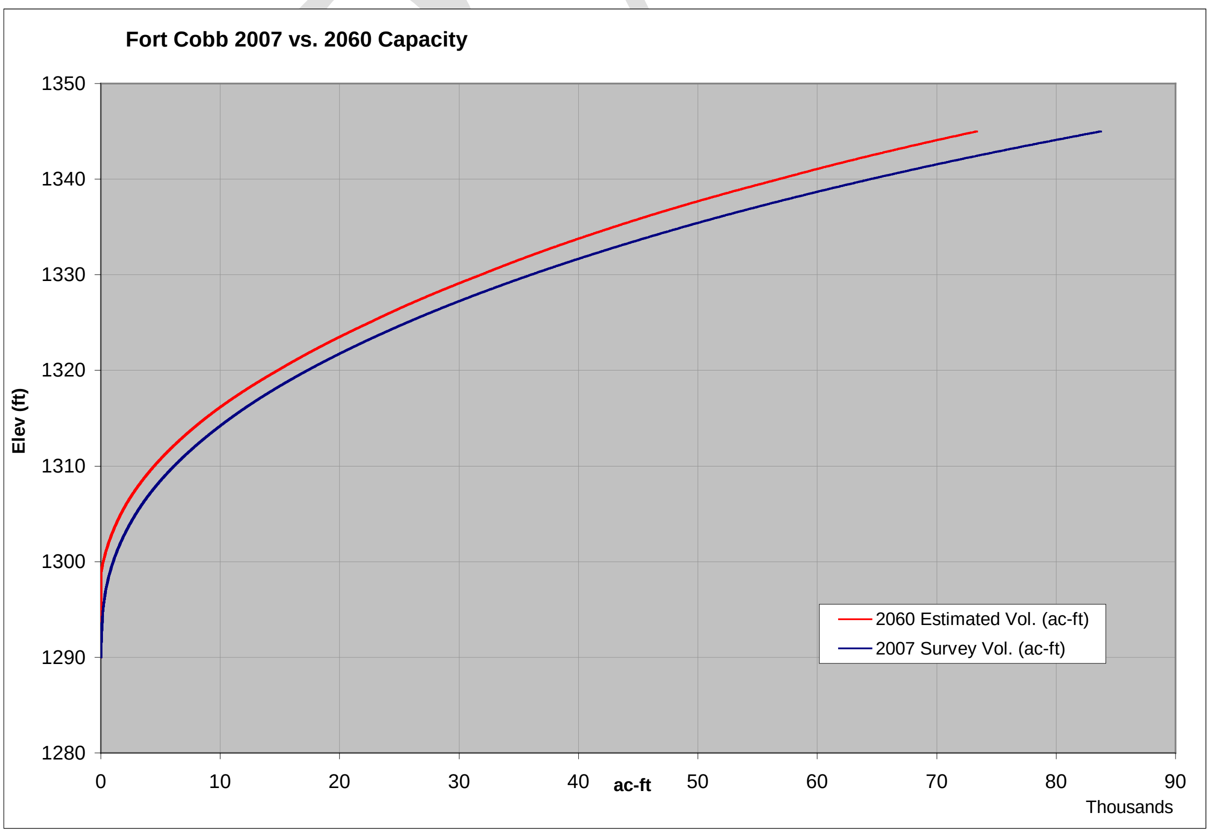
Precipitation Rates (Inches/Month)
Fort Cobb Reservoir 2009 Yield Study

Post-Construction
TSC Climate Change Study (Base Precip)
Mesonet Data for Fort Cobb Gage
"Precip" from Water Supply Report

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1926	6.77	1.42	1.35	2.9	3.17	3.77	0.25	0	0	2.34	1.31	0.63	23.91
1927	7.45	0.68	2.27	2.27	4.28	0.87	0	0.01	1.92	1.49	0	1.83	23.07
1928	0	1.21	1.35	7.03	3.29	4.84	3.3	0.86	0.02	0.68	2.74	5.77	31.09
1929	13.46	2.46	0.93	0.21	1.13	4.23	0	1.34	0	3.91	1.39	2.19	31.25
1930	3.87	1.42	7.79	7.03	1.58	0.76	0.16	0.9	0	2.67	0.82	1.78	28.78
1931	1.38	2.83	3.03	2.61	3.92	0.76	3.11	3.96	1.67	2.34	1.78	1.43	28.82
1932	0.59	1.1	0.81	1.41	2.73	1.48	1.8	1.34	0.21	2.13	0	2.5	16.10
1933	9.1	2.83	1.23	3.81	2.51	3.22	2.35	2.11	1.77	0.28	1.9	3.51	34.62
1934	13.46	3.25	1.1	3.81	0.86	0.87	2.8	4.29	0.34	2.1	1.15	0.46	34.49
1935	0	3.32	0.02	2.57	5.57	0.21	0.73	1.34	0	2.13	2.66	1.43	19.98
1936	0	1.42	0.81	0	1.58	4.41	0.97	0.94	0.02	0.64	1.31	1.33	13.43
1937	3.04	6.92	1.36	2.16	4.86	0.7	1.71	4.65	1.77	0.92	0.82	4.7	33.61
1938	0	3.26	2.07	1.79	1.55	0.7	0.98	0.9	0.21	0.53	0.28	0.49	12.76
1939	3.51	3.07	3.4	2.37	1.47	5.82	0.9	4.65	0	0.06	0.76	2.88	28.89
1940	0.59	2.83	1.14	2.73	3.17	3.18	2.9	0.01	1.4	2.13	6.16	1.43	27.67
1941	3.87	3.26	1.23	2.73	8.6	5.88	1.86	4.65	3.38	1.92	1.9	2.91	42.19
1942	4.07	2.32	1.07	3.36	1.27	4.53	6.2	0.5	0.74	1.32	0.76	7.94	34.08
1943	9.1	3.25	0.64	2.37	1.64	3.18	0.73	0.14	1.4	0.92	1.31	7.94	32.62
1944	4.3	2.32	0.02	4.33	0.86	4.84	0.25	1.34	1.38	0	1.64	0.63	21.91
1945	0.31	3.32	0.79	3.36	0.92	2.99	0.25	0.44	3.38	0.33	0	2.19	18.28
1946	5.25	5.12	1.23	2.73	6.42	0.83	1.71	0.25	1.4	2.37	2.66	1.83	31.80
1947	0.64	1.42	7.79	0.25	7.31	0.7	1.86	0.94	0.25	1.78	5.78	0.63	29.35
1948	13.46	2.83	0.79	1.4	0.86	4.84	2.35	0.44	1.28	0.33	1.81	2.19	32.58
1949	3.51	2.46	2.62	0.45	8.6	2.91	2.35	1.2	3.23	2.67	0	2.84	32.84
1950	0.64	4.23	1.14	0.45	7.31	0.76	1.13	4.29	0	1.76	0	0.03	21.74
1951	0.59	1.87	0.64	2.57	1.58	0.06	0.03	0.23	1.4	0.64	1.15	0.84	11.60
1952	0.61	4.23	1.3	2.61	3.29	8.26	1.08	0.9	0	1.76	0.71	1.37	26.12
1953	4.07	0.55	1.35	4.05	2.51	4.41	5.6	0.97	0.25	0.03	1.15	5.97	30.91
1954	0.25	6.92	0.94	1.47	7.31	3.22	0.97	3.96	2.17	0.28	1.31	1.23	30.03
1955	0.59	2.83	1.1	5.47	10.85	1.45	1.21	0.23	1.4	0.03	0	2.19	27.35
1956	0.25	4.23	1.14	0.37	3.29	3.18	5.9	2.9	1.28	3.91	0.76	1.82	29.03
1957	0.61	1.1	3.29	5.22	10.85	4.23	1.77	0.14	3.38	2.67	1.73	0.35	35.34
1958	1.51	1.06	3.17	2.9	1.03	4.41	4.52	2.9	2.15	0.06	0.49	1.83	26.03
1959	0.03	0.24	1.23	2.48	8.6	4.61	8.5	1.8	0	5.78	0.24	3.51	37.02
1960	0.95	1.79	1.10	0.45	3.92	0.76	2.99	3.96	1.50	5.82	0.07	1.78	25.09
1961	0.18	1.21	2.27	0.30	2.43	5.08	5.16	2.20	7.29	2.32	2.98	0.84	32.26
1962	0.25	0.23	0.49	4.88	4.40	7.96	2.86	0.70	3.52	2.34	0.82	1.23	29.68
1963	0.07	0.22	1.36	1.91	1.27	5.82	1.21	1.02	6.90	0.51	2.66	0.26	23.21
1964	0.83	2.35	0.81	0.37	5.55	1.09	0.16	3.81	6.11	0.68	4.42	0.46	26.64
1965	0.60	0.68	1.30	4.20	4.82	4.81	0.35	4.65	7.38	1.86	0.00	2.84	33.49
1966	0.59	2.83	1.07	2.87	1.07	5.78	0.10	7.48	3.06	0.53	0.23	0.63	26.24
1967	0.00	0.00	1.73	4.33	2.77	1.97	3.19	0.86	5.30	1.78	0.19	1.43	23.55
1968	2.31	1.19	0.94	3.37	4.78	3.11	3.11	1.15	4.98	2.10	6.35	1.10	34.49
1969	0.00	1.74	2.32	1.40	6.12	3.77	0.79	3.55	3.23	2.29	0.03	1.40	26.64
1970	6.12	3.77	0.79	3.55	3.23	2.29	0.03	0.04	0.00	0.33	2.14	2.79	25.08
1971	2.76	2.66	1.14	2.10	2.51	1.08	0.47	0.29	0.72	1.12	0.00	0.63	15.48
1972	3.47	4.37	2.95	4.36	4.86	3.56	0.73	2.16	0.00	0.00	0.28	3.16	29.90
1973	3.51	0.96	2.88	0.55	0.86	4.72	2.90	0.90	2.60	0.92	8.42	2.56	31.78
1974	4.07	1.95	3.76	0.32	7.31	2.64	0.97	0.49	0.00	1.53	1.78	2.16	26.98
1975	5.25	0.00	0.70	4.36	3.56	2.91	1.13	1.20	2.24	2.75	1.64	1.43	27.17
1976	9.10	3.07	7.79	3.36	1.47	0.87	1.80	0.97	0.00	0.11	2.07	4.70	35.31
1977	2.96	1.87	0.74	2.61	5.57	3.30	0.00	0.12	0.25	1.49	0.50	2.19	21.60
1978	13.46	3.26	1.14	2.16	1.13	1.88	2.14	0.01	0.34	1.76	0.71	0.35	28.34
1979	7.45	3.55	0.36	1.52	3.29	0.06	2.07	0.00	1.28	0.66	2.74	3.70	26.68
1980	3.43	4.79	1.35	2.51	0.80	0.80	2.80	1.40	1.88	1.67	2.05	1.37	24.85
1981	11.13	3.58	0.00	1.10	0.97	0.70	0.25	1.34	0.05	0.33	2.70	2.39	24.54
1982	4.30	3.25	3.40	2.57	1.64	1.11	1.84	0.23	1.55	0.28	1.50	0.90	22.57
1983	11.66	4.23	1.38	0.00	1.96	0.21	2.37	0.85	0.78	1.92	1.71	1.33	28.40
1984	4.07	5.41	0.02	1.79	0.98	10.85	0.75	0.47	0.00	0.64	2.89	2.50	30.37
1985	0.64	4.47	0.28	0.21	0.33	2.08	1.86	4.29	1.92	2.99	5.78	2.23	27.08
1986	0.91	6.63	0.57	1.74	4.20	4.53	1.08	0.00	0.00	0.03	0.94	2.30	22.93
1987	10.72	2.46	1.11	2.39	8.51	7.29	3.30	0.44	1.38	3.64	1.31	0.06	42.61
1988	10.12	6.92	2.01	1.47	3.17	2.16	2.35	2.11	1.45	0.00	4.00	7.34	43.10
1989	0.59	1.96	2.62	0.62	8.92	1.48	2.21	0.25	1.55	1.52	1.79	0.03	23.54
1990	6.42	11.69	0.93	2.73	5.54	3.18	0.00	0.08	1.77	4.78	6.16	3.02	46.30
1991	4.58	1.42	3.18	2.37	4.74	0.94	2.35	0.72	0.74	0.00	1.90	2.19	25.13
1992	6.77	5.12	1.25	5.07	6.42	2.99	2.73	4.15	1.62	0.58	1.16	2.00	39.86
1993	6.81	6.13	3.83	7.03	1.55	0.16	5.90	2.99	2.09	2.13	2.31	5.77	46.70
1994	8.34	3.32	4.14	2.27	3.02	1.11	1.69	1.13	0.12	1.39	2.38	5.97	34.88
1995	3.04	3.92	3.03	0.75	1.35	1.51	6.20	0.48	0.72	0.12	2.26	2.81	26.19
1996	7.57	11.87	1.76	5.74	6.90	0.83	0.55	1.12	0.02	0.00	1.39	0.63	38.38
1997	1.38	5.25	4.68	8.14	1.79	1.45	1.71	0.29	0.37	3.76	0.17	7.94	36.93
1998	3.87	2.32	2.04	3.81	4.28	3.22	0.98	3.49	2.17	1.82	5.29	1.61	34.90
1999	0.97	0.77	0.13	1.41	0.37	3.67	4.02	0.94	1.67	0.43	3.73	4.01	22.12
2000	4.26	6.47	2.34	0.25	2.03	2.70	0.05	4.57	0.42	1.32	5.18	2.88	32.47
2001	6.94	6.57	1.50	0.00	1.22	8.26	2.03	1.49	1.73	2.37	1.28	0.49	33.88
2002	7.45	0.55	0.63	3.68	0.70	0.20	0.98	0.30	3.20	1.06	1.81	4.44	25.00
2003	1.77	4.39	1.96	1.42	2.73	5.88	0.9	2.35	0.02	0.86	1.15	2.22	25.65
2004	1.23	7.06	1.28	3.26	0.92	0.98	1.29	0.76	1.35	1.34	5.24	2.19	26.90
2005	0.31	4.27	4.73	2.32	1.02	4.84	5.6	0.5	2.2	1.89	0.36	0.5	28.54
2006	2.31	4.71	0.68	5.47	1.58	2.85	0	0.23	0.21	0.13	2.1	1.82	22.09
2007	2.62	3.52	0.64	4.05	2.43	3.03	0.73	2.11	1.4	0.88	5.06	2.91	29.38
2008	11.62	11.81	2.07	9.88	0.71	3.81	0.13	2.04	0.56	2.31	4.43	3.97	53.34

Appendix E – Area and Capacity Curves





Appendix F –Inflow Records

Corrected "Computed Inflow" from Water Supply Report (1000 ac-ft)

Fort Cobb Reservoir 2009 Yield Study

Post-Construction

These values include river flow, rainfall, and also any losses due to seepage. Water Supply Report data is corrected using end of month reservoir elevations from Hydromet, referencing the appropriate area-capacity table to eliminate occasional errors in the records. Negative values are included representing a net loss due to seepage and/or any groundwater interactions.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1959				0.0	4.5	1.8	5.6	0.4	5.7	8.4	1.2	4.5	32.13
1960	2.9	4.4	3.6	1.5	2.3	0.7	2.0	0.7	0.7	8.1	2.0	2.4	31.24
1961	0.9	2.5	2.8	1.8	1.9	5.1	3.5	1.0	6.8	2.6	5.1	2.4	36.35
1962	1.6	2.5	2.1	4.0	3.3	7.6	1.4	0.9	2.8	1.8	1.5	2.0	31.58
1963	1.4	2.3	3.3	3.0	2.3	8.8	1.7	0.2	3.2	1.4	1.2	1.0	29.71
1964	1.9	3.2	2.6	2.7	6.7	3.4	0.4	2.6	2.7	0.8	5.4	1.2	33.47
1965	1.3	2.2	3.1	3.2	6.2	5.4	1.1	1.2	30.8	4.5	1.7	3.8	64.41
1966	1.4	3.3	3.2	2.8	2.0	3.3	1.9	6.0	1.4	0.7	1.0	0.8	27.78
1967	1.1	1.1	2.6	7.1	1.7	2.3	1.8	0.3	3.9	0.9	0.7	1.2	24.55
1968	2.7	3.1	2.6	4.0	8.9	5.4	8.7	3.2	2.4	2.6	3.8	3.0	50.41
1969	1.8	2.5	3.8	2.8	12.6	4.3	0.6	0.6	1.8	0.6	0.9	1.3	33.74
1970	1.3	1.7	2.8	4.6	4.1	2.0	0.5	2.9	0.3	0.5	0.2	0.8	21.66
1971	1.2	1.6	1.3	1.2	2.6	6.3	0.9	3.2	2.5	3.0	0.9	4.4	29.02
1972	0.9	1.4	0.9	2.8	2.6	1.3	1.2	0.1	0.0	0.5	1.2	1.0	13.88
1973	3.9	1.5	16.5	7.7	3.0	3.1	2.5	-0.5	5.5	2.6	1.6	1.1	48.56
1974	1.7	2.3	2.2	2.8	7.8	0.8	1.6	10.2	2.3	1.2	10.0	1.2	44.10
1975	3.5	3.6	0.9	5.8	15.6	11.7	13.5	4.3	0.9	1.7	2.6	2.7	66.78
1976	2.2	2.0	3.0	6.5	3.4	1.4	1.0	0.6	3.7	1.4	0.8	1.3	27.23
1977	1.7	2.5	2.0	2.8	28.3	6.6	0.8	1.5	0.8	1.1	0.2	0.0	48.15
1978	5.9	2.2	2.9	3.4	8.1	2.1	0.1	0.5	1.7	0.0	1.0	0.8	28.60
1979	-2.6	1.6	4.2	3.7	5.5	4.0	1.0	0.8	0.3	0.2	1.2	1.1	21.09
1980	1.4	1.6	2.2	3.1	12.5	13.6	0.6	2.2	0.5	0.2	0.6	0.7	39.27
1981	2.0	1.4	2.5	2.1	2.5	4.7	1.9	1.3	1.9	5.0	1.8	1.0	28.03
1982	4.7	1.8	2.8	1.9	43.0	6.6	-0.6	1.0	1.0	0.5	0.9	1.4	64.98
1983	1.2	2.1	3.9	2.7	3.7	8.3	1.0	-0.7	-0.1	16.9	1.2	1.0	41.02
1984	1.6	3.9	2.8	2.9	1.6	3.0	0.4	0.1	-0.6	1.0	0.9	2.4	20.06
1985	1.3	3.1	5.6	2.8	1.4	4.2	0.8	0.4	1.4	4.9	1.3	1.4	28.72
1986	1.5	1.9	2.0	2.8	13.0	6.1	1.1	-0.3	23.5	28.4	5.1	3.2	88.28
1987	3.0	6.9	4.6	3.1	33.7	18.7	3.5	2.1	3.0	2.4	2.3	3.1	86.34
1988	6.5	3.3	11.2	12.7	2.4	2.8	1.9	1.4	6.5	1.7	3.6	2.0	55.87
1989	2.9	2.8	4.1	0.3	10.3	38.2	1.9	2.2	6.4	4.7	2.2	2.1	78.07
1990	5.0	6.6	21.3	8.1	17.7	4.1	2.2	4.1	2.3	1.4	3.6	2.5	78.84
1991	4.6	3.3	3.7	3.6	7.1	6.7	1.7	3.7	4.4	2.6	3.2	11.9	56.42
1992	5.7	4.1	4.1	3.1	5.6	6.7	5.7	6.9	2.4	1.9	8.1	10.7	65.03
1993	9.2	7.2	9.2	8.3	46.2	7.6	4.9	2.4	3.4	1.9	2.8	3.8	106.87
1994	3.7	3.9	9.9	13.6	6.2	1.9	-1.3	1.9	1.0	1.0	11.1	2.7	55.57
1995	3.2	2.8	7.2	4.2	15.9	49.2	1.4	11.8	8.5	3.9	3.5	4.3	115.82
1996	3.2	4.0	4.2	3.6	4.2	10.2	3.4	8.9	2.9	2.8	4.3	3.8	55.37
1997	3.4	9.4	4.2	19.5	18.4	9.7	2.3	4.1	3.9	3.8	3.1	7.4	89.17
1998	9.2	5.9	25.4	8.9	4.6	2.3	1.7	1.1	2.3	2.2	3.3	5.6	72.61
1999	1.8	1.5	7.3	7.3	6.3	5.9	4.2	1.7	1.0	2.1	1.5	8.6	49.12
2000	0.4	4.3	11.0	11.0	14.7	12.8	2.4	1.2	0.5	7.6	2.8	3.5	72.14
2001	6.1	8.6	7.7	3.2	14.5	3.9	1.1	2.8	0.6	1.0	1.6	1.5	52.78
2002	2.7	2.0	2.7	5.3	3.3	7.6	2.3	1.2	1.7	4.7	2.4	3.0	38.79
2003	0.7	1.9	4.0	3.2	2.7	5.8	1.5	1.6	0.3	1.4	1.3	1.6	26.11
2004	2.4	2.4	15.7	3.1	1.6	2.7	2.4	1.5	0.8	2.4	4.7	2.2	41.87
2005	3.5	4.5	2.9	2.1	2.9	11.9	1.1	6.3	2.9	4.4	1.5	1.8	45.60
2006	2.3	2.0	3.5	2.9	3.1	4.1	1.0	2.6	1.0	1.4	1.3	1.6	26.85
2007	1.8	1.6	7.1	5.0	17.8	30.0	9.9	38.3	3.9	6.8	2.4	4.8	129.42
2008	5.0	8.9	16.3	19.5	10.0	7.1	2.1	6.6	1.6	2.7	1.9	1.6	83.31

Land Treatment (LT) Depletions (ac-ft)

Fort Cobb Reservoir 2009 Yield Study

From Table 10 - Fort Cobb DPR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1926	137	159	334	603	292	821	586	474	725	449	91	128	4799
1927	120	176	281	938	308	1057	488	322	383	220	75	103	4471
1928	129	132	230	533	395	1176	877	284	54	136	94	116	4156
1929	127	137	541	886	792	482	166	73	524	305	102	95	4230
1930	127	174	182	386	725	421	0	0	64	254	97	119	2549
1931	125	142	332	654	439	570	317	158	52	247	119	118	3273
1932	131	239	184	170	180	1635	249	104	108	92	68	154	3314
1933	108	121	166	187	85	684	142	330	458	89	68	130	2568
1934	119	158	227	215	68	979	0	210	404	175	80	97	2732
1935	133	127	336	467	836	436	201	129	267	161	94	115	3302
1936	128	117	201	0	665	348	0	0	578	186	67	101	2391
1937	130	127	256	268	413	796	0	136	344	159	81	103	2813
1938	131	133	259	526	574	647	120	2	91	42	82	97	2704
1939	137	243	253	187	0	1560	276	191	55	0	68	101	3071
1940	131	150	202	247	110	102	541	143	161	29	184	0	2000
1941	189	211	32	729	1075	1057	73	182	130	823	81	136	4718
1942	0	148	93	1061	40	260	237	465	673	219	25	136	3357
1943	0	80	158	97	972	142	58	5	45	165	8	56	1786
1944	201	51	761	955	265	1418	262	199	202	148	227	237	4926
1945	245	58	533	1076	0	1676	1289	218	535	104	0	24	5758
1946	227	128	34	185	413	851	585	345	375	63	302	100	3608
1947	118	0	47	978	1514	325	390	35	0	11	8	311	3737
1948	0	120	349	150	148	1123	143	136	0	0	34	0	2203
1949	281	529	134	154	2693	1307	0	65	127	158	0	113	5561
1950	43	97	0	89	1210	581	1202	749	266	0	0	0	4237
1951	85	302	146	39	905	1227	59	22	138	82	52	63	3120
1952	94	109	155	255	643	157	128	68	36	33	33	48	1759
1953	65	71	167	299	114	53	855	121	71	217	57	72	2162
1954	82	82	140	149	554	134	35	24	18	22	23	31	1294
1955	48	62	79	155	1441	731	107	576	147	554	62	70	4032
1956	85	135	131	138	211	101	39	13	6	0	0	0	859

Inflow Records (1000 ac-ft)

"Inflow Offset By Seepage" in model

Fort Cobb Reservoir 2009 Yield Study

Pre-Construction

Undepleted River Inflow from Definite Plan Report

Oct 1956 thru Mar 1959 equal to 95.4% of Cobb Creek near Ft Cobb gaging station per 1957 Definite Plan Report (RO Study)

