

**Placer County Water Agency
Middle Fork American River Project
(FERC No. 2079)**

FINAL

**AQ 8 – RESERVOIR FISH HABITAT
TECHNICAL STUDY REPORT – 2011**



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1.0 INTRODUCTION

This report describes the AQ 8 – Reservoir Fish Habitat study conducted by the Placer County Water Agency (PCWA) in accordance with the AQ 8 – Reservoir Fish Habitat Technical Study Plan (AQ 8 – TSP). The AQ 8 – TSP was included in the Supporting Document (SD) H of the Pre-Application Document (PAD) for the Middle Fork American River Project (MFP or Project) (PCWA 2007a).

The purpose of the study is to characterize the effects of historic and future Project operations on reservoir fish habitat (reservoir elevation/volume and suitable water temperature/dissolved oxygen). Future operations analyzed in this report are based on Proposed Action included in PCWA's Application for New License (License Application [PCWA 2011a]). Results from three study elements could change if the Proposed Action in the License Application is modified. If this occurs, then the affected study elements will be discussed in consultation with the MFP Plenary during development of the PM&Es and appropriate supplemental data will be provided to the group, if necessary. The study elements that could potentially change if there are modifications to the Proposed Action include the following:

- Daily water surface elevation patterns and pool volumes for each reservoir under future Project operations.
- Hourly water surface elevations and pool volumes for Ralston Afterbay under future Project operations.
- Water temperature and dissolved oxygen for each reservoir under future Project operations.

The draft report was distributed to the MFP Plenary on December 15, 2010 for a 30-day comment period. The comment period ended on January 15, 2011, with no comments received.

The following sections provide a detailed description of the study objectives, study implementation, extent of the study area, study approach, study results, and literature cited.

2.0 STUDY OBJECTIVES

The objective of the reservoir fish habitat study is to:

- Characterize the management of reservoir water surface elevations and its relationship to availability of fish habitat under historic and future Project operations including consideration of potential Project improvements¹ (betterments)

¹ For the License Application the term "betterment" was replaced with the term "improvement," which is used in this document.

Figure AQ 8-1 shows the AQ 8 – TSP study objectives and the study elements associated with the objective. It also shows where information developed is documented.

3.0 STUDY IMPLEMENTATION

Study elements described in the AQ 8 – TSP (PCWA 2007a) were completed in 2009 and 2010. A summary of the study elements that have been completed, outstanding study elements, and any deviations or proposed modifications to the AQ 8 – TSP are discussed in the following subsections.

3.1. STUDY ELEMENTS COMPLETED

The following study elements were completed:

- Summarized current fish species assemblage data, stocking records, and fishing success for Project reservoirs. Detailed information is available in the AQ 2 – Fish Population Technical Study Report (AQ 2 – TSR) (PCWA 2011b) and the REC 2 – Recreation Visitors Surveys Technical Study Report (REC 2 – TSR) (PCWA 2011c).
- Characterized historic daily water surface elevation patterns and pool volumes from 1975–2007 at each reservoir using available water surface elevation gage records.
- Characterized the future daily water surface elevation patterns and pool volumes of each reservoir associated with the Proposed Action (which includes the potential Hell Hole Reservoir Seasonal Storage Increase Project improvement) using the Project Operations Model (PCWA 2011a).
- Characterized historic hourly water surface elevation patterns and pool volumes at Ralston Afterbay when peaking operations were occurring using data collected March 2007–June 2010 (note: historic hourly water elevation data prior to March 2007 was not available).
- Characterized the future hourly water surface elevation patterns and pool volumes at Ralston Afterbay associated with the Proposed Action (which includes the potential Hell Hole Reservoir Seasonal Storage Increase Project improvement).
- Summarized water temperature and dissolved oxygen profile data for each Project reservoir under existing operations and qualitatively estimated effects of the Proposed Action (which includes the potential Hell Hole Reservoir Seasonal Storage Increase Project improvement) on water temperature and dissolved oxygen.
- Summarized the characteristics (volume, depth, surface area) of the Existing FERC Minimum Pools and the Proposed Action Minimum Pools at French Meadows and Hell Hole Reservoirs.

3.2. DEVIATIONS FROM TECHNICAL STUDY PLAN

There was one deviation from the AQ 8 – TSP. The AQ 8 – TSP included a component to characterize the effects of future Project operations with the potential Hell Hole Seasonal Storage Increase improvement on reservoir elevations/volumes and water quality (temperature and dissolved oxygen). However, the TSP did not specify the objective of the comparison or how the comparison would be conducted, nor did the TSP define the baseline (reference) condition. Therefore, in this analysis, future operations of the MFP were evaluated in the context of the new license conditions outlined in PCWA's Proposed Action included in PCWA's License Application (PCWA 2011a). Future operations of the MFP included incorporation of the Hell Hole Reservoir Seasonal Storage Increase improvement (the only improvement under consideration by PCWA in the new license).

3.3. OUTSTANDING STUDY ELEMENTS

There are no outstanding study elements.

3.4. PROPOSED MODIFICATION TO TECHNICAL STUDY PLAN

There are no proposed modifications to the AQ 8 – TSP.

4.0 EXTENT OF STUDY AREA

The study area includes the Project reservoirs, including French Meadows Reservoir, Hell Hole Reservoir, Middle Fork Interbay, and Ralston Afterbay (Map AQ 8-1).

5.0 STUDY APPROACH

The study approach contains the methods used to describe: (1) reservoir fish species assemblages, stocking, and fishing success; (2) water surface elevation and storage volume patterns; (3) reservoir water temperature and dissolved oxygen; and (4) minimum pool habitat characteristics.

5.1. FISH SPECIES ASSEMBLAGES, STOCKING, AND FISHING SUCCESS

5.1.1. Fish Species Assemblages

Fish populations were sampled in 2007 and 2008 at the four reservoirs for the AQ 2 – TSR (PCWA 2011b). Specific methods used to sample the fish populations are described in the AQ 2 – TSR (PCWA 2011b). The data for each reservoir are summarized in this report to characterize the current fish species assemblage present.

5.1.2. Stocking

Historical fish stocking records were obtained from California Department of Fish and Game (CDFG) Region II files for the development of the PAD (Supporting Document SD F, Section 6.0 Fish and Aquatic Resources (PCWA 2007a) (Appendix A). The

information presented in the PAD was reviewed and updated to include recent stocking records through 2009. The stocking data are summarized in this report.

5.1.3. Fishing Success

Fishing success was determined from the results of angler surveys completed for the REC 2 – TSR (General Visitor Surveys – Form A) in the summer of 2008 (PCWA 2011c). The locations for the recreation surveys and survey questions were developed in consultation with the Recreation Technical Working Group (TWG) (REC 2 – TSR (PCWA 2011c) for survey details). For these surveys, people intercepted at Hell Hole and/or French Meadows reservoirs and Ralston Afterbay that identified fishing as their primary activity were asked questions that pertained specifically to fishing (e.g., angler effort, success, preferences, and satisfaction). Survey responses were used to estimate catch per unit effort (CPUE) as a measure for fishing success. Angler surveys were not conducted at Middle Fork Interbay because of very limited recreation use.

5.2. WATER SURFACE ELEVATION AND STORAGE VOLUME PATTERNS

Reservoir water surface elevations and pool volumes were characterized for historic reservoir operations and future reservoir operations (based on the Project operations model results). The water surface elevations were converted to pool volumes using existing reservoir elevation-storage relationships.

5.2.1. Historic Reservoir Elevations and Volumes

Average daily reservoir operations were characterized for all of the reservoirs and hourly operations were characterized for Ralston Afterbay.

Average Daily Operations

Historic 1975–2007 average daily water surface elevations and pool volumes at French Meadows Reservoir, Hell Hole Reservoir, Middle Fork Interbay, and Ralston Afterbay were characterized by plotting the existing gaging data. Data for French Meadows and Hell Hole Reservoir were obtained from the USGS gages (Gage No. 11427400 and 11428700, respectively). Data for Middle Fork Interbay (USGS Gage No. 11427766) and Ralston Afterbay (USGS Gage No. 114233210) were obtained from PCWA records.

Minimum pool volumes are specified in the existing FERC License for French Meadows and Hell Hole reservoirs. The minimum pools and water year types in the existing FERC License are shown in Table AQ 8-1a. The water surface elevations and pool volumes for French Meadows and Hell Hole reservoirs were plotted with the existing FERC minimum pools and year types (wet, normal, dry) established in the original FERC license (based on the April Bulletin 120 Folsom Reservoir unimpaired inflow forecast).

Hourly Operations at Ralston Afterbay

Hourly water surface elevation data for Ralston Afterbay were available from 21 March 2007 to 8 June 2010 (some missing data exist during this time period). The data were compiled and plotted to describe within-day patterns in water surface elevations and pool volumes. The data were collected specifically for this technical study by installing a gage at Ralston Afterbay. The water surface elevation gage (pressure transducer) was installed in March 2007. The gage is mounted in one of the wells in Ralston Afterbay Dam and collects data at an hourly interval. Data were downloaded manually approximately once every one to two months.

5.2.2. Future Reservoir Elevations and Volumes

Future Project operations were analyzed in this report based on Proposed Action included in PCWA's License Application (PCWA 2011a). The Proposed Action includes the Hell Hole Reservoir Seasonal Storage Increase improvement. Estimates of the water surface elevations and pool volumes at French Meadows and Hell Hole reservoirs were developed using the Project Operations Model (Appendix C3, PCWA 2011a). The Proposed Action was modeled over the 1975–2007 period of record. Details of the Proposed Action modeling approach are provided in (Appendix B).

Average Daily Operations

Average daily water surface elevation plots from the Proposed Action were compared to the historic operations. The minimum pool elevations in the Proposed Action (Table AQ 8-1b) were included on the plots. In addition, a table showing the average change in water depth and volume at the two reservoirs as a result of the Proposed Action was developed.

Daily water surface elevations at Middle Fork Interbay and Ralston Afterbay were discussed qualitatively in comparison to historic operations. These reservoirs are not operated for storage; therefore, daily operations will not change with future operations. Further, Middle Fork Interbay elevation is kept relatively constant during normal operations of the MFP (the exception is during the maintenance outage when the reservoir is lowered or when it is lowered to manage high winter/spring inflow events). Hourly water surface elevations at Ralston Afterbay were obtained from the Operations Model (see below).

Hourly Operations at Ralston Afterbay

Future hourly operations of Ralston Afterbay were compared to historic hourly operations by discussing how the reservoir is operated and by using an example of the Proposed Project modeled operations compared to historic operations (August 1–31, 2007).

5.3. RESERVOIR WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen in the reservoirs were characterized: (1) for historic conditions (2005–2008); and (2) for future conditions as a result of implementing the Proposed Action in French Meadows and Hell Hole reservoirs only.

The following temperature and dissolved oxygen levels were assumed to provide aquatic habitat for coldwater species (salmonids):

- Approximately 68°F (20°C) or less is reported to be suitable for coldwater species growth (Hokanson et al. 1975; USEPA 1986; Bjornn and Reiser 1991) and 75°F (24°C) or less is reported as a short-term critical maximum temperature (USEPA 1986; Bjornn and Reiser 1991). Temperatures that support growth of hardhead and other cyprinids can be higher. The preferred temperature of hardhead reportedly is several degrees higher than rainbow trout and when given the opportunity they avoid temperature less than about 62°F (Klimley et al. 2010).
- Minimum dissolved oxygen concentrations of 5 mg/l or more (USEPA 1986; Bjornn and Reiser 1991) are reported to maintain suitable coldwater habitat and 7 mg/l or greater provide optimum habitat conditions (Basin Plan Objective [CVRWQCB 2007]). For hardhead and other cyprinids and catostomids 5 mg/l or greater is assumed to be optimal.

5.3.1. Historic Conditions

Water temperature and dissolved oxygen profiles measured in Hell Hole Reservoir, French Meadows Reservoir, and Ralston Afterbay between 2005 and 2008 (Table AQ 8-2; Appendix C, Maps C-1, C-2, and C-3) were graphed for each month and compared to identify the shapes of the profiles, depths of the thermoclines, and ranges of temperatures and dissolved oxygen measured. Sampling at the reservoirs was typically conducted once a month from either June or July through October. At Middle Fork Interbay, the temperature and dissolved oxygen into and out of the reservoir was sampled. Middle Fork Interbay is small (water residence time is a matter of hours) and remains completely mixed; therefore, the temperature and dissolved oxygen in the outflow from the reservoir represents the conditions in reservoir.

The temperature and dissolved oxygen data summarized in this report were previously reported in other reports, including the 2005 and 2006 Water Temperature Study Reports (PCWA 2006a and PCWA 2007b), AQ 4 – Water Temperature Modeling TSR (AQ 4 – TSR) (PCWA 2011d), and AQ 11 – Water Quality TSR – 2008 (AQ 11 – TSR) (PCWA 2011e). These reports also included some data collected in French Meadows and Hell Hole reservoirs in 2004. The sampling protocols used and locations of the profile sampling sites are described in detail in each of the reports.

In addition to the temperature profile data at Ralston Afterbay, water temperatures were continuously monitored from July 10–October 1, 2006 at six locations distributed longitudinally within Ralston Afterbay (Map C-3). Each logger was installed at approximately 1 meter depth (PCWA 2007c). The goal of this continuous monitoring

was to characterize the longitudinal temperature profile within Ralston Afterbay. Sampling protocols and monitoring site selection rationale are reported in the Ralston Afterbay Reconnaissance-Level Hardhead Water Temperature Suitability Investigation Study Plan (PCWA 2006b) and the 2006 Ralston Afterbay Water Temperature Investigation Study Report (PCWA 2007c). Water temperature profiles were also collected at these monitoring locations three times in summer and fall 2006 (Table AQ 8-2).

5.3.2. Future Operations

The potential changes in water quality in French Meadows Reservoir and Hell Hole reservoirs as a result of the implementation of the Proposed Action were evaluated qualitatively. Because the water surface elevation changes were relatively small compared to historical reservoir elevations, the potential effects to temperature and dissolved oxygen in the reservoirs were small and assessed qualitatively using the existing temperature and dissolved oxygen data as a reference point.

5.4. MINIMUM POOL HABITAT CHARACTERISTICS

An analysis of the reservoir minimum pools was developed to characterize the availability of the fish habitat related to operations of the Project reservoirs under the existing and future operations of the MFP. The reservoir characteristics (Table AQ 8-3) and existing FERC License and future (Proposed Action) minimum pools were used in the analysis for French Meadows and Hell Hole reservoirs (Table AQ 8-1a, b). At Ralston Afterbay and Middle Fork Interbay there are no FERC minimum pool requirements. These reservoirs must be lowered for annual maintenance and inspection each year and periodically they are lowered to the inactive pool level to facilitate the removal of sediment. Typical operations were characterized for Middle Fork Interbay and Ralston Afterbay.

Reservoir characteristics for the existing FERC License and Proposed Action minimum pools, by water year type, were developed for French Meadows and Hell Hole reservoirs based on the September/October through May minimum pool levels. The characterization included percent of total pool volume, maximum minimum pool depth, average minimum pool depth, minimum pool surface area, approximate reservoir inflow during late summer, and refill rates.

6.0 STUDY RESULTS

6.1. RESERVOIR FISH SPECIES ASSEMBLAGES, STOCKING, AND FISHING SUCCESS

6.1.1. Fish Species Assemblages

All of the MFP reservoirs contained rainbow and brown trout (Tables AQ 8-4 and AQ 8-5). Hell Hole Reservoir had the greatest species diversity with four additional species (six total), including lake trout, kokanee salmon, Tui chub, and Sacramento sucker. French Meadows Reservoir had two additional species (four total), Tui chub and

kokanee salmon (only one individual was captured²). Ralston Afterbay contained hardhead (a sensitive³ species), Sacramento pikeminnow, and Sacramento sucker, in addition to rainbow and brown trout. Only rainbow and brown trout were present in Middle Fork Interbay.

The catch rates of salmonids in each of the reservoirs were similar (Figure AQ 8-2; Table AQ 8-5). Ralston Afterbay and Hell Hole Reservoir both had large catch rates of Sacramento Sucker. Details regarding the reservoir fish populations and gillnet sampling results can be found in the AQ 2 – TSR (PCWA 2011b).

6.1.2. Stocking

Historical stocking records for each reservoir (construction completed in approximately 1967) are summarized below.

French Meadows Reservoir

Fish stocking records for the Middle Fork American River around and upstream of the present day French Meadows Reservoir date back to the 1930s, and indicate that brown trout, rainbow trout, brook trout, and steelhead all were planted in the river. French Meadows Reservoir stocking records were obtained for 1968 to 1971 and 2001 to 2009 (Appendix A); although, it is likely that French Meadows Reservoir has been stocked annually since the completion of French Meadows Dam. During the last nine years, primarily rainbow trout have been stocked at an average of 10,517 catchables/year (2001–2009) (Appendix A).

Hell Hole Reservoir

Hell Hole Reservoir has been stocked extensively in the past with a variety of salmonid species, including rainbow trout (including Eagle Lake strain), brown trout, brook trout, cutthroat trout (and cutthroat-rainbow hybrids), lake trout, kokanee, and Coho salmon. Recent management includes the stocking of brown trout and kokanee (Appendix A). Between 2001 and 2009, an average of 24,566 kokanee fingerlings/year and 5,542 brown trout catchables/year were stocked. Lake trout that were originally stocked in the 1970s apparently are self-sustaining in Hell Hole Reservoir and were captured during gill net surveys and present in angler surveys (PCWA 2011b).

Middle Fork Interbay

No fish stocking records were located for Middle Fork Interbay. Fish stocking records indicate that the Middle Fork American River (in general) was stocked almost annually from 1926–1953 with rainbow trout (Appendix A). The number of rainbow trout stocked was as high as 60,000. Between 20,000 and 90,000 brown trout were stocked for 9 out of 10 years from 1930–1939. Brook trout and steelhead also were stocked on one

² Kokanee are not stocked in French Meadows Reservoir. The one fish captured appears to be an anomaly.

³ Hardhead are a USDA Forest Service sensitive species and a California Department of Fish and Game species of special concern

occasion each. Fish are not currently stocked and more recent stocking records for the Middle Fork American River were not located.

Ralston Afterbay

No fish stocking records were located for Ralston Afterbay; although, the fish population likely reflects stocking that has occurred in the Middle Fork American and Rubicon rivers upstream of Ralston Afterbay. Records obtained for the Rubicon River indicated that it was extensively stocked from 1928 through 1953 (Appendix A). Predominantly rainbow trout and brown trout were stocked, although brook trout and steelhead also were stocked. Post-1953 Rubicon River stocking records were not located and, under its current designation as a Wild Trout Stream, the Rubicon River is not stocked with trout (PCWA 2007a).

6.1.3. Fishing Success

Angler fishing success at Hell Hole Reservoir, French Meadows Reservoir, and Ralston Afterbay is provided in Table AQ 8-6. The CPUE for all species combined was 0.6 fish/hour at Hell Hole Reservoir and Ralston Afterbay, and 0.5 fish/hour at French Meadows Reservoir (PCWA 2011c). Refer to REC 2 – TSR for additional information on the angler survey results at the reservoirs (PCWA 2011c).

6.2. WATER SURFACE ELEVATION AND STORAGE VOLUME PATTERNS

Historic and future reservoir elevations and volumes are summarized below.