Post-Construction

"Inflow" from Water Supply Report minus precipitation minus any reported seepage

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1926	2.69	2.75	4.70	6.43	3.03	7.10	5.51	3.31	5.60	6.50	2.13	2.99	52.73
1927	2.36	3.04	3.96	10.01	3.20	9.14	4.60	2.24	2.96	3.18	1.75	2.40	48.84
1928	2.54	2.28	3.24	5.69	4.11	10.16	8.25	1.98	0.25	1.96	2.20	2.72	45.38
1929	2.49	2.37	7.61	9.45	8.23	4.16	1.56	0.30	4.04	4.42	2.39	2.23	49.27
1930	2.69	3.00	2.56	4.12	7.54	3.64	0.00	0.00	0.50	3.67	2.25	2.79	32.76
1931	2.45	2.46	4.67	6.98	4.56	4.93	2.98	1.10	0.40	3.56	2.80	2.75	39.64
1932	2.58	4.14	1.55	1.81	1.87	14.13	2.34	0.73	0.84	1.34	1.60	3.59	36.50
1933	2.12	2.10	2.33	2.00	0.53	5.91	1.33	2.30	3.54	1.30	1.60	3.04	28.10
1934	2.35	2.73	3.20	2.29	0.71	8.46	0.00	1.47	3.12	2.52	1.87	2.28	30.99
1935	2.60	2.19	4.73	4.99	8.69	3.77	1.89	0.90	2.06	2.33	2.20	2.70	39.06
1936	2.50	2.02	2.83	0.00	6.91	3.01	0.00	0.00	4.46	2.69	1.57	2.35	28.34
1937	2.56	2.19	3.61	2.86	4.30	6.88	0.00	0.95	2.66	2.30	1.89	2.40	32.59
1938	2.57	2.30	3.64	5.61	5.97	5.59	1.13	0.01	0.71	0.36	1.92	2.26	32.06
1939	2.70	4.20	3.56	2.00	0.00	13.48	2.60	1.34	0.43	0.00	1.58	2.36	34.23
1940	2.57	2.59	1.27	2.63	1.15	0.88	5.09	1.00	1.24	0.59	1.62	1.66	22.29
1941	2.34	2.11	1.92	7.45	9.65	9.25	1.21	1.13	0.91	11.31	3.07	3.23	53.57
1942	2.54	2.67	2.58	8.90	2.18	1.99	1.55	2.54	5.09	2.40	2.30	3.05	37.77
1943	2.65	2.28	2.50	2.14	7.30	1.67	1.04	0.41	0.45	1.10	1.15	1.71	24.38
1944	2.37	2.00	5.78	9.13	2.87	13.46	1.84	1.23	1.02	1.60	2.19	3.17	46.67
1945	3.23	2.71	4.11	13.63	2.17	17.36	10.09	1.89	4.60	2.62	2.10	2.39	66.90
1946	3.27	2.78	2.45	2.47	3.43	8.83	8.30	1.46	1.93	1.36	2.68	2.18	41.14
1947	2.40	1.82	2.25	7.37	11.74	2.45	3.24	0.55	0.37	0.55	0.88	3.31	36.94
1948	1.80	2.49	3.68	1.98	1.29	9.38	1.74	0.79	0.58	0.65	1.25	1.44	27.07
1949	2.40	5.94	2.52	2.28	39.66	9.10	1.23	0.83	0.87	1.36	1.38	2.05	69.62
1950	2.09	2.19	2.03	1.70	6.28	3.77	9.12	5.56	2.60	1.38	1.65	1.93	40.30
1951	2.18	2.81	2.44	1.87	9.45	8.62	1.01	0.52	0.83	0.71	1.22	1.47	33.11
1952	1.85	1.89	2.19	2.72	6.68	1.36	1.20	0.48	0.28	0.47	0.78	1.12	21.00
1953	1.28	1.22	2.36	3.20	1.18	0.46	8.04	0.85	0.55	3.14	1.36	1.69	25.32
1954	1.60	1.41	1.98	1.59	5.75	1.15	0.33	0.17	0.14	0.32	0.54	0.72	15.70
1955	0.94	1.08	1.12	1.65	14.97	6.32	1.01	4.02	1.14	8.01	1.46	1.63	43.32
1956	1.66	2.33	1.85	1.47	2.19	0.88	0.37	0.07	0.03	0.33	0.52	0.73	12.43
1957	0.84	0.97	1.42	6.49	6.43	5.59	0.85	0.27	0.62	0.70	0.89	1.12	26.18
1958	1.46	1.34	2.19	2.30	0.88	5.98	0.83	0.23	0.26	0.35	0.65	0.91	17.38
1959	1.22	1.15	1.28	0.00	1.60	0.24	2.70	-0.21	5.69	6.48	1.16	3.31	24.63
1960	2.55	3.81	3.27	1.32	0.98	0.39	1.00	-0.65	0.20	6.11	1.98	1.81	22.77
1961	0.86	2.04	1.99	1.70	1.07	3.35	1.75	0.26	4.33	1.82	4.14	2.14	25.47
1962	1.52	2.44	1.94	2.37	1.77	4.94	0.41	0.69	1.61	1.03	1.27	1.59	21.57
1963	1.33	2.22	2.82	2.32	1.85	6.83	1.33	-0.19	0.90	1.26	0.34	0.87	21.88
1964	1.58	2.39	2.29	2.58	4.86	3.06	0.37	1.27	0.59	0.58	3.86	1.06	24.48
1965	1.08	1.93	2.70	1.81	4.59	3.78	0.95	-0.41	28.28	3.89	1.68	2.84	53.11
1966	1.23	2.34	2.84	1.81	1.69	1.36	1.86	3.45	0.35	0.56	0.89	0.54	18.92
1967	1.06	1.06	2.03	5.61	0.74	1.59	0.70	0.02	2.14	0.32	0.59	0.74	16.60
1968	1.91	2.67	2.26	2.83	7.31	4.36	7.69	2.78	0.75	1.89	1.70	2.62	38.77
1969	1.79	1.94	3.05	2.36	10.56	2.98	0.38	-0.59	0.74	-0.18	0.87	0.86	24.75
1970	-0.75	0.46	2.50	3.40	3.01	1.20	0.44	2.92	0.33	0.36	-0.55	-0.15	13.19
1971	0.23	0.66	0.96	0.47	1.73	5.91	0.78	3.15	2.21	2.66	0.90	4.14	23.79
1972	-0.31	-0.05	-0.07	1.32	0.94	0.11	0.96	-0.65	-0.05	0.52	1.12	-0.06	3.79
1973	2.75	1.15	15.51	7.53	2.70	1.54	1.52	-0.80	4.63	2.32	-1.21	0.20	37.84
1974	0.35	1.60	0.95	2.73	5.34	-0.10	1.29	9.99	2.27	0.71	9.44	0.44	35.00
1975	1.72	3.55	0.62	4.33	14.40	10.76	13.15	3.88	0.10	0.81	2.08	2.22	57.61
1976	-0.92	0.94	0.37	5.34	2.95	1.07	0.40	0.25	3.69	1.41	0.07	-0.25	15.32
1977	0.71	1.87	1.75	1.90	26.45	5.46	0.76	1.45	0.67	0.56	-0.02	-0.70	40.86
1978	1.41	1.07	2.49	2.66	7.71	1.43	-0.64	0.54	1.61	-0.59	0.71	0.64	19.04
1979	-5.15	0.37	4.08	3.20	4.43	4.02	0.31	0.76	-0.08	0.00	0.26	-0.10	12.08
1980	0.23	0.03	1.73	2.30	12.25	13.29	-0.38	1.68	-0.10	-0.34	-0.07	0.27	30.89
1981	-1.79	0.21	2.49	1.72	2.16	4.50	1.77	0.83	1.88	4.91	0.85	0.22	19.75
1982	3.21	0.73	1.64	1.00	42.46	6.23	-1.19	0.95	0.43	0.42	0.36	1.12	57.36
1983	-2.74	0.70	3.43	2.68	3.02	8.23	0.20	-1.09	-0.42	16.20	0.59	0.51	31.32
1984	0.23	2.06	2.75	2.26	1.31	-0.66	0.19	-0.04	-0.58	0.74	-0.03	1.57	9.81
1985	1.11	1.58	5.49	2.74	1.31	3.53	0.17	-1.07	0.80	3.94	-0.68	0.66	19.59
1986	1.19	-0.36	1.77	2.24	11.55	4.58	0.70	-0.26	23.54	28.38	4.81	2.41	80.54
1987	-0.67	6.09	4.18	2.27	30.79	16.25	2.32	1.92	2.55	1.12	1.80	3.05	71.66
1988	3.05	0.90	10.47	12.15	1.31	2.01	1.11	0.64	5.99	1.63	2.26	-0.54	41.01
1989	2.67	2.09	3.23	0.06	7.24	37.66	1.15	2.08	5.82	4.14	1.61	2.08	69.85
1990	2.76	2.59	20.96	7.16	15.78	2.99	2.21	4.06	1.67	-0.20	1.52	1.44	62.93
1991	3.07	2.76	2.60	2.77	5.48	6.36	0.94	3.43	4.18	2.56	2.54	11.20	47.89
1992	3.44	2.41	3.63	1.37	3.43	5.69	4.73	5.55	1.88	1.66	7.73	10.06	51.58
1993	6.92	5.11	7.95	5.88	45.65	7.53	2.93	1.36	2.66	1.18	2.04	1.89	91.12
1994	0.91	2.76	8.48	12.84	5.23	1.48	-1.92	1.53	0.96	0.45	10.22	0.69	43.63
1995	2.11	1.50	6.12	3.90	15.42	48.74	-0.72	11.57	8.22	3.80	2.72	3.28	106.66
1996	0.61	-0.08	3.53	1.60	1.86	9.85	3.19	8.52	2.86	2.74	3.77	3.60	42.06
1997	2.88	7.60	2.60	16.72	17.73	9.23	1.68	3.98	3.75	2.46	3.05	4.66	76.35
1998	7.85	5.09	24.76	7.62	3.15	1.18	1.34	-0.15	1.57	1.56	1.50	5.05	60.52
1999	1.42	1.17	7.26	6.76	6.14	4.61	2.78	1.37	0.43	1.94	0.26	7.18	41.31
2000	-1.08	2.13	10.21	10.84	13.97	11.87	2.33	-0.42	0.30	7.11	1.06	2.50	60.82
2001	3.69	6.35	7.14	3.20	14.07	1.11	0.38	2.32	0.01	0.22	1.16	1.36	41.00
2002	0.18	1.74	2.44	4.03	3.07	7.51	1.93	1.06	0.55	4.28	1.75	1.47	30.01
2003	0.10	0.39	3.30	2.68	1.71	3.83	1.15	0.81	0.29	1.11	0.87	0.86	17.12
2004	2.00	0.02	15.21	1.92	1.30	2.33	1.92	1.22	0.31	1.90	2.90	1.41	32.45
2005	3.34	2.98	1.24	1.28	2.52	10.21	-0.84	6.10	2.17	3.73	1.33	1.56	35.61
2006	1.48	0.35	3.25	1.05	2.57	3.10	0.96	2.50	0.86	1.34	0.61	1.00	19.07
2007	0.88	0.40	6.87	3.59	16.93	28.96	9.67	37.57	3.38	6.46	0.66	3.80	119.18
2008	1.01	4.91	15.54	16.14	9.68	5.78	2.01	5.91	1.41	1.88	0.40	0.28	64.95

Appendix G –Climate Change Adjustment Factors

Climate Change Adjustment Factors (%)

Inflow

Climate Change Scenario

		1	2	3	4	5
		drier less warming	drier more warming	wetter more warming	wetter less warming	middle
1	Jan	90.1%	77.0%	107.9%	118.0%	102.9%
2	Feb	102.0%	84.3%	103.0%	114.2%	105.9%
3	Mar	102.6%	74.9%	98.6%	113.1%	102.4%
4	Apr	94.8%	74.3%	111.9%	114.0%	99.2%
5	May	93.1%	70.3%	133.4%	113.9%	99.1%
6	Jun	87.1%	63.8%	154.7%	120.5%	102.3%
7	Jul	87.0%	73.8%	138.9%	106.6%	101.4%
8	Aug	82.8%	66.0%	150.4%	117.0%	101.6%
9	Sep	96.2%	77.4%	135.1%	128.9%	109.3%
10	Oct	97.6%	79.6%	112.9%	123.7%	109.3%
11	Nov	86.4%	78.1%	104.9%	120.8%	102.7%
12	Dec	88.3%	71.2%	110.1%	124.0%	107.5%
	Annual	0.930	0.742	1.215	1.182	1.037

Precipitation

Climate Change Scenario

	1	2	3	4	5
	drier less warming	drier more warming	wetter more warming	wetter less warming	middle
Jan	96.5%	93.4%	99.1%	102.8%	98.7%
Feb	97.0%	100.6%	98.5%	112.8%	109.9%
Mar	109.5%	102.6%	107.1%	121.1%	111.8%
Apr	100.6%	107.5%	101.3%	107.3%	104.4%
May	115.3%	97.0%	102.7%	113.1%	112.1%
Jun	103.1%	90.6%	101.9%	107.0%	97.5%
Jul	90.8%	86.6%	116.6%	105.8%	99.4%
Aug	99.7%	88.5%	117.0%	105.5%	100.8%
Sep	100.5%	89.3%	116.5%	109.5%	103.1%
Oct	95.0%	83.8%	109.3%	99.2%	100.7%
Nov	94.4%	83.0%	109.6%	107.4%	99.3%
Dec	103.1%	88.8%	108.4%	107.1%	102.2%

Evaporation

Climate Change Scenario

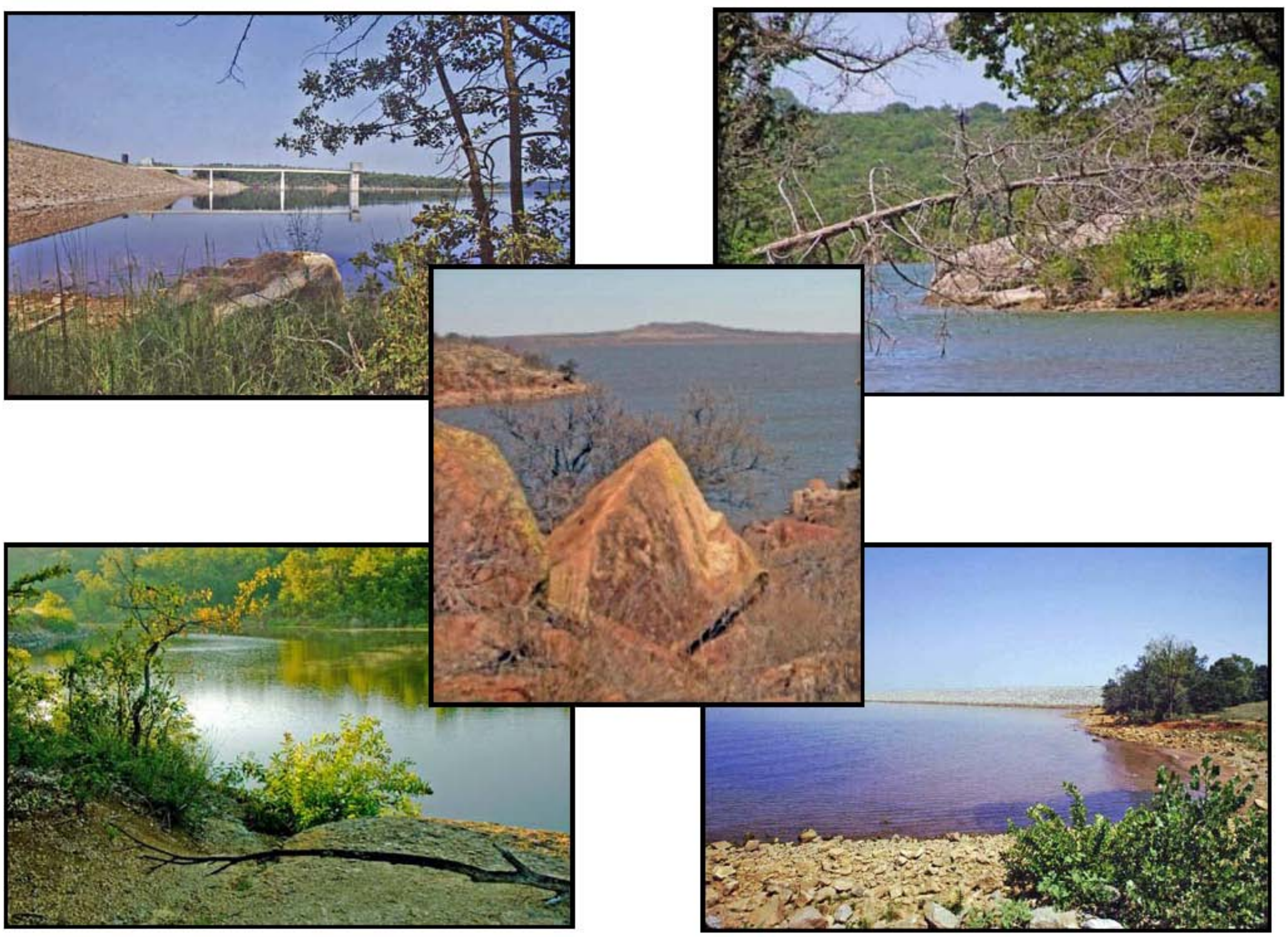
	1	2	3	4	5
	drier less warming	drier more warming	wetter more warming	wetter less warming	middle
Jan	102.0%	102.6%	102.7%	102.2%	102.4%
Feb	116.2%	124.5%	126.2%	117.3%	121.3%
Mar	105.9%	109.8%	110.0%	106.5%	107.8%
Apr	104.3%	107.2%	106.6%	104.5%	105.9%
May	105.3%	107.3%	107.7%	105.5%	106.6%
Jun	105.4%	108.9%	108.4%	105.7%	106.6%
Jul	108.5%	112.7%	111.0%	108.1%	110.3%
Aug	103.5%	105.9%	104.7%	103.2%	104.3%
Sep	107.3%	115.4%	110.7%	106.7%	109.9%
Oct	109.6%	117.8%	113.0%	109.2%	112.0%
Nov	104.3%	107.8%	106.0%	104.3%	105.3%
Dec	102.7%	104.7%	104.0%	102.7%	103.2%

Appendix H –Technical Memorandum: *Climate Change and Hydrology Scenarios for Oklahoma Yield Studies*, Reclamation Technical Service Center, April 2010

RECLAMATION
Managing Water in the West

Technical Memorandum 86-68210-2010-01

Climate Change and Hydrology Scenarios for Oklahoma Yield Studies



U.S. Department of the Interior
Bureau of Reclamation

April 2010

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Technical Memorandum 86-68210-2010-01

Climate Change and Hydrology Scenarios for Oklahoma Yield Studies

Prepared by:

Technical Service Center
Water Resources Planning and Operations Support Group
Water and Environmental Resources Division (86-68210)
Levi Brekke, Tom Pruitt, and Del Smith

Peer Review by:

Nancy Parker (86-68210)

U.S. Department of the Interior
Bureau of Reclamation

April 2010

Executive Summary

The Reclamation Oklahoma-Texas Area Office (OTAO) is re-evaluating the firm yield of seven Reclamation reservoirs in Oklahoma. The yield determination approach is similar to the method used in the original Bureau of Reclamation (Reclamation) planning studies. The study is based on hydrologic and weather variability observed from 1926–2008. These observations have been translated into 1926–2008 assumed monthly time series for reservoir inflow (had the reservoir existed for the entire historical period), reservoir evaporation, and reservoir precipitation. This historical hydroclimate then is used as an assumption for the future hydroclimate when assessing water availability from each reservoir during the next 50 years. The updated yield results are meant to serve future water planning in the State, especially in cases where the updated yield has changed significantly.

One question facing the yield assessment is how sensitive the results are to assumptions about future climate over Oklahoma and Texas. A change in the regional precipitation aspects of climate would affect water supply through changes in reservoir inflow and reservoir precipitation. Likewise, a change in the regional temperature aspects of climate would affect water supply through changes in reservoir evaporation and watershed evapotranspiration.

Given that the yield assessment already considers reservoir sedimentation projections through 2060, it was decided to develop yield assessment assumptions for a range of future climates also through 2060, where the future climate definitions are based on current climate change science. The merit of doing this analysis is that a sense of yield uncertainty and, thus, a more robust characterization of yield would be conveyed to subsequent water planning efforts. The objectives of this study were to (1) define climate change scenarios (i.e., changes in monthly climate from an historical period to a future period), (2) assess changes in reservoir inflow, precipitation, and evaporation associated with each scenario, and then (3) use those changes to generate "alternative historical" data series for reservoir inflow, precipitation, and evaporation for use in conducting alternative yield assessments (i.e., one for each climate change scenario). One theme within these objectives is that priority was placed on retaining our sense of the region's historical hydroclimate variability observed from 1926–2008 (e.g., envelope of monthly and annual possibilities, interarrival of drought and surplus periods) but shifted to represent a scenario change in monthly hydroclimate.

Definition of future climate change scenarios, in part, is motivated by awareness of recent climate observations but ultimately rooted in contemporary climate projection (or climate simulation) information. Recent observations suggest that the global climate system has been warming and is likely to continue warming

during the 21st century. Evidence also suggests that warming has been experienced over much of the United States during the 20th century. Climate simulation models have been developed and applied to reproduce global to continental temperature trends during the 20th century. Successes in these efforts have built confidence in use of these models to project future climate conditions under scenarios of future greenhouse gas emission rates. This study bases climate change definitions on the results of these global climate simulations, spatially downscaled over the Oklahoma/Texas region.

Review of current downscaled climate projections over the study region suggests a consensus message that the southern Great Plains are likely to be warmer in the future. However, the rate of warming varies among climate projections. Review of these same projections suggests that regional precipitation change may vary from drier to wetter over the southern Great Plains. On the whole, in order to relate this yield assessment to the breadth of current climate projection information, it was decided to focus on projected climate change over the region measured from climate during 1950–1999 to climate during 2030–2059. It was then decided to define five climate change scenarios based on review of downscaled projections discussed above: four scenarios to represent the range of projected changes from less to more warming, paired with drier to wetter conditions, and a fifth scenario to represent the central tendency of projected changes. So in summary, the analytical outline features three steps mapping to the three objectives mentioned above:

1. Define five climate change scenarios that reflect current climate projections and reflect climate projection uncertainty and central tendency over Oklahoma and North Texas.

2. Assess hydrologic response under each climate change scenario in each watershed using comparative hydrologic simulations: one with historical observed weather and one with weather adjusted for change in monthly temperature and precipitation.

3. Assess reservoir precipitation and evaporation response under each climate change scenario, where evaporation response is related to temperature change.

Stepping down into the details of defining climate change scenarios and assessing hydrologic conditions, there were several candidate methodologies that could be borrowed from peer-reviewed literature. In this study, the preferred technique was steered by three scoping decisions, including the first decision reflected in Step 1 above, involving the definition of five representative climate change scenarios. The second and third decisions are:

- Portray change in monthly climate variability rather than monthly climate mean.

- Emphasize consensus change information from a collective of projections.

Available peer-reviewed techniques have been demonstrated to address the first two scoping decisions, but not necessarily the third. The priority to emphasize consensus climate change information from climate projections motivated the decision to modify an available peer-reviewed technique to be informed by a collective, or "ensemble," of climate projections rather than a single climate projection. Given that a new technique is being introduced for supporting the yield assessment, it was decided to show the merits of the new technique through comparative application with two predecessor peer-reviewed techniques, including the one that was modified for purposes here. The three techniques are similar in that they each focus on period-change in monthly climate (i.e., temperature and precipitation). Their applications differ in terms of (1) what monthly climate aspects are reflected in the climate change definitions and (2) how many climate projections inform the climate change definitions. The techniques are labeled here as:

- ***Delta*****:** where the analysis reflects change in period monthly mean temperature and precipitation over the study region, sampled from a single climate projection

- ***Hybrid-Delta (HD)*****:** where the analysis reflects change in period monthly distributions of temperature and precipitation over the study region, sampled from a single climate projection

- ***Ensemble Hybrid-Delta (HDe)*****:** **(*chosen technique*)** where the analysis reflects change in period monthly distributions of temperature and precipitation over the study region, sampled from an ensemble of climate projections.

Delta might be thought of as reflecting change in "climate norms." *HD* and *HDe* might be thought of as reflecting change in "the envelope of climate variability." *Delta* and *HD* both involve defining a climate change scenario based on information from a single climate projection. *HDe* involves defining a climate change scenario based on pooled information from a collection of climate projections. The reason for doing the latter is to address an interpretation question about a computed period change within a single climate projection: is the computed change actually "climate change" or misunderstood multidecadal climate variability within the projection? The interpretation issues stem from the facts that contemporary climate projections are produced by a collective of global climate models (GCM) that express multidecadal variability to variable degree and that the projections do not all originate from a common initial climate system condition (e.g., state of the oceans in 1900 or 2000). *HDe* addresses this interpretation concern by defining climate change scenarios that emphasize consensus monthly changes from a collection of climate projections. This would seem to mute the significance of GCM differences in simulating multidecadal variability and effects of inconsistent initial conditions among the projections.

For each technique (*Delta*, *HD*, and *HDe*), five climate change scenarios were defined and carried forward to the response analyses: four scenarios to "bracket" the projected climate changes from 1950–1999 to 2030–2059 and a fifth to reflect the central tendency of projected changes. For each climate change scenario, associated weather inputs were generated to drive both hydrologic modeling and the analyses on change in reservoir precipitation and evaporation. Hydrologic modeling was performed using an application of the Variable Infiltration Capacity model in each of the seven reservoir basins in this study. Change in reservoir evaporation was based on the empirical relationship between historical evaporation and temperature at each reservoir.

Results show that all three techniques lead to a generally consistent portrayal of annual changes in reservoir hydroclimate. However, for the portrayal of monthly changes in reservoir hydroclimate (i.e., inflow, precipitation, and evaporation), the *HDe* stands out relative to *Delta* or *HD* techniques by portraying more consistent, and perhaps more realistic, month-to-month changes. This attribute stems from emphasizing consensus change information from a collective of projections and is viewed as a desirable trait of hydroclimate scenarios for framing the yield sensitivity analysis.

Deliverables from this analysis are five *HDe*-based scenarios of changes in mean-monthly runoff at each of the seven reservoir basins in this study and also change in mean-annual reservoir inflow. These changes then are used to adjust the default 1926–2008 historical time series for monthly inflow. Deliverables also include five HDe-based scenarios of changes in watershed mean-monthly precipitation and temperature, which are then used to adjust the default 1926–2008 historical time series of reservoir precipitation and evaporation, respectively.

This analysis is designed to provide some quantitative illustration of how runoff in Reclamation's Oklahoma reservoir watersheds would respond to range of future climate possibilities. The study was designed to take advantage of best available datasets and modeling tools and to follow methodologies documented in peer-reviewed literature where possible. However, there are a number of analytical uncertainties that are not reflected in study results, including uncertainties associated with future global climate forcings, global climate simulation, climate projection bias-correction, climate projection spatial downscaling, generating weather sequences consistent with climate projections, and how to best simulate natural runoff response to changes in climate.

Contents

Figures

Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
%	percent
ALTUS	Lugert-Altus Reservoir on the North Fork of the Red River, W.C. Austin Project above Lake Altus
ARBUC	Lake of the Arbuckles on Rock Creek tributary of the Washita River, Arbuckle Project
BCSD	Bias Correction Spatial Disaggregation
CMIP	Coupled Model Intercomparison Project (CMIP1, CMIP2, and CMIP3 are CMIP phases 1, 2, and 3, respectively)
COBB	Fort Cobb Reservoir on Pond (Cobb) Creek tributary of the Washita River, Washita Project
COOP I.D.	identification number for station in NWS Cooperative Observer Program
DCP	Downscaled Climate Projections
Delta	Delta method for assessing hydrologic impacts, where "climate change" weather reflects change in period monthly mean temperature and precipitation sampled from a single projection
ET	evapotranspiration
FOSS	Foss Reservoir on the Washita River, Washita Project
GCM	General Circulation Model, or Global Climate Model
GHG	greenhouse gas
GP	Great Plains
HD	Hybrid-Delta method for assessing hydrologic impacts, where "climate change" weather reflects change in period monthly distributions of temperature and precipitation sampled from a single projection
HDe	Ensemble Hybrid-Delta method for assessing hydrologic impacts, where "climate change" weather reflects change in period monthly distributions of temperature and precipitation sampled from a pooled ensemble of projections
IPCC	Intergovernmental Panel on Climate Change
km	kilometer

LCRA/SAWS	Lower Colorado River Authority (TX)/San Antonio Water System (TX)
MCGEE	McGee Creek Reservoir on McGee Creek, McGee Creek Project
MTNPA	Tom Steed Reservoir on West Otter Creek, Mountain Park Project
NARCCAP	North American Regional Climate Change Assessment Program
NORMA	Lake Thunderbird on Hog Creek and Little River, Norman Project
NWS	National Weather Service
OK	Oklahoma
OTAO	Oklahoma-Texas Area Office
RCM	Regional Climate Model
SWE	snow water equivalent
TX	Texas
USGCRP	U.S. Global Change Research Program
VIC	Variable Infiltration Capacity hydrologic model
WCRP	World Climate Research Programme

1. Introduction

The Reclamation Oklahoma-Texas Area Office (OTAO) is re-evaluating the firm yield of seven Bureau of Reclamation (Reclamation) reservoirs in Oklahoma:

- ALTUS: Lugert-Altus Reservoir on the North Fork of the Red River above Lake Altus Dam
- ARBUC: Lake of the Arbuckles on Rock Creek, tributary of the Washita River above Lake of the Arbuckles Dam
- FOSS: Foss Reservoir on the Washita River above Foss Dam
- COBB: Fort Cobb Reservoir on Pond (Cobb) Creek tributary of the Washita River above Fort Cobb Dam
- MCGEE: McGee Creek Reservoir on McGee Creek above McGee Creek Dam
- MTNPA: Tom Steed Reservoir on West Otter Creek supplemented by Elk Creek via the Bretch Diversion Canal above Mountain Park Dam
- NORMA: Lake Thunderbird on Hog Creek and Little River above Norman Dam

The yield determination approach is similar to the method used in the original Reclamation planning studies. The study is based on hydrologic and weather variability observed from 1926–2008. These observations have been translated into 1926–2008 assumed monthly time series for reservoir inflow (had the reservoir existed for the entire historical period), reservoir evaporation, and reservoir precipitation. This historical hydroclimate then is used as an assumption for the future hydroclimate when assessing water availability from each reservoir during the next 50 years. The updated yield results are meant to serve future water planning in the State, especially in cases where the updated yield has changed significantly.

One question facing the yield assessment is how sensitive the results are to assumptions about future climate over Oklahoma and Texas. A change in the regional precipitation aspects of climate would affect water supply through changes in reservoir inflow and reservoir precipitation. Likewise, a change in the regional temperature aspects of climate would affect water supply through changes in reservoir evaporation and watershed evapotranspiration (ET).

Given that the yield assessment already considers reservoir sedimentation projections through 2060, it was decided to develop yield assessment assumptions for a range of future climates also through 2060, where the future climate definitions are based on current climate change science. The merit of doing this analysis is that a sense of yield uncertainty and, thus, a more robust characterization of yield would be conveyed to subsequent water planning efforts. The objectives of this study were to (1) define climate change scenarios (i.e., changes in monthly climate from an historical period to a future period), (2) assess changes in reservoir inflow, precipitation, and evaporation associated with each scenario, and then (3) use those changes to generate "alternative historical" data series for reservoir inflow, precipitation, and evaporation for conducting alternative yield assessments (i.e., one for each climate change scenario). One theme within these objectives is that priority was placed on retaining our sense of the region's historical hydroclimate variability observed from 1926–2008 (e.g., envelope of monthly and annual possibilities, interarrival of drought and surplus periods) but shifted to represent a scenario change in monthly hydroclimate.

Definition of future climate change scenarios, in part, is motivated by awareness of recent climate observations but ultimately rooted in contemporary climate projection (or climate simulation) information. Recent observations suggest that the global climate system has been warming and likely is to continue warming during the 21st century, partly due to human activities translating into greenhouse gas emissions (Intergovernmental Panel on Climate Change [IPCC] 2007). Evidence also suggests that warming has been experienced over much of the United States during the 20th century (U.S. Global Change Research Program [USGCRP] 2009). Climate simulation models have been developed and applied to reproduce global to continental temperature trends during the 20th century (IPCC 2007). Successes in these efforts have built confidence in using these models to project future climate conditions under scenarios of future greenhouse gas emission rates. This study bases climate change definitions on the results of these global climate simulations, spatially downscaled over the Oklahoma/Texas region.

Review of current downscaled climate projections over the study region suggests a consensus message that the southern Great Plains likely are to be warmer in the future. However, the rate of warming varies among climate projections. Review of these same projections suggests that regional precipitation change may vary from drier to wetter over the southern Great Plains. On the whole, to relate this yield assessment to the breadth of current climate projection information, it was decided to focus on projected climate change over the region measured from climate during 1950–1999 to climate during 2030–2059. It was then decided to define five climate change scenarios based on review of downscaled projections discussed above: four scenarios to represent the range of projected changes from less to more warming paired with drier to wetter conditions and a fifth scenario to represent the central tendency of projected changes. So in summary, the analytical outline features three steps mapping to the three objectives mentioned above:

1. Define five climate change scenarios that reflect current climate projections and reflect climate projection uncertainty and central tendency over Oklahoma and north Texas.

2. Assess hydrologic response under each climate change scenario in each watershed using comparative hydrologic simulations: one with historical observed weather and one with weather adjusted for change in monthly temperature and precipitation.

3. Assess reservoir precipitation and evaporation response under each climate change scenario, where evaporation response is related to temperature change.

Stepping down into the details of defining climate change scenarios and assessing hydrologic conditions, there were several candidate methodologies that could be borrowed from peer-reviewed literature. In this study, the preferred technique was steered by three scoping decisions, including the first decision reflected in Step 1 above, involving the definition of five representative climate change scenarios. The second and third decisions are:

- Portray change in monthly climate variability rather than monthly climate mean.

- Emphasize consensus change information from a collective of projections.

Available peer-reviewed techniques have been demonstrated to address the first two scoping decisions, but not necessarily the third. The priority to emphasize consensus climate change information from climate projections motivated the decision to modify an available peer-reviewed technique to be informed by a collective, or "ensemble," of climate projections rather than a single climate projection. Given that a new technique is being introduced for supporting the yield assessment, it was decided to show the merits of the new technique through comparative application with two predecessor peer-reviewed techniques, including the one that was modified for purposes here. The three techniques are similar in that they each focus on period change in monthly climate (i.e., temperature and precipitation). Their applications differ in terms of (1) what monthly climate aspects are reflected in the climate change definitions and (2) how many climate projections inform the climate change definitions. The techniques are labeled here as:

- ***Delta* (e.g., Hamlet and Lettenmaier 1999, Miller et al. 2003):** where the analysis reflects change in period monthly mean temperature and precipitation over the study region, sampled from a single climate projection

- ***Hybrid-Delta (HD)* (Lower Colorado River Authority(TX)/San Antonio Water System (TX) [LCRA/SAWS 2008]):** where the analysis reflects change in period monthly distributions of temperature and precipitation over the study region, sampled from a single climate projection

- ***Ensemble Hybrid-Delta (HDe)*: (*chosen technique*)** where the analysis reflects change in period monthly distributions of temperature and precipitation over the study region, sampled from an ensemble of climate projections.

Delta might be thought of as reflecting change in "climate norms." *HD* and *HDe* might be thought of as reflecting change in "the envelope of climate variability." *Delta* and *HD* both involve defining a climate change scenario based on information from a single climate projection. *HDe* involves defining a climate change scenario based on pooled information from a collection of climate projections. The reason for doing the latter is to address an interpretation question about a computed period change within a single climate projection: is the computed change actually "climate change" or misunderstood multidecadal variability within the projection? The interpretation issues stem from the facts that contemporary climate projections are produced by a collective of global climate models (GCM) that express multidecadal variability to variable degree, and that the projections do not all originate from a common initial climate system condition (e.g., state of the oceans in 1900 or 2000). The issues differences in variability expression among models and differences in initial condition assumptions for future simulations can lead to regional multidecadal variability that varies from projection to projection, both in amplitude and phase (Giorgi 2005); both have implications for interpreting any projection-specific period change as discussed above. *HDe* addresses this interpretation concern by defining climate change scenarios that emphasize consensus monthly changes from a collection of climate projections. This would seem to mute the significance of GCM differences in simulating multidecadal variability and effects of inconsistent intitial conditions among the projections.

For each technique (*Delta*, *HD*, and *HDe*), five climate change scenarios were defined and carried forward to response analyses: four scenarios to "bracket" the projected climate changes from 1950–1999 to 2030–2059 and a fifth to reflect the central tendency of projected changes. For each climate change scenario, associated weather inputs were generated to drive both hydrologic modeling and the analyses on change in reservoir precipitation and evaporation. Hydrologic modeling was performed using an application of the Variable Infiltration Capacity

(VIC) model in each of the seven reservoir basins in this study. Change in reservoir evaporation was based on the empirical relationship between historical evaporation and temperature at each reservoir.

2. Defining Climate Change Scenarios

The first task in the analytical outline involves assessing climate changes within contemporary climate projections and then selecting, or "defining," climate changes to serve as scenarios of monthly change for use in subsequent tasks. The focus is on changes in monthly temperature and precipitation over the study region. Thus, defining climate change scenarios involves:

- Surveying available climate projection information over the study region.
- Deciding whether to eliminate some of the projections from consideration.
- Defining climate change scenarios from the remaining climate projections under consideration.

The third step was conducted in two ways, as mentioned in the "Introduction." Each way is tailored for the weather generation method to be featured in the hydrologic response assessment of Task 2. The first way involves use of single climate projections to define climate change scenarios and supports the *Delta* and *HD* methods of weather generation. The second way is ensemble-informed and supports the *HDe* method of weather generation.

2.1 Survey of Available Climate Projections

During the past decade, global climate projections have been made available through the efforts of the World Climate Research Programme (WCRP) Coupled Model Intercomparison Project (CMIP), which has advanced in three phases (CMIP1 [Meehl et al. 2000], CMIP2 [Covey et al. 2003], and CMIP3 [Meehl et al. 2007]). The WCRP CMIP3 efforts were fundamental to completing the *IPCC Fourth Assessment Report* (IPCC 2007). The CMIP3 dataset was produced using climate models that include coupled atmosphere and ocean general circulation models, each applied to simulate global climate response to various future greenhouse gas (GHG) emissions paths (IPCC 2000) from various end-of-20th century climate conditions ("runs"). The emissions paths vary from lower to higher emissions rates, depending on global technological and economic developments during the 21st century.

One issue with the CMIP3 dataset and climate models projections, in general, is that the spatial scale of climate model output is too coarse for regional studies on water resources response (Maurer et al. 2007). Spatial downscaling of GCM outputs typically is conducted to address this issue. By definition, spatial downscaling is the process of taking GCM output on simulated climate and translating that to a finer spatial scale that is more meaningful for analyzing local and regional climate conditions. Many downscaling methods have been developed, all of which have strengths and weaknesses. Several reports offer discussion on the various methodologies, notably the *Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment* (IPCC 2007 (Chapter 11, Regional Climate Projections), Wigley, 2004, Brekke et al. 2009 (Appendix B)). The various methodologies might be classified into two classes: dynamical, where a fine scale regional climate model (RCM) with a better representation of local terrain simulates climate processes over the region of interest; and statistical, where large-scale climate features are statistically related to fine scale climate for the region.

To date, there has not been a demonstration of dynamical downscaling to produce an archive that comprehensively reflects the 100+ CMIP3 climate projections available, particularly to characterize climate projection uncertainty throughout the 21st century. While there are new efforts to downscale multiple climate projections using multiple RCMs, such as the North American Regional Climate Change Assessment Program (NARCCAP, http://www.narccap.ucar.edu/), the computational requirements of RCM implementation for more than a few years of simulation have limited the feasibility of using dynamical downscaling for the purpose above. Among the various statistical methods that might be considered for the given purpose, certain characteristics are desirable:

- Well tested and documented, especially in applications in the United States.
- Automated and efficient enough to feasibly permit the downscaling of many 21st century climate projections, thereby permitting more comprehensive assessments of regional to local climate projection uncertainty.
- Able to produce output that statistically matches historical observations.
- Capable of producing spatially continuous, fine-scale gridded output of precipitation and temperature suitable for water resources and other watershed-scale impacts analysis.

One technique that satisfies these criteria is the Bias-Correction and Spatial Disaggregation (BCSD) approach of Wood et al. (2002). This technique was used to generate downscaled translations of 112 CMIP3 projections, which are available online at the "Bias-Corrected and Downscaled WCRP CMIP3 Climate Projections" archive[1] (Downscaled Climate Projections [DCP] archive). These projections were produced collectively by 16 different CMIP3 models simulating 3 different emissions paths (e.g., B1 (low), A1b (middle), A2 (high)) from different end-of-20th century climate conditions. Compared to dynamical

[1] http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/.

downscaling approaches, the BCSD method has been shown to provide downscaling capabilities comparable to other statistical and dynamical methods in the context of hydrologic impacts (Wood et al. 2004). However, dynamical downscaling also has been shown to identify some local climate effects and land-surface feedbacks that BCSD cannot readily identify (Salathé et al. 2007). Another potential limitation of BCSD, like any statistical downscaling method, is the assumption of some statistical stationarity in the relationship between GCM-scale precipitation and temperature and finer-scale precipitation and temperature.

The DCP archive data were used as the initial set of climate projections considered for defining climate change scenarios in this study. The decision follows approached used in recent Reclamation studies (Reclamation 2008, Reclamation 2009). Each climate projection is specified on a monthly time step from 1950 to 2099 and at roughly a 12-kilometer (km) (1/8 degree [º]) spatial resolution over the contiguous United States. DCP data were surveyed for this study within a region that encapsulates the seven reservoir watersheds considered in the yield assessment (Figure 1). Note that this large-region view is only used in Task 1 to select projections or projection-ensembles to inform climate change scenarios. Moving on to Task 2, the spatially distributed information from these DCP data are related to the hydrologic response analysis.

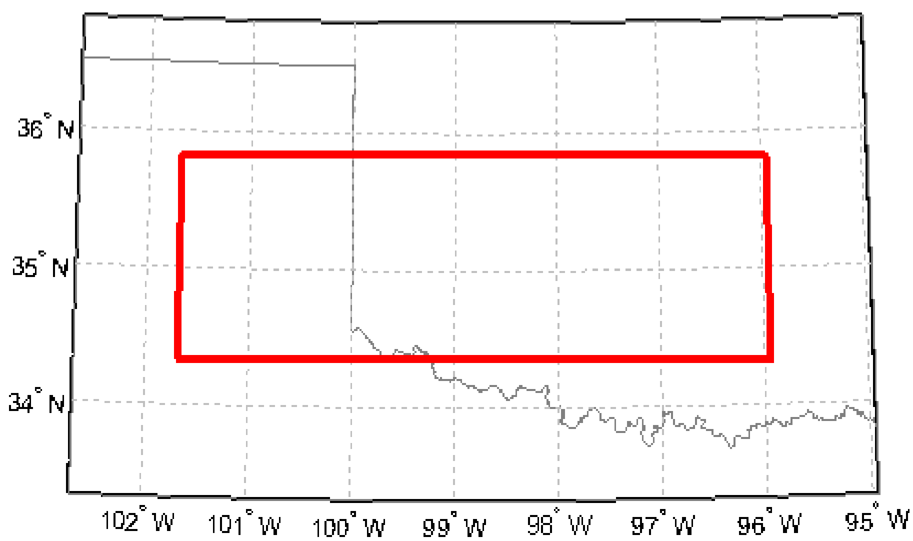


Figure 1. Study Region of Climate Projections Survey and Climate Change Scenario Definition.

2.2 Considering Elimination of Climate Projections Based on Credibility

The next step involves defining climate change scenarios from the surveyed projections. Before defining such scenarios, deliberations were made on whether to first eliminate some of the climate projections from consideration. For example, one might rationalize exclusion of projections viewed to be less credible than others, perhaps based on an unequal regard for the different future climate forcings, represented in the collection of projections, or based on a view that some GCMs used to generate projections are more credible than others based on their relative skill in simulating the past. Ultimately, a rationale was adopted, following similar rationale stated in earlier Reclamation studies (Reclamation 2008,[2] Reclamation 2009), whereby it was judged that there is unclear basis for excluding climate projections based on relative emissions likelihoods or relative GCM simulation skill. Thus, all surveyed projections were kept in consideration during the definition of climate change scenarios.

2.3 Defining Climate Change Scenarios – Projection-specific Approach

As stated at the beginning of this chapter, the final step involves defining climate change scenarios from the climate projections under consideration. As will be shown in this section, contemporary climate projections over Oklahoma and north Texas all suggest a warmer future to lesser or greater degrees. For precipitation, they suggest a future ranging from drier to wetter. To represent these possibilities, this task involves defining climate change scenarios that bracket uncertainty, namely that they vary from less to more warming and drier to wetter conditions and also a climate change scenario that represents the middle tendency of this information.

This scenario definition task was conducted two ways. The first way supports weather generation for hydrologic modeling using the *Delta* and *HD* techniques. In this approach, individual climate projections are identified to provide climate change scenarios (i.e., changes in period monthly temperature and precipitation conditions). The approach for identifying these individual projections was introduced in Reclamation (2008) and later applied in Reclamation (2009). It features a four-factor rationale that leads to selection of: (a) four climate projections that express change in period-climate that “bracket” changes from all projections and (b) a fifth climate projection that expresses change in period-climate that is among the center of changes from all projections. The four factors are:

[2] Reclamation 2008, Appendix R, section 2.2.1, available at: http://www.usbr.gov/mp/cvo/ocap_page.html.

- #1: Climate Change Location
    - o Choice: Region-mean condition over the Oklahoma (OK)/Texas (TX) region (Figure 1)[3]
- #2: Simulated Climate Periods Within Climate Projections
    - o Choice: historical = 1950–1999, future = 2030–2059
- #3: Climate Change Metrics for Assessing Spread of Projected Changes
    - o Choice: Change in period mean-annual temperature and precipitation, region-average
- #4: Climate Change Range of Interest
    - o Choice: Following Reclamation (2008), define the change range of interest as the intersection of 10- to 90-percentile changes in temperature and 10- to 90-percentile changes in precipitation. Also following Reclamation (2009), define the intersection of median change in temperature and median change in precipitation as the central tendency of interest.

Given these considerations, five projections were identified for how they expressed paired changes in mean-annual precipitation and temperature that come closest to the 5-percentile intersects of interest:

- drier, less warming (10 percent [%] P change, 10% T change)
- drier, more warming (10% P change, 90% T change)
- wetter, more warming (90% P change, 90% T change)
- wetter, less warming (90% P change, 90% T change)
- central tendency, or middle (50% P change, 50% T change)

Figure 2 and Figure 3 illustrate implementation of the four-factor rationale. Following Factor #1, monthly temperature and precipitation projections were first

[3] Factor #1 may seem to be at odds with the objectives of the hydrologic response assessment that follows in Task 2. Specifically, it may be questioned that this assessment of the spread of projected climate changes is based on changes in region-average climate, which contrasts with the changes in spatially distributed climate featured in the hydrologic response assessment (Task 2). A reason for the region-average focus in Task 1 is that the hydrologic response assessment that follows should have consistent projections underlying the analysis at each watershed; and, thus, projections-based definition of climate change scenarios should be regionally consistent. Factor #3 also may seem at odds, given that we're focused in Task 1 on change in period mean-annual climate and that the hydrologic assessment is focused on change in period mean-monthly climate. A reason for the period-mean annual focus in Task 1 is that, while many climate metrics may be used to judge climate projections spread, such as change in monthly or seasonal conditions, it is assumed that change in annual conditions affects a broad set of monthly to annual hydrologic conditions and, therefore, serves as a reasonable basis for judging spread of projected changes.

obtained for the study region (Figure 1). These monthly data were regionally averaged and aggregated to annual series, as shown on Figure 2. Viewing the envelope of projected conditions as it evolves through time (i.e., light red on top panel and light blue on bottom panel), it would appear that the region is projected to become warmer during the 21st century, with perhaps growing uncertainty on the annual temperature condition during any given year. Likewise, it would appear that the region's expected annual precipitation might remain steady but with possibly growing uncertainty on the annual precipitation condition during any given year.