6.2.1. Historic Reservoir Elevations and Volumes

Average Daily Operations

Average daily reservoir water surface elevations and volumes results are discussed separately for the large reservoirs (French Meadows and Hell Hole reservoirs) and the medium reservoirs (Middle Fork Interbay and Ralston Afterbay).

Large Reservoirs

French Meadows has a maximum active storage of 127,358 ac-ft (1,408 surface acres) and a maximum depth of 214 ft (maximum operating elevation to bottom of dead pool). Hell Hole Reservoir has a maximum active storage of 205,057 ac-ft (1,253 surface acres) and a maximum depth of about 378 ft (maximum operating elevation to bottom of dead pool). Both reservoirs are operated to store and release water for water supply and power generation purposes.

French Meadows and Hell Hole reservoirs are operated partly as a large combined storage facility. Water is transported into Hell Hole Reservoir through the French Meadows – Hell Hole Tunnel/French Meadows Powerhouse. The balance of total storage in the two reservoirs can be adjusted based the amount of water transported

from French Meadows Reservoir to Hell Hole Reservoir and by the amount of water released from Hell Hole Reservoir for power production/water supply.

Figures AQ 8-3 and AQ 8-4 show daily elevations and volumes in the two reservoirs from 1975–2007. The lowest storage occurs during the fall/winter of the driest years and/or series of driest years (e.g., 1976–1977, 1990–1992, 2001). Typically in the driest years, French Meadows Reservoir stayed above about 5,180 ft and Hell Hole Reservoir above about 4,480 ft, both well above the existing FERC minimum pool levels (Figures AQ 8-5 and AQ 8-6). The lowest combined storage was about 70,400 ac-ft (December–January, 1991–1992).

The lowest reservoir elevations (and storage) occurred in December–February and the highest elevations (and storage) occurred in June–early July (Figures AQ 8-7a, b and AQ 8-8a–b). This seasonal pattern represents the typical winter/spring refill and summer/fall evacuation cycle of the reservoirs. The low elevation period occurs during the coldest months and is relatively short lived with reservoir refill occurring typically in March–May. The driest years have both the lowest December–February carryover storage and the lowest June–early July refill storage.

Medium Reservoirs

Middle Fork Interbay and Ralston Afterbay do not have seasonal fill and release patterns like Hell Hole or French Meadows reservoirs (Figures AQ 8-9 and AQ 8-10); they are operated as afterbays and forebays to Project powerhouses. Water surface elevations and pool volumes in Middle Fork Interbay are, in general, fairly constant throughout most of the year, ranging from about 2,524 to 2,528 feet elevation. Under typical operations, water discharged into Middle Fork Interbay through Middle Fork Powerhouse is directly diverted to Ralston Powerhouse, which results in no net changes to the reservoir elevation. Ralston Afterbay water surface elevations are more variable because water discharged into Ralston Afterbay through Ralston Powerhouse is often de-coupled from water diverted through Oxbow Powerhouse. This decoupling results in reservoir elevations that fluctuate on an hourly and daily basis. Water surface elevations typically range from about 1,169 to 1,175 ft elevation. During the fall, both reservoirs are drawn down at least to the level of the bottom of the spill gates for annual maintenance and inspection (Middle Fork Interbay = 2,510 ft; Ralston Afterbay = 1,149 ft) (Table AQ 8-3). Periodically the reservoirs are lowered farther for sediment removal/maintenance. Middle Fork Interbay, for example is lowered for sediment removal on the average of every 5.8 years and sediment removal occurs at Ralston Afterbay an average of every 4.6 years (PCWA 2011a, Table 7.7-11).

Hourly Operations at Ralston Afterbay

The Ralston Afterbay water surface elevation fluctuates daily (Figure AQ 8-11a and AQ 1-11b) because of peaking inflows from Ralston Powerhouse (e.g., 924 cfs). In addition, Oxbow Powerhouse outflow (maximum outflow of about 1,025 cfs) is often run asynchronously to Ralston Powerhouse inflows during the summer to meet recreational boating releases (Oxbow Powerhouse releases often start earlier than Ralston

Powerhouse releases). Ralston Afterbay is relatively small (1,804 acre ft active storage) and has relatively narrow elevation operating band (e.g., about 400–700 acre ft). Elevations fluctuated between about 1,167 and 1,177 ft (about 700 acre ft) during the March 2007 to June 2010 period (ignoring the seasonal maintenance outages). The upper elevation is near the top of the reservoir (top of spill gates is 1,179 ft) and the lower elevation is at a safe and reliable operating elevation for the Oxbow Powerhouse intake (e.g., vortex formation could occur if the reservoir was lowered too low). Some examples of daily fluctuations are shown in Figure AQ 8-11b. A narrower, more conservative operating band (1,169 to 1,175 ft) is often used at Ralston Afterbay (about 400+ acre ft) because it meets typical daily operations needs and avoids potential issues associated with vortex formation and sediment mobilization/turbidity.

6.2.2. Future Reservoir Elevations and Volumes

Average Daily Operations

The Proposed Action section in PCWA's License Application (PCWA 2011a) includes increased instream flows, modified minimum pool requirements, and the Hell Hole Seasonal Storage Increase improvement. The improvement increases the total storage of Hell Hole Reservoir by 6 ft or 7,600 ac-ft. The potential improvement would affect how water is stored/balanced in both French Meadows and Hell Hole reservoirs. However, the affect on reservoir water surface elevations and depth are relatively small. The 1975–2007 modeled reservoir traces for the modeled Proposed Action and historic conditions (No Action) are shown in Appendix B along with the historic reservoir elevations.

The model results of the Proposed Action show limited overall change to elevations and volume in the two reservoirs as compared to historic (No Action) conditions. In most water year types the lowest and highest water surface elevations are similar. The only exception is for the Proposed Action - Future Demand model run which is an estimate of how the Project would operate at build-out consumptive water demand. In that case (Proposed Action - Future Demand), water levels are lower in critical and extreme critical water year types than historic (No Action) water levels.

Table AQ 8-7 shows that during the summer/early fall season when the Proposed Action would affect elevations, the percent differences in depth and volume are relatively small compared to the historic (No Action) alternative (maximum average monthly changes of -6% to 4%). Depending on the water balance between French Meadows and Hell Hole reservoirs, the overall differences could be smaller.

Under the future Proposed Project, the Hell Hole Reservoir Seasonal Storage Increase improvement would be effective in 14 years of the 33 year period of record. However, only about 10 of those years are significant. Four of the years, the improvement only increases water surface elevations about 1.5 feet or less and only for a few days. On average during each of the 14 years when additional water would be temporarily stored in Hell Hole Reservoir, the water surface elevation in Hell Hole Reservoir would be above the historic reservoir maximum elevation for 31 days.

Future daily average water surface elevations at Middle Fork Interbay and Ralston Afterbay would not change compared to historic water surface elevations. The two reservoirs would continue to be operated as they are now. Each year the reservoirs would be drawn down to at least the level of the bottom of the spill gates for maintenance and inspection. They would also continue to be drawn down periodically for sediment management.

Hourly Operations at Ralston Afterbay

Under the Proposed Action, Ralston Afterbay would operate very similar to historic operations (Figure AQ 8-11a, b). Generally, the reservoir operates in a maximum elevation band from about 1,167 and 1,177 ft (daily fluctuations), when the powerhouses are operating. Typically, the daily operations are between a narrower band of about 1,169 and 1,175 ft. The Operations Model is constrained to operate between this narrower elevation band as it provides a safety buffer that would minimize the chance of a spill at the top of the reservoir gates or vortex formation at the Oxbow Powerhouse intake (below 1,167 ft). Figure AQ 8-11b shows an example of the Proposed Action Operations model hourly output. In this example, the model has smaller daily fluctuations than historical; however, it would best to assume future operations would be similar to historical because the model is a simplistic approximation of complex real-time decision-making.

6.3. RESERVOIR WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen data collected in the large reservoirs (French Meadows Reservoir, Hell Hole Reservoir) and in the medium reservoirs (Ralston Afterbay, Middle Fork Interbay) during 2005–2008 are summarized below in the historic conditions section. Maps of the sampling locations and figures showing the water temperature and dissolved oxygen profiles are provided in Appendix C. A qualitative assessment of the effects of the Proposed Action (including the Hell Hole Reservoir Seasonal Storage Increase improvement) on temperature and dissolved oxygen is provided in the future operations section.

6.3.1. Historic Conditions

Large Reservoirs

In French Meadows and Hell Hole reservoirs, reservoir temperature and dissolved oxygen profile sampling was conducted at three locations in each reservoir (Appendix C, Maps C-1 and C-2). In general, a site was selected near the dam, near the middle of the reservoir, and at the upstream end of the reservoir. The reservoir profile measurements generally included water temperature and dissolved oxygen at 1-meter (m) depth intervals throughout the depth of the reservoir. The following summarizes the reservoir temperature and dissolved oxygen profile data.

French Meadows Reservoir

A summary of temperature and dissolved oxygen profiles plotted at the sampling site near the dam is shown in Figure AQ 8-12. The French Meadows Reservoir temperature profile data from June–October at each of the individual sampling locations and sampling dates are provided in Appendix C, Figures C-1 to C-3. The dissolved oxygen profiles are in Figures C-4 to C-5.

Temperature in the reservoir ranged from about 42°F in the hypolimnion to about 72°F at the water surface. The majority of the water column in all samples provided coldwater for fish growth and surface temperature never approached critical maximum temperatures. The hypolimnion temperatures were very similar for all months and years sampled (42–47°F). The surface water temperature ranged from 54–72°F. Surface temperatures were coolest in June and October (e.g., 54°F to 60°F), and were warmest in July and August (greater than 66°F). The depth of the thermoclines ranged from about 20 to 75 feet deep. The depth of the thermocline was shallowest in June and July and became progressively deeper from August through October.

During the 2005–2008 sampling period, dissolved oxygen was typically greater than 5–6 mg/l (protective of coldwater salmonid species [USEPA 1986; Bjornn and Reiser 1991]) throughout the water column. There was generally always large amounts of the water column either in the epilimnion or hypolimnion with dissolved oxygen 7 mg/l or greater (Basin Plan objective [CVRWQCB 2007]), and in all but one sampling, the majority of the hypolimnion dissolved oxygen was 5 mg/l or greater.

Dissolved oxygen concentration typically reflected the temperature differences in the epilimnion and hypolimnion (less dissolved oxygen in the warmer water). In the hypolimnion, the dissolved oxygen concentration was typically the same throughout the depth of the hypolimnion and there was little depletion of the dissolved oxygen even into the fall. However, during October 2008 sampling, hypolimnetic dissolved oxygen levels were low relative to the other years sampled. The October 2008 dissolved oxygen profile exhibited concentrations in the hypolimnion ranging from just under 5 mg/l near the metalimnion to 3 mg/l at the reservoir bottom (Figure C-4). The proximate cause of the low dissolved oxygen level is unknown. Periodically very low dissolved oxygen levels were observed very near the water-sediment interface (Figure AQ 8-12).

Hell Hole Reservoir

A summary of the temperature and dissolved oxygen profiles plotted together at the sampling site near the dam is shown in Figure AQ 8-13. The Hell Hole Reservoir temperature profile data from June–October at each of the individual sampling locations on each sampling date are provided in Figures C-6 to C-8 in Appendix C. The dissolved oxygen profiles are in Figures C-9 to C-10.

Temperature in the reservoir ranged from about 42°F in the hypolimnion to about 69°F at the water surface. Nearly all of the water column in the profiles provide water suitable for salmonid fish growth. Further surface temperatures never approached

critical maximum temperatures. The hypolimnion temperatures, for all months and years sampled, ranged from approximately 42°F–50°F. The surface water temperature ranged from 54°F–69°F. Surface temperatures were coolest in June and October (e.g., 54°F to 60°F), and were warmest in July and August (greater than 65°F). The shapes of the temperature profiles did not exhibit distinct thermoclines. Often during the summer there was a very shallow, warm epilimnion (e.g., 20 feet) and then a long gradual thermocline over a wide range of depths (100+ feet). In September and October the epilimnion was the most fully developed and much deeper, 100–150 feet. The lack of a distinct thermocline may be related operations of the French Meadows Powerhouse at Hell Hole Reservoir, which discharges up to 400 cfs of cold water diverted from French Meadows Reservoir into Hell Hole Reservoir throughout the spring, summer, and fall.

During the 2005–2008 sampling period, dissolved oxygen was greater than 6 mg/l and typically greater than 7 mg/l. There were always large portions of the water column with dissolved oxygen concentrations 7.0 mg/l or greater (CVRWQCB 2007). Dissolved oxygen concentration typically was similar throughout the water column and there was no indication of depletion of the dissolved oxygen in the hypolimnion (Figure C-9). Periodically in the dissolved oxygen profiles low dissolved oxygen was observed very near the water-sediment interface (Figure AQ 8-13).

Medium Reservoirs

Middle Fork Interbay is relatively small. It has a maximum active storage of 173 ac-ft (7.6 surface acres) and a maximum depth of 64 ft (maximum operation elevation to streambed) (Table AQ 8-3). Ralston Afterbay is about 10 times larger with a maximum active storage of 1,804 ac-ft (76.8 surface acres) and a maximum depth of 79 ft (maximum operation elevation to streambed). Both reservoirs are coldwater reservoirs with high oxygen concentrations. Both reservoirs operate as forebays and afterbays for upstream and downstream powerhouses.

Because both reservoirs are small compared to the typical water volumes that flow through them, they have low residence times and there is limited opportunity for the development of temperature stratification or oxygen depletion. For Middle Fork Interbay with a typical flow through of about 900 cfs the residence time of water would be a few hours. For Ralston Afterbay with a typical flow through of 1,000 cfs would have a residence time of less than about 24 hours.

In Ralston Afterbay, water temperature and dissolved oxygen profile sampling was conducted at one location near the dam (Appendix C, Map C-3). Middle Fork Interbay is generally completely mixed; therefore, water temperature and dissolved oxygen profile samples were not collected. Water temperature and dissolved oxygen was sampled at the inflow and outflow of the reservoir.

Middle Fork Interbay

Water in Middle Fork Interbay was cold due to the cold water inflows (from Middle Fork Powerhouse that originates from the bottom of Hell Hole Reservoir) and had high dissolved oxygen concentrations. The temperature and dissolved oxygen conditions are suitable for coldwater species. Because of its small size and the daily power operations that discharge water into and divert water out of Middle Fork Interbay, the reservoir does not stratify (completely mixed). Water temperature at the outflow of the reservoir represents the water temperature in the reservoir. Release water temperatures were nearly always below 55°F. Only on few days (2006–2008) did daily average water temperature range between 55 and 60 °F (PCWA 2011a, Figure 7.5-1b).

Dissolved oxygen concentration samples collected immediately upstream, in, and downstream of Middle Fork Interbay in the spring and fall ranged from 7.7 to 9.3 mg/l (PCWA 2008). The oxygen concentrations were greater than the Basin Plan objective (CVRWQCB 2007) of 7.0 mg/l.

Ralston Afterbay

A summary of the water temperature and dissolved oxygen profiles plotted together is shown in Figure AQ 8-14. The Ralston Afterbay temperature profile data from June–October for each individual sampling date are provided in Figure C-11 in Appendix C. The dissolved oxygen profiles are in Figure C-12.

Ralston Afterbay was relatively cold with high oxygen concentrations. The temperature and dissolved oxygen conditions are suitable for coldwater species and suitable for hardhead. Hardhead are present in the reservoir; however, the temperature is colder than reported preferred temperatures. Coldwater fish Cold water inflows from Ralston Powerhouse were the dominate factor affecting water temperature in Ralston Afterbay during the summer and fall. Temperature stratification of the reservoir was very weak. Water temperature ranged from about 48–53°F at the bottom of the reservoir to a maximum at the water surface of about 66°F (range 53–66°F). In the top 6–14 feet of the reservoir there was often a 5–15°F linear warming profile (bottom to top) during the summer; however, on some sampling dates there was very little warming of the surface layer. Dissolved oxygen concentrations were always greater than 7 mg/l (Basin Plan objective [CVRWQCB 2007]). Dissolved oxygen concentration was the lowest at the surface and highest at the bottom of the reservoir (up to about 11 mg/l), inversely related to the observed water temperatures.

Based on the six continuous monitoring locations (2006) established longitudinally within the reservoir, Ralston Afterbay exhibits longitudinal surface temperature gradients of approximate 4–5°F degrees. Water temperature warmed in a downstream direction (Figure AQ 8-15, Figures C-13 to B-16). Water was coldest near the Ralston Powerhouse inflow and warmest near the dam. The continuous temperature data also showed that the reservoir can warm significantly during the maintenance outage when Ralston Powerhouse is not operating and water levels are drawn down (Figure AQ 8-15).

6.3.2. Future Operations

The Proposed Action results in very limited change in depth and volume to Hell Hole Reservoir and/or French Meadows Reservoir (Section 6.2.2). In some years, Hell Hole Reservoir water surface elevations during the early summer could be at most 6 ft higher than it would be without the seasonal storage increase improvement, representing a x% increase.

Because there is very limited effect on the depth and volume of Hell Hole Reservoir as a result of the Proposed Action, it is anticipated that the seasonal storage increase would have a very limited effect, if any, on the water temperature and/or the dissolved oxygen profiles. Similarly for French Meadows Reservoir, the Proposed Action is anticipated to have a negligible effect on reservoir temperature and dissolved oxygen profiles.

6.4. MINIMUM POOL HABITAT CHARACTERISTICS

Figures AQ 8-16 a–c show the reservoir elevation versus volume, surface area, and average depth relationships for French Meadows and Hell Hole reservoirs. The existing FERC license and the Proposed Action minimum pool characteristics (percent of maximum volume, maximum minimum pool depth, average minimum depth, minimum pool area, late summer inflows, and refill potential) are shown in Tables 8-8a,b, respectively.

The Proposed Action minimum pool levels are the same elevation as the existing FERC License minimum pool levels, except that the water year types are different and the number of years that the lowest minimum pools would occur are greatly reduced in the Proposed Action. In French Meadows Reservoir the lowest minimum pool (5,152 ft) would be applicable in 15% of the water years (critical and extreme critical) for the Proposed Action compared to 24% of the years in the existing FERC License (Tables 8-1a,b). In Hell Hole Reservoir the lowest minimum pool elevation (4,341 ft) would be applicable 3% of the years in the Proposed Action versus 24% of the years in the existing FERC License.

Generally, the modeled water surface elevations for the Proposed Action do not encroach on the minimum pools (Appendix B) and the overwinter pools likely would be greater than the minimum pools shown in Tables AQ 8-8a,b. The exception to this occurs for the Proposed Action – Future Demand where in critical and extreme critical years the modeled water surfaces in both French Meadows and Hell Hole reservoirs are close to the minimum pool levels specified in the Proposed Action (Tables AQ 8–8b).

7.0 SUMMARY

- All of the reservoirs contain rainbow and brown trout. Hell Hole Reservoir also has a kokanee and lake trout fishery. Ralston Afterbay contains hardhead, which is a sensitive species.
- The two large reservoirs (French Meadows and Hell Hole) are stocked with fish annually. French Meadows Reservoir is currently stocked with catchable

rainbow trout and Hell Hole Reservoir is stocked with fingerling kokanee salmon and catchable brown trout.