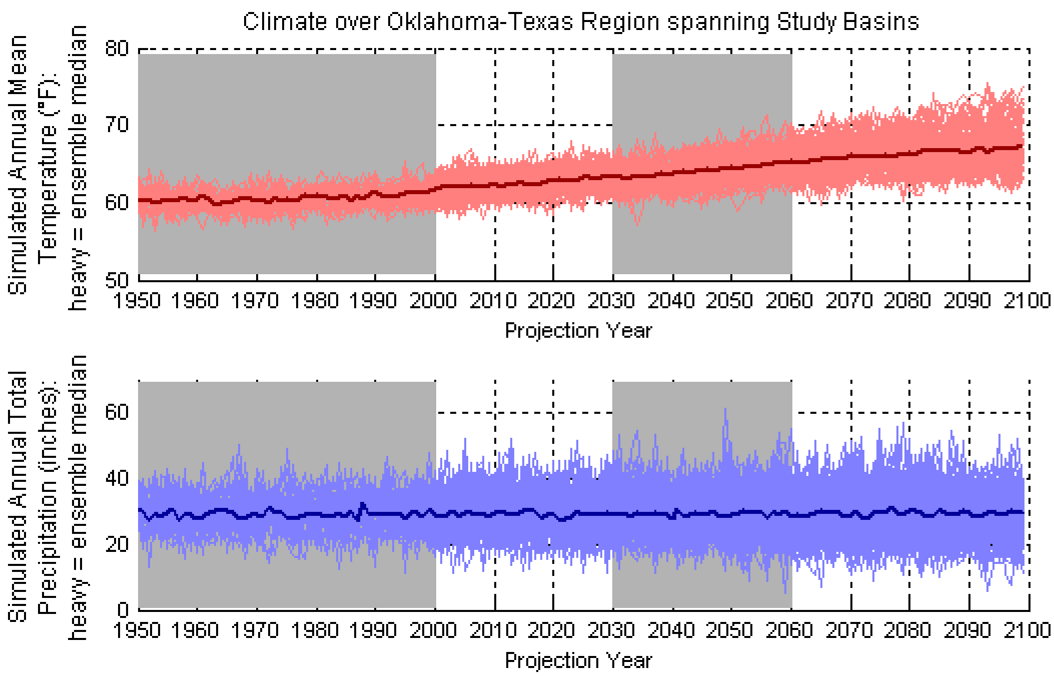


Figure 2. Annual Climate Projections Spatially Averaged in Study Region.

Switching to a projection-specific period change view, different impressions emerge on climate projection uncertainty relative to those from the time-series ensemble view. The projection-specific period change view underlies definition of climate change scenarios in this approach. Figure 2 highlights the climate change assessment periods (Factor #2) as gray boxes: historical (1950–1999) and future (2030–2059).[4] Following Factor #3, period-mean annual conditions

---

[4] Notice that the climate projections occupy a common envelope of variability during the historical period of 1950–1999. This is by design of the bias-correction procedure applied to the raw GCM outputs before spatial downscaling (http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/#About). In this procedure, each raw GCM projection is adjusted to reflect the same monthly 1950–1999 period distribution (i.e., period statistics) as an observed historical reference dataset (Maurer et al. 2002). This procedure does not force projections to have common sequencing characteristics, which vary due to differences in the originating climate model and in the assumed climate-system state (e.g., distributed ocean heat)

were computed for each projection (112), period (historical 50-year and future 30-year), and variable (temperature and precipitation). Figure 3 shows the rank distribution of projected period-mean temperature changes (upper left panel), period-mean precipitation changes (lower right panel) and paired changes (upper right panel). The 10-, 50-, and 90-percentile changes (Factor #4) are highlighted for both temperature and precipitation changes (black diamonds on upper left and lower right panels). The 10- and 90-percentile changes in temperature and precipitation intersect to produce the change range of interest shown on Figure 3 upper right panel (gray region). The 50-percentile changes in both variables intersect to produce central change of interest. Five projections are then indentified for how they express paired change in temperature and precipitation that most closely match the T/P percentile intersects mentioned above. The paired changes of these projections are shown on Figure 3 as black filled circles.

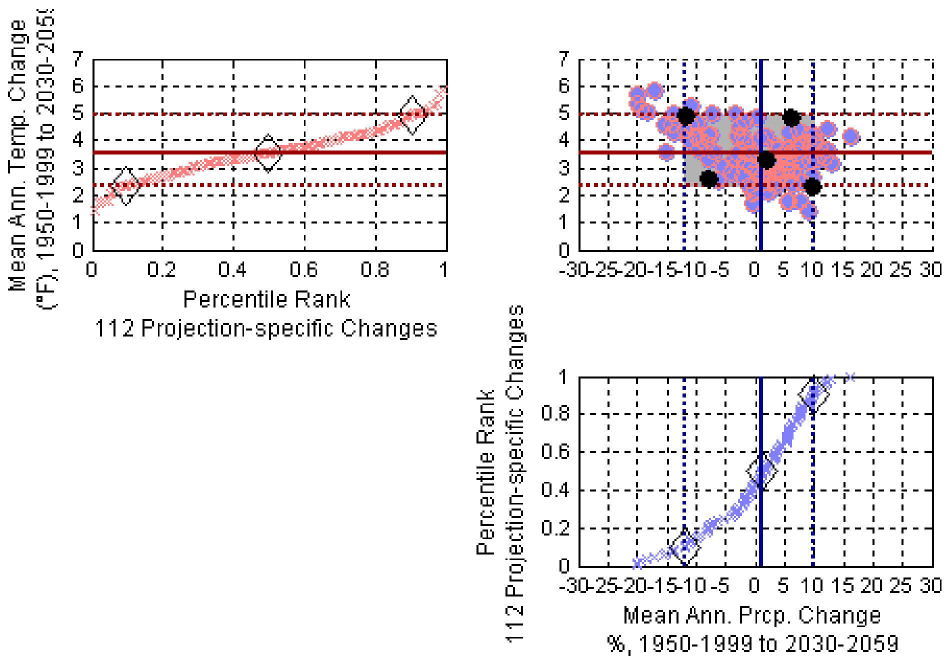


Figure 3. Selecting Individual Projections to Underlie Climate Change Scenarios.

In summary, this first way of defining climate change scenarios, focusing on information from single climate projections, led to selection of five climate projections for use in the *Delta* and *HD* weather generation techniques of Task 2. The projections are:

- (drier, less warming) mri_cgcm2_3_2a, run 3, emissions A2
- (drier, more warming) inmcm3_0, run 1, emissions A2

---

at the start of 20th century climate simulations. After year 2000, climate projections reflect scenario greenhouse gas forcings and not actual emissions.

- (wetter, more warming) ncar_ccsm3_0, run 1, emissions A1b
- (wetter, less warming) csiro_mk3_0, run 1, emissions A2
- (middle) cccma_cgcm3_1, run 4, emissions B1

2.4 Defining Climate Change Scenarios – Ensemble-informed Approach

The second way of defining climate change scenarios supports weather generation for hydrologic modeling using the *HDe* technique. Although the projection-specific approach is easy to implement, the matter of interpreting computed changes in period-mean climate is more challenging. As with any period change approach for defining climate scenarios, the goal is to be able to interpret such changes as "climate change possibilities" and not a blend of some climate change and some misunderstood multi-decadal, or low frequency, variability. The matter of low frequency variability is relevant when interpreting period-mean changes in projected precipitation (Giorgi 2005). It is understood that historical regional precipitation has varied on multidecadal time scales and other lower frequencies. It also is understood that GCMs express different degrees of low-frequency climate variability on global to regional scales. Thinking ahead to Task 2, where climate changes are identified from Task 1 projections and then superimposed on historical climate variability to generate weather inputs for hydrologic models, the concern is that there may be a "double counting" of climate variability, where projected changes in climate are misinterpreted as climate change (rather than sampled cycles of natural variability) and mistakenly superimposed on the historical envelope of hydroclimate variability used in the yield assessment. The consequence of doing this is to potentially feature an amplified sense of climate change possibility in the yield sensitivity analysis, contributing to an amplified sense of uncertainty.

To reduce the concern of double counting climate variability, an alternative approach (*HDe*) is introduced where climate change scenarios are defined so that they emphasize consensus change information from a collective of projections rather than information from individual projections. Doing so also reduces the matter of sampling change information from projections that address lesser or greater degrees of low frequency climate variability. The merits of this approach will be revealed and discussed in the context of hydrologic modeling results of Task 2. For this discussion, the intent is to describe how climate projection ensembles are defined to generate climate change scenarios that are qualitatively similar to scenarios developed using the projection-specific approach (drier, less warming; drier, more warming, etc.).

Initially, the definition of climate change scenarios for *HDe* is similar to that for *Delta* and *HD* and follows the same first three factors discussed in section 2.3.

The difference is Factor #4, which is modified to focus on threshold period-temperature and period-precipitation changes to define projection ensembles. Specifically, the 50th percentile temperature and precipitation changes are used to partition the space into four nonoverlapping quadrants, representing the four ensembles that will define "bracketing" climate change scenarios. Next, the 25th to 75th percentile temperature and precipitation changes are used to define an interquartile change quadrant, defining an ensemble to inform the "middle" climate change scenario. Figure 4illustrates implementation of this procedure. The figure shows the same 112 projection-specific pairings of changes in mean-annual temperature and precipitation as shown in the upper right panel of Figure 3. Projection-specific paired changes are highlighted to denote ensemble membership

- (drier, less warming) gold asterisks
- (drier, more warming) red triangles
- (wetter, more warming) green "x"
- (wetter, less warming) blue crosses
- (middle) orange circles

Note that the ensemble membership of the interquartile quadrant (middle) overlaps with membership in the four other quadrants. The sum of membership in the four perimeter quadrants is 112, but membership is not equal between these four quadrants, as shown.

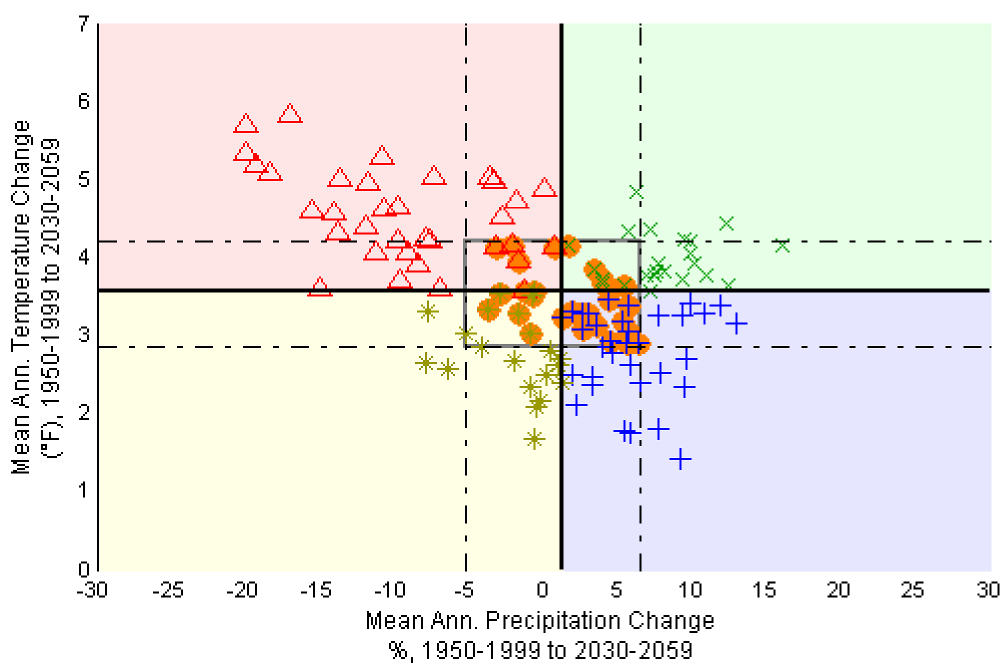


Figure 4. Selecting Projection Ensembles to Underlie Climate Change Scenarios.

3. Hydrologic Response Assessment

Given the five climate change scenarios defined for a given technique (Delta, HD, and HDe), the next task in the analytical outline involves assessing surface water hydrologic response to changes in monthly temperature and precipitation associated with each scenario. The task involves:

- Selecting a hydrologic model to simulate surface water conditions under different climates.
- Developing input weather data satisfying model input requirements and being consistent with the monthly climate change scenarios of Task 1.
- Conducting simulations and reporting results.

3.1 Hydrologic Model Description

Hydrologic simulation was conducted using an Arkansas-Red River Basin application of the Variable Infiltration Capacity hydrologic model (Liang et al. 1994).[5] The VIC model has been used to support hydrologic impacts assessments in many Western United States river basins, including California's Central Valley (Van Rheenan et al. 2004, Maurer 2007, Anderson et al. 2008, Reclamation 2008), the Colorado River Basin (Christensen et al. 2004, Christensen and Lettenmaier 2007), the Columbia-Snake Basin (Payne et al. 2004), and the southern Great Plains (LCRA/SAWS 2008).

The Arkansas-Red VIC application was developed at the University of Washington and has been used to support experimental hydrologic forecasting activities.[6] The application is gridded at a spatial resolution of 1/8º, meaning that surface water balance is simulated through time for grid cells that are roughly 12 x 12 km square (see Figure 5, gray grid of squares). The application simulates surface water balance on a daily time-step, forced by input gridded daily time series of precipitation, minimum temperature, maximum temperature, and wind speed. At the end of simulation, gridded runoff results are routed to runoff locations of interest.

In approaching this study, it was recognized that this VIC application could benefit from calibration refinement. Biases between observed and VIC-simulated

[5] http://www.hydro.washington.edu/Lettenmaier/Models/VIC/.

[6] Personal communication, Dr. Andrew Wood, National Weather Service (NWS) Colorado Basin River Forecast Center, who maintained the Arkansas-Red VIC application while at The University of Washington and shared the application for uses here.

hydrologic conditions may be apparent when reviewing results presented later in this chapter. However, the significance of these biases is somewhat muted based on how the VIC simulation results are being used to inform the yield sensitivity analysis. Specifically, the VIC-simulated results are assessed for percentage changes in mean-monthly runoff, which then is used to scale historical observed reservoir inflow variability in the yield sensitivity analysis. Thus, the focus is on how the VIC model portrays runoff response to climate change, which is revealed by conducting comparative VIC simulations under two different climates (i.e., historical observed and a future climate reflecting one of the climate change scenarios tiering from historical observed) rather than how it simulates magnitude runoff under any individual climate.

For this study, focus was placed on the hydrologic response within seven reservoir watersheds (Figure 5). Hydrologic modeling was conducted only for these watersheds after stenciling out the grid cells from the Arkansas-Red VIC application overlying these watersheds. Each VIC application grid cell may be thought of as containing a water balance model that is independent of other grid cell conditions. This is because VIC is a surface water simulation model that assumes no lateral subsurface flow. This aspect of VIC is convenient in that it permits grid cells of interest to be isolated and simulated, as opposed to having to simulate the entire Arkansas-Red domain.

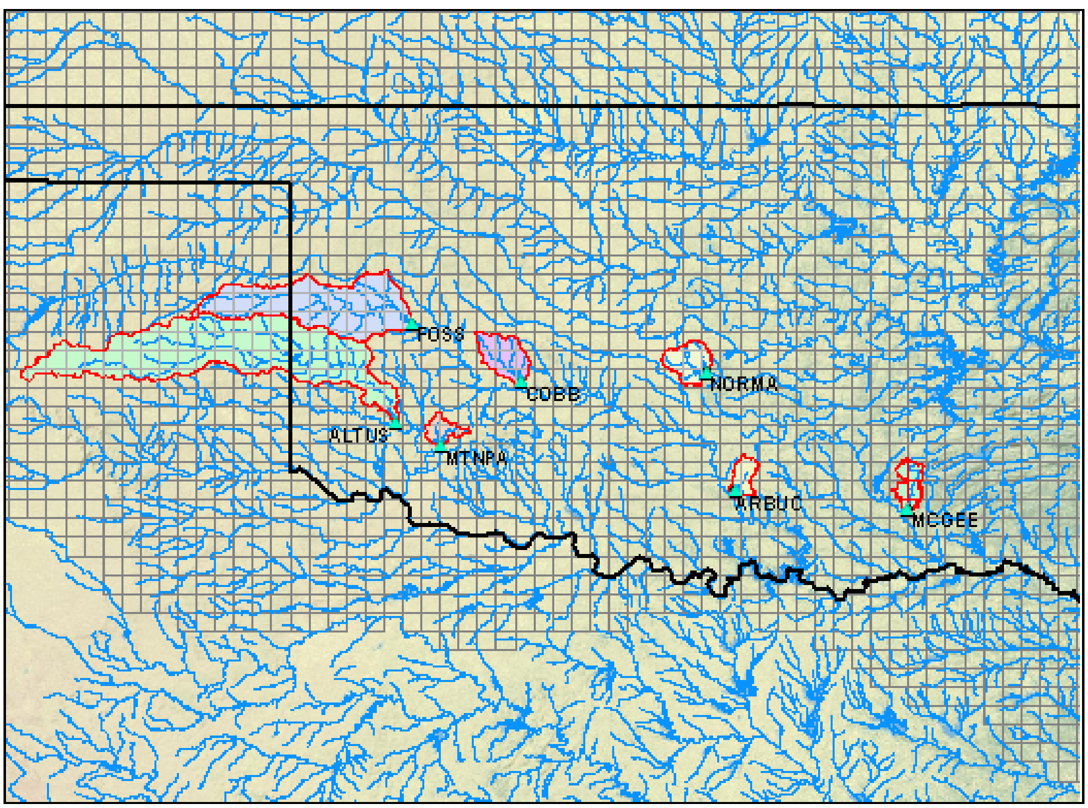


Figure 5. Study Basins.

3.2 Development of Weather Inputs

The Arkansas-Red VIC application is packaged with a "Base" set of historical, gridded daily weather inputs reflecting weather station observations during 1950–1999 (Maurer et al. 2002).[7] For Task 2, this Base 50-year weather sequence is used as the base climate condition, and simulated runoff using these weather data are used as a Base 50-year hydrologic sequence. For each climate change scenario in Task 1, a 50-year gridded daily weather sequence was generated to reflect the given scenario's future monthly climate, as changed from the Base historical climate. This means that 15 "Future Climate" weather sequences were generated, corresponding to 5 climate change scenarios associated with each of 3 climate change assessment techniques (*Delta*, *HD*, and *HDe*).

The following sections highlight differences between the mechanics of generating weather sequences corresponding to each technique. The implications for generated weather then are illustrated using the example of 1950–1999 May precipitation at a VIC grid cell over Lake Altus. Before proceeding with technique descriptions, the following list outlines aspects of Future Climate weather generation common to each technique:

- Weather sequences are generated on a 1/8º grid-cell specific basis, reflecting changes in monthly climate over that grid cell.

- Resultant daily gridded weather sequences are generated for four variables, as required by VIC: precipitation, minimum temperature, maximum temperature, and wind speed. However, only daily precipitation, minimum temperature, and maximum temperature are adjusted to reflect changes in monthly climate relative to Base weather. Wind speed sequences are kept the same as Base.

- Precipitation adjustments reflect percentage changes in a given month's condition. Temperature adjustments reflect incremental changes in monthly condition, with the same incremental change applied to both minimum and maximum temperature variables.

- Monthly Future Climate weather sequences are first generated. Monthly sequences are then temporally disaggregated to daily sequences. The disaggregation preserves the daily pattern of weather within a specific month of the Base period (e.g., Base January 1961 and Future Climate January 1961 will have perfectly correlated daily sequence), but with the pattern shifted (temperature) or scaled (precipitation) to reflect change in that month's climate. Put another way, each daily Future Climate weather sequence reflects the same sequencing aspects as the Base weather,

[7] This is the same gridded historical observations dataset that guided the bias-correction and spatial downscaling of GCM data, producing the downscaled climate projections used in Task 1.

including interarrival of droughts, storms, etc., but adjusted to reflect change in monthly temperature and precipitation conditions.

3.2.1 Technique #1 – *Delta*

The *Delta* technique involves identifying a vector of 12-month-specific adjustment factors for precipitation and 12-month-specific adjustment factors for temperature. For a given month and variable, the adjustment factor is applied uniformly to a calendar month's 50 values in the Base weather sequence to produce corresponding values for the Future Climate weather sequence (e.g., 50 May precipitation totals from Maurer et al. 2002 are all adjusted by a common May precipitation-adjustment factor from a given *Delta* climate change scenario). The adjustment factors are computed as change in period monthly mean using the same periods used in Task 1 (i.e., change in a given climate projection's 1950–1999 mean to its 2030–2059 mean). The vector of 12-month-specific adjustment factors is computed for each grid cell, variable (temperature and precipitation), and climate change scenario (five from Task 1, Approach 1).

3.2.2 Technique #2 – Hybrid-Delta (*HD*)

The *HD* technique involves identifying a vector of adjustment factors reflecting a unique period-change in monthly condition at each rank-percentile of a given month's climate condition. Thus, the adjustment differs for relatively drier to wetter precipitation conditions and for relatively cooler to warmer temperature conditions. Like the *Delta* technique, climate change is defined in this *HD* application using a single climate projection and using periods from Task 1: 1950–1999 to 2030–2059. Also like the *Delta* method, the *HD* technique is applied on a projection-, month-, variable-, and grid cell-specific basis. The key difference between *Delta* and *HD* is that the *HD* requires adjustment factors that vary by climate "year-type." This is done by identifying three rank-distributions for a given set of variable, month, grid cell location, and climate change scenario. The rank-distributions are respectively fit to:

(a) Observed Historical: 50 values from the 1950–1999 Base weather sequence discussed above (Maurer et al. 2002),

(b) Simulated Historical: 50 values from the given projection's simulated historical 1950–1999, and

(c) Simulated Future: 30 values from the given projection's simulated future 2030–2059.

The *HD* technique proceeds where percentile-specific changes are computed by comparing distributions Simulated Historical and Simulated Future. To ease the calculation, the values of distribution Simulated Future are first interpolated from 30-percentile positions to the same 50-percentile positions as distribution Simulated Historical (i.e., 1/51 to 50/51, on a 1/51 increment). As with *Delta* technique and period-mean change, the *HD* technique and percentile-specific change is computed as percentage change for precipitation and incremental change for temperature (at every percentile). These computed changes constitute the percentile-vector of adjustment factors that vary with climate year-type and vary according to the given month, grid cell, and underlying climate projection. Percentile-specific changes then are imposed on the values from distribution Observed Historical (i.e., comprised of Base monthly weather values) corresponding to the same percentiles of adjustment, generating a distribution of Future Climate monthly weather values for the given month. These monthly data then are arranged in time consistent with the Base weather sequence, followed by daily disaggregation.

3.2.3 Technique #3 – Ensemble Hybrid-Delta (*HDe*)

The *HDe* technique is identical to the *HD* technique except that, rather than construct distributions Simulated Historical and Simulated Future using data from a single climate projection, these distributions are constructed using pooled data from an ensemble of climate projections. The projection ensembles were defined in Task 1. Thus, the amount of fitting data for distribution Simulated Historical is 50 period values for the given month (1950–1999) x N projections in the given projection ensemble, and the amount of fitting data for distribution Simulated Future is 30 period values for the given month (2030–2059) x N projections. For example, the “drier, more warming” projection ensemble has 34 projections. Thus, distribution Simulated Historical was fit to 50 x 34 values for a given month (or 1,700 values) and distribution Simulated Future was fit to 30 x 34 values for the same month (or 1,020 values). To ease calculations, distributions Simulated Historical and Simulated Future are first interpolated to a common set of percentile positions (0.001 to 0.999 on a 0.001 increment). The percentile-vector of adjustment factors is then computed only at the percentile positions of distribution Observed Historical (1/51 to 50/51 on a 1/51 increment).

3.2.4 Example Application of Techniques #1 through #3

The application of each technique is illustrated on Figure 6 through Figure 11. The example involves generating Future Climate monthly May precipitation totals at a VIC grid cell overlying Lake Altus (Figure 6). Figure 7 shows the Base weather series (or, Observed Historical weather series) of monthly (blue line) and May-only precipitation (black circles). For each climate change scenario and each technique (*Delta*, *HD*, and *HDe*), a unique series of monthly May precipitation is generated, for a total of 15 series. Switching from the series view to the distribution view, Figure 8 shows three panels corresponding to the three adjustment techniques. Each panel shows the Observed Historical distribution of 50 May precipitation values (black circles) and five Simulated Historical distributions. In the first two panels (*Delta* and *HD*), the Simulated Historical distributions come from a common set of five climate projections (Task 1, Approach 1).