- Fishing success at the reservoirs ranges from 0.5–0.6 fish/hour.
- The two large reservoirs (French Meadows and Hell Hole) are operated for seasonal water storage. The highest reservoir elevations occur in June–early July and the lowest reservoir elevations occur in December–February.
- The large reservoirs have FERC minimum pool requirements specified by water year type. They typically do not reach the minimum pool levels (existing FERC or Proposed Action) except during the driest years (critical and extreme critical) under full water demand (i.e., Proposed Action – Future Demand scenario).
- The medium sized reservoirs (Middle Fork Interbay and Ralston Afterbay) do not operate as seasonal storage reservoirs. Middle Fork Interbay is typically operated at a constant elevation near the top of the reservoir. Ralston Afterbay is operated within the top 12 feet of the reservoir and the elevation fluctuates on a daily basis due to operation of the powerhouses and to provide downstream recreational flow. Both reservoirs are annually lowered for gate inspection and both are periodically lowered even farther for sediment management.
- The future minimum pool levels in the large reservoirs under the Proposed Action are similar to the existing FERC License minimum pool levels; however, the Proposed Action minimum pool levels reduce the frequency of years that the lowest minimum pool levels would be in effect.
- All of the reservoirs provide high quality coldwater fish habitat under existing conditions and the Proposed Action. Temperature throughout the reservoir water column is typically in the suitable range suitable for coldwater fish growth, temperatures do not approach critical high temperatures for coldwater fish species even in the epilimnion, and dissolved oxygen concentrations are suitable throughout the reservoirs. In Ralston Afterbay where hardhead reside, the dissolved oxygen concentration is high and the temperature is suitable.

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TABLES

Table AQ 8-1a. Existing FERC Minimum Pool Requirements and Water Year Types.

Water Year Type	Forecast / Folsom Reservoir ¹	License Requirement				Number of Years (1975–2007)	Proportion of Years (1975–2007)
		June–Sept		Oct–May			
		Elevation (ft)	Volume (ac-ft)	Elevation (ft)	Volume (ac-ft)		
French Meadows Reservoir							
Wet	> 2,000,000 ac-ft	5197	60,000	5186	50,000	18	55%
Normal	1,200,000 – 2,000,000 ac-ft	5197	60,000	5152	25,000	7	21%
Dry	< 1,200,000 ac-ft	5157	28,000	5120	8,700	8	24%
Hell Hole Reservoir							
Wet	> 2,000,000 ac-ft	4482	70,000	4451	50,000	18	55%
Normal	1,200,000 – 2,000,000 ac-ft	4482	70,000	4402	25,000	7	21%
Dry	< 1,200,000 ac-ft	4404	26,000	4341	5,500	8	24%

¹Forecast / Folsom Reservoir = Minimum pool elevation requirements are implemented on June 1 of each year based on the California Department of Water Resources Bulletin 120 May forecast.

Table AQ 8-1b. Proposed Action Minimum Pool Requirements and Water Year Types.

Proposed Action Minimum Pool Requirement ¹						Number of Years (1975–2007)	Proportion of Years (1975–2007)
Water Year Type	Forecast / Folsom Reservoir ¹	June–Sept ²		Sept ³ –May			
		Elevation (ft)	Volume (ac-ft)	Elevation (ft)	Volume (ac-ft)		
French Meadows Reservoir							
Wet	≥ 3,400,000 ac-ft	5,208	70,000	5,152	25,000	12	36%
Above Normal	2,400,000 – <3,400,000 ac-ft	5,208	70,000	5,152	25,000	4	12%
Below Normal	1,500,000 – <2,400,000 ac-ft	5,200	62,500	5,152	25,000	6	18%
Dry	1,000,000 – <1,500,000 ac-ft	5,200	62,500	5,152	25,000	6	18%
Critical	600,000 – <1,000,000 ac-ft	5,157	28,000	5,152	25,000	4	12%
Extreme Critical	< 600,000 ac-ft	5,157	28,000	5,120	8,700	1	3%
Hell Hole Reservoir							
Wet	≥ 3,400,000 ac-ft	4,530	106,500	4,451	50,000	12	36%
Above Normal	2,400,000 – <3,400,000 ac-ft	4,530	106,500	4,451	50,000	4	12%
Below Normal	1,500,000 – <2,400,000 ac-ft	4,530	106,500	4,402	25,000	6	18%
Dry	1,000,000 – <1,500,000 ac-ft	4,482	70,000	4,402	25,000	6	18%
Critical	600,000 – <1,000,000 ac-ft	4,482	70,000	4,402	25,000	4	12%
Extreme Critical	< 600,000 ac-ft	4,404	26,000	4,341	5,500	1	3%

¹Forecast / Folsom Reservoir = Minimum pool elevation requirements are implemented on June 1 of each year based on the California Department of Water Resources Bulletin 120 May forecast.

²Minimum pool requirements end on Labor Day.

³Minimum pool requirements begin one day after Labor Day.

Table AQ 8-2. Reservoir Water Temperature and Dissolved Oxygen Profile Sampling Dates.

Year	Sampling Dates
French Meadows Reservoir	
2004	Sept 7, Sept 20, Sept 30, Oct 13
2005	Jun 15, Jul 15, Aug 16, Sept 19, Oct 25
2006	Jul 7, Aug 10, Sep 9, Oct 28
2007	May 30, Jul 12, Aug 2, Aug 31
2008	Jun 4, Jul 10, Aug 7, Aug 15, Sep 16, Oct 17
Hell Hole Reservoir	
2004	Sept 7, Sept 20, Sept 30, Oct 13
2005	Jun 15, Jul 15, Aug 16, Sept 20, Oct 24
2006	Jul 7, Aug 10, Sep 9, Oct 28
2007	Jul 13, Aug 2, Aug 30
2008	Jun 13, Jul 11, Aug 7, Aug 15, Sep 16, Oct 17
Ralston Afterbay	
2005	Jul 14, Aug 16, Sept 19, Oct 25
2006 ¹	Jul 10, Aug 9, Oct 1
2007	Jun 8, Jul 13, Aug 1, Sep 7
2008	Jun 4, Jul 10, Aug 14, Aug 28, Sep 17, Oct 27

¹The September profile could not be performed due to the Ralston Ridge Fire.

Table AQ 8-3. Reservoir Details.

FRENCH MEADOWS DAM (LL ANDERSON DAM) AND FRENCH MEADOWS RESERVOIR	
Elevation of Spillway Crest	5,244.5 ft
Maximum Operating Water Surface	5,262.0 ft
Minimum Operating Water Surface	5,125 ft
Gross Storage	134,993 ac-ft
Dead Storage (as constructed), at Tunnel Intake lip	7,635 ac-ft
Active Storage (as constructed)	127,358 ac-ft
Area at Maximum Operating Water Surface	1,408 acres
Area at Minimum Operating Water Surface	434 acres
Depth at Minimum Operating Water Surface	77 ft
Shoreline at Maximum Operating Water Surface	9 miles
HELL HOLE DAM AND RESERVOIR	
Elevation of Spillway Crest	4,630 ft
Maximum Operating Water Surface	4,630 ft
Minimum Operating Water Surface	4,340 ft
Gross Storage	207,590 ac-ft
Dead Storage (as constructed), at Tunnel Intake lip	2,533 ac-ft
Active Storage (as constructed)	205,057 ac-ft
Area at Maximum Operating Water Surface	1,253 acres
Area at Minimum Operating Water Surface	185 acres
Depth at Minimum Operating Water Surface	88 ft
Shoreline at Maximum Operating Water Surface	11 miles
MIDDLE FORK INTERBAY	
Elevation of Top of Gates	2,530 ft
Elevation of Sill of Gates	2,510 ft
Number of Gates	4
Type of Gates	Radial
Size of Gates	20 ft x 20 ft
Maximum Operating Water Surface	2,529 ft
Minimum Operating Water Surface	2,502 ft
Normal Operating Water Surface	2,527 ft
Gross Storage	175 ac-ft
Dead Storage (as constructed), at Tunnel Intake lip	2 ac-ft
Active Storage (as constructed)	173 ac-ft
Area at Maximum Operating Water Surface	7 acres
Area at Minimum Operating Water Surface	3 acres
Depth at Minimum Operating Water Surface	37 ft
RALSTON AFTERBAY	
Elevation of Top of Gates	1,179 ft
Elevation of Sill of Gates	1,149 ft
Number of Gates	5
Type of Gates	Radial
Size of Gates	30 ft x 40 ft
Maximum Operating Water Surface	--
Minimum Operating Water Surface	--
Normal Operating Water Surface	--
Gross Storage (as constructed)	2,782 ac-ft
Dead Storage (as constructed)	--
Active Storage (as constructed)	1,804 ac-ft
Area at Maximum Operating Water Surface	--
Area at Minimum Operating Water Surface	--
Depth at Minimum Operating Water Surface	--

Table AQ 8-4. Summary of Fish Species Observed during the 2007-2008 Fish Population Sampling¹ (●).

Study Site	Sampling Dates	Sample Type	Fish Species ²							
			RBT	BNT	HH	SPM	SS	KOK	TCB	LKT
Reservoirs										
French Meadows	9/11/07-9/13/07	Gill netting	●	●				● ³	●	
Hell Hole	9/10/07-9/12/07	Gill netting	●	●			●	●	●	●
Middle Fork Interbay	9/20/07-9/21/07	Gill netting	●	●						
Ralston Afterbay	9/13/07; 6/26/08; 9/4/08	Gill netting/ electrofishing/ sonar	●	●	●	●	●			

¹Table modified from data presented in Table AQ 2-4 (PCWA 2009b).

²Species: RBT = Rainbow Trout; BNT = Brown Trout; HH = Hardhead; SPM = Sacramento Pikeminnow; SS = Sacramento Sucker; KOK = Kokanee; TCB = Tui Chub; LKT = Lake Trout.

³Only 1 Kokanee was captured in French Meadows Reservoir. No record of Kokanee stocking in French Meadows exists. This fish was believed to be an anomaly.

Table AQ 8-5. 2007-2008 Summary of Fish Captured during Reservoir Gill Netting.

Date	Reservoir Location	Study Site	Total Hours	Number of Fish ¹ Captured							
				RBT	BNT	HH	SPM	SS	KOK	TCB	LKT
Ralston Afterbay											
September 2007	Upper	RA-3A	19.33	1	1		2	18			
		RA-3B	20.00	3	4	2	12				
		Total	39.33	4	5	2	2	30			
	Middle	RA-2A	17.00		3	2	11				
		RA-2B	18.92		2	1	2	10			
		Total	35.92		5	3	2	21			
	Lower	RA-1A	17.58	1		1	8				
		RA-1B	17.83	1			7				
		Total	35.41	2		1	15				
June 2008	Upper	RA-3A	21.17	3		3	18				
		RA-3B	21.07		1		11				
		Total	42.24	3	1	3	29				
	Middle	RA-2A	20.15	1	3		17				
		RA-2B	20.72	2	3		2	13			
		Total	40.87	3	6		2	30			
	Lower	RA-1A	19.95	2	1		16				
		RA-1B	19.57				9				
		Total	39.52	2	1		25				
September ² 2008	Upper	RA-3A	20.18	4	1		1	14			
		RA-3C	20.50		1		8				
		Total	117	4	2		1	22			
	Middle	RA-2C	19.40				4				
		RA-2D	19.67				9				
		Total	39.07				13				
	Lower	RA-1A	18.25	1			1	15			
		RA-1C	19.20	1	2		3				
		Total	37.45	2	2		1	18			
Middle Fork Interbay											
September 2007	Upper	INT-U1b	19.33	1	3						
		Total	19.33	1	3						
	Middle	INT-L1b	20.35	1							
		Total	40.52	1	2						
	Lower	INT-U2b	20.08	3	2						
		Total	20.08	3	2						
French Meadows Reservoir											
September 2007	Upper	FM-1A	26.50	4	6						
		FM-1B	24.00		9						
		FM-1C	15.58		1						
		FM-1D	13.78		2						
		Total	79.86	4	18						
	Middle	FM-2A	22.67		2						
		FM-2B	21.75	2	3						
		FM-2C	18.5	1	1			1			
		FM-2D	18.17							1	
		Total	81.09	3	6			1		1	
	Lower	FM-3A	21.00								
		FM-3B	21.33		2						
		FM-3C	20.50								
		FM-3D	20.08	1	2						
Total		82.91	1	4							
Hell Hole Reservoir											
September 2007	Upper	HH-1A	15.50		2			30		1	1
		HH-1B	18.00		3		20		1		
		HH-1C	21.17		4		26	1			
		HH-1D	20.83		1		7			1	
		Total	75.50		10		83	1	2	2	
	Middle	HH-2A	17.75		2		5				
		HH-2C	21.75		1				1		
		Total	39.50		3		5		1		
	Lower	HH-3A	18.75		3		1	2			
		HH-3B	18.83		2		2	5	2		
		HH-3C	21.00		5		6	3	1		
		HH-3D	20.88				1	1			
		Total	79.46		10		10	11	3		

¹Species: RBT = Rainbow Trout, BNT = Brown Trout, HH = Hardhead, SPM = Sacramento Pikeminnow, SS = Sacramento Sucker, KOK = Kokanee, TCB = Tui Chub, LKT = Lake Trout.

²Placement of nets during September 2008 were modified for catching fish for methylmercury sampling. No nets were deployed at the bottom of the water column.

Table AQ 8-6. Summary of Fishing Success at Project Reservoirs¹.

Reservoir	Number of Respondents	Catch per Unit Effort (CPUE) (# Fish per Hour)
Hell Hole Reservoir	70	0.6 ($s^2 = 0.7$)
French Meadows Reservoir	50	0.5 ($s = 0.5$)
Ralston Afterbay	4	0.6 ($s = 0.5$)

¹Based on results of angler surveys that were completed for the REC 2 –TSR (PCWA 2009c).

²Standard deviation.

Table 8-7. Average Percent Change by Month in Reservoir Volume and Depth for Future Operations (Proposed Action) Versus the Historic Conditions (No-Action Alternative) (1975-2007).

Reservoir	Jun	Jul	Aug	Sep	Oct	Average
French Meadows Reservoir						
Percent Change in Reservoir Volume	-2%	-3%	-5%	-6%	-1%	-4%
Percent Change in Reservoir Depth	-1%	-1%	-2%	-2%	0%	-2%
Hell Hole Reservoir						
Percent Change in Reservoir Volume	4%	1%	-1%	-3%	0%	0%
Percent Change in Reservoir Depth	2%	1%	-1%	-1%	0%	0%

Table AQ 8-8a. Attributes of Existing FERC Minimum Pools at French Meadows and Hell Hole Reservoirs¹.

Reservoir - Water Year Type	Folsom Reservoir Inflow Forecast (million ac-ft)	Minimum Pool Volume (ac-ft) / Elevation (ft) (Jun-Sep)	Minimum Pool Volume (ac-ft) / Elevation (ft) (Oct-May)	Maximum Reservoir Volume (ac-ft)	Maximum Area (acres)	Maximum Reservoir Depth (ft)	% of Total Volume (Oct - May)	Max Minimum Pool Depth (ft)	Average Minimum Pool Depth ² (ft)	Minimum Pool Area ² (acres)	Refill Potential (Days and cfs, Based on Late Summer Inflows) ³
French Meadows Reservoir											
Wet	> 2.0	60,000 / 5,197	50,000 / 5,186	134,993	1,408	214	37.0%	146	60	834	>120 day, ~7 cfs
Normal	1.2 - 2.0	60,000 / 5,197	25,000 / 5,152				18.5%	112	42	596	>120 day, ~4 cfs
Dry	< 1.2	28,000 / 5,157	8,700 / 5,120				6.4%	79	25	354	>120 day, ~3 cfs
Hell Hole Reservoir											
Wet	> 2.0	70,000 / 4,482	50,000 / 4,451	207,590	1,253	378	24.1%	198	84	592	>120 day, ~25 cfs
Normal	1.2 - 2.0	70,000 / 4,482	25,000 / 4,402				12.0%	150	58	433	>120 day, ~10 cfs
Dry	< 1.2	26,000 / 5,500	5,500 / 4,341				2.6%	89	29	192	>120 day, ~10 cfs

¹Middle Fork Project data were supplied to Dale Hepworth for this analysis, see Appendix C Attachment A for his credentials.

²Values were calculated as approximations (Volume / Area = Average Depth).

³Average September inflow.

Table AQ 8-8b. Attributes of Proposed Action Minimum Pools at French Meadows and Hell Hole Reservoirs¹.

Reservoir - Water Year Type	Folsom Reservoir Inflow Forecast (million ac-ft)	Minimum Pool Volume (ac-ft) / Elevation (ft) (Jun-Sep)	Minimum Pool Volume (ac-ft) / Elevation (ft) (Oct-May)	Maximum Reservoir Volume (ac-ft)	Maximum Area (acres)	Maximum Reservoir Depth (ft)	% of Total Volume (Oct-May)	Max Minimum Pool Depth (ft)	Average Minimum Pool Depth ² (ft)	Minimum Pool Area ² (acres)	Refill Potential (Days and cfs, Based on Late Summer Inflows) ³
French Meadows Reservoir											
Wet	≥ 3.4	70,000 / 5,280	25,000 / 5,152	134,993	1,408	214	18.5%	112	42	596	>120 day, ~8 cfs
Above Normal	2.4 - <3.4	70,000 / 5,280	25,000 / 5,152				18.5%	112	42	596	>120 day, ~5 cfs
Below Normal	1.5 - <2.4	62,500 / 5,200	25,000 / 5,152				18.5%	112	42	596	>120 day, ~5 cfs
Dry	1.0 - <1.5	62,500 / 5,200	25,000 / 5,152				18.5%	112	42	596	>120 day, ~3 cfs
Critical	0.6 - <1.0	28,00 / 5,157	25,000 / 5,152				18.5%	112	42	596	>120 day, ~2 cfs
Extreme Critical	< 0.6	28,00 / 5,157	8,700 / 5,120				6.4%	79	25	354	>120 day, ~1 cfs
Hell Hole Reservoir											
Wet	≥ 3.4	106,500 / 4,530	50,000 / 4,451	207,590	1,253	378	24.1%	198	84	592	>120 day, ~30 cfs
Above Normal	2.4 - <3.4	106,500 / 4,530	50,000 / 4,451				24.1%	198	84	592	>120 day, ~14 cfs
Below Normal	1.5 - <2.4	106,500 / 4,530	25,000 / 4,402				12.0%	150	58	433	>120 day, ~11 cfs
Dry	1.0 - <1.5	70,000 / 4,482	25,000 / 4,402				12.0%	150	58	433	>120 day, ~8 cfs
Critical	0.6 - <1.0	70,000 / 4,482	25,000 / 4,402				12.0%	150	58	433	>120 day, ~10 cfs
Extreme Critical	< 0.6	26,000 / 4,404	5,500 / 4,341				2.6%	89	29	192	>120 day, ~4 cfs

¹Middle Fork Project data were supplied to Dale Hepworth for this analysis, see Appendix C Attachment A for his credentials.²Values were calculated as approximations (Volume / Area = Average Depth).³Average September inflow.

FIGURES

Figure AQ 8-1. Reservoir Fish Habitat Study Objectives, Related Study Elements, and Reports.