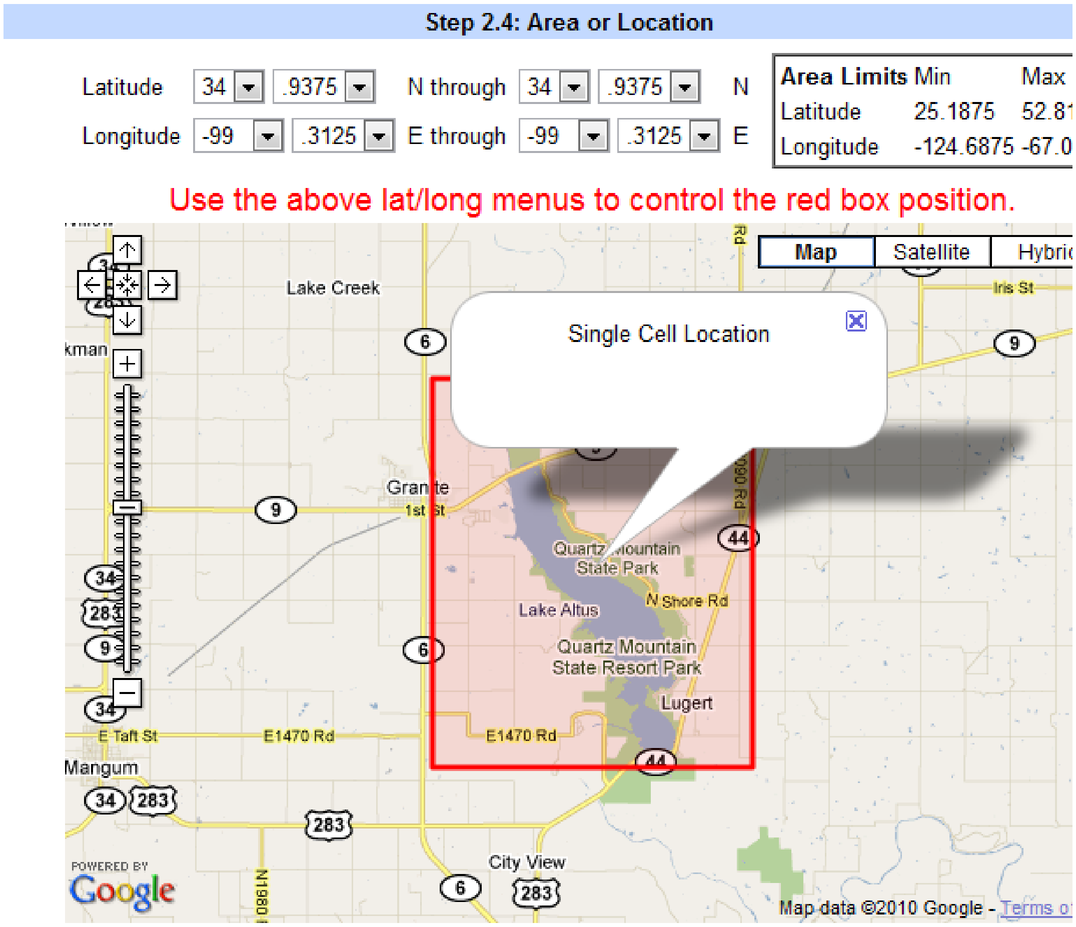


Figure 6. Example Weather Generation – Grid-Cell Location over Lake Altus.

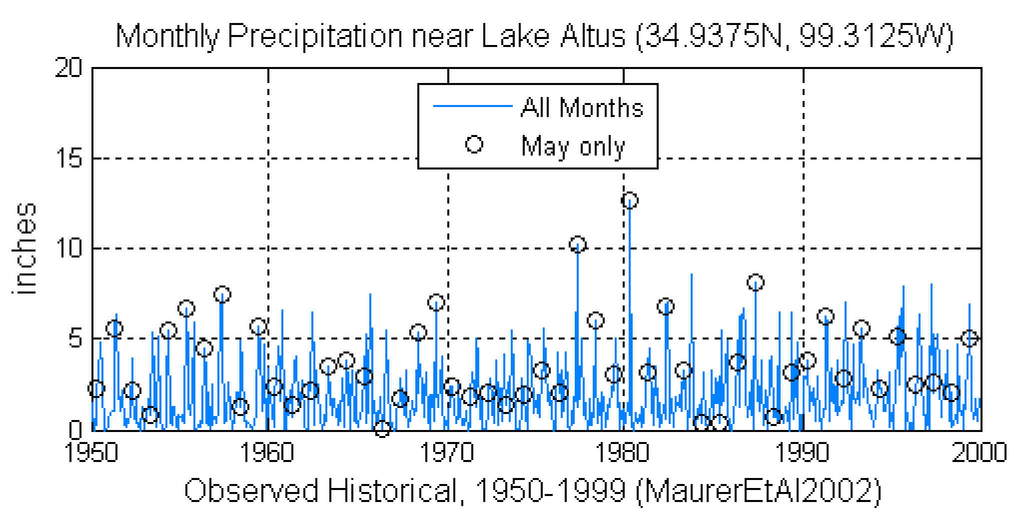


Figure 7. Example Weather Generation – Observed Historical Monthly Precipitation 1950–1999, Highlighting May Values.

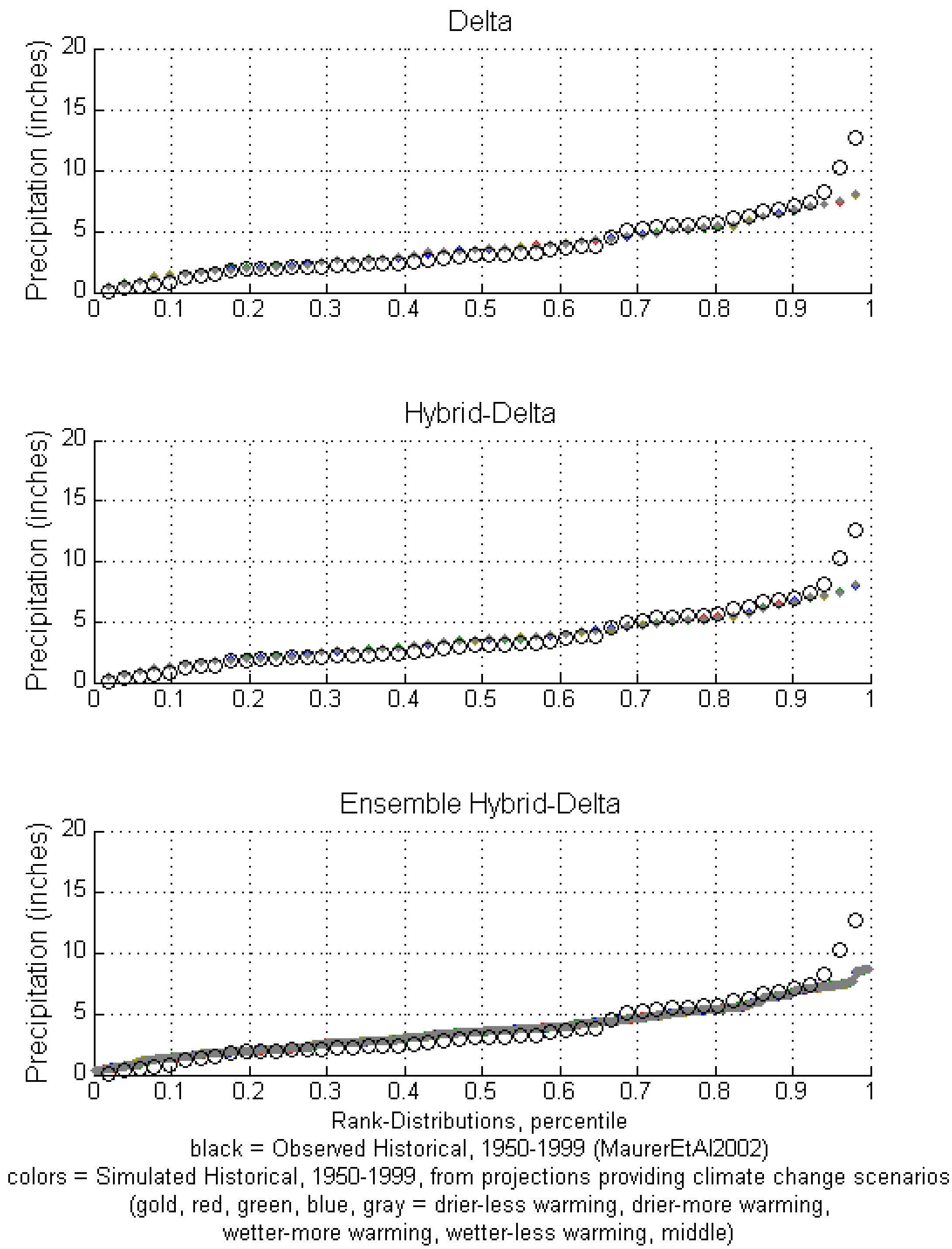


Figure 8. Example Weather Generation – Rank-Distributions of May Precipitation, Observed and Simulated Historical.

.

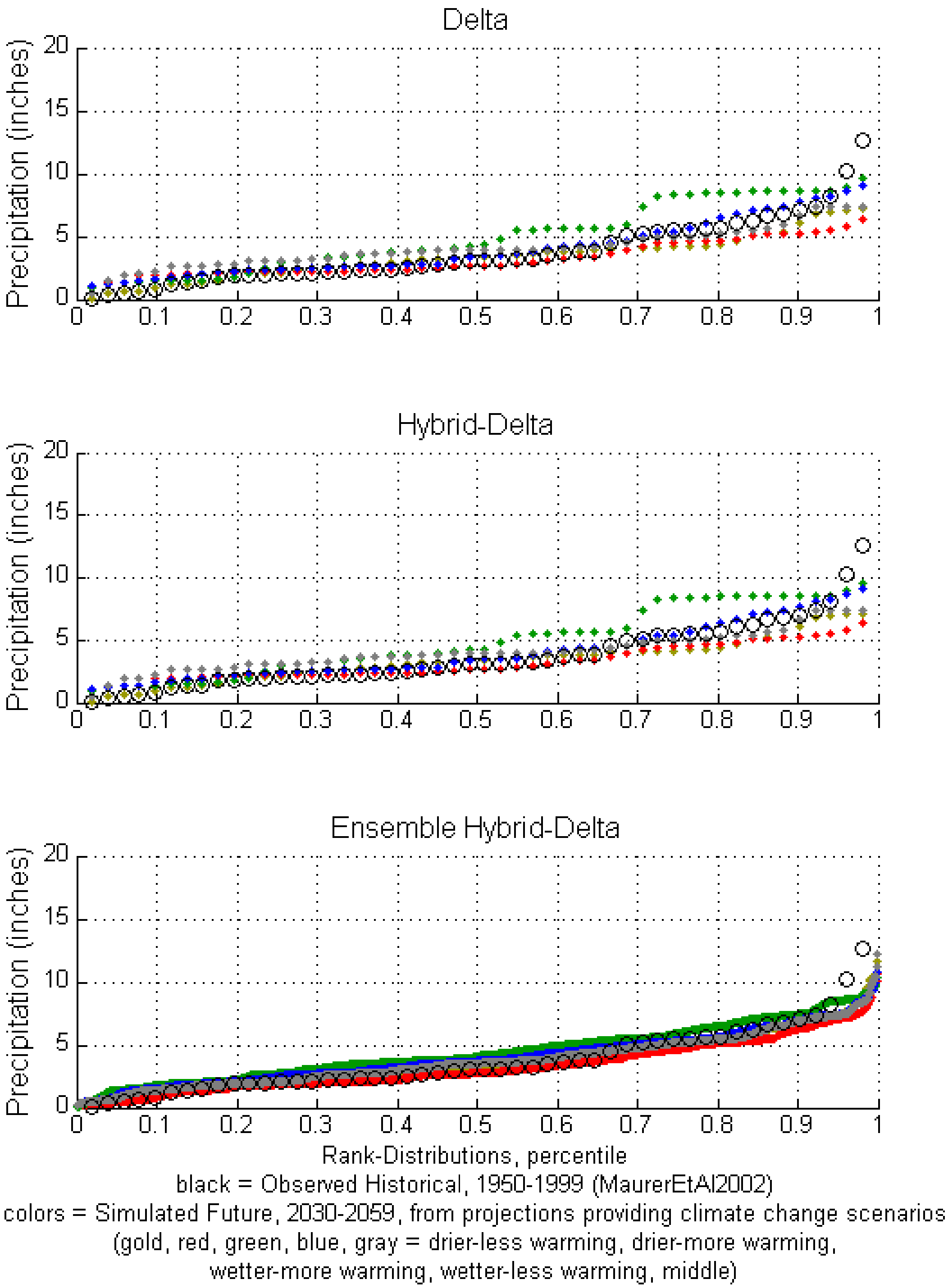


Figure 9. Example Weather Generation – Rank-Distributions of May Precipitation, Observed Historical and Simulated Future.

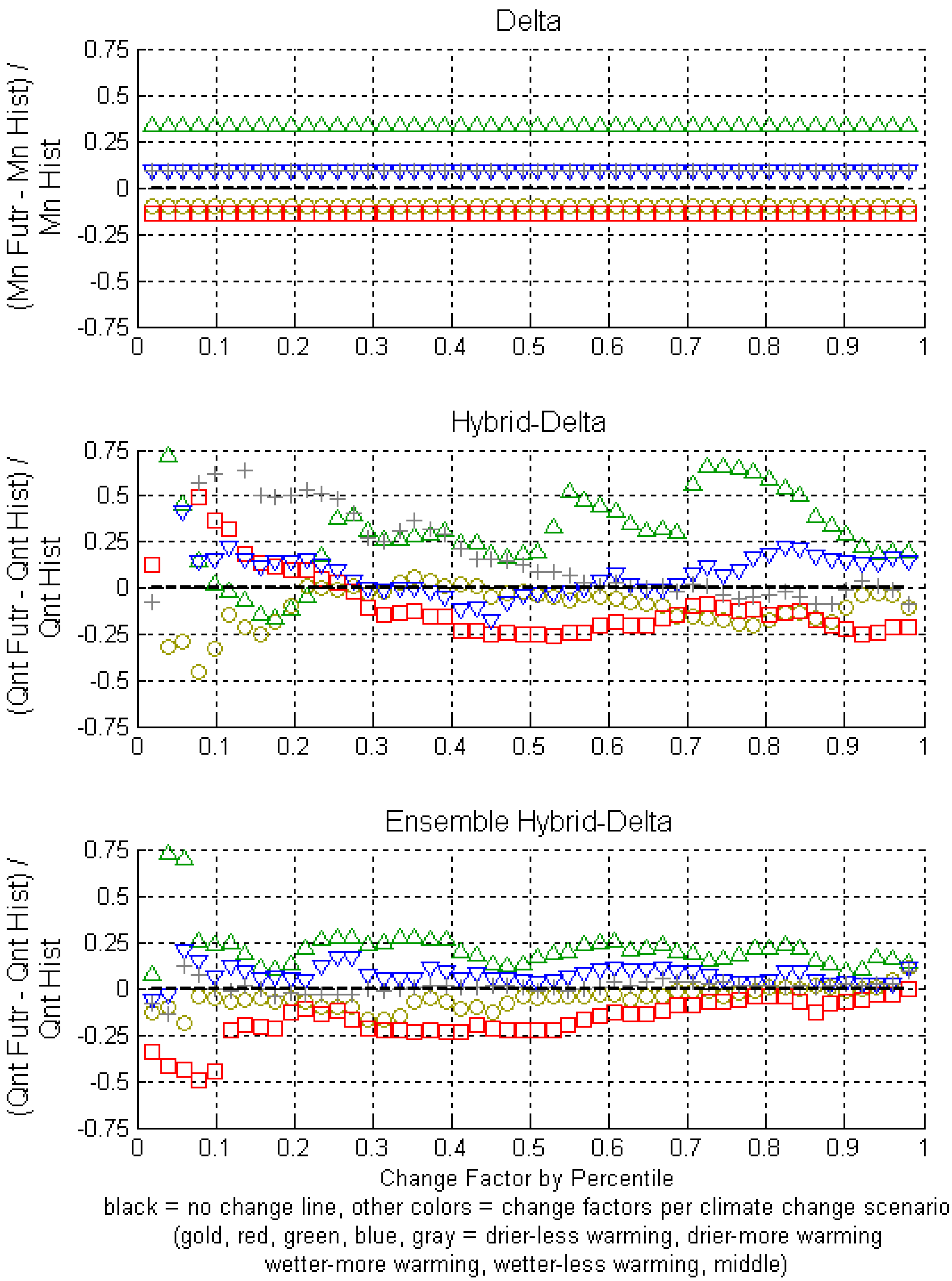


Figure 10. Example Weather Generation – Precipitation Adjustment Factors at Observed Historical May Percentiles.

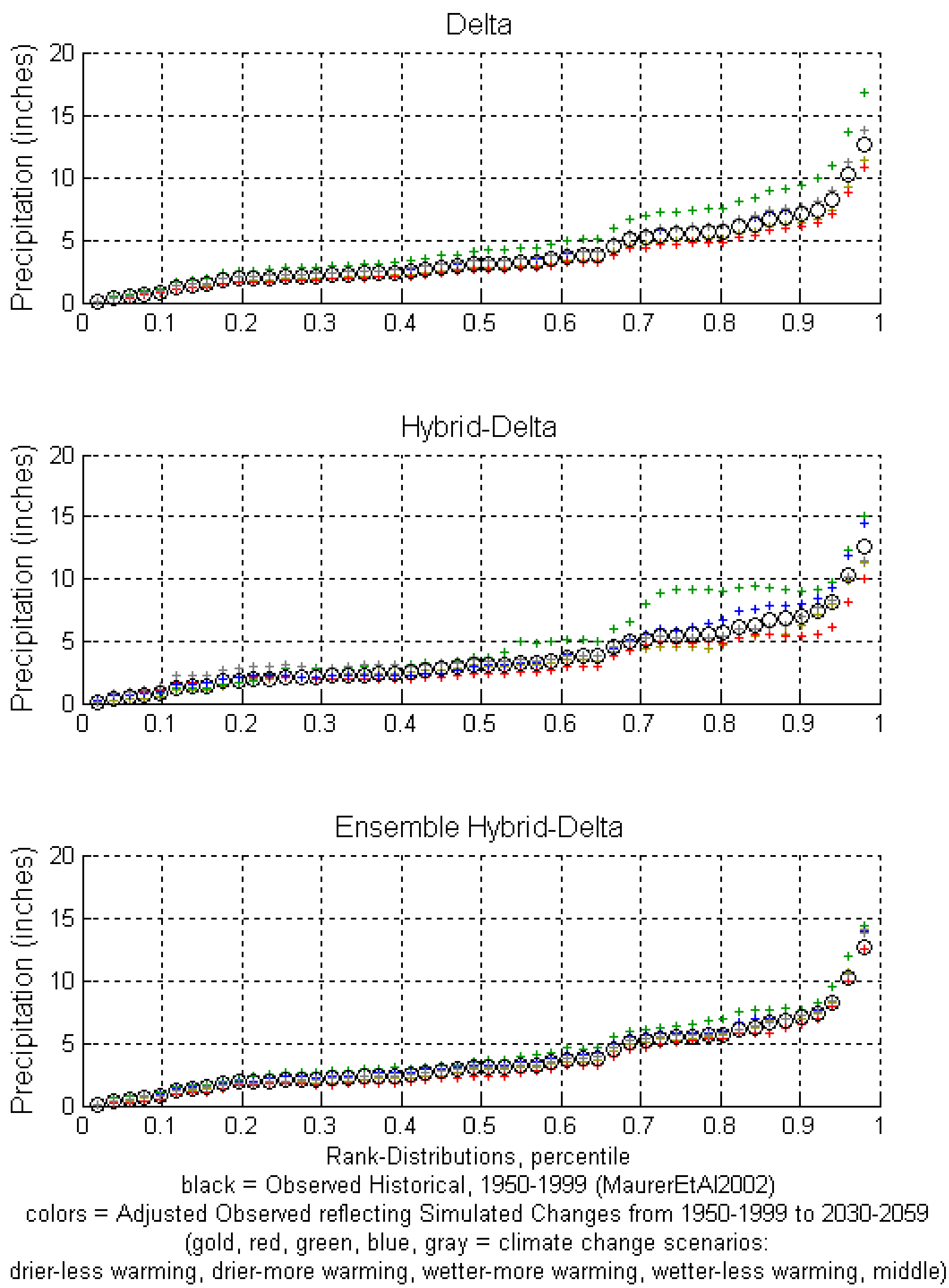


Figure 11. Example Weather Generation – "Future Climate" May Precipitation Reflecting Percentile Adjustments.

For the third panel, the Simulated Historical distributions come from five projection ensembles (Task 1, Approach 2). It may be noticed that the Simulated Historical distributions are identical on all three panels. This is a byproduct of the bias-correction procedure applied to the GCM output feeding the DCP archive used in this study, where GCM outputs were adjusted to be consistent with the 1950–1999 period monthly statistics of Maurer et al. 2002, which also provides the Base weather data used in Task 2. It also may be noticed that the Observed Historical (Base) distribution does not match Simulated Historical at this grid cell. This is a byproduct of the spatial downscaling step of BCSD (section 2.1) that occurs after the GCM bias-correction. The bias-correction is performed at a coarser spatial scale (2º) and forces GCM output to be consistent with Maurer et al. 2002 data aggregated to the 2º scale. The bias-corrected data are then spatially downscaled to 1/8º data using a disaggregation scheme that does not completely translate 2º bias-correction into 1/8º bias-correction.

Figure 9 is similar to Figure 8, except that each panel shows the five Simulated Future distributions reflecting simulated 2030–2059 rather than the Simulated Historical distributions reflecting simulated 1950–1999. As mentioned, each Simulated Future distribution was initially fit to 30 values and then interpolated to the same 50-percentile positions as the Simulated Historical distribution. The top two panels (*Delta* and *HD*) show an identical set of Simulated Future distributions because each set originates from a common set of five climate projections. The third panel (*HDe*) shows a different set of Simulated Future distributions because they each arise from ensembles of projections. In the *HDe* technique, the use of a projection-ensemble to construct the underlying Simulated Future distributions tends to smooth out the pattern of expected May conditions across the percentiles. For example, compare the Simulated Future distributions of *HD* and *HDe* for the “wetter, less warming” scenario (green lines); focusing only on an individual projection (HD), the implication is that nearly 30% of Mays will have at least 8 inches of precipitation, but focusing on a collection of “wetter, more warming” projections (HDe), the implication changes and less than 10% of Mays have precipitation greater than 8 inches.

Moving to the calculation of adjustment factors, Figure 10 shows adjustment factors at the Base distribution’s percentile positions.

- Using the *Delta* method, the top panel illustrates how a common adjustment for a given climate change scenario (i.e., underlying climate projection) is applied at all percentile positions of the Base distribution. For example, the “wetter, more warming” climate change scenario (green) involves increasing all Base (Observed Historical) May precipitation totals by 33% whereas the “drier, more warming” scenario (red) involves a -14% decrease.

- Using the *HD* method, the middle panel illustrates how the adjustment factor varies by percentile position, meaning that “climate change” adjustment varies by year-type.

- Using the *HDe* method, the bottom panel illustrates similar information as the middle panel, but showing only adjustment factors at percentile positions from the Base distribution. In the *HDe* technique, the use of a projection-ensemble to construct the underlying Simulated Historical and Simulated Future distributions tends to smooth out the pattern of Adjustment Factors across the percentiles. Note particularly how the “wetter, more warming” scenario of HD (green) experiences a dramatic reduction in positive adjustment during relatively wetter May months (percentiles between 0.5 and 0.9).

Finally, the percentile-vectors of each technique and each climate change scenario are imposed on the Base distribution to construct Future Climate distributions (Figure 11). The theme illustrated on comparison of the adjustment factor vectors (Figure 10) is repeated here, as the *HDe* technique tends to deemphasize large wet-May changes in precipitation suggested by the *HD* technique, which may have been overstated due to its projection-specific view of climate change. Yet, compared to the *Delta* technique, the *HDe* technique still expresses some relatively different adjustments by climate year-type.

3.3 Hydrologic Modeling Results

This section summarizes hydrologic modeling inputs and outputs, with discussion focusing on the runoff outputs that inform yield sensitivity analysis. Results are summarized graphically, focusing on four variables.

- VIC input temperature (Tavg[8])
- VIC input precipitation (Prcp[8])
- VIC-simulated runoff (Q[8])
- VIC-simulated watershed evapotranspiration (Evap[8])

For the first two variables, the gridded daily VIC inputs of daily precipitation, minimum temperature, and maximum temperature are aggregated over each watershed into basin-mean monthly series of precipitation and temperature.[9] For the third variable, daily gridded VIC runoff is routed to the dam locations corresponding to the seven reservoir watersheds (Figure 5), producing a daily

[8] Label for this variable on Figure 12 and Figure 13.

[9] For temperature, the gridded VIC inputs of daily minimum and maximum temperatures are first averaged into a gridded daily mean temperature, which is then subjected to the daily-to-monthly time aggregation and gridded to basin-mean spatial aggregation mentioned above.

runoff series at each location that is then aggregated to monthly runoff for discussion purposes here. For the fourth variable, VIC evapotranspiration is aggregated from daily to monthly and from gridded to basin-mean, just like input temperature and precipitation.