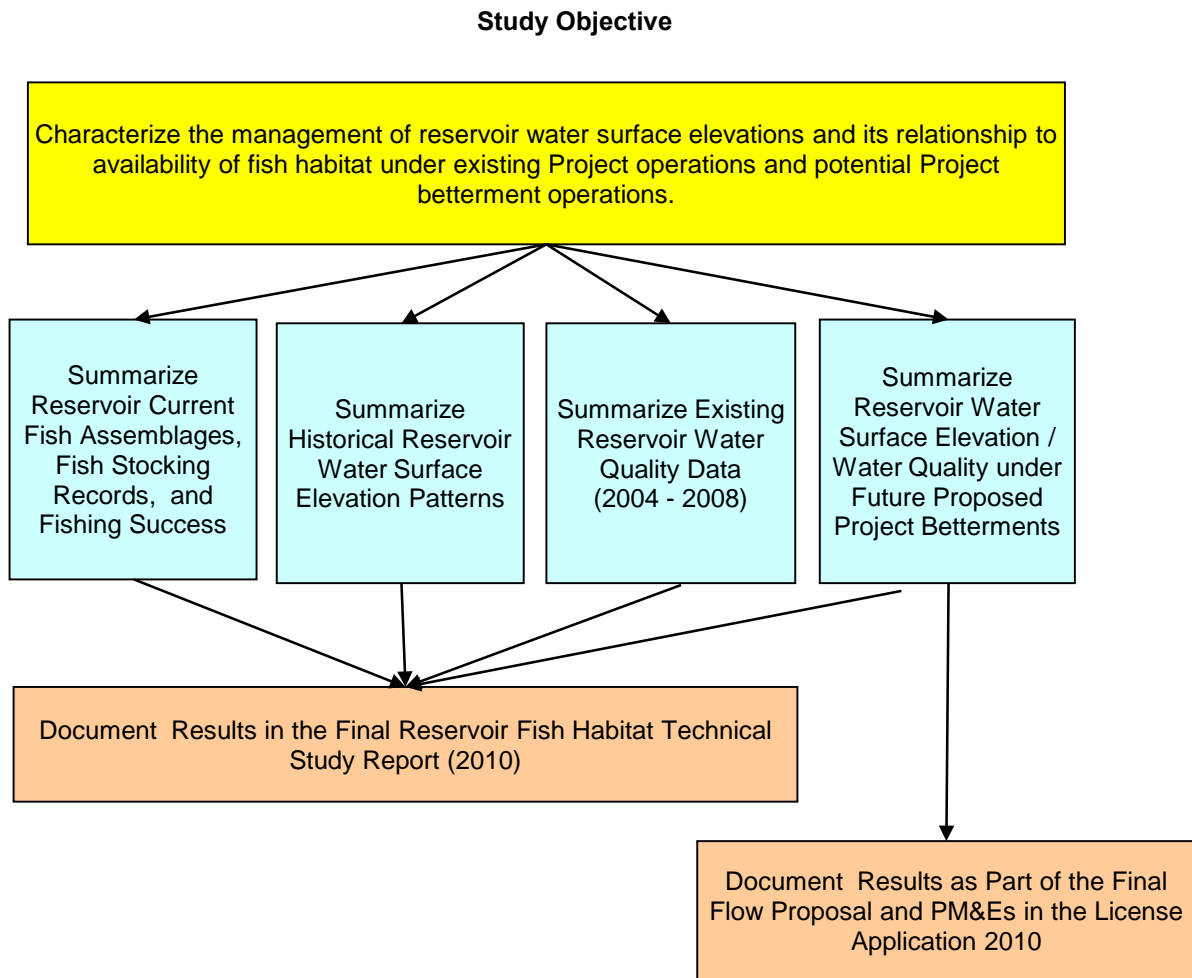
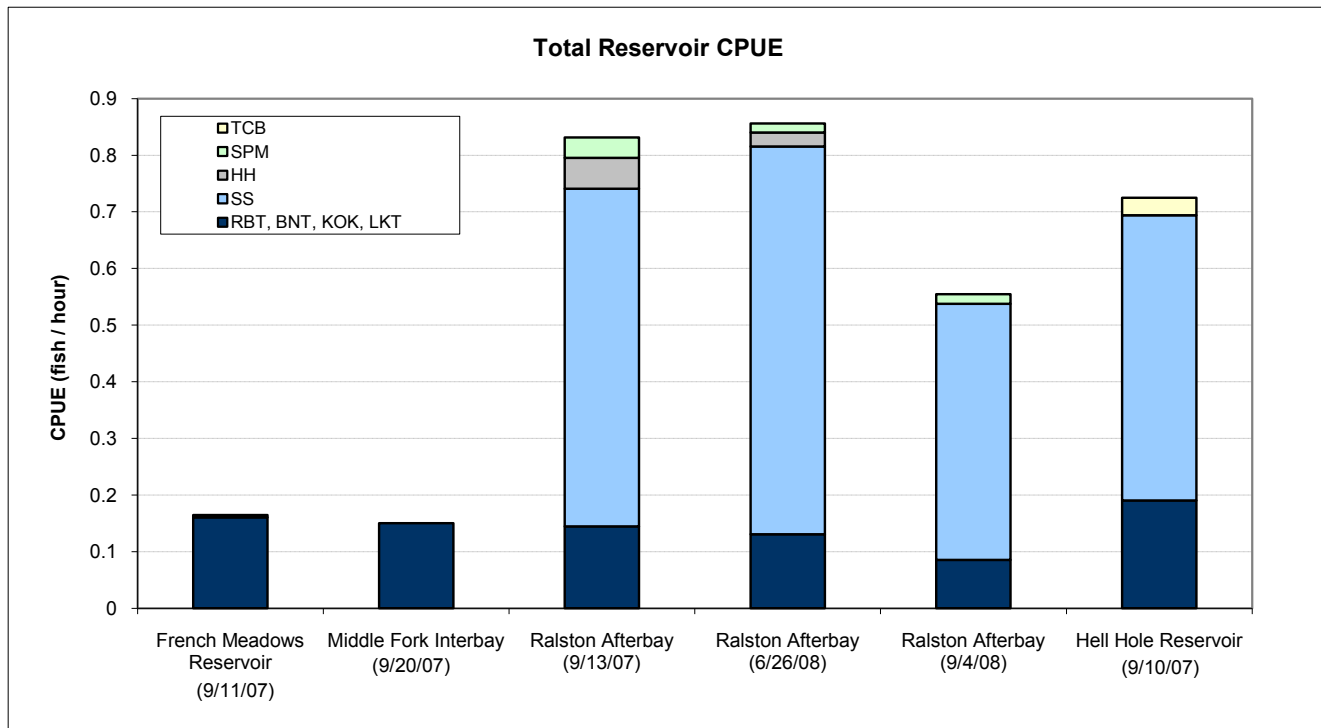


Figure AQ 8-2. Gill Netting Catch per Unit Effort (CPUE) (Fish per Hour) for Fish Species¹ in French Meadows Reservoir, Hell Hole Reservoir, Middle Fork Interbay, and Ralston Afterbay.²



¹TCB = Tui Chub; SPM = Sacramento Pikeminnow; HH = Hardhead; SS = Sacramento Sucker, RBT = Rainbow Trout; BNT = Brown Trout; KOK = Kokanee Salmon; LKT = Lake Trout

²Study locations were altered on 9/4/08 for methylmercury fish tissue sampling efforts. Nets were not deployed at the bottom of the water column, fewer suckers were collected.

Figure AQ 8-3. French Meadows Reservoir Historic Daily Water Surface Elevation and Pool Volume Patterns (1975 - 2007).

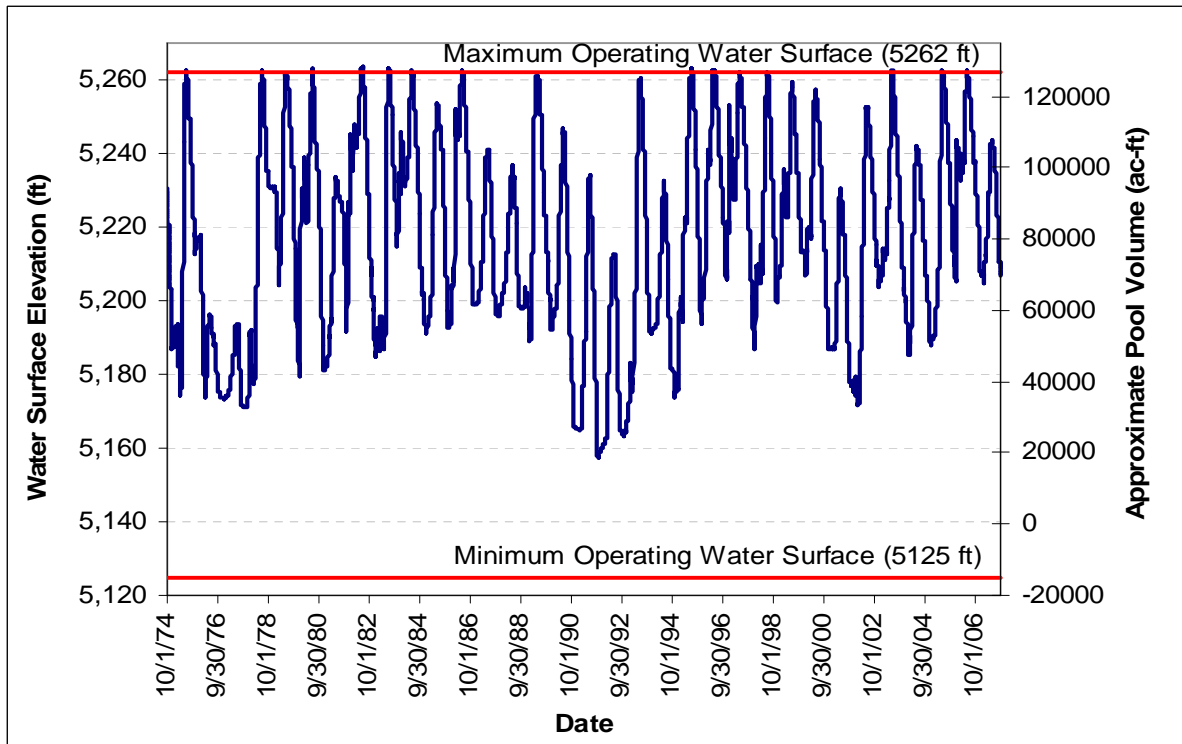


Figure AQ 8-4. Hell Hole Reservoir Historic Daily Water Surface Elevation and Pool Volume Patterns (1975 - 2007).

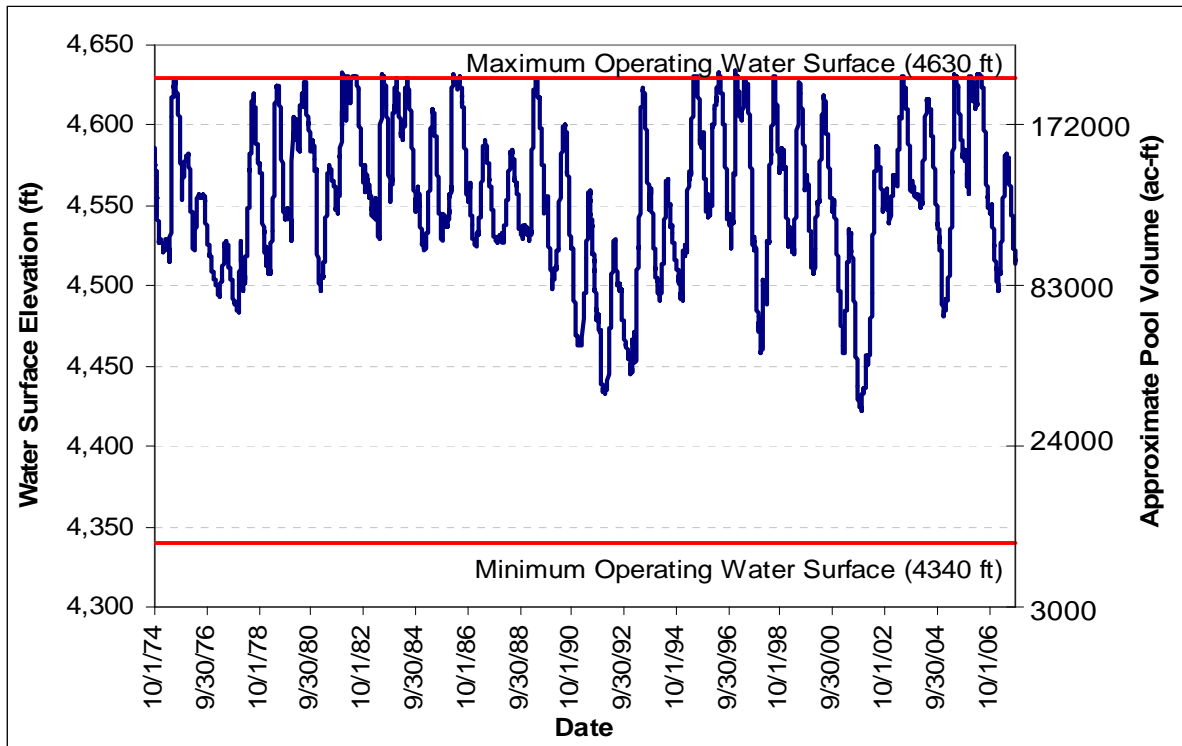


Figure AQ 8-5. French Meadows Reservoir Historic Water Surface Elevation Traces (1975– 2007) and Existing FERC License Minimum Pool Requirement by Year Type.

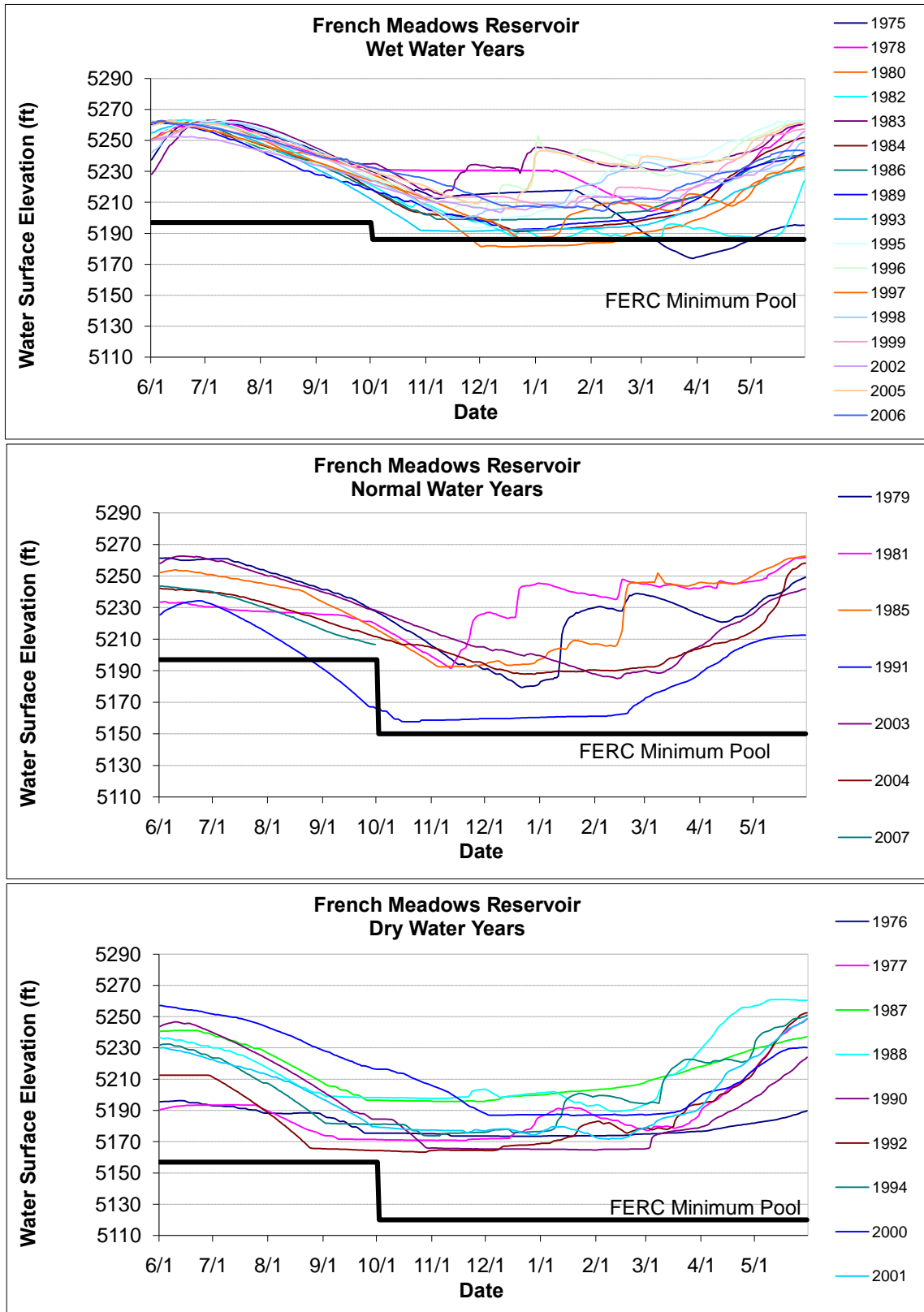


Figure AQ 8-6. Hell Hole Reservoir Historic Water Surface Elevation Traces (1975– 2007) and Existing FERC License Minimum Pool Requirement by Year Type.