For each watershed and climate (Base historical, five *Delta* future climate, five *HD* future climates, and 5 *HDe* future climates), the monthly mean VIC inputs and outputs were assessed. Figure 12 shows monthly mean conditions for a single basin example, ALTUS. The figure shows 12 plot panels—4 variables (rows) by 3 weather generation techniques (columns). On each panel, there are six patterns of monthly mean condition, corresponding to six climates (Base historical and five futures). For the future climates, the color coding is consistent with that shown on Figure 8 through Figure 11.

Results indicate that the monthly mean conditions can be sensitive to the weather generation technique. This is shown more clearly on Figure 13 where <u>changes</u> in monthly mean condition are shown for the five climate change scenarios, each measured relative to Base historical.

- For temperature, it is clear that warming is expected during all calendar months for each climate change scenario considered. However, it's also clear that the *HDe* technique portrays smoother month-to-month climate changes relative to those portrayed by *Delta* and *HD* technique. The temperature changes shown for the *Delta* and *HD* techniques are the same because change in monthly mean is being sampled from a common set of underlying projections; however, if the interest was placed on change in monthly distributions, the plot would show differences between the *Delta* and *HD* temperature variabilities (section 3.2).

- For precipitation, the portrayal of month-to-month changes appears to be very sensitive to weather generation technique. The *Delta* and *HD* techniques portray change directions that flip from positive to negative, or vice versa, in more stark and frequent fashion relative to the changes portrayed by the *HDe* technique. As with temperature, the monthly mean precipitation changes from the *HDe* technique follow somewhat smooth month-to-month transitions along a given climate change scenario, emphasizing consensus change information from the ensemble of climate projections informing that scenario. It is noted that, while there do not appear to be months with a consensus sign of precipitation change across scenarios from the *Delta* and *HD* techniques, there does appear to be consensus across scenarios for some months using the *HDe* technique, notably the increase in precipitation during winter months (December–February).

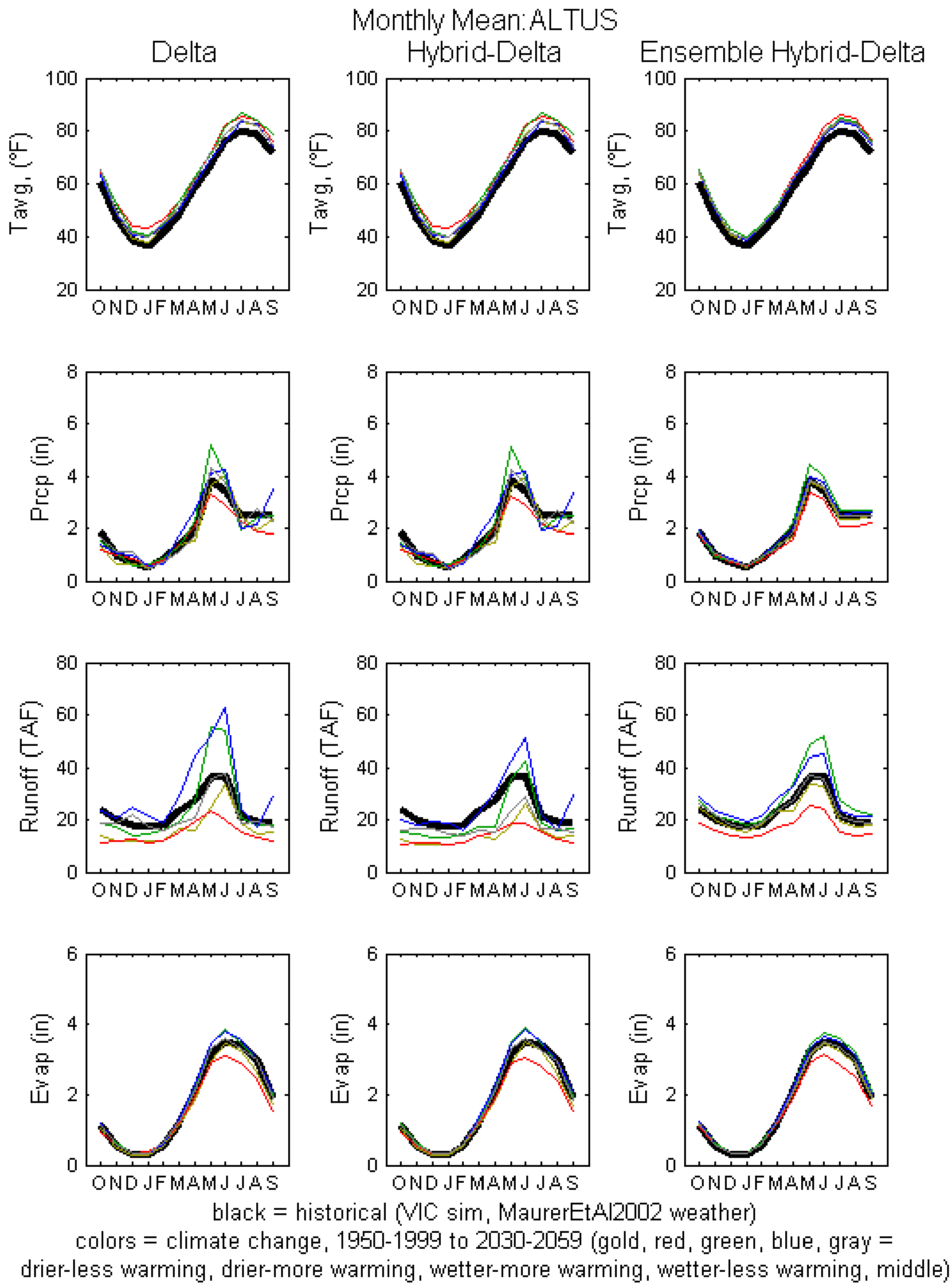


Figure 12. Mean Monthly Temperature, Precipitation, Runoff, and Evaporation – ALTUS.

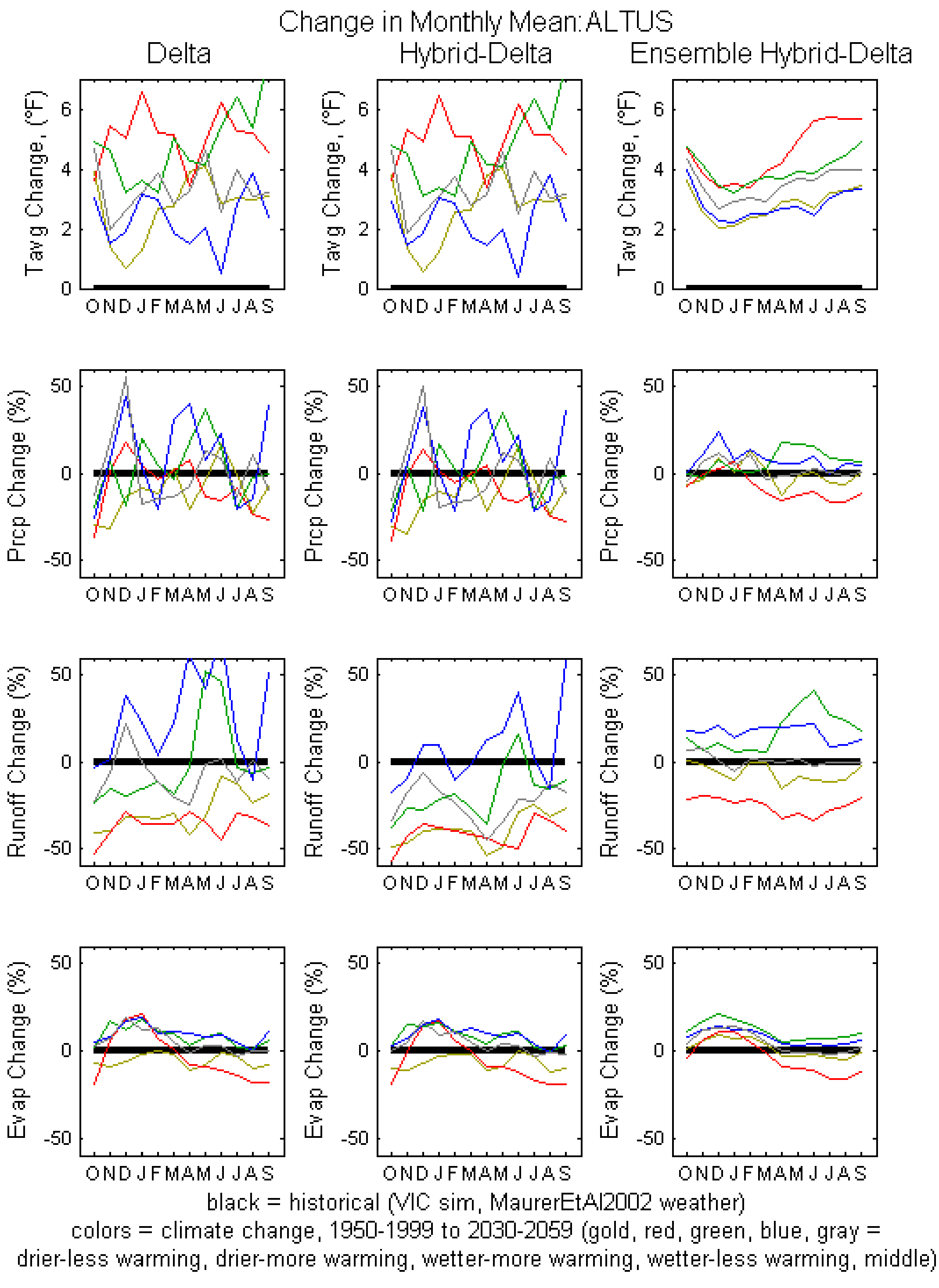


Figure 13. Change in Mean Monthly Temperature, Precipitation, Runoff, and Evaporation – ALTUS.

- For runoff, the portrayal of month-to-month impacts by each technique exhibits similar themes as those discussed for precipitation; the month-to-month runoff impacts reflecting weather generated using the *HDe* technique tend to transition more smoothly than impacts reflecting weather generated using the *Delta* or *HD* technique.

- For watershed evapotranspiration, the themes discussed above also are exhibited. However, it also appears that the amount of evapotranspiration change doesn't necessarily follow the amount of temperature change. This is because the opportunity for evapotranspiration depends not only on the atmospheric demand (related to temperature) but also the soil moisture supply. Increases in winter precipitation should lead to increased soil moisture and increased supply of water for evapotranspiration during those months.

Focusing on runoff, Figure 14 through Figure 16 each show changes in mean monthly runoff for all seven basins corresponding to the three techniques, respectively. Results show that themes found at Lake Altus are similar to themes found at the other reservoir watersheds.

Switching perspective from monthly to annual, Figure 17 shows mean annual conditions for the four variables at each basin, with results specific to variables and weather generation techniques arranged as shown on Figure 12. Figure 18 shows change in mean annual conditions at each basin, also with results arranged by variable and weather generation technique.

3.4 Using Runoff Results in the Yield Sensitivity Analysis

Proceeding to the yield sensitivity analysis, it was understood that either the *Delta*, *HD*, or *HDe* results for changes in 50-year mean-monthly runoff (Figure 14, Figure 15, or Figure 16) would be used to adjust a base sequence of 1926–2008 monthly inflows at each reservoir. Based on the following two reasons, it is recommended that the *HDe* results for change in 50-year mean-monthly runoff be used in the yield sensitivity analysis (Figure 16). The first reason relates to portrayal of month-to-month hydroclimatic changes (temperature, precipitation, and runoff) and an interest in portraying changes that are more consistent when progressing through months. Such portrayal would seem to emphasize monthly climate changes that are more interseasonally coherent. Relative to *Delta* and *HD* results, the *HDe* results show more interseasonal coherency. The second reason is that the *HDe* technique reflects consensus monthly climate conditions in an ensemble of climate projections, whereas *Delta* and *HD* techniques reflect monthly conditions from individual projections.

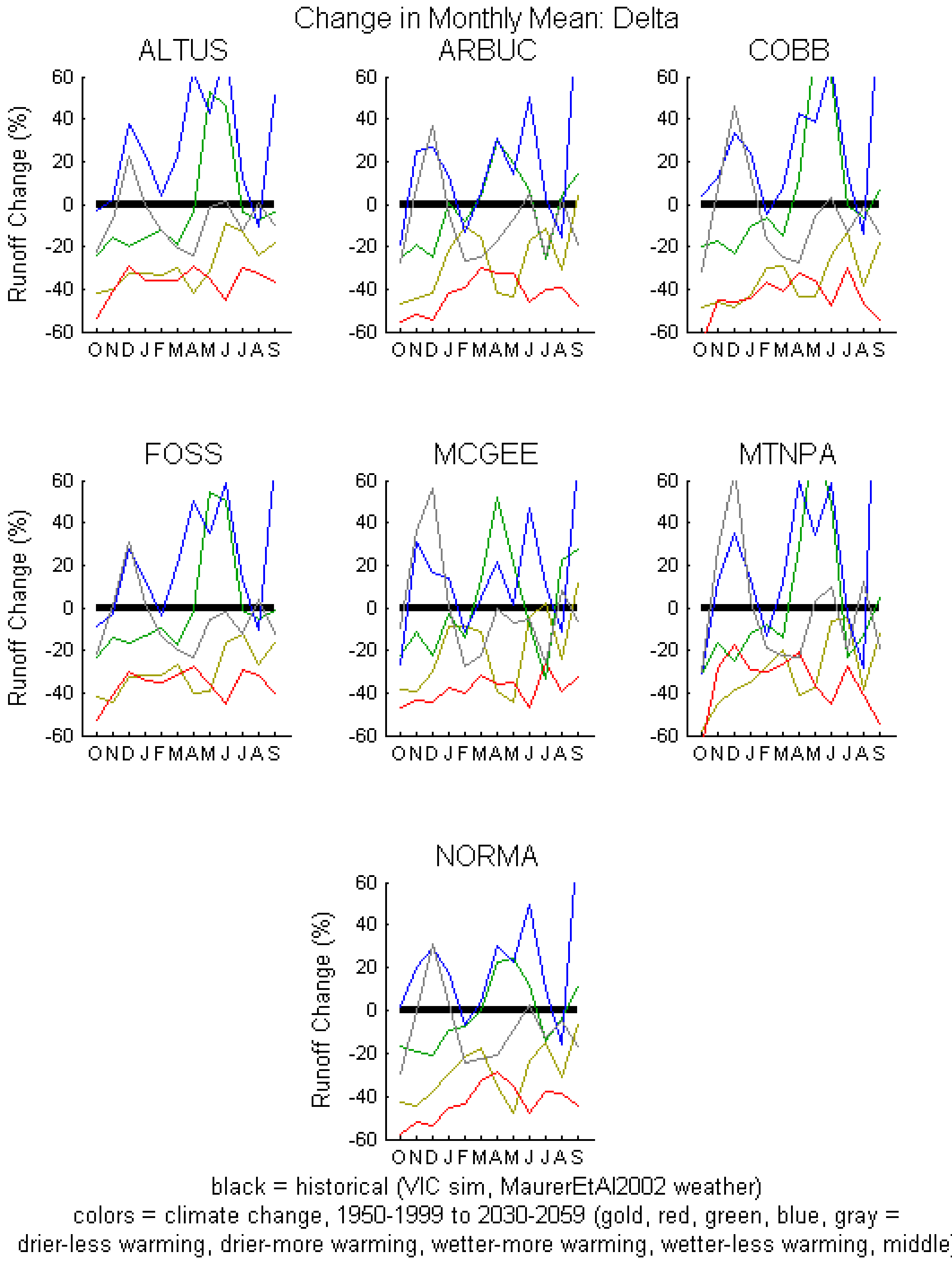


Figure 14. Change in Mean Monthly Runoff – All Basins – Weather Generated Using Delta Method.

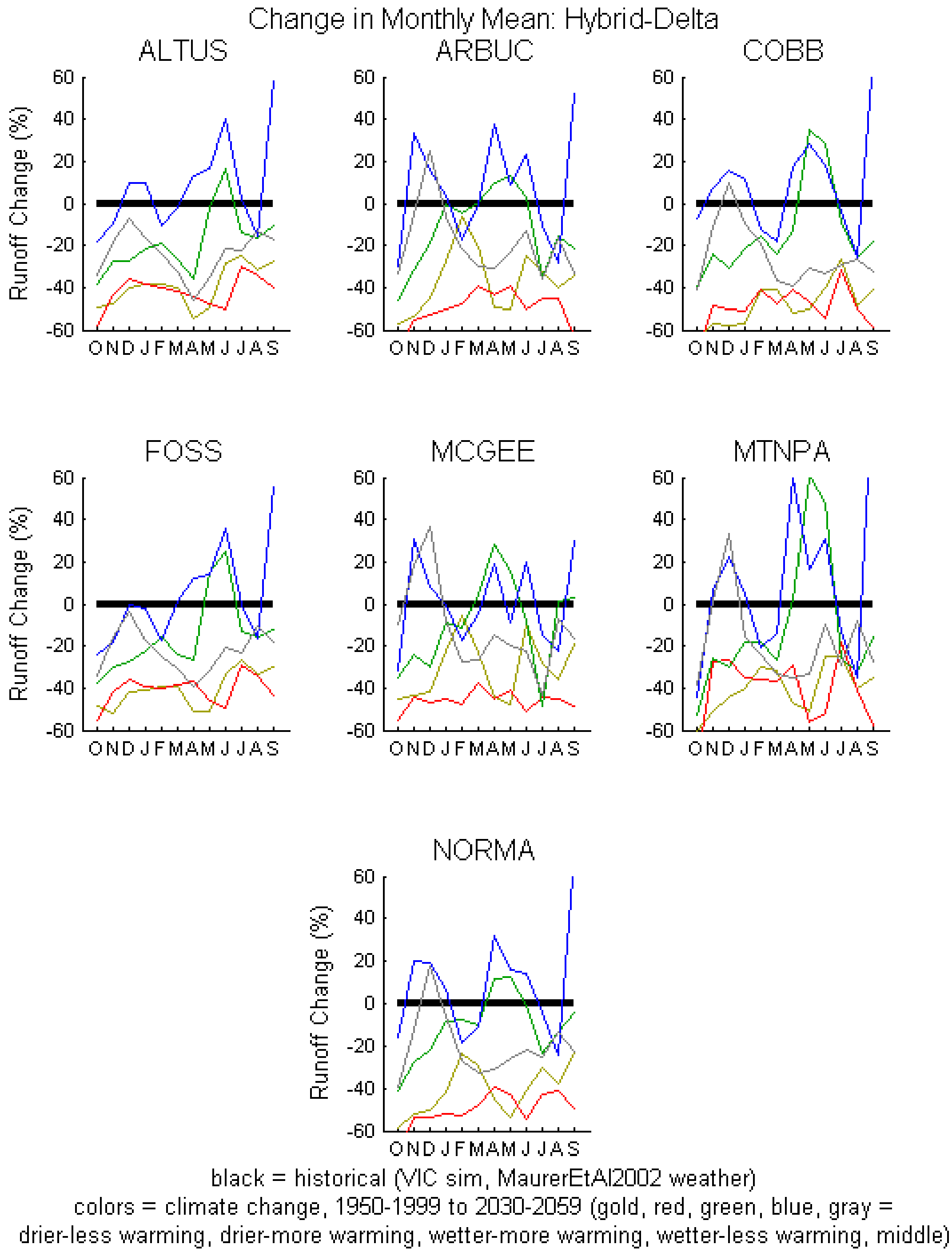


Figure 15. Change in Mean Monthly Runoff – All Basins – Weather Generated Using HD Method.

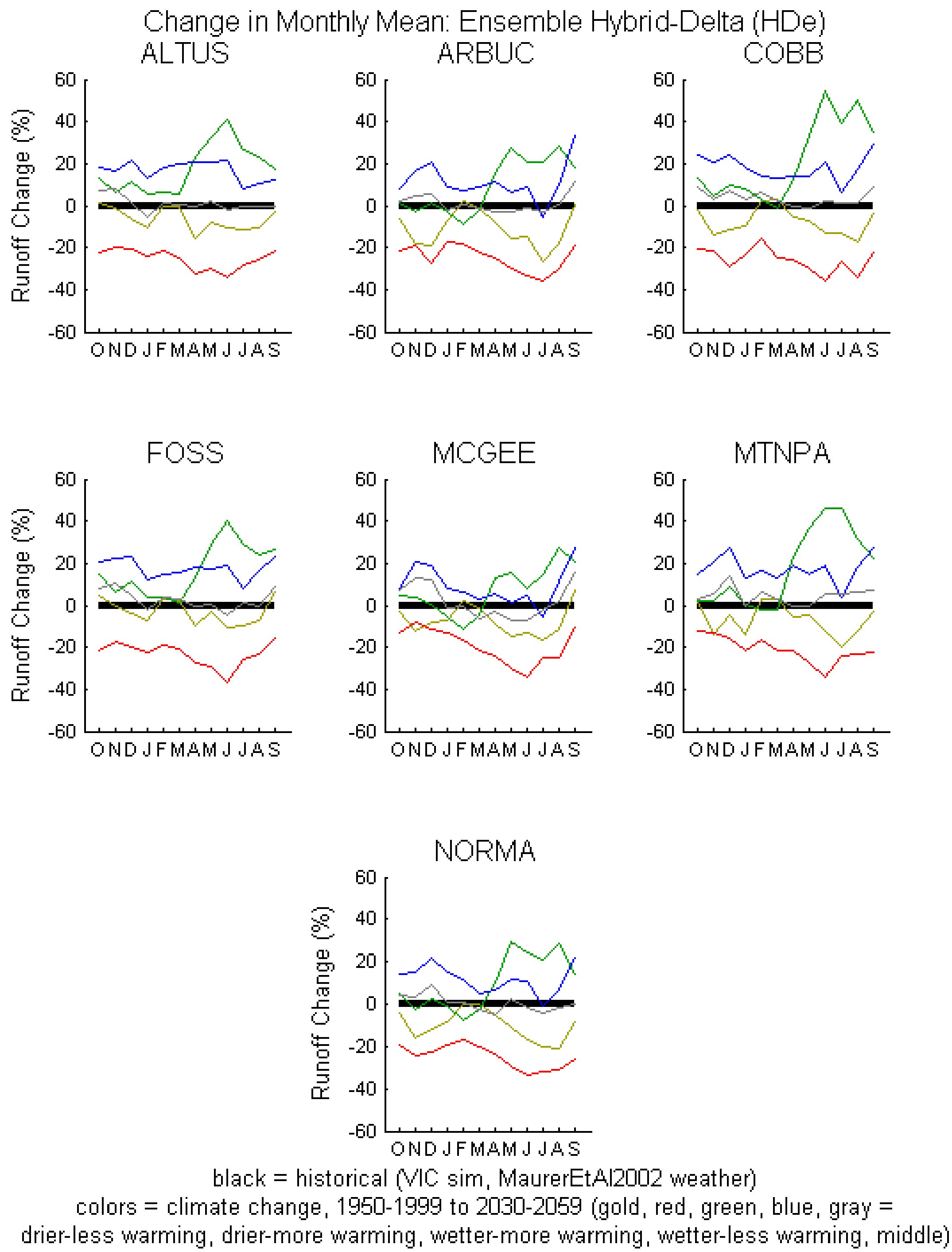


Figure 16. Change in Mean Monthly Runoff – All Basins – Weather Generated Using HDe Method.