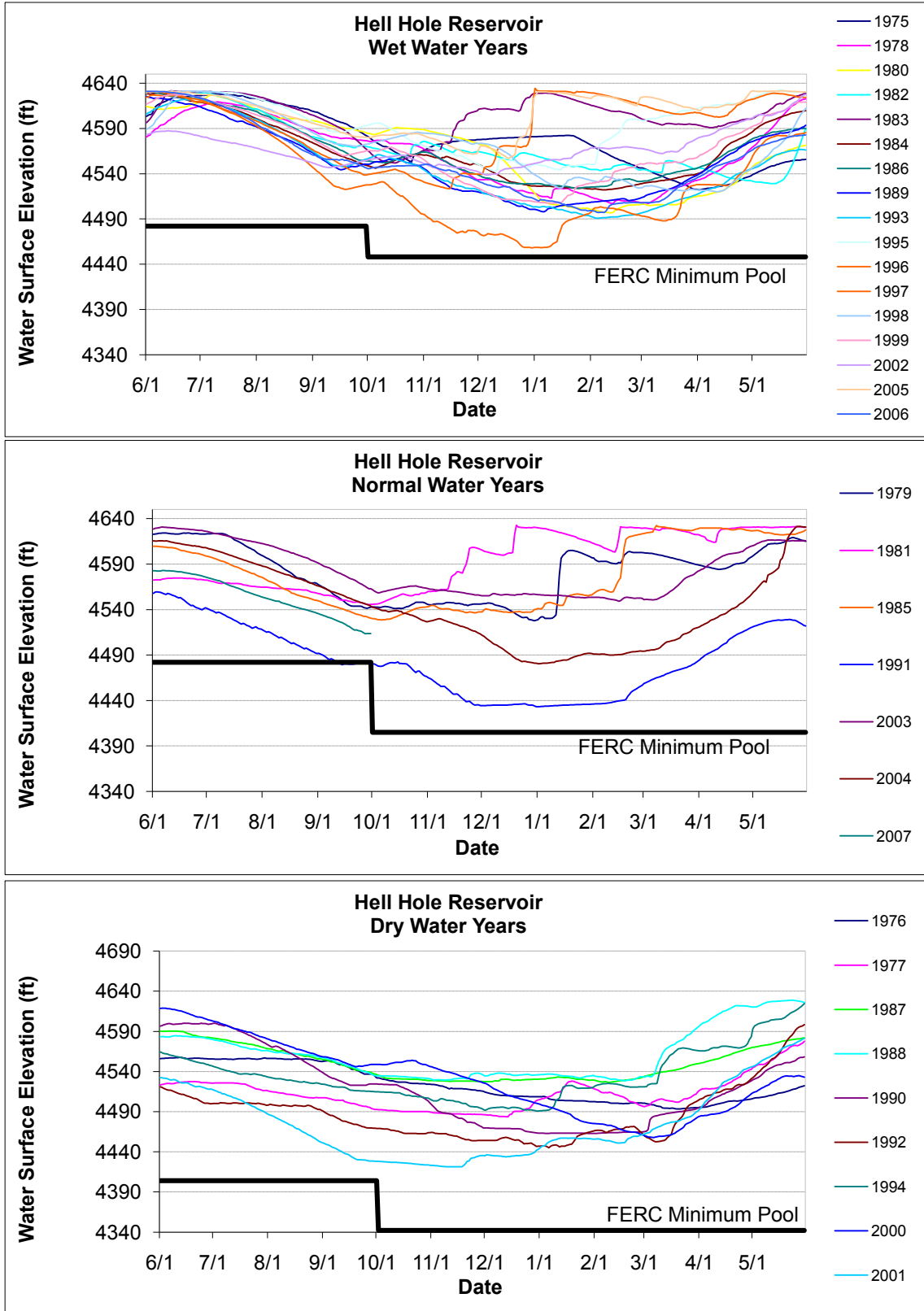
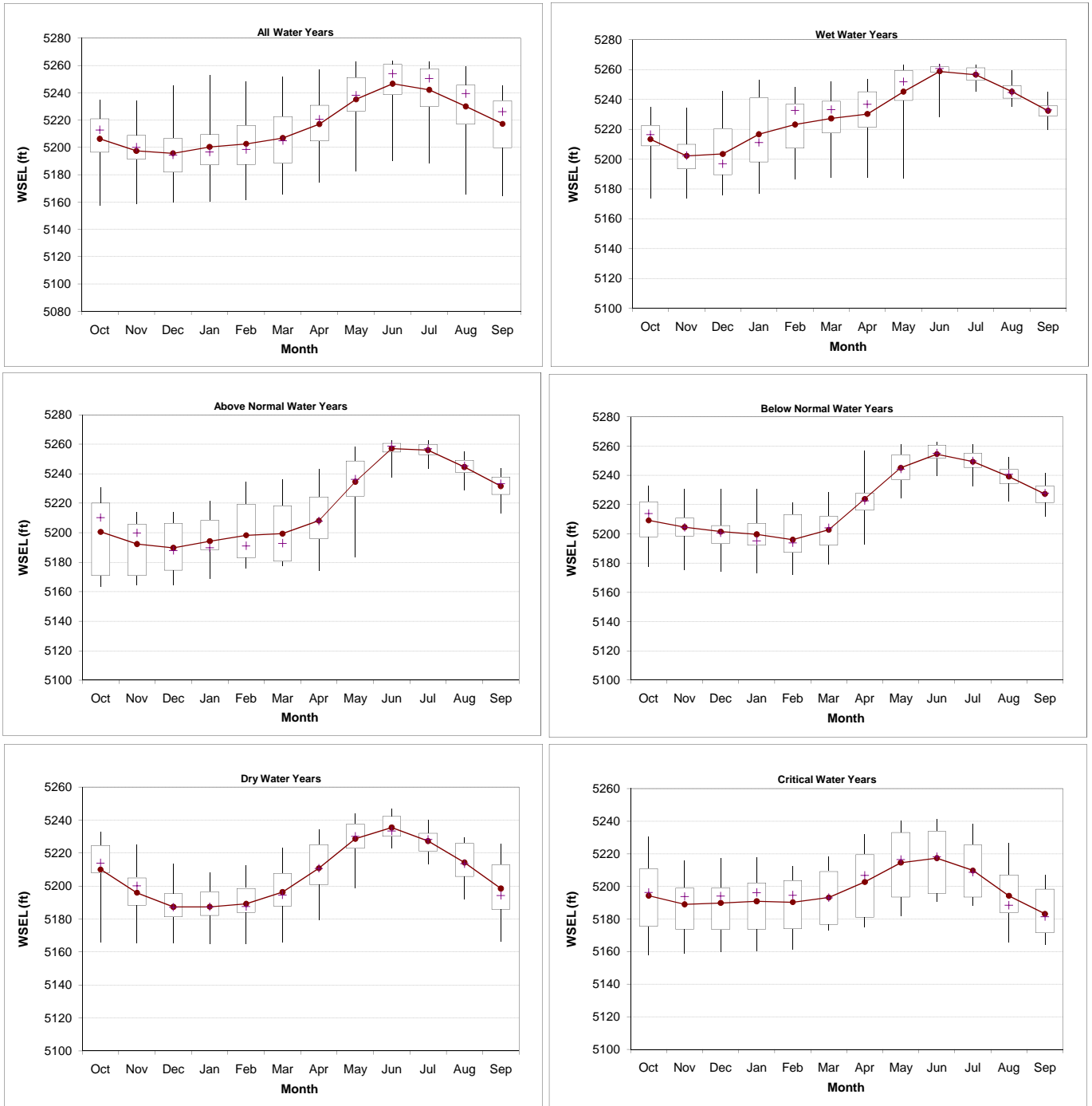


Figure AQ 8-7a. French Meadows Reservoir Historic Monthly Average Water Surface Elevations by Year Type (1975 – 2007) (Includes Median, Quartile, Minimum, and Maximum Elevations).



¹ WSEL = water surface elevation

Figure AQ 8-7b. French Meadows Reservoir Historic Monthly Average Water Storage by Year Type (1975 – 2007) (Includes Median, Quartile, Minimum, and

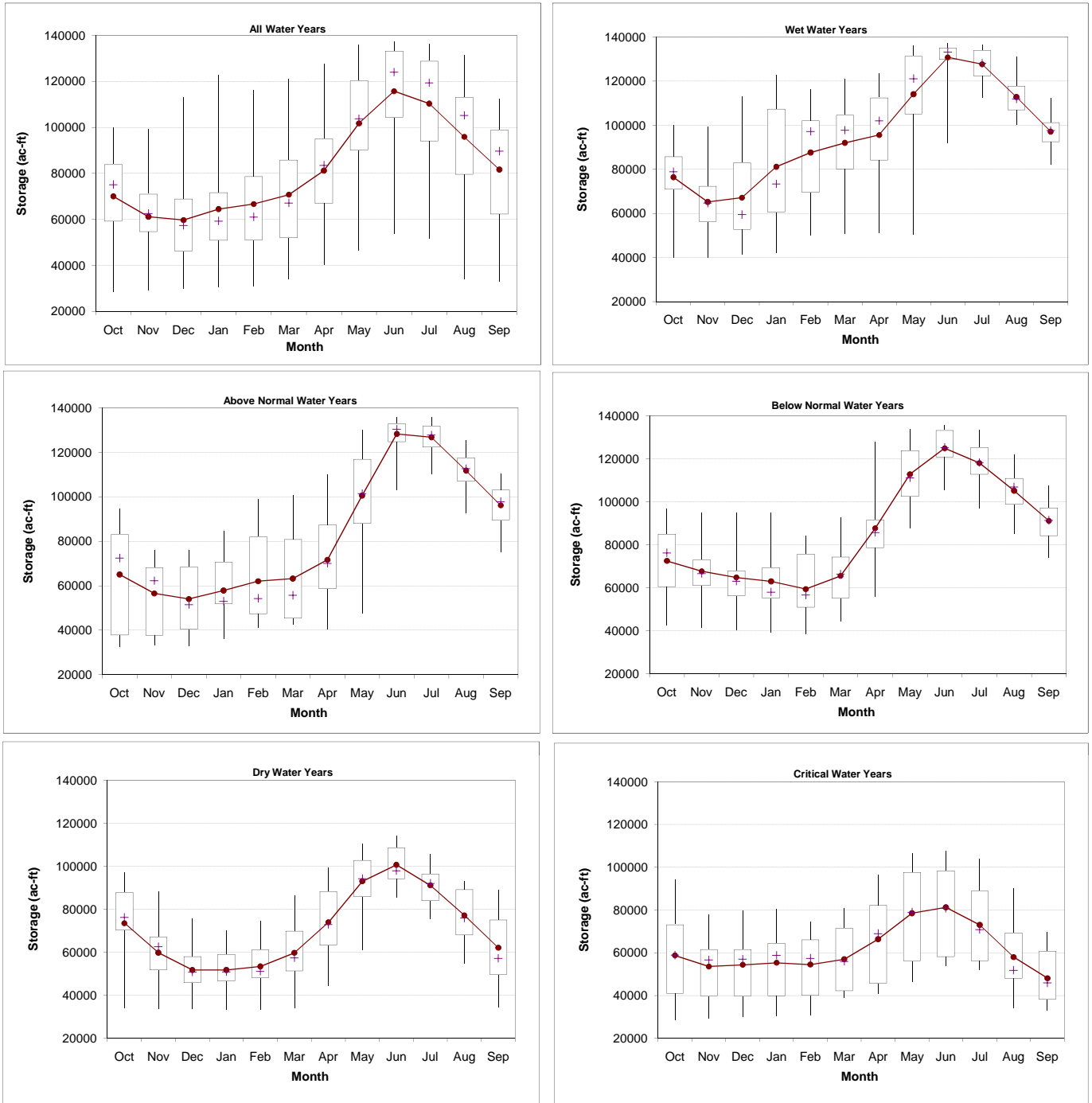
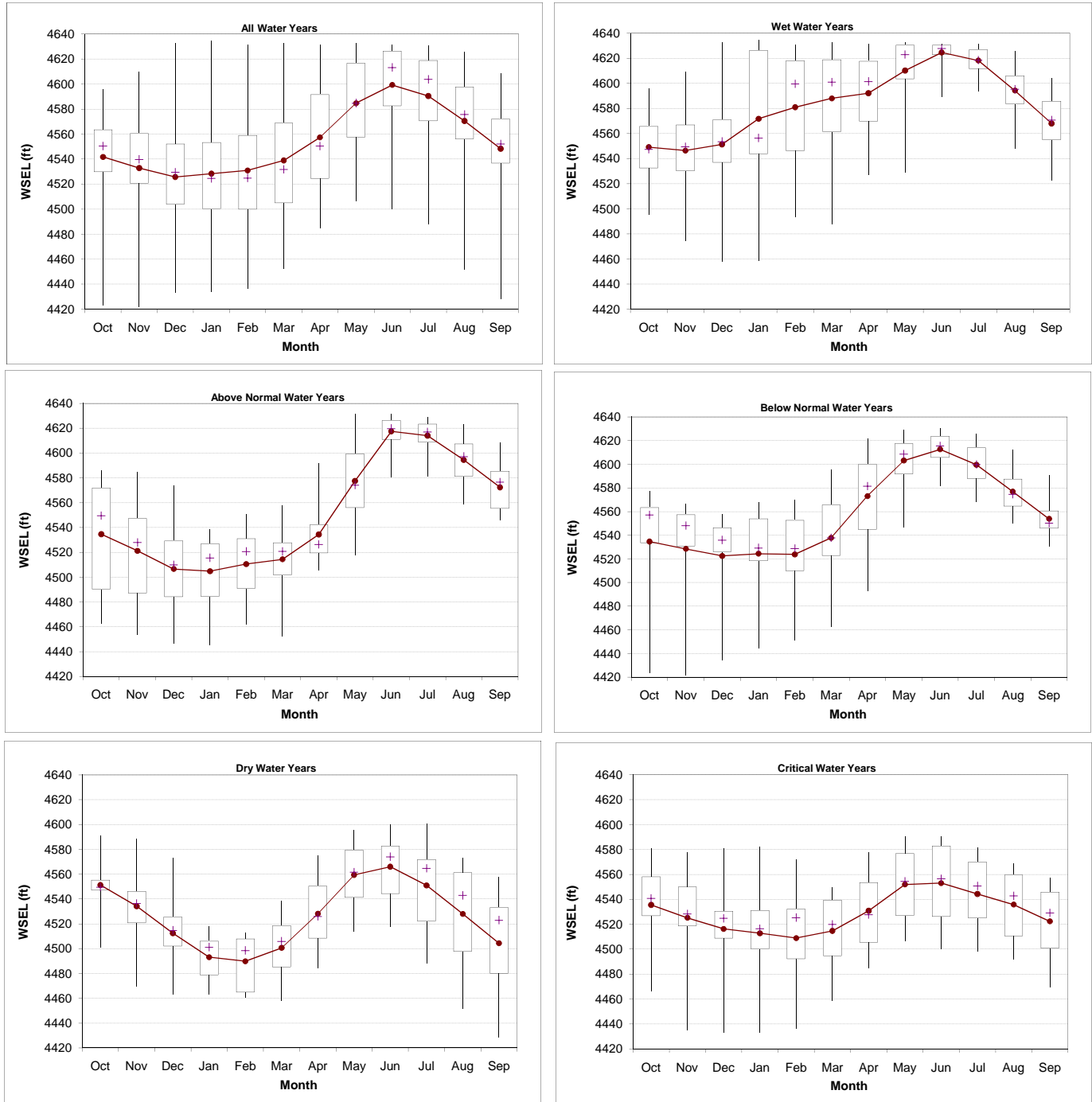


Figure AQ 8-8a. Hell Hole Reservoir Historic Monthly Average Water Surface Elevations by Year Type (1975 – 2007) (Includes Median, Quartile, Minimum, and Maximum Storage).



¹ WSEL = water surface elevation

Figure AQ 8-8b. Hell Hole Reservoir Historic Monthly Average Water Storage by Year Type (1975 – 2007) (Includes Median, Quartile, Minimum, and Maximum)

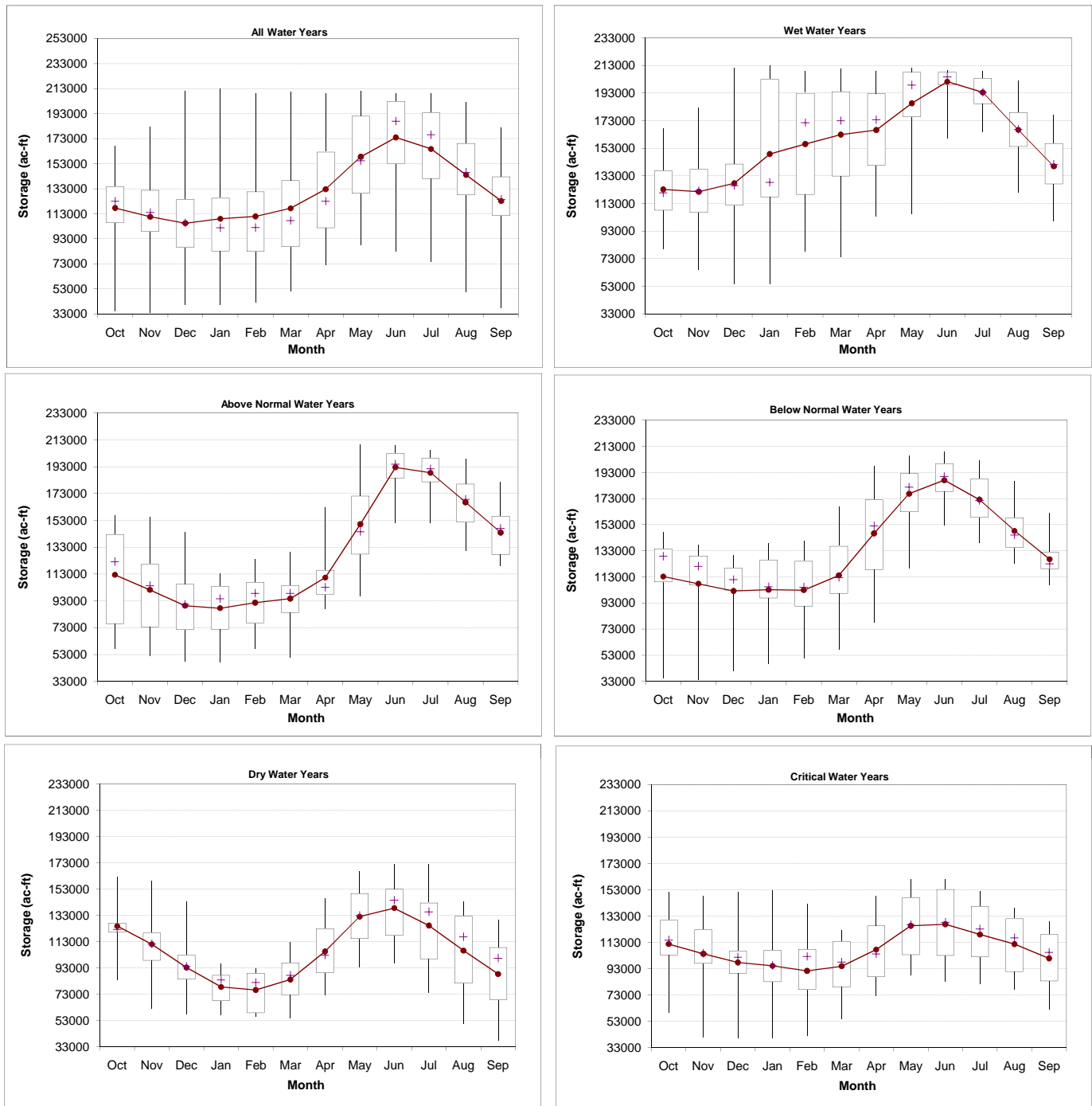


Figure AQ 8-9. Middle Fork Interbay Historic Daily Water Surface Elevation and Pool Volume Patterns (1975 - 2007).

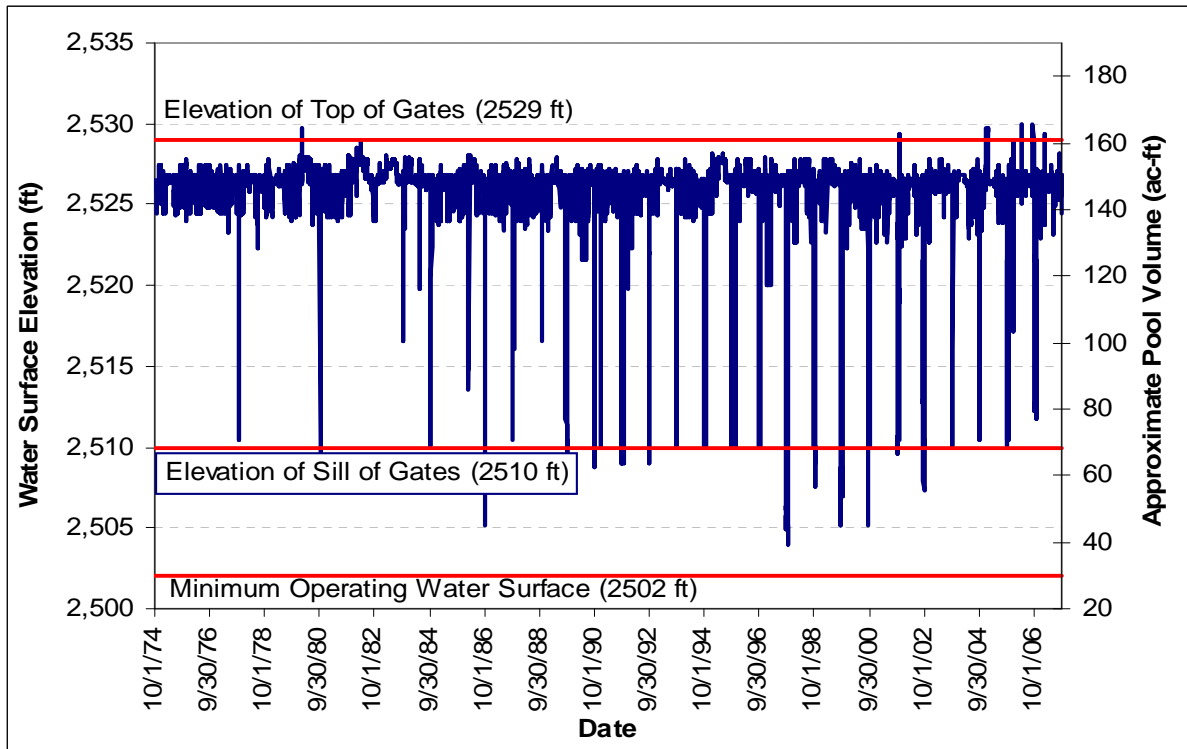


Figure AQ 8-10. Ralston Afterbay Historic Daily Water Surface Elevation and Pool Volume Patterns (1975 - 2007).

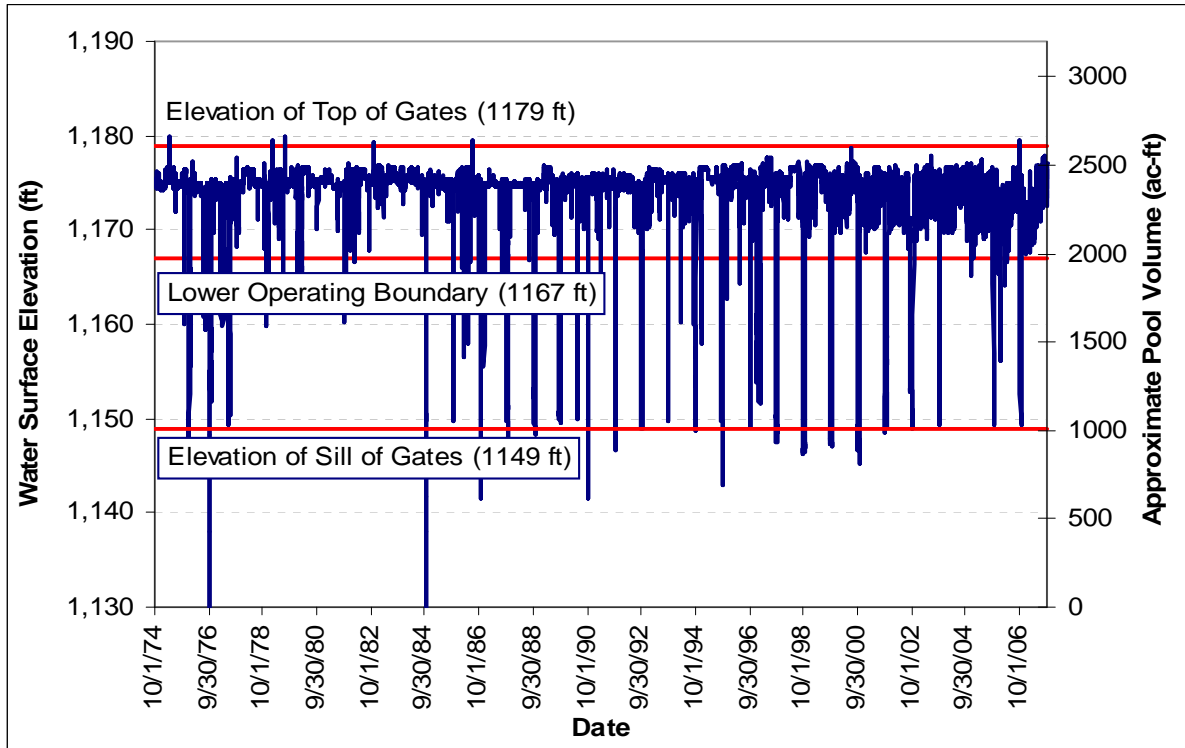


Figure AQ 8-11a. Ralston Afterbay Historic Hourly Water Surface Elevations and Pool Volumes from March 21, 2007 to June 8, 2010.

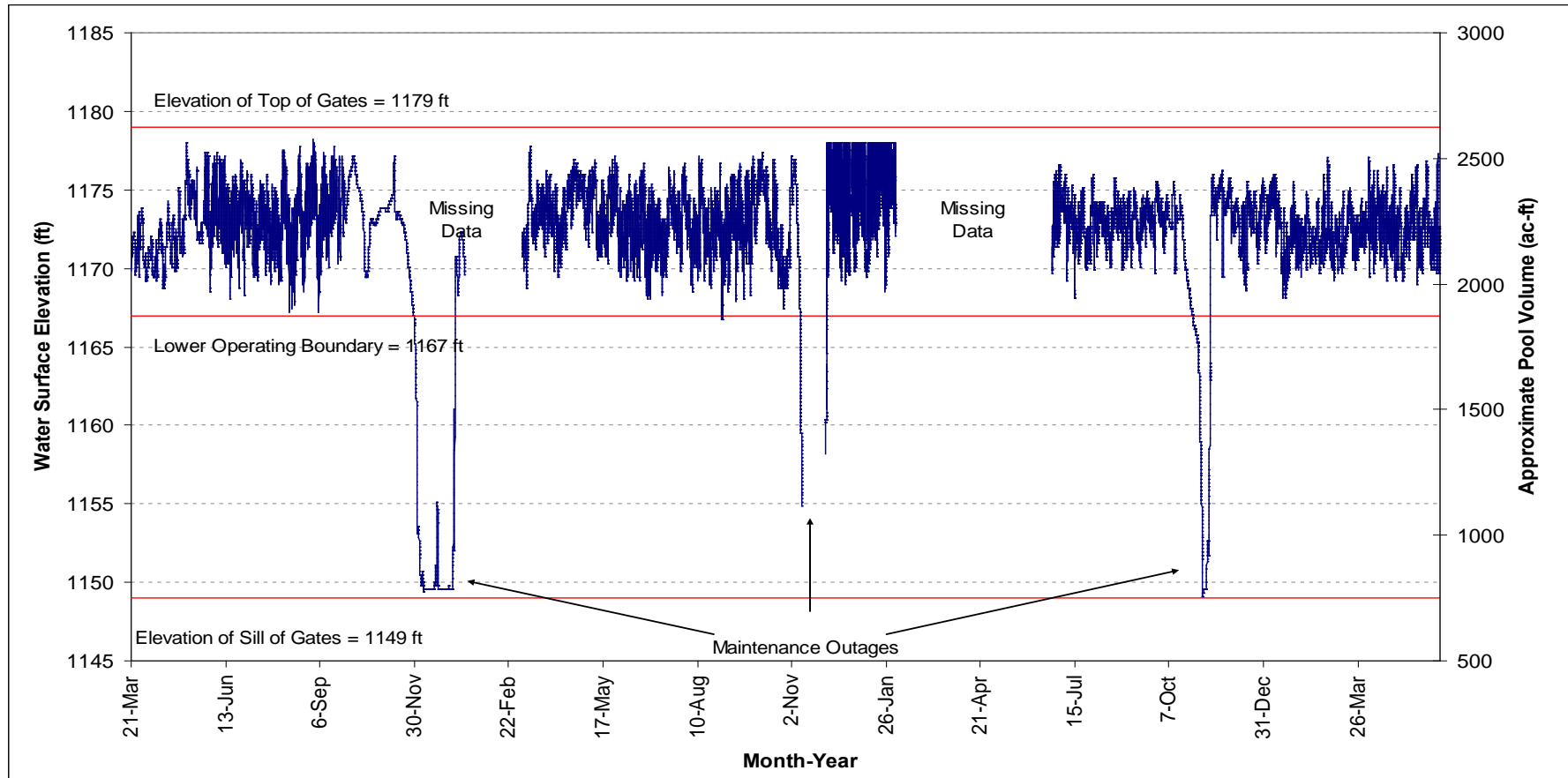


Figure AQ 8-11b. Ralston Afterbay Historic and Future (Proposed Action) Hourly Water Surface Elevations and Pool Volumes (August 1 - 31, 2007).

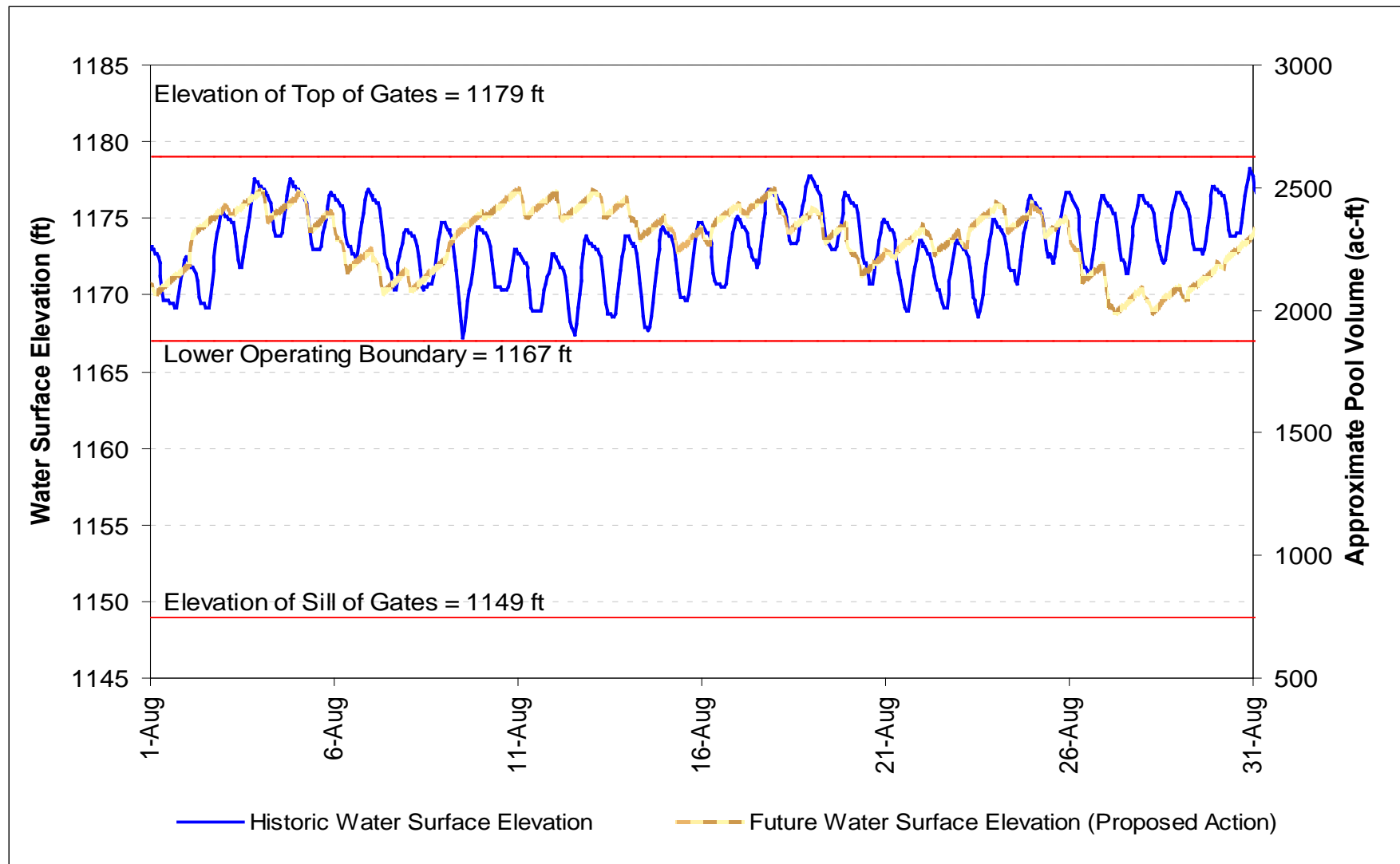


Figure 8-12. French Meadows Reservoir Water Temperature and Dissolved Oxygen Profiles at Site FM1 for all Years (2005-2008) and Sampling Months (June-October).

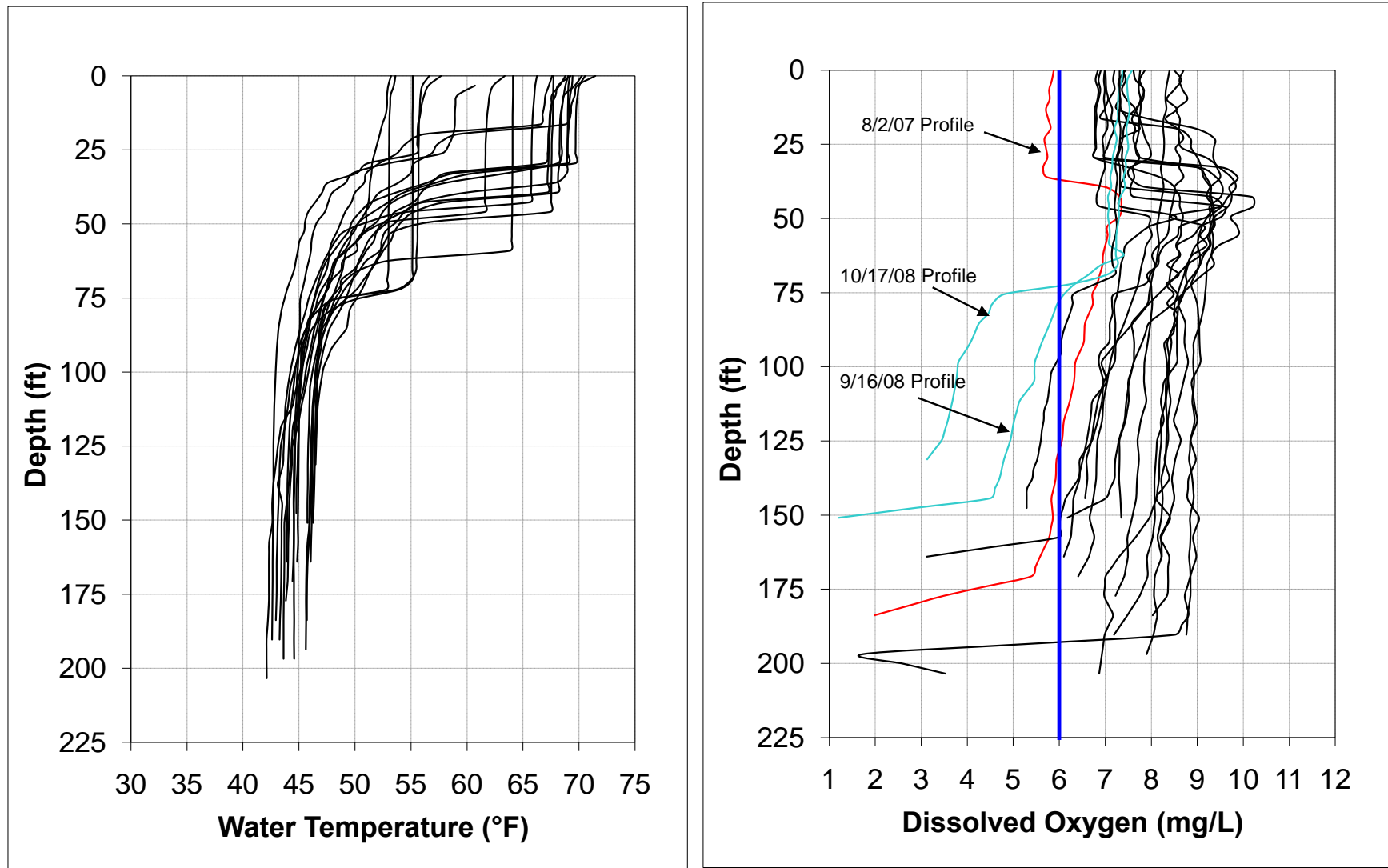


Figure 8-13. Hell Hole Reservoir Water Temperature and Dissolved Oxygen Profiles at Site HH1 for all Years (2005-2008) and Sampling Months (June-October).

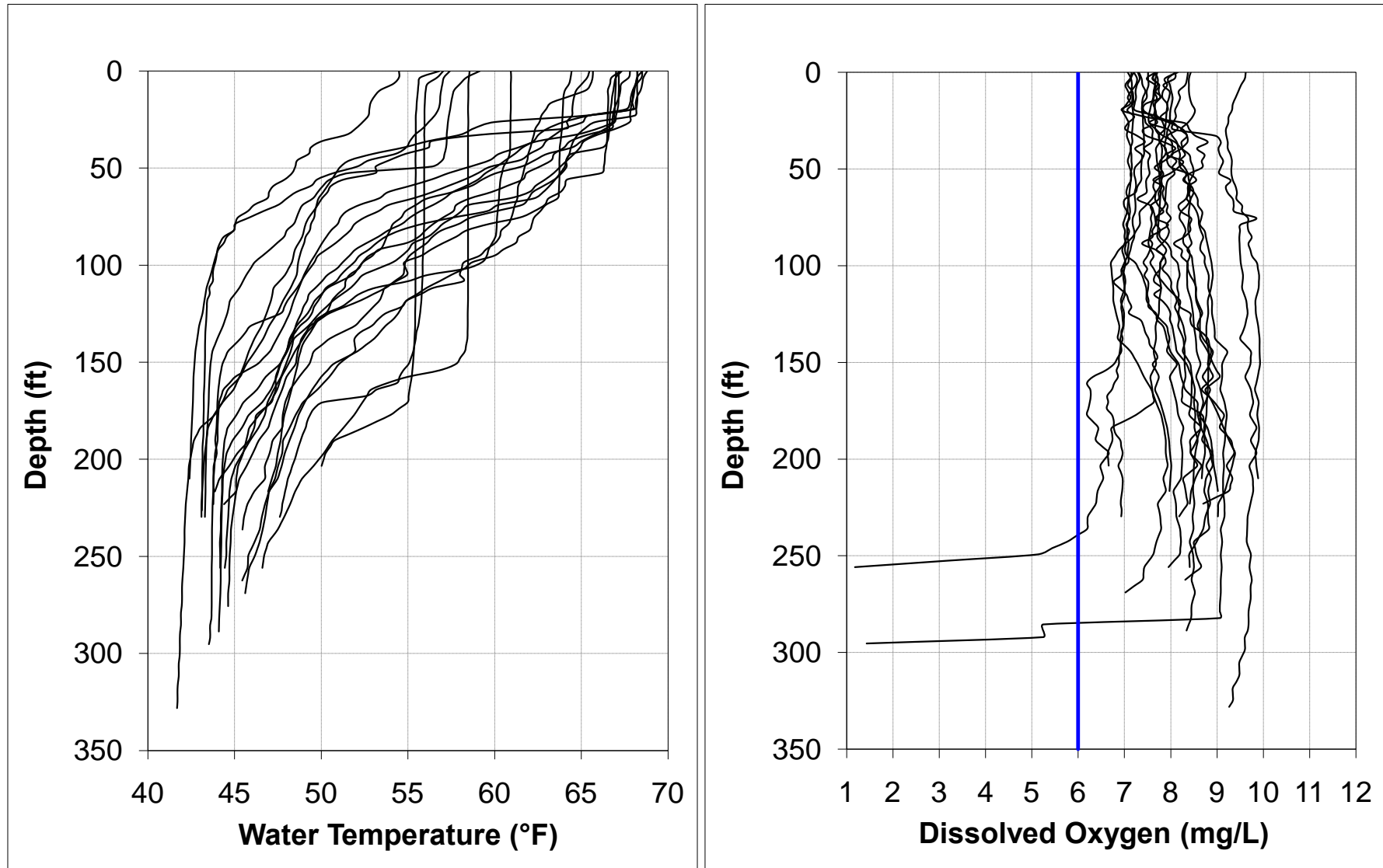


Figure 8-14. Ralston Afterbay Water Temperature and Dissolved Oxygen Profiles at Site RA1 for all Years (2005-2008) and Sampling Months (June-October).