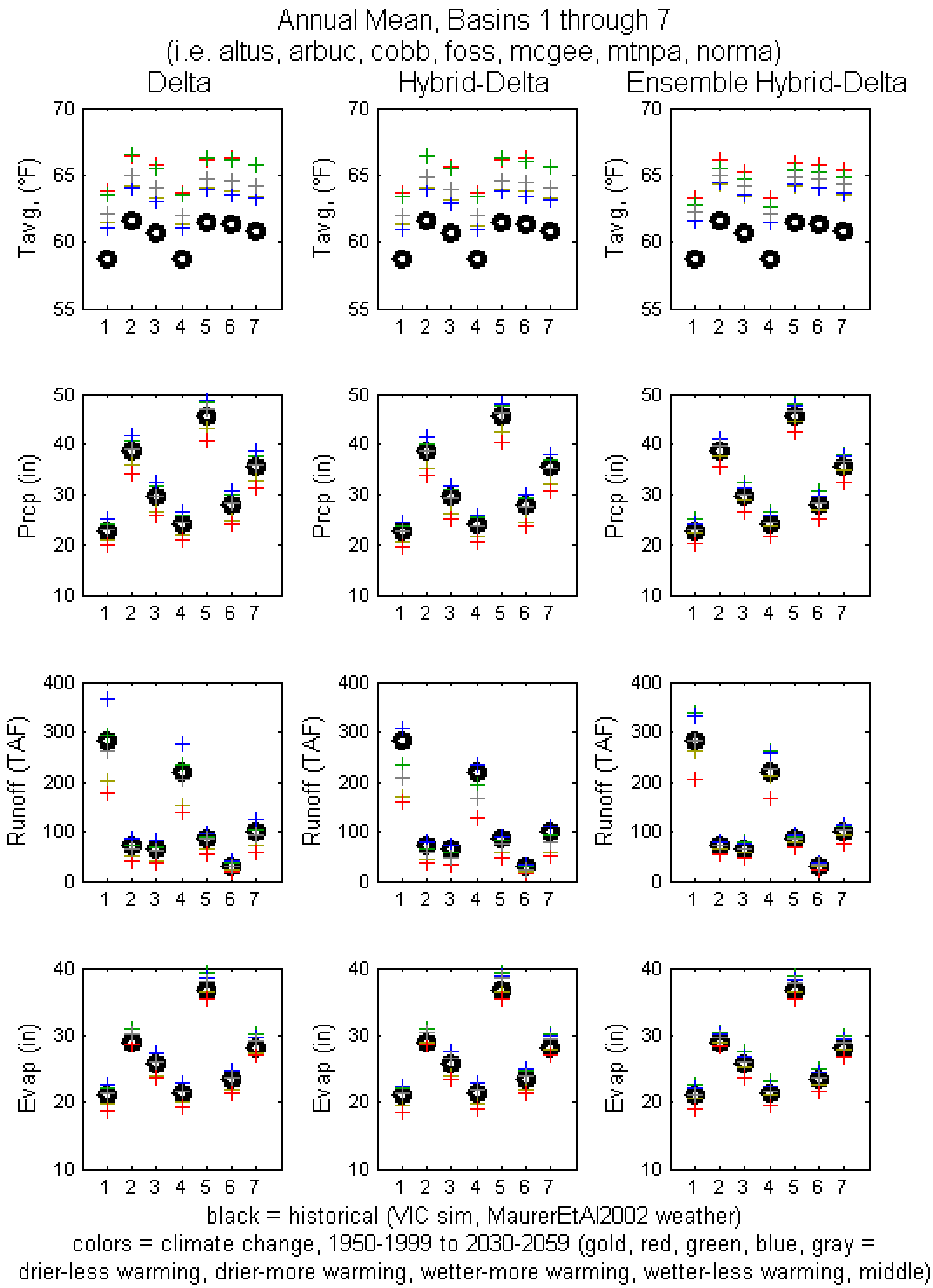


Figure 17. Annual Mean Temperature, Precipitation, Runoff, and Evaporation – All Basins.

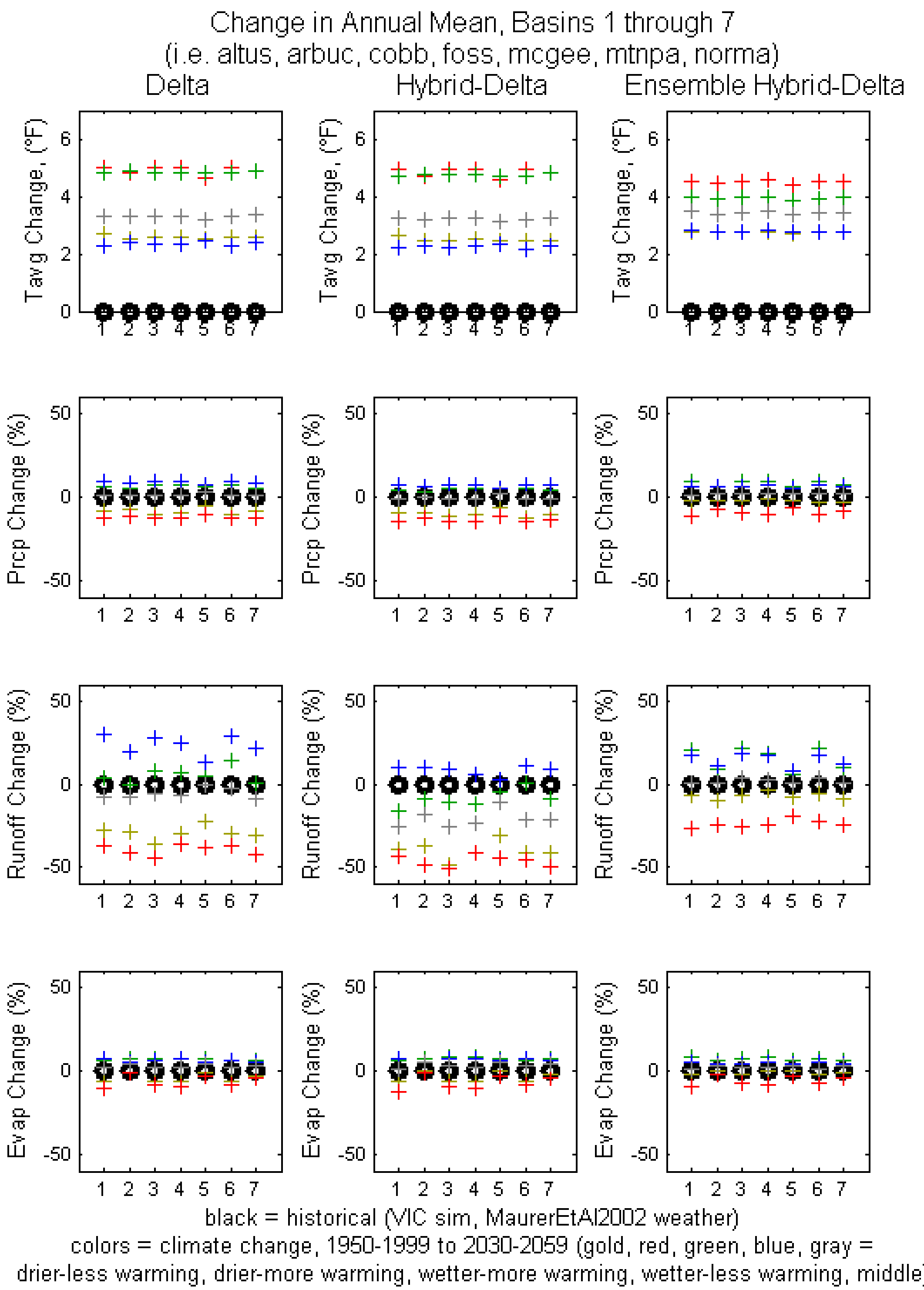


Figure 18. Change in Annual Mean Temperature, Precipitation, Runoff, and Evaporation – All Basins.

It is recommended that, for each scenario, both the changes in mean-monthly and mean-annual runoff be used to adjust the Base monthly reservoir inflow series at a given reservoir used in the yield assessment (i.e., for water years 1926–2008, understanding that this period contrasts with the 50-year duration of Base weather and hydrologic sequences featured in the VIC-simulated hydrologic response assessment just discussed). The need for this two-stage inflow adjustment follows reasoning offered in Reclamation (2008) and arises from how the VIC simulation of historical runoff at a reservoir location is biased relative to the yield assessment's Base historical inflow series at this location during the common historical period. This is because the VIC application was calibrated using historical runoff information that overlapped but did not completely coincide with streamflow and impairments information used to generate the yield assessment's Base inflow series. The consequence of this bias is that when the VIC-simulated changes in mean-monthly runoff are imposed on Reclamation's estimated historical monthly inflows at a given reservoir, then resultant inflow series may express a change in mean annual inflow that differs from VIC-simulated change in mean annual runoff. To reflect the VIC-simulated change in mean annual runoff and, thus, change in long-term water balance, the second inflow series adjustment is necessary and involves scaling the entire series so that the change in 83-year mean annual inflow equals the VIC-simulated change in 50-year mean annual runoff. Ideally, this step would be rendered unnecessary by recalibrating the VIC application to reproduce Reclamation historical inflows (presuming they are natural inflow estimates). However, such model development activity was outside the scope of this effort.

4. Precipitation and Evaporation at Reservoirs

In addition to reflecting runoff impacts, the yield sensitivity analysis is scoped to consider climate change effects on the reservoir precipitation and evaporation conditions. This section describes how time series of reservoir precipitation and evaporation were developed.

4.1 Historical Reservoir Precipitation

Monthly reservoir precipitation estimates have been recorded at each reservoir since time of construction. These data are being used in the yield assessment, which is framed by hydroclimate variability for a period that spans preconstruction to postconstruction conditions: 1926–2008. Reservoir precipitation prior to construction had to be estimated using a data-filling procedure tiering from nearby, or "proxy," station precipitation and temperature information (P_{pxy} and T_{pxy}). Additionally, there are months of missed reporting in the reservoir precipitation series during the postconstruction period, which meant the data-filling procedure had to address these months also. The goal with data-filling was to produce Base reservoir precipitation series estimated from 1926–2008 that could then be adjusted using the *HDe* change in 50-year mean monthly precipitation over the reservoir watershed to generate Adjusted reservoir precipitation series for the given climate change scenario.

The selected nearby precipitation stations are listed in table 1. These stations have monthly data that span the yield assessment period of 1926–2008. However, these station series also have months of missed reporting, which needed to be filled before filling gaps in the reservoir precipitation data (P_{res}).

Table 1. Proxy Precipitation Stations Used To Fill Gaps in Historical Reservoir Precipitation Series

Reservoir	Proxy Precipitation Station (*Ppxy*)*	COOP I.D.
ALTUS	ELK CITY, OKLAHOMA	342849
ARBUC	SULPHUR PLATT NATIONAL PARK, OKLAHOMA	348587
FOSS	HAMMON 1 NNE, OKLAHOMA	343871
COBB	CLOUD CHIEF 2 SE, OKLAHOMA	341927
MCGEE	DAISY 4 ENE, OKLAHOMA	342354
MTNPA	HOBART FAA AP, OKLAHOMA	344204
NORMA	NORMAN 3 S, OKLAHOMA	346386

* Each proxy station informed the given reservoir's Detailed Planning Report (DPR), except for Altus where the DPR does not indicate which precipitation station was used.

The gap filling procedure is a resampling technique that is first operated on the P_{pxy} data and involves steps outlined below. The procedure is applied to a successive pairs of P_{pxy} stations and on a month-specific basis. The ordering of station pairs was influenced by geographic proximity of stations and the need for stations having fewer gaps to be filled first so that they could serve as guides for filling the stations having more gaps. This resulted in the following order of station pairs for mutual gap filling: ALTUS-FOSS, MTNPA-NORMA, MTNPA[10]-FOSS,[10] FOSS-ALTUS,[10] MTNPA-NORMA,[10] MTNPA-COBB,[10] NORMA-ARBUC,[10] and NORMA-MCGEE.[10] For a given station pair and a given month, the following procedure was used:

- Label the stations S1 and S2.
- Identify months when data are reported for S1 (i.e., n1), when data are reported for S2 (i.e., n2), and when these reporting sets intersect (i.e., n1n2). Let n1n2 serve as the set of paired S1 and S2 values from which fill-values are sampled.
- Proceed to fill gap months of S1. Focus on the gap months of S1 for which data were reported for S2. Loop through these S2 values, identifying closest S2 values from the intersect set (n1n2), and identifying the months of these closest values. For these months, get the corresponding S1 values and adopt those values as the fill estimates for S1 during the corresponding gap months.
- Proceed to fill gaps months of S2 in a similar fashion, focusing on the gap months of S2 for which data were reported for S1, etc.

After filling gaps in each P_{pxy} station series, the gap-filling procedure was used again, but this time where S1 and S2 were set to be P_{pxy} and P_{res} data at a given reservoir. In this case, the *S1* series has no gaps, and the procedure only needs to address gaps in S2.

Figure 19 illustrates the results from the procedure, highlighting months where P_{res} at ALTUS was estimated based on P_{pxy} at Elk City, Oklahoma. The figure panels correspond to calendar months, each showing P_{pxy} versus P_{res}. Inspection shows that there is significant error in the relationship between P_{pxy} and P_{res} that, thus, affects gap-fill estimates. Ideally, this procedure would be applied with station-data having a higher correlation with P_{res}. However, due to the period of the yield assessment (1926–2008), the availability of well-correlated P_{pxy} and P_{res} data was limited.

---

[10] This station's gaps were completely filled after this pairing.

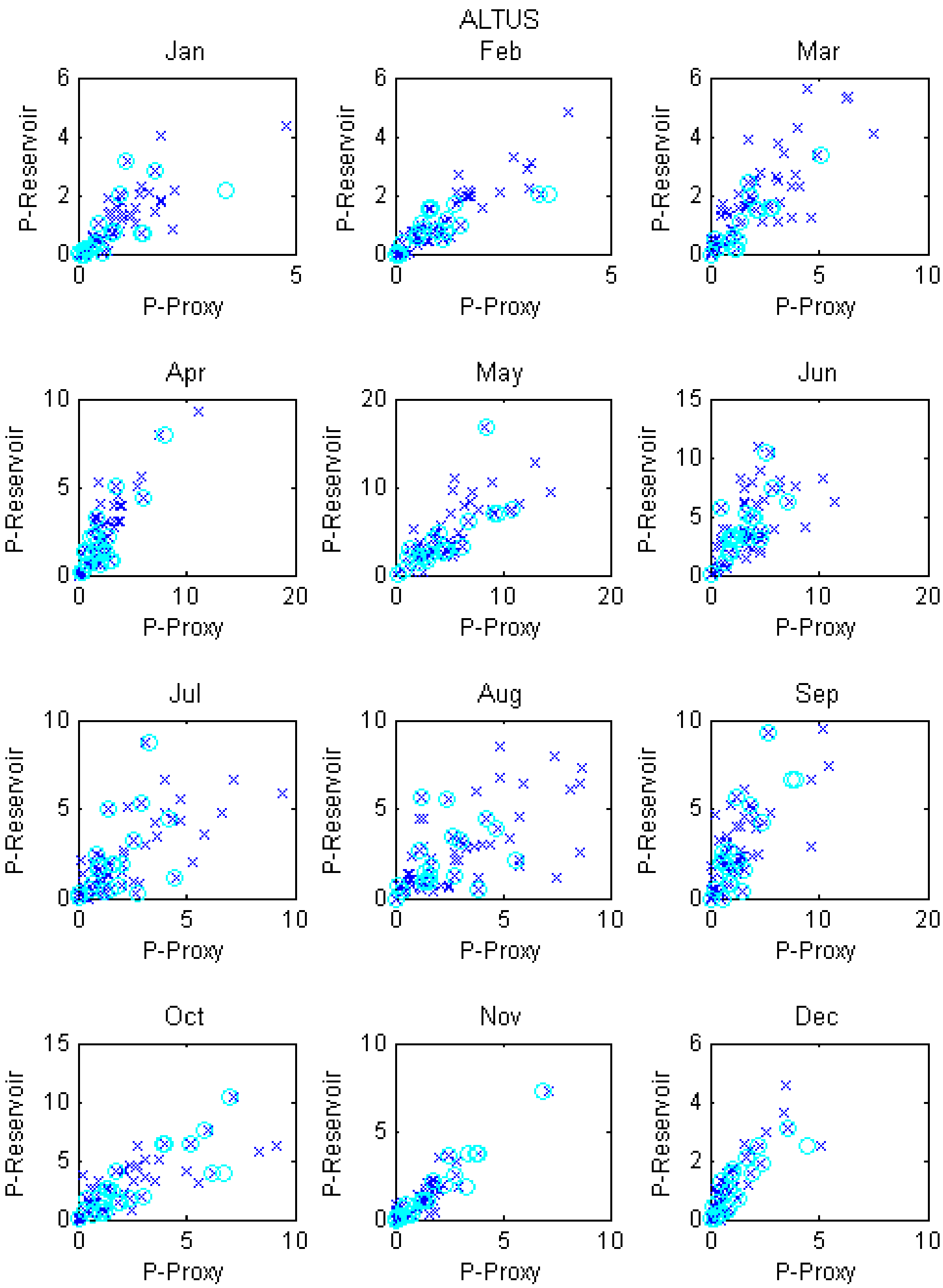


Figure 19. Reservoir Precipitation, Observed and Estimated Based on P_{pxy} data – ALTUS.

4.2 Historical Reservoir Evaporation

As for precipitation, monthly reservoir evaporation estimates have been recorded at each reservoir since time of construction, and there are gaps to fill during the preconstruction period and for months after construction where reports are missing.

The procedure to estimate gaps in the reservoir evaporation series is similar to that used to estimate reservoir precipitation gaps. The key difference is that temperature variability is assumed to be a proxy for evaporation variability, which was done by assuming that reservoir evaporation changes proportionally to temperature change. This assumption is questionable, recognizing that a variety of meteorological conditions affect reservoir evaporation rates (e.g., temperature, radiation, wind speed). However, only temperature data were available for the complete period of 1926–2008; and, therefore, this approximation was used.

Given this presumption, the gap-filling procedure operated on proxy precipitation was applied here to the proxy temperature (T_{pxy}). The gap-filling procedure operated on proxy; and reservoir precipitation was then applied but using proxy temperature and reservoir evaporation (E_{res}). There are two notable caveats in this application:

- Since T_{pxy} data at McGee were not available for the 1926–2008 period, T_{pxy} for Arbuckle were used as a surrogate.
- Also, since E_{res} data for Altus were not availble for the 1926–2008 period, E_{res} from Foss were used as a surrogate.

Given these caveats, the gap-filling for T_{pxy} followed the same succession of proxy station pairs as P_{pxy}, resulting in filled T_{pxy} series. The latter then were used to fill gaps in E_{res}.

Figure 20 illustrates results gap-filling at Lake Altus, where E_{res} at Lake Altus was estimated based on T_{pxy} at Elk City, Oklahoma (green circles). As was discussed for the filling of reservoir precipitation, there is significant error in the relationship between T_{pxy} and E_{res} that, thus, affects gap-fill estimates. Ideally, this procedure would be applied with T_{pxy} having a higher correlation with E_{res}.

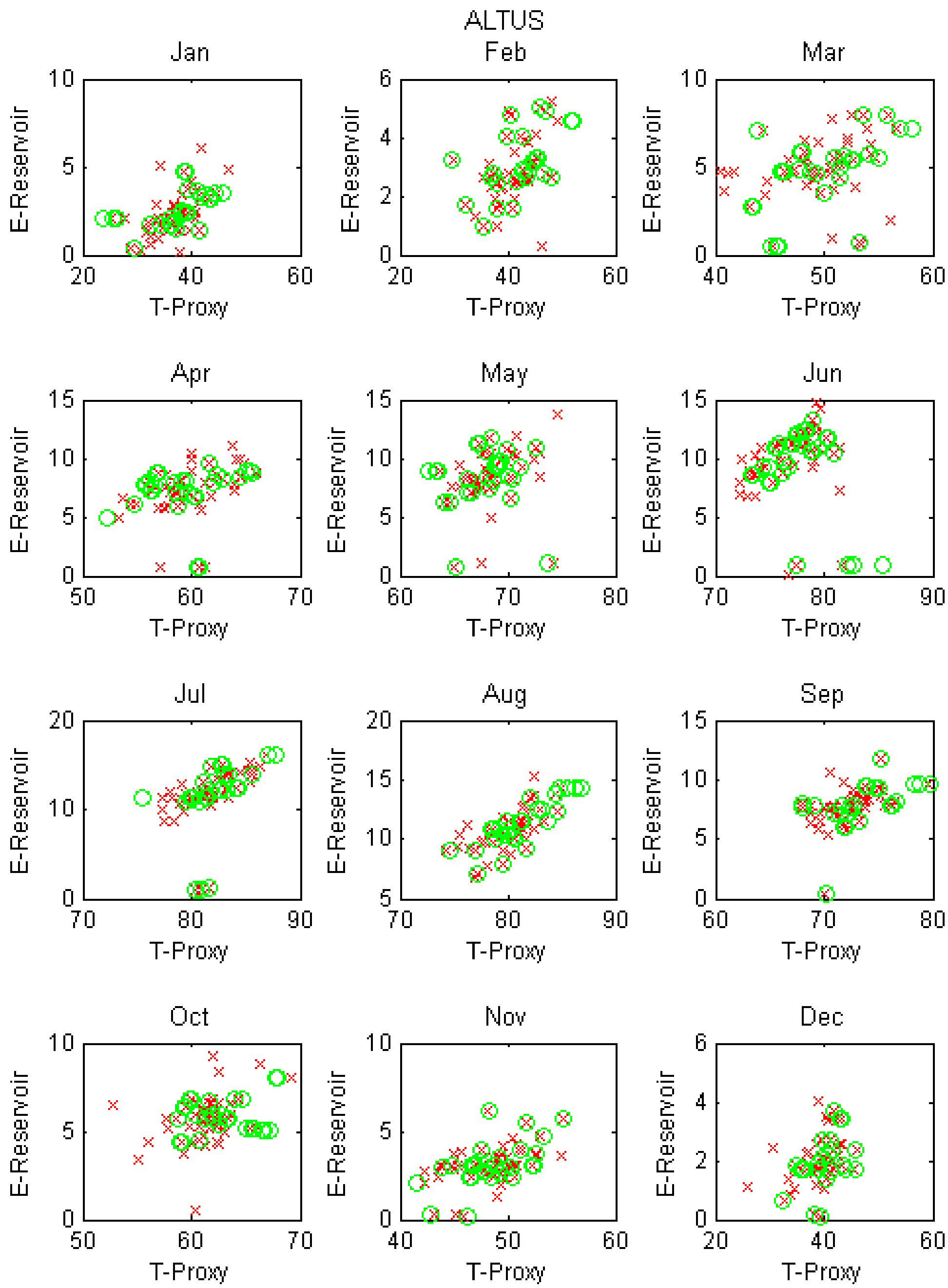


Figure 20. Reservoir Evaporation, Observed and Estimates Based on T_{pxy} Data–ALTUS.

4.3 Estimating Climate Change Reservoir Precipitation and Evaporation

Mean-monthly watershed precipitation and temperature changes from the *HDe* analysis were used to generate "climate change" reservoir precipitation and evaporation series, each tiering from the base 1926–2008 monthly series discussed earlier.

Precipitation was addressed first. For each reservoir and *HDe* climate change scenario, a "climate change" reservoir precipitation series was generated as the Base historical reservoir precipitation series scaled by the ratio changes in 50-year mean-monthly precipitation averaged over the reservoir watershed (Figure 13, right column, second row). This scaling was done on a month-specific basis. Evaporation was addressed next. For each reservoir and climate change scenario, a set of monthly adjustment factors was identified as the product of a given month's "evaporation sensitivity to temperature change" (E_{sens}) and the 50-year mean change in watershed temperature for that month. Development of E_{sens} was based on regression of E_{res} and T_{pxy} data during the historical period.[11] The slopes of these monthly regressions were assumed to be monthly estimates of E_{sens}. Figure 21 shows example estimates of monthly E_{sens} at Lake Altus. "Climate change" reservoir evaporation time series were then estimated as the base E_{res} series incrementally adjusted by the product of E_{sens} and HDe change in watershed temperature. Table 2 summarizes impacts on reservoir evaporation, listing the percentage change in mean monthly depth of evaporative loss, where the mean is computed for all months during 1926–2008 (n = 996).

Table 2. Reservoir Evaporation, Percentage Change in Mean Monthly Loss (inches) by Climate Change Scenario

Climate Change Scenario	ALTUS	ARBUC	FOSS	COBB	MCGEE	MTNPA	NORMA
HDe Drier, Less Warming	6.7	2.6	6.2	6.2	1.7	8.0	3.1
HDe Drier, More Warming	10.7	4.3	10.3	10.4	2.6	13.1	5.2
HDe Wetter, More Warming	9.5	3.8	8.9	9.0	2.3	11.3	4.5
HDe Wetter, Less Warming	6.7	2.6	6.2	6.2	1.7	7.9	3.2
HDe Middle	8.4	3.3	7.9	7.9	2.1	9.9	3.9

[11] Based on graphical inspection of Eres values, there was some concern about some extreme minimum and maximum E_{res} reports at several reservoirs. To eliminate the influence of these extremes on the regression analyses, the regression equations were fit to (E_{res}, T_{pxy}) data pairs involving E_{res} values in between the 10^{th} and 90^{th} percentile E_{res} values.