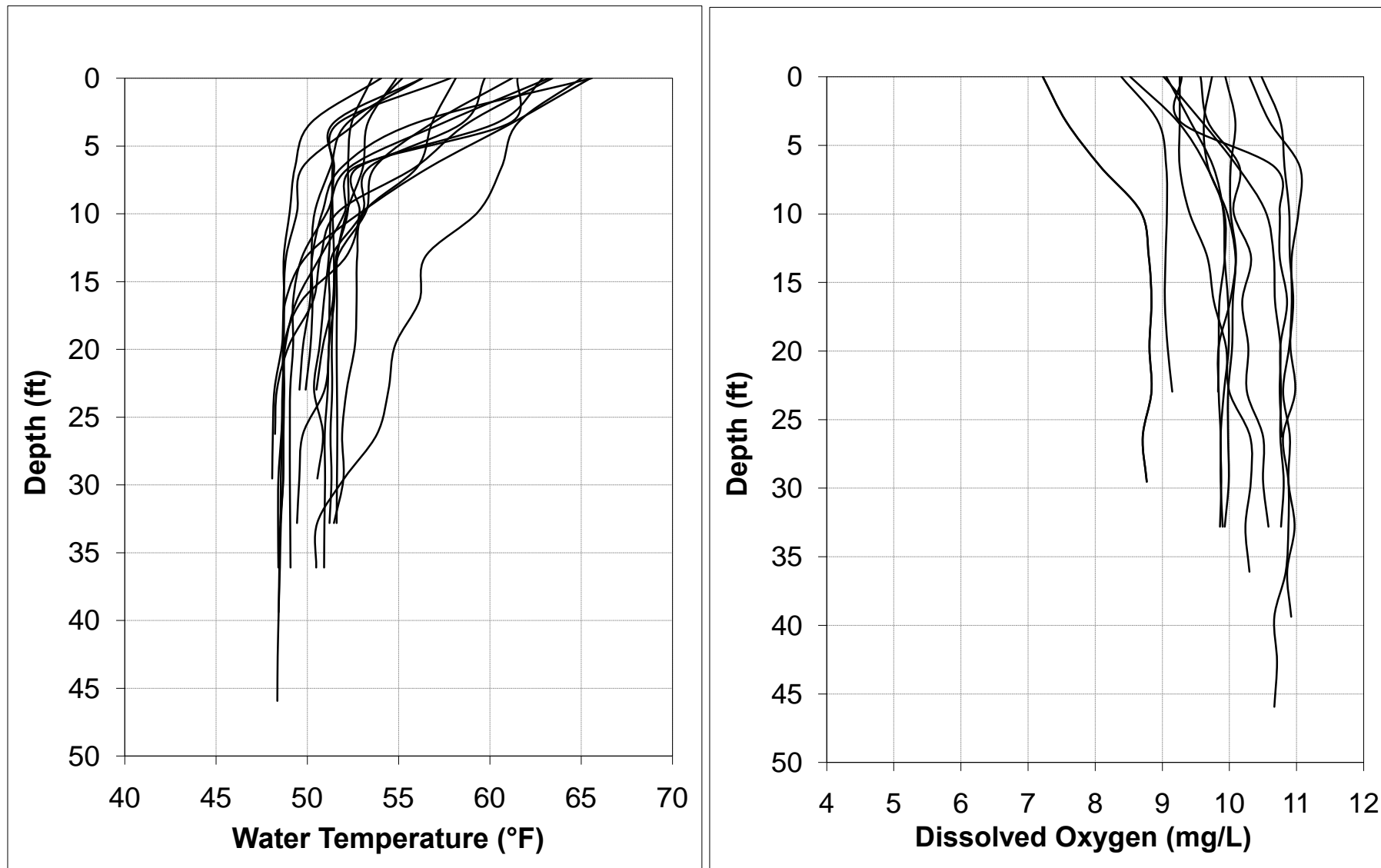


Figure 8-15. Comparison of Average Daily Temperature at the Six Ralston Afterbay Continuous Monitoring Sites¹ Over the 2006 Sampling Period.

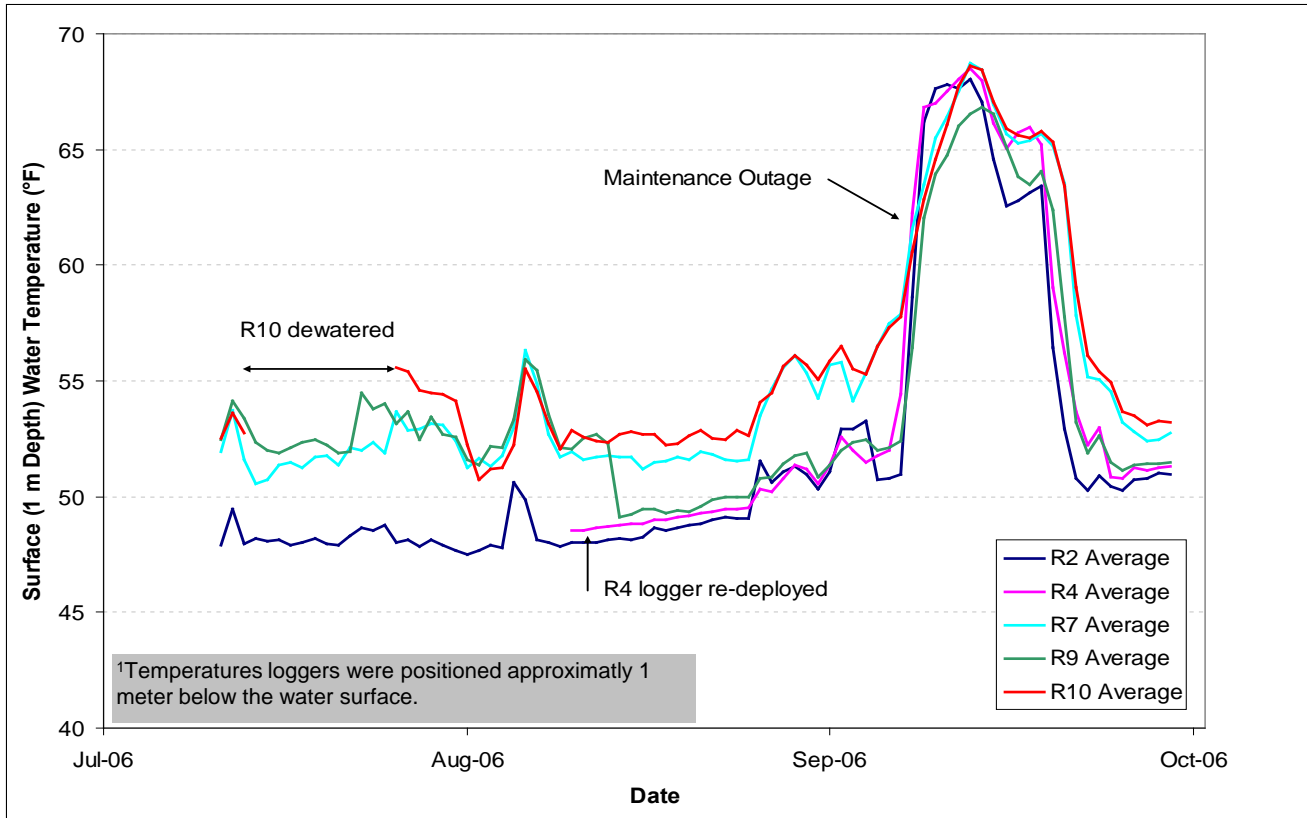


Figure AQ 8-16a. French Meadows and Hell Hole Reservoir Water Surface Elevation - Volume Relationship.

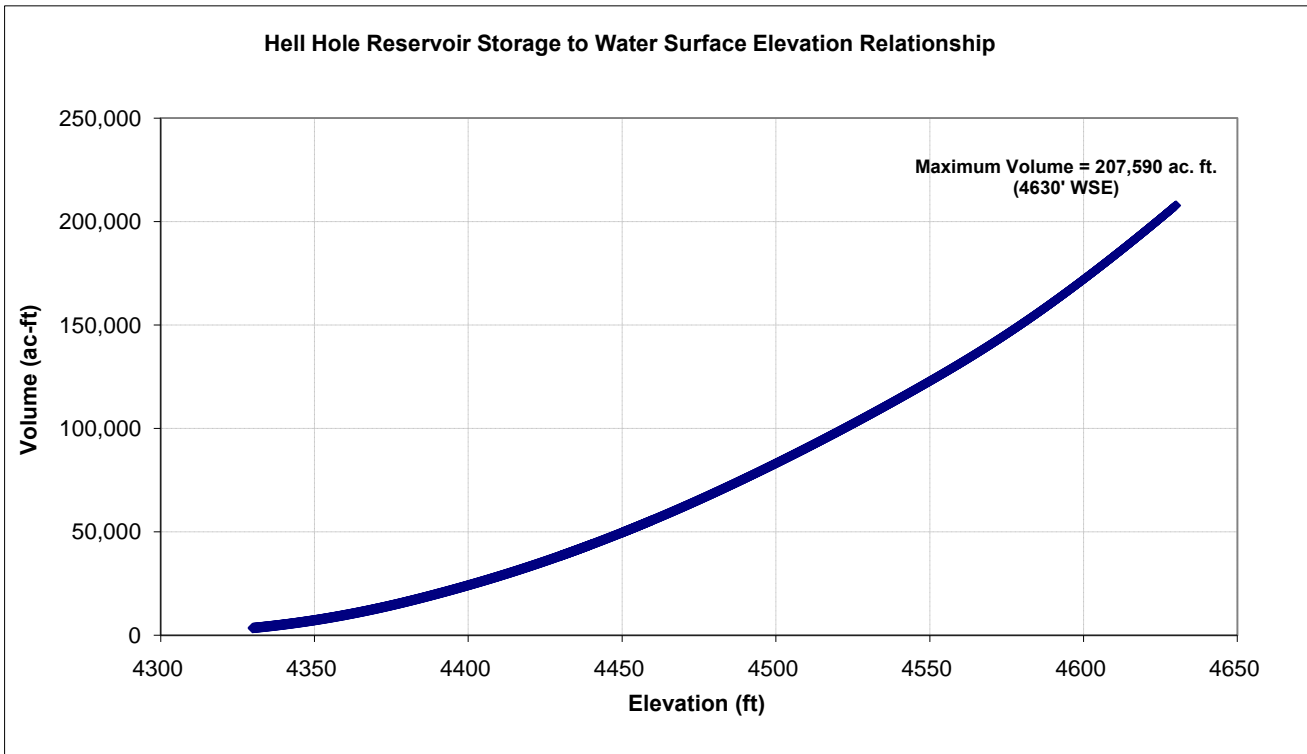
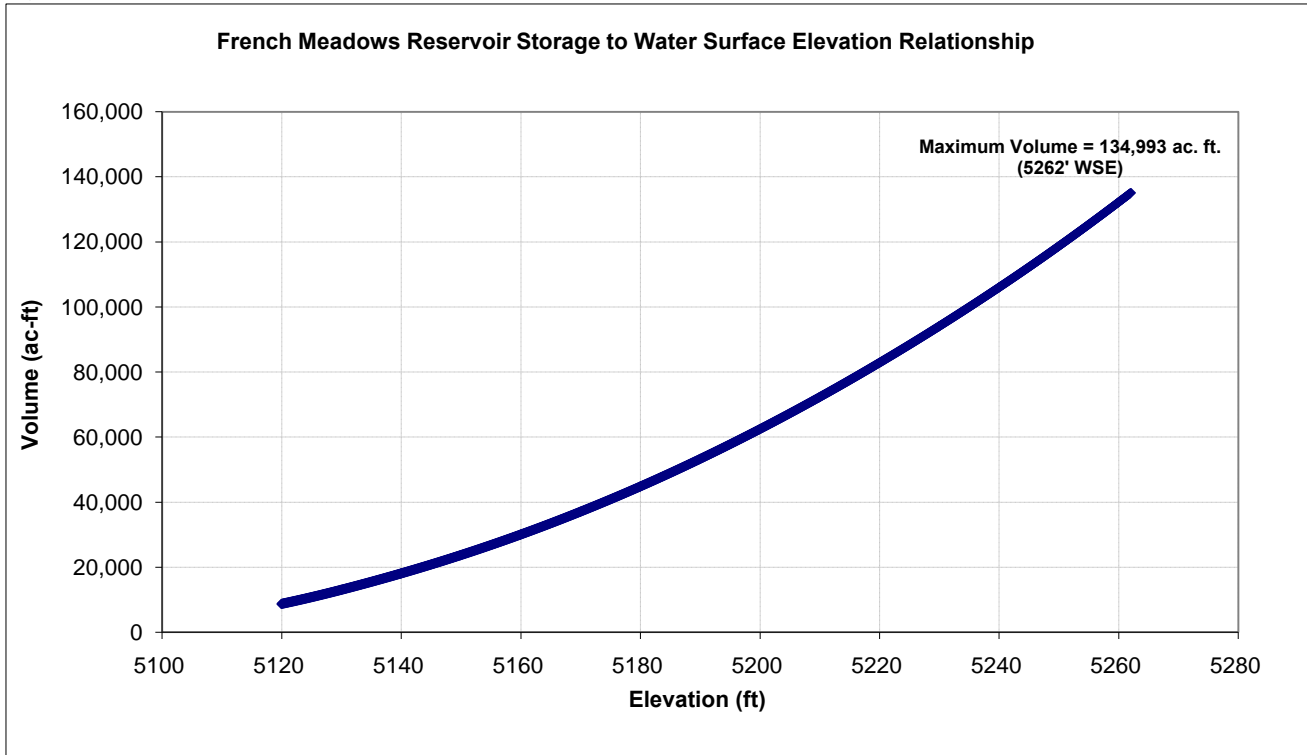


Figure AQ 8-16b. French Meadows and Hell Hole Reservoir Water Surface Elevation - Area Relationship.