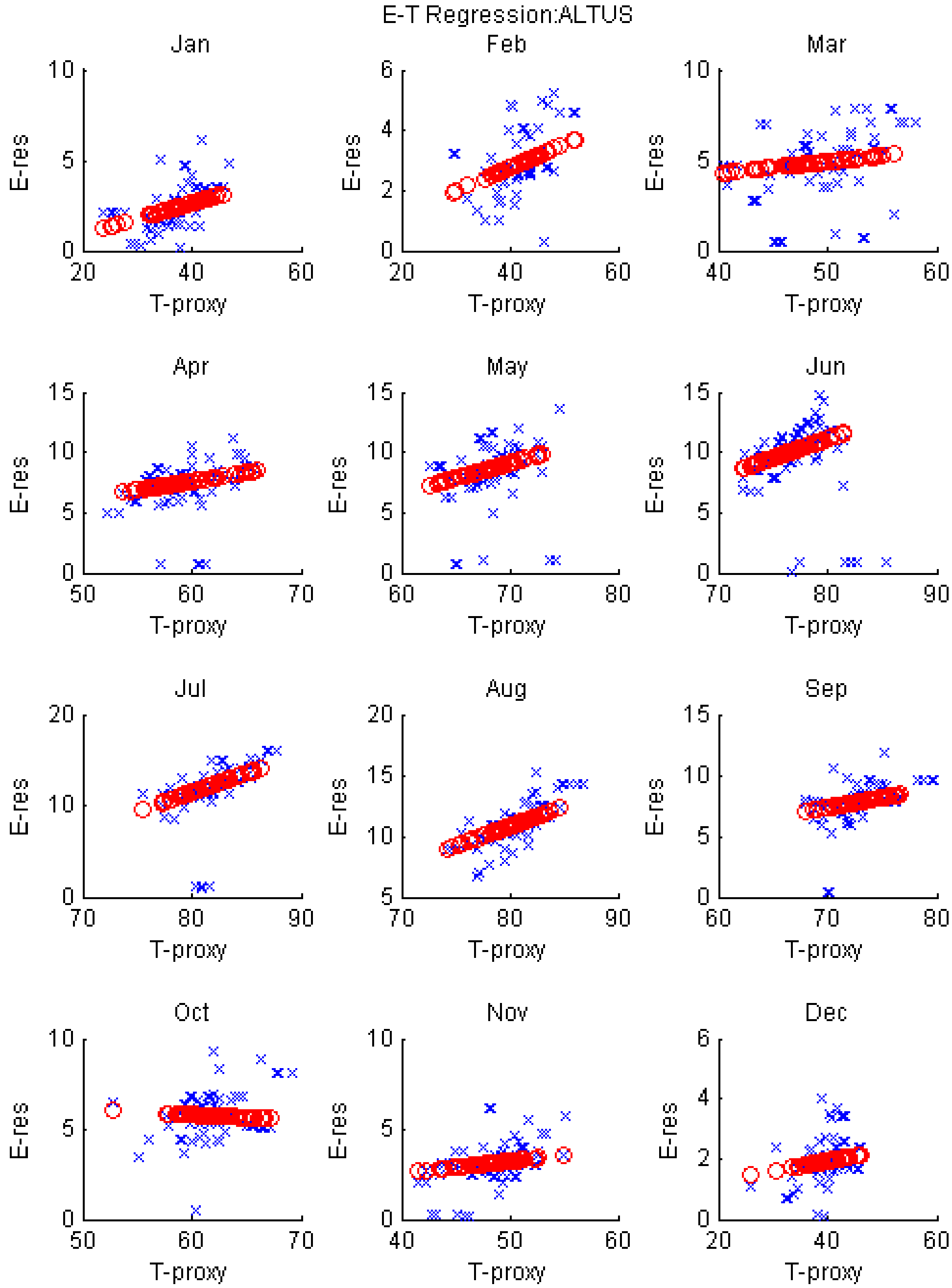


Figure 21. Regression Relationship Between Reservoir Evaporation and Nearby Temperature (*E_{sens}*).

(Figure shows scatter of all paired T_{pxy} and E_{res} data (i.e., E-res and T-proxy), and then the regression fits to all pairs containing E_{res} data within the 10- to 90-percentile range of E_{res} values.)

5. Uncertainties

This analysis is designed to provide some quantitative illustration of how runoff in Reclamation's Oklahoma reservoir watersheds might respond to a range of future climate possibilities. The study was designed to take advantage of best available datasets and modeling tools and to follow methodologies documented in peer-reviewed literature. However, there are a number of analytical uncertainties that are not reflected in study results, including uncertainties associated with the following analytical areas:

- **Global climate forcing:** Although the study considers climate projections representing a range of future greenhouse emission paths, the uncertainties associated with these pathways are not explored in this analysis. Such uncertainties include those introduced by assumptions about technological and economic developments, globally and regionally; how those assumptions translate into global energy use involving GHG emissions; and biogeochemical analysis to determine the fate of GHG emissions in the oceans, land, and atmosphere. Also, not all of the uncertainties associated with climate forcing are associated with GHG assumptions. Considerable uncertainty remains associated with natural forcings, with the cooling influence of aerosols being regarded as the most uncertain on a global scale (e.g., figure SPM-2 in IPCC 2007).

- **Global climate simulation:** While this study considers climate projections produced by state-of-the-art coupled ocean-atmosphere climate models and even though these models have shown an ability to simulate the influence of increasing GHG emissions on global climate (IPCC 2007), there are still uncertainties about our understanding of physical processes that affect climate, how to represent such processes in climate models (e.g., atmospheric circulation, clouds, ocean circulation, deep ocean heat update, ice sheet dynamics, sea level, land cover effects from water cycle, vegetative other biological changes), and how to do so in a mathematically efficiently manner given computational limitations.

- **Climate projection bias-correction:** This study is designed on the philosophy that GCM biases toward being too wet, too dry, too warm, or too cool should be identified and accounted for as bias-corrected climate projections data prior to use in implications studies like this sensitivity analysis. Bias-correction of climate projections data affects results on incremental runoff and water supply response.

- **Climate projection spatial downscaling:** This study uses projections that have been empirically downscaled, using spatial disaggregation on a monthly time-step (following GCM bias-correction on a monthly time-step). Although this technique has been used to support numerous water resources impacts studies (e.g., Van Rheenan et al. 2004, Maurer and Duffy 2005, Maurer 2007, Anderson et al. 2008, LCRA/SAWS 2008, Reclamation 2008, Reclamation 2009), uncertainties remain about the limitations of empirical downscaling methodologies. One potential limitation relates to how empirical methodologies require historical reference information use on spatial climatic patterns at the downscaled spatial resolution. These finer-grid patterns are implicitly related to historical large-scale atmospheric circulation patterns, which presumably would change with global climate change. Application of the historical finer-grid spatial patterns to guide downscaling of future climate projections implies an assumption that the historical relationship between finer-grid surface climate patterns and large-scale atmospheric circulation is still valid under the future climate. In other words, the relationship is assumed to have statistical stationarity. In actuality, it is possible that such stationarity will not hold at various space and time scales, over various locations, and for various climate variables. However, the significance of potential nonstationarity in empirical downscaling methods and the need to utilize alternative downscaling methodologies remains to be established.

- **Generating weather sequences consistent with climate projections:** This study uses three different techniques to generate weather sequences for hydrologic modeling that reflect observed historical climate variability blended with projection information on changes in period monthly conditions. The first two techniques have been demonstrated in previous applications (Delta in Hamlet and Lettenmaier 1999, Miller et al. 2003, and many others; HD in LCRA/SAWS 2008), and the third technique is introduced as an ensemble extension of HD. However, other techniques might have been considered (e.g., generation of weather sequences that conform to the transient development of climate, as featured in Christensen and Lettenmaier 2007). Choice of weather generation technique depends on aspects of climate change that are being targeted in a given study. Preference among available techniques remains to be established.

- **Natural runoff response:** This study analyzes natural runoff response to changes in precipitation and temperature while holding other watershed features constant. Other watershed features might be expected to change as climate changes and affects runoff (e.g., potential ET given temperature changes, vegetation affecting ET and infiltration, etc.). On the matter of land cover response to climate change, the runoff models' calibrations would have to change if land cover changed because the models were calibrated to represent the historical relationship between weather and runoff as mediated by historical land cover. Adjustment to watershed land cover and model parameterizations were not considered due to lack of available information to guide such adjustment.

6. References

Anderson, J., F. Chung, M. Anderson, L. Brekke, D. Easton, M. Ejeta, R. Peterson, and R. Snyder(2008). "Progress on Incorporating Climate Change into Management of California's Water Resources", Climatic Change, Springer, Netherlands, 89, Supplement 1, 91–108.

Brekke, L.D., J.E. Kiang, J.R. Olsen, R.S. Pulwarty, D.A. Raff, D.P. Turnipseed, R.S. Webb, and K.D. White (2009). Climate change and water resources management—A federal perspective: U.S. Geological Survey Circular 1331, 65 p. (Also available online at http://pubs.usgs.gov/circ/1331/.)

Christensen, N.S., A.W. Wood, N. Voisin, D. Lettenmaier (2004). "The Effects of Climate Change on the Hydrology and Water Resources of the Colorado River basin," Climate Change 62: 337–363.

Christensen, N.S. and D.P. Lettenmaier (2007). "A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin," Hydrology and Earth System Sciences," 11, 1417–1434.

Covey, C., K.M. AchutaRao, U. Cubasch, P.D. Jones, S.J. Lambert, M.E. Mann, T.J. Phillips, and K.E. Taylor (2003). "An Overview of Results from the Coupled Model Intercomparison Project," Global and Planetary Change, 769, 1–31.

Giorgi, F. (2005). "Interdecadal variability of regional climate change: implications for the development of regional climate change scenarios," Meteorol Atmos Phys 89, 1–15.

Hamlet, A.F., and D.P. Lettenmaier (1999). "Effects of climate change on hydrology and water resources in the Columbia River Basin." Journal of the American Water Resources Association 35(6):1597–1623.

Intergovernmental Panel on Climate Change (IPCC) (2007). "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change." [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available at http://www.ipcc.ch/ipccreports/ ar4-wg1.htm.LCRA/SAWS 2008.

IPCC (2000). "Special Report on Emissions Scenarios," (Nakicenovic, N. and R. Swart [eds.]). Cambridge University Press, Cambridge, United Kingdom, 599 pp. Available at http://www.grida.no/climate/ipcc/emission/.

Liang, X, D.P. Lettenmaier, E.F. Wood, and S.J. Burges (1994). "A simple hydrologically based model of land surface water and energy fluxes for general circulation models," Journal of Geophysical Research, 99(D7), 14415–14428.

Maurer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy (2007). "Fine-resolution climate projections enhance regional climate change impact studies," Eos Trans. AGU, 88(47), 504.

Maurer, E.P. (2007). "Uncertainty in hydrologic impacts of climate change in the Sierra Nevada, California under two emissions scenarios," Climatic Change, 82, 309–325.

Maurer, E.P. and P.B. Duffy (2005). "Uncertainty in projections of streamflow changes due to climate change in California." Geophysical Research Letters DOI 10.1029/2004GL021462.

Maurer, E.P., A.W. Wood, J.C. Adam, D.P. Lettenmaier, and B. Nijssen (2002). "A Long-Term Hydrologically-Based Data Set of Land Surface Fluxes and States for the Conterminous United States," Journal of Climate 15(22), 3237–3251.

Meehl, G.A., George J. Boer, Curt Covey, Mojib Latif, and Ronald J. Stouffer (2000). "The Coupled Model Intercomparison Project (CMIP)," Bulletin of the American Meteorological Society, 81(2), 313–318.

Meehl, G.A. C. Covey, T. Delworth, M. Latif, B. Mcavaney, J.F.B. Mitchell, R.J. Stouffer, and K.E. Taylor (2007). "THE WCRP CMIP3 MULTIMODEL DATASET – A New Era in Climate Change Research," Bulletin of the American Meteorological Society, 88(9), 1383–1394.

Miller, N.L., K. Bashford, and E. Strem (2003). "Potential Climate Change Impacts on California Hydrology," Journal of the American Water Resources Association, 39, 771–784.

Payne, J.T., A.W. Wood, A.F. Hamlet, R.N. Palmer, and D.P. Lettenmaier, (2004). "Mitigating the effects of climate change on the water resources of the Columbia River basin," Climatic Change, 62(1-3):233–256.

Reclamation (2008). "Sensitivity of Future CVP/SWP Operations to Potential Climate Change and Associated Sea Level Rise," Appendix R in Biological Assessment on the Continued Long-term Operations of the Central Valley

Project and the State Water Project, prepared by Bureau of Reclamation, U.S. Department of the Interior, August 2008, 134 pp.

Reclamation (2009). "Sensitivity of Future Central Valley Project and State Water Project Operations to Potential Climate Change and Associated Sea Level Rise," attachment to Appendix I in Second Administrative Draft Program EIS/EIR - San Joaquin River Restoration Program, 110 pp.

Salathé, E.P., P.W. Mote, M.W. Wiley (2007). "Review of scenario selection and downscaling methods for the assessment of climate change impacts on hydrology in the United States pacific northwest," International Journal of Climatology, 27: 1611–1621.

U.S. Global Change Research Program (USGCRP) (2009). Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press. 196pp.

Van Rheenen N.T., A.W. Wood, R.N. Palmer, D.P. Lettenmaier (2004). "Potential implications of PCM climate change scenarios for Sacramento-San Joaquin River Basin hydrology and water resources," Climatic Change, 62, 257–281.

Wigley, T.M.L. (2004). "Input Needs for Downscaling of Climate Data," discussion paper prepared for California Energy Commission Public Interest Energy Research Program, Rep 500-04-027.

Wood, A.W., E.P. Maurer, A. Kumar, and D.P. Lettenmaier (2002). Long-range experimental hydrologic forecasting for the Eastern United States, J. Geophysical Research-Atmospheres, 107(D20), 4429, doi:10.1029/2001JD000659.

Wood, A.W., L.R. Leung, V. Sridhar, and D.P. Lettenmaier (2004). "Hydrologic implications of dynamical and statistical approaches to downscaling climate model outputs," Climatic Change, 15, 189–216.

Appendix A
Literature Summary on Hydrologic and Water Resources Impacts in the Great Plains Region

This appendix presents a synthesis of climate change literature relevant to hydrology and water resources impacts in the Bureau of Reclamation's (Reclamation's) Great Plains (GP) Region. The summary is a reprint of information originally issued in Reclamation (2009). Summaries generally are divided in terms of studies focused on historical or projected impacts and studies including projected climate change impacts to environmental resources and ecosystems. At present, there is a greater body of literature concerning historical and projected climate and hydrologic changes relative to literature on environmental resources and ecosystem impacts. There is also a greater body of literature concerning impacts in the mountain headwaters and high plains west of the 100th meridian. This section summarizes findings from recent studies (1997–2007) demonstrating evidence of regional climate change during the 20th century and exploring water resources impacts associated with various climate change scenarios.

A.1 Historical Climate and Hydrology

It appears that all areas of the GP Region have become warmer, and some areas received more winter precipitation during the 20th century. Cayan et al. (2001) reports that Western United States spring temperatures have increased 1.8–5.4 degrees Fahrenheit (°F) (1–3 degrees Celsius [°C] () since the 1970s. Based on data from the United States Historical Climatology Network, temperatures have risen approximately 1.85 °F (1.02 °C) in the northern GP to approximately 0.63 °F (0.35 °C) in the southern GP since 1901. That dataset also reveals an increase in annual precipitation of more than 4 percent (%) in the northern GP and 10% in the southern GP over the same time period. The trend was more consistent in the southern GP. Regonda et al. (2005) reports increased winter precipitation trends during 1950–1999 at many Western U.S. sites, including numerous sites in the western GP Region, but a consistent region-wide trend is not apparent.

Coincident with these trends, the western GP Region also experienced a general decline in spring snowpack, reduced snowfall to winter precipitation ratios, and earlier snowmelt runoff. Reduced snowpack and snowfall ratios are indicated by analyses of 1948–2001 snow water equivalent (SWE) measurements at 173 Western U.S. stations (Knowles et al. 2007). Regonda et al. (2005) reports monthly SWE trends during 1950–1999 and suggests that there were statistically significant declines in monthly SWE over roughly half of the Western U.S. sites evaluated for the period 1970–1998. Among those sites, there was no regional consensus among SWE trends over southern Montana to Colorado; however, the regional consensus over western Montana appeared to be a decrease in monthly SWE

These findings are significant for regional water resources management and reservoir operations because snowpack traditionally has played a central role in determining the seasonality of natural runoff. In many GP Region headwater basins, the precipitation stored as snow during winter accounts for a significant portion of spring and summer inflow to lower elevation reservoirs. The mechanism for how this occurs (with precipitation being equal) is that warmer temperatures in these watersheds cause reduced snowpack development during winter, more runoff during the winter season, and earlier spring peak flows associated with an earlier snowmelt.

Warming-induced increases in thunderstorm activity of the GP region (and most of contiguous United States) (Changnon 2001) has led to an increase in heavy precipitation events since 1900 (Groisman 2004). Further, most of that increase has occurred in the last three decades. Garbrecht et al. (2004) found increasing GP precipitation trends led to large increases in streamflow but lesser increases in evapotranspiration (ET).

A.2 Projected Future Climate and Hydrology

Given observed trends in regional warming and declining snowpack conditions, studies have been conducted to relate potential future climate scenarios to runoff and water resources management impacts. Such studies are particularly relevant to the western GP headwaters and the central to northern High Plains. For the GP Region east of the High Plains, and especially in the southern GP, ET demands and warm-season precipitation play a more prominent role in determining local hydrologic conditions relative to water management and generally more so relative to the influence of headwaters snowpack and snowmelt timing.

The findings of six case studies on the sensitivity of water resources to climate change are reported by Lettenmier et al. (1999). One of the case studies was for the Missouri River system. It found that snow accumulation, while important on the western headwaters of the Missouri system, plays only a modest role in total system runoff, and reduced precipitation combined with increasing potential evapotranspiration play a major role in system runoff reductions.

A study by Hotchkiss et al. (2000) addresses the ability to incorporate complex operation rules for multiple reservoirs into a hydrologic model capable of assessing climate change impacts on water resources of large, completely managed river basins. This study was part of an overall effort to address climate change related impacts within the Missouri River Basin. A soil and water assessment numerical modeling tool was used to simulate surface water hydrology that was successfully calibrated to historical conditions; however, its snowmelt component was problematic, thus limiting useful results.

Loáiciga et al. (2000) identified potential impacts of climate change scenarios on management of the Edwards Aquifer system in western Texas. The study reports that the Edwards Aquifer appears to be very vulnerable to warming trends based on current levels of extraction and projected future pumping rates.

Elgaali et al. (2007) and Ojima et al. (1999) report potential climate change impacts on water resources and demands in the GP Region. Changes in agricultural water demands were evaluated based on climate change scenarios using crop consumptive use methods. Both studies project future increases in crop water consumptive use ranging from 20–60% by the end of the 21st century.

Rosenberg et al. (1999) reports impacts on surface water runoff and associated water supplies in the Ogallala Aquifer region under several climate change scenarios, including how changes in atmospheric carbon dioxide impact photosynthesis and ET. Water yield in the Arkansas-White-Red River Basin decreased under all scenarios.

Switching consideration to flood risk management, Lettenmier et al. (1999) reported improved flood control conditions for the Missouri River system under certain climate change scenarios where flood risk is driven by monthly to seasonal phenomena rather than storm or storm pattern phenomena. Hamlet and Lettenmaier (2007) report that simulations suggest that warming over the 20th century has resulted in changes in flood risks in many parts of the Western United States that are broadly characterized by midwinter temperatures and that colder, snowmelt basins typically show reductions in flood risks because of snowpack reductions. In any case, consideration of these results should be complemented by the understanding that many flood risk management situations in the GP Region are driven by potential for local, convective precipitation events. There are still many uncertainties associated with interpreting projected trends in local, convective precipitation potential based on results from current climate models.

A.3 Studies of Impacts on Environmental Resources

Johnson et al. (2005) used a wetland simulation model to predict significant climate change impacts to the northern pothole prairie region. The findings indicate that the most productive habitat for breeding waterfowl would shift to the eastern part of the region under warmer and drier conditions. Conly and Garth van der Kamp (2001) reported wetland and associated wildlife impacts related to climate and land use changes. Wetland water level data were coupled with meteorological data in a numerical model to simulate water level changes resulting from climate change. Poiani and Johnson (1993) also used a numerical model to simulate wetland hydrology and vegetation impacts due to climate change.

Covich et al. (1997) summarizes available information on patterns of spatial climate variability and identifies subregions of importance to ecological processes within the Great Plains. Climate sensitive areas of the Great Plains range from cold-water systems (springs, and spring fed streams) to warmer, temporary systems (intermittent streams, ponds, pothole wetlands, playas).

A.4 References

Cayan, D.R., S.A. Kammerdiener, M.D. Dettinger, J.M. Caprio, and D.H. Peterson. 2001. “Changes in the Onset of Spring in the Western United States.” Bulletin of the American Meteorology Society 82(3): 399–415.

Changnon, S.A. 2001. “Thunderstorm rainfall in the conterminous United States.” Bulletin of the American Meteorology Society, 82, 1925–1940.

Conly, F.M., and G. van der Kamp. 2001. “Monitoring the Hydrology of Canadian Prairie Wetlands to Detect the Effects of Climate Change and Land Use Changes.” Environmental Monitoring and Assessment 67 (1, 2): 195–215.

Covich, A.P., S.C. Fritz, P.J. Lamb, R.D. Marzolf, W.J. Matthews, K.A. Poiani, E.E. Prepas, M.B. Richman, T.C. Winter. 1997. “Potential Effects of Climate Change on Aquatic Ecosystems of the Great Plains of North America.” Hydrological Processes 11(8):993–1021.

Elgaali, E., L A. Garcia, and D.S. Ojima. 2007. “High resolution modeling of the regional impacts of climate change on irrigation water demand.” Climatic Change, Volume 84, Numbers 3–4.

Garbrecht, J.D., M. Van Liew, and G.O. Brown. 2004. “Trends in Precipitation, Streamflow, and Evapotranspiration in the Great Plains of the United States.” Journal of Hydrologic Engineering, 9(5):360–367.

Groisman, P.Y., R.W. Knight, T.R. Karl, D.R. Easterling, B. Sun, and J.H. Lawrimore. 2004. “Contemporary Changes of the Hydrological Cycle over the Contiguous United States: Trends Derived from in situ Observations." Journal of Hydrometeorololgy 5, 64–85, 2004.

Hamlet, A.F., and D.P. Lettenmaier. 2007. "Effects of 20th century warming and climate variability on flood risk in the Western United States." Water Resources Research 43, W06427, doi:10.1029/2006WR005099.

Hotchkiss R.H., S.F. Jorgensen, M.C. Stone, T.A. Fontaine. 2000. "Regulated River Modeling for Climate Change Impact Assessment: The Missouri River." Journal of the American Water Resources Association 36 (2): 375–386.

Johnson, C.W., B.V. Millet, T. Gilmanov, R.A. Voldseth, G.R. Guntenspergen, and D.E. Naugle. 2005. "Vulnerability of Northern Prairie Wetlands to Climate Change." BioScience, October 2005/Vol. 55 No. 10:863–872.

Knowles, N., M. Dettinger, and D. Cayan. 2007. Trends in Snowfall Versus Rainfall for the Western United States, 1949–2001. Prepared for California Energy Commission Public Interest Energy Research Program, Project Report CEC-500-2007-032.

Lettenmaier, D.P., A.W. Wood, R.N. Palmer, E.F. Wood, and E.Z. Stakhiv. 1999. "Water Resources Implications of Global Warming: A U.S. Regional Perspective." Climatic Change 43(3): 537–79.

Loáiciga, H.A., D.R. Maidment, and J B. Valdes. 2000. "Climate-change impacts in a regional karst aquifer," Texas. Journal of Hydrology, (227): 173–194.

Ojima D., L. Garcia, E. Elgaali, K. Miller, T.G.F. Kittel, J. Lackett. 1999. "Potential Climate Change Impacts on Water Resources in the Great Plains." Journal of the American Water Resources Association 35 (6): 1443–1454.

Poiani, K.A., and W.C. Johnson. 1993. "Potential Effects of Climate Change on a Semi-Permanent Prairie Wetland." Climatic Change 24: 213–232.

Reclamation. 2009d. "Literature Synthesis on Climate Change Implications for Reclamation's Water Resources," Technical Memorandum 86-68210-091, September 2009, 290 pp.

Regonda, S.K., B. Rajagopalan, M. Clark, and J. Pitlick. 2005. "Seasonal Cycle Shifts in Hydroclimatology Over the Western United States." Journal of Climate 18(2): 372–384.

Rosenberg, N.J., D.J. Epstein, D. Wang, L. Vail, R. Srinivasan, and J.G. Arnold. 1999. "Possible Impacts of Global Warming on the Hydrology of the Ogallala Aquifer Region." Climatic Change 42(4): 677–692.