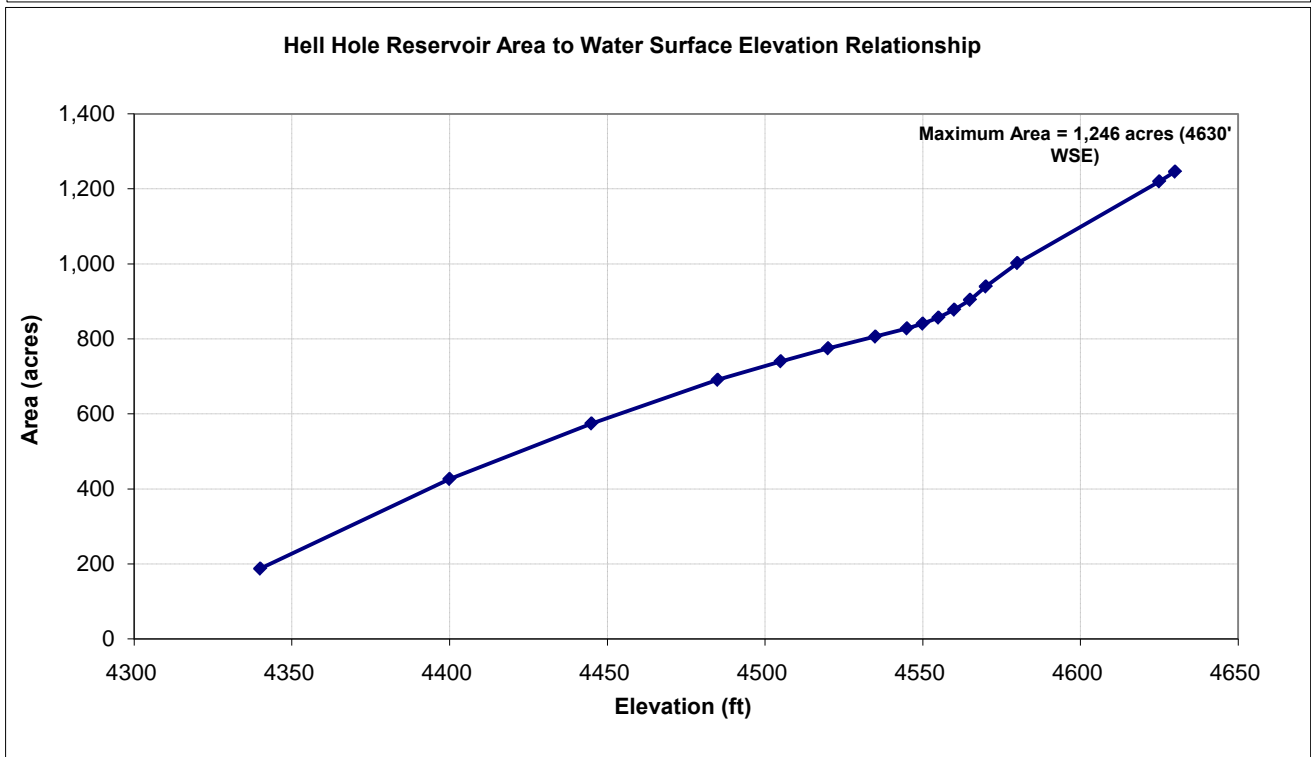
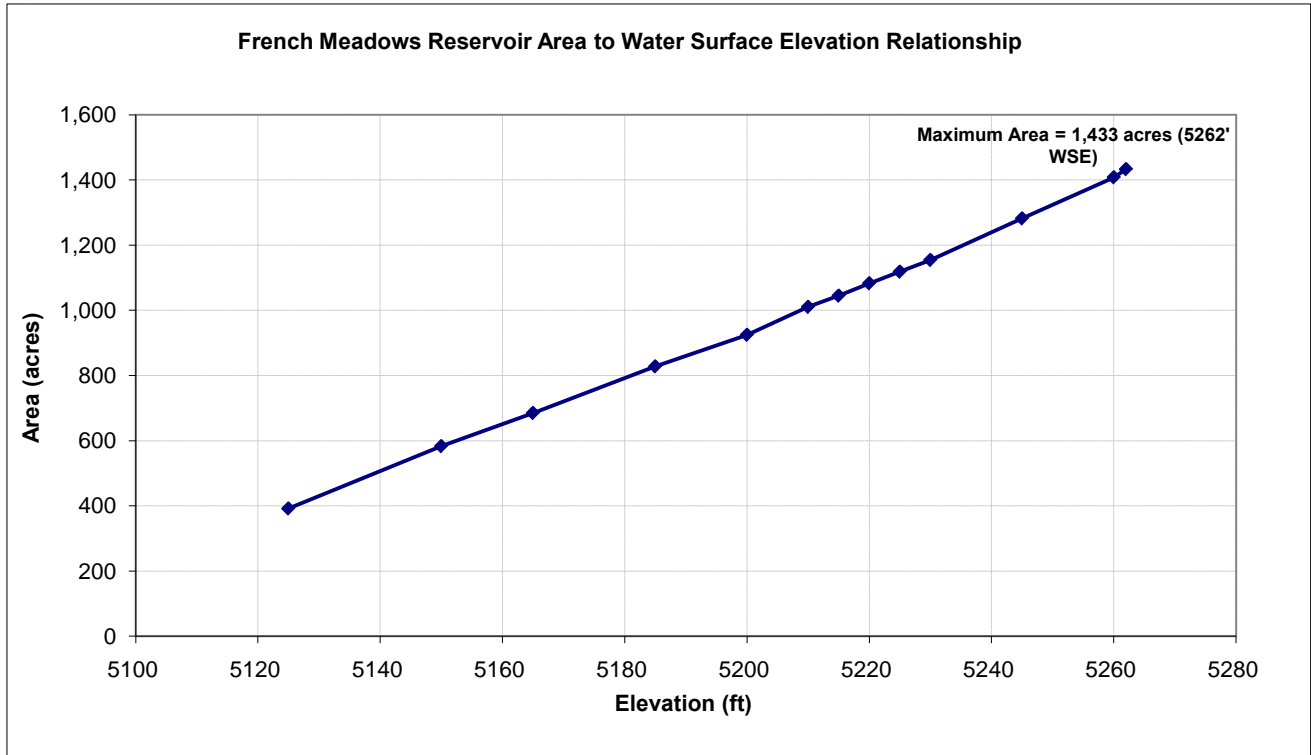
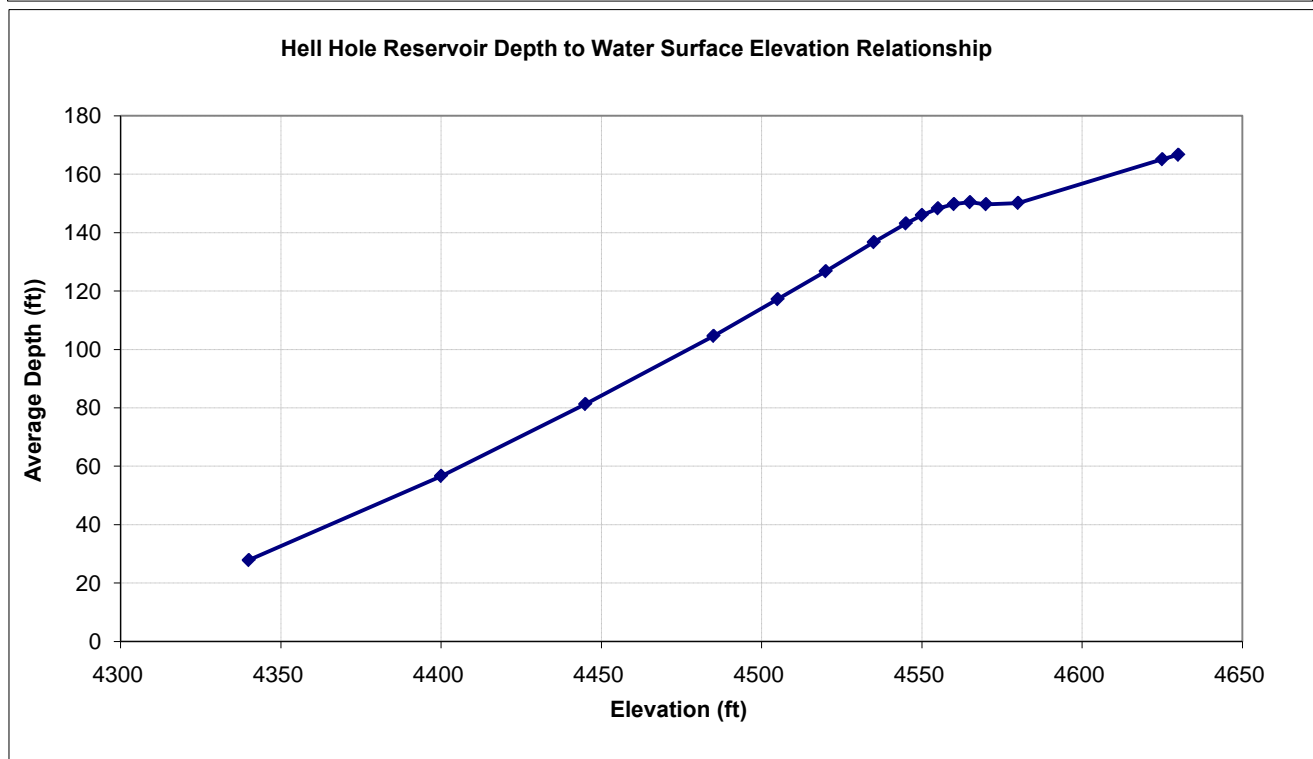
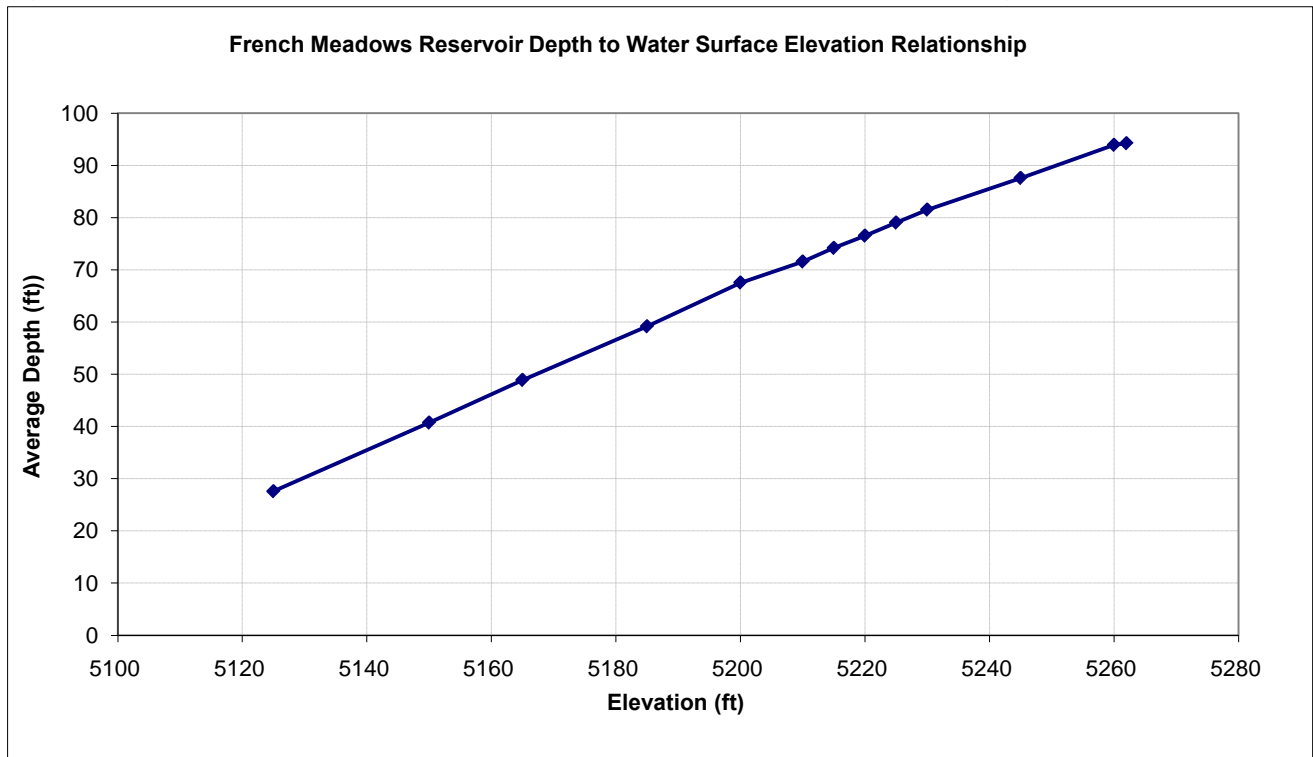


Figure AQ 8-16c. French Meadows and Hell Hole Reservoir Water Surface Elevation - Average Depth Relationship.



MAPS

APPENDIX A

Historical Fish Stocking Records in Hell Hole and French Meadows Reservoirs and the Rubicon and Middle Fork American Rivers

List of Tables

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Table AQ A-2.	Historical Fish Stocking Records for Hell Hole Reservoir.
Table AQ A-3.	Historical Fish Stocking Records for French Meadows Reservoir.
Table AQ A-4.	Historical Fish Stocking Records for the Rubicon River.

Table A-1. Historical Fish Stocking Records for the Middle Fork American River.

Year	Number of Fish Stocked			
	Rainbow Trout	Brown Trout	Brook Trout	Steelhead
1926	5,000			
1929	14,000			
1930	40,000	30,000		19,000
1931	23,000	30,000		
1932	28,000	40,000		
1933	30,000	30,000	10,000	
1934	20,000	90,000		
1935	60,000	50,000		
1936	15,000			
1937		30,000		
1938	22,600	20,900		
1939	11,750	20,100		
1942	9,000			
1943	15,000			
1945	4,000			
1946	4,000			
1947	5,000			
1948	2,500			
1949	8,000			
1950	11,376			
1951	15,518			
1952	17,002			
1953	12,627	2,240		

Table A-2. Historical Fish Stocking Records for Hell Hole Reservoir.

Year	Number of Fish Stocked (Fish/lb) ¹						
	Rainbow Trout ²	Brown Trout	Lake Trout	Kokanee	Coho Salmon	Cutthroat Trout ³	Brook Trout
1967	60,000						
1968	32,386						
1969	1,855	6,500					
1970	5,040						
1971	10,780						
1972	20,500						
1973	10,200					6,000	
1974	1,000				1,000	5,004	
1975						4,950	3,740
1976		10,200				22,300	
1978			2,852				
1979			3,000				
1989				45,000			
1992				73,500			
1994				74,960			
1995				71,750			
1996				51,975			
1997				50,050			
1998				35,600			
1999				25,000			
2000				25,026			
2001		6,380 (2.2)		26,600 (266)			
2002		8,100 (2.7)		25,272 (312)			
2003		7,500 (2.5)		24,960 (192)			
2004		4,200 (2.1)		22,275 (135)			

Table A-2. Historical Fish Stocking Records for Hell Hole Reservoir (continued).

Year	Number of Fish Stocked (Fish/lb) ¹						
	Rainbow Trout ²	Brown Trout	Lake Trout	Kokanee	Coho Salmon	Cutthroat Trout ³	Brook Trout
2005		4,400 (2.2)		25,000 (520)			
2006		3,600 (1.8)		14,350 (128)			
2007		3,800 (1.9)		16,416 (456)			
2008		4,700 (1.7)		37,950 (154)			
2009		7,200 (2.4)		28,272 (114)			

¹ Fish per pound data applied where available.

²Includes 2,800 Eagle Lake rainbows planted in 1971.

³Including cutthroat hybrids.

Table A-3. Historical Fish Stocking Records for French Meadows Reservoir.

Year	Number of Fish Stocked (Fish/lb) ¹		
	Rainbow Trout	Brown Trout	Eagle Lake Trout
1968	29,938		
1969	60,255		
1970	100,600		
1971	79,480		3,000
2001	10,050 (2.0)		
2002	12,500 (1.8)		4,000 (2.0)
2003	9,700 (1.9)		
2004	5,200 (1.7)		
2005	5,500 (1.8)		
2006	5,900 (2.0)		
2007	7,200 (1.8)		1,500 (1.5)
2008	12,800 (2.6)		
2009	20,300 (2.9)		

¹ Fish per pound data applied where available.

Table A-4. Historical Fish Stocking Records for the Rubicon River.

Year	Number of Fish Stocked			
	Rainbow Trout	Brown Trout	Brook Trout	Steelhead
1928		2,380	8,572	
1931		35,000		
1932		31,000		
1933		30,000		
1934	15,000	30,000		
1935		24,000		
1936	11,500	30,000	10,000	
1937		35,000		5,000
1938	4,500	30,000		
1939	30,000			
1940	60,000			
1941	60,000			
1942	27,740			
1943	44,120			
1944	41,430			
1945	28,000			
1946	33,960			
1947	10,200			
1948	28,020			
1949	13,780			
1950	20,000			
1951	18,410			
1952	18,960			
1953	20,000			

APPENDIX B

Comparison of French Meadows and Hell Hole Reservoir Elevations for the Future Proposed Action (including Hell Hole Seasonal Storage Increase Improvement) and the Historic Conditions (No-Action Alternative).

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- Figure B-4. Hell Hole Reservoir Water Surface Elevation in Relation to the Hell Hole Boat Ramp Operational Range During Dry Water Years.
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Details of the Hydrology Analysis in that Draft License Application that includes the Hell Hole Seasonal Storage Increase

Historic conditions in the Draft License Application are generally called **existing conditions**. The hydrology used to represent **existing conditions (No-Action Alternative)** in almost all the analyses was the historical impaired hydrology in the reservoirs (1975 to 2007). Historic MFP operations, however, have changed over time (1975 to 2007) based on changes in consumptive water demand, power demands, facility upgrades, and routine maintenance activities. Therefore, in some locations the historical empirical hydrology does not accurately represent existing conditions (current operations) of the MFP under the current license conditions. For example: (1) historic reservoir elevations were the result of much lower water demand than exists currently; and (2) historic diversions in the small streams were reduced due to debris build-up at the intakes or to prevent turbine damage from rocks during high-flow events. Planned screen/intake modifications will alleviate the small diversion issues in the future under the No-Action Alternative allowing unimpeded (full) diversion up to the existing water rights and FERC license conditions.

An additional model run was developed to more accurately reflect current and future operations of the MFP under the No-Action Alternative (existing FERC license conditions) in Hell Hole and French Meadows reservoirs. This model run is referred to as the No-Action Alternative – **Existing License Conditions (ELC)**. The model run included unimpeded diversion rates at the small diversion and uses modeling parameters in the reservoirs that approximate current operations (e.g., total reservoir carryover target of 142,000 ac-ft on December 31, approximate water balancing between reservoirs, 30-day annual maintenance outage period in October).

The hydrology used to represent the Proposed Action in almost all the analyses includes an operations model run of the MFP with modified/new Project facilities; new instream flow and reservoir minimum pool measures; existing operating agreements and contracts; an additional water right (i.e., Hell Hole Reservoir Seasonal Storage Increase Improvement requires a new non-consumptive water right); and existing consumptive water demand (42,000 ac-ft/year). This model run is referred to as **Proposed Action** (sometimes referred to **Proposed Action – Existing Demand**).

A second model run of the Proposed Action was also developed that incorporates operations of the MFP with future consumptive water demand under full build-out (120,000 ac-ft/year). This model run is referred to as **Proposed Action – Future Demand**. The two Proposed Action model runs are very similar (almost indistinguishable) in terms of instream flows in the different water years in the bypass reaches. The primary difference of consequence between these model runs is the water surface elevation in Hell Hole and French Meadows reservoirs in some water years. In the **Proposed Action – Future Demand** run, reservoir water levels are lower due to increased water deliveries compared to the Proposed Action – Existing Demand.

Figures

Figure B-1. Hell Hole Reservoir Water Surface Elevation in Relation to the Hell Hole Boat Ramp Operational Range during Wet Water Years.

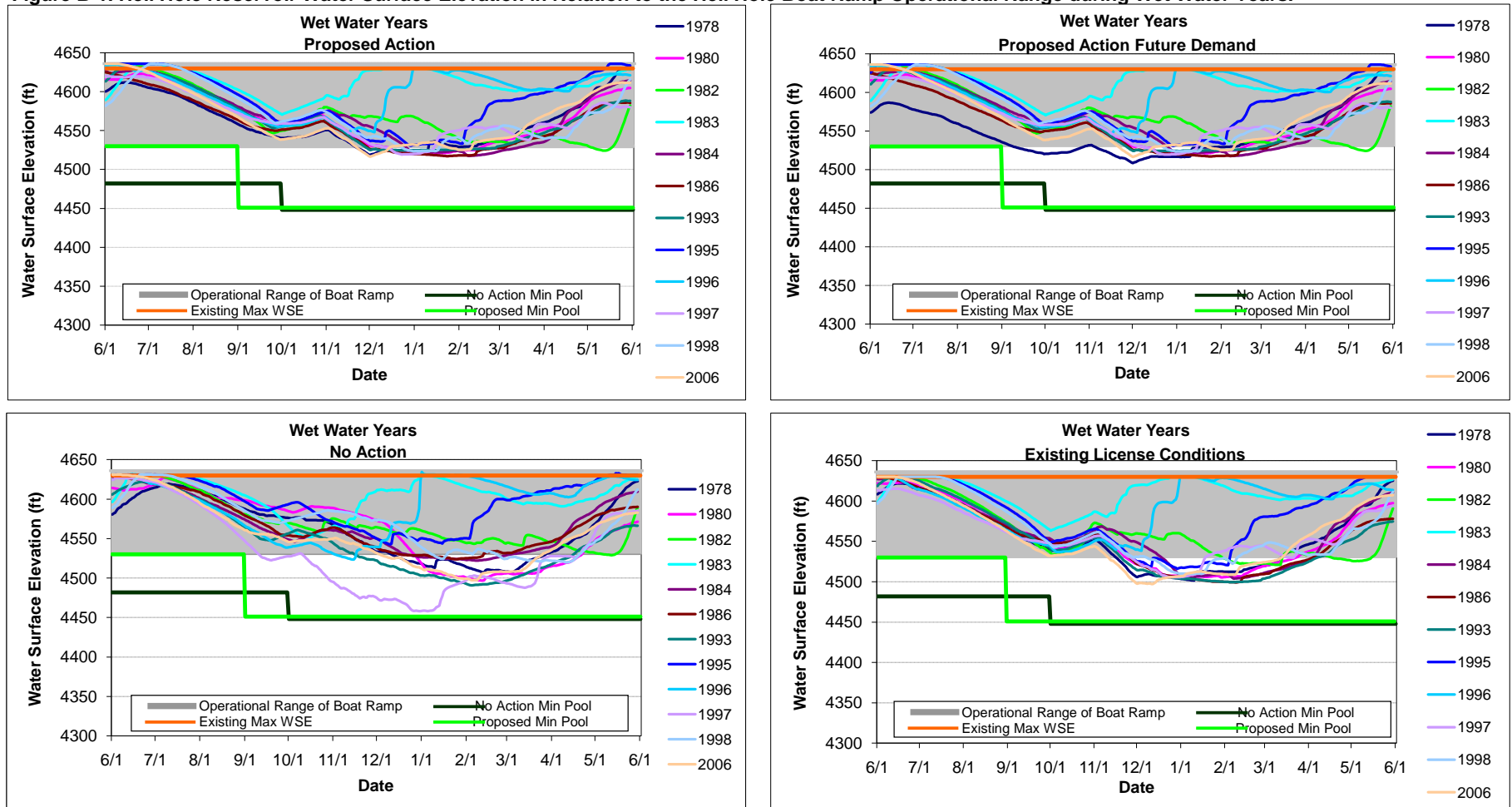


Figure B-2. Hell Hole Reservoir Water Surface Elevation in Relation to the Hell Hole Boat Ramp Operational Range during Above Normal Water Years.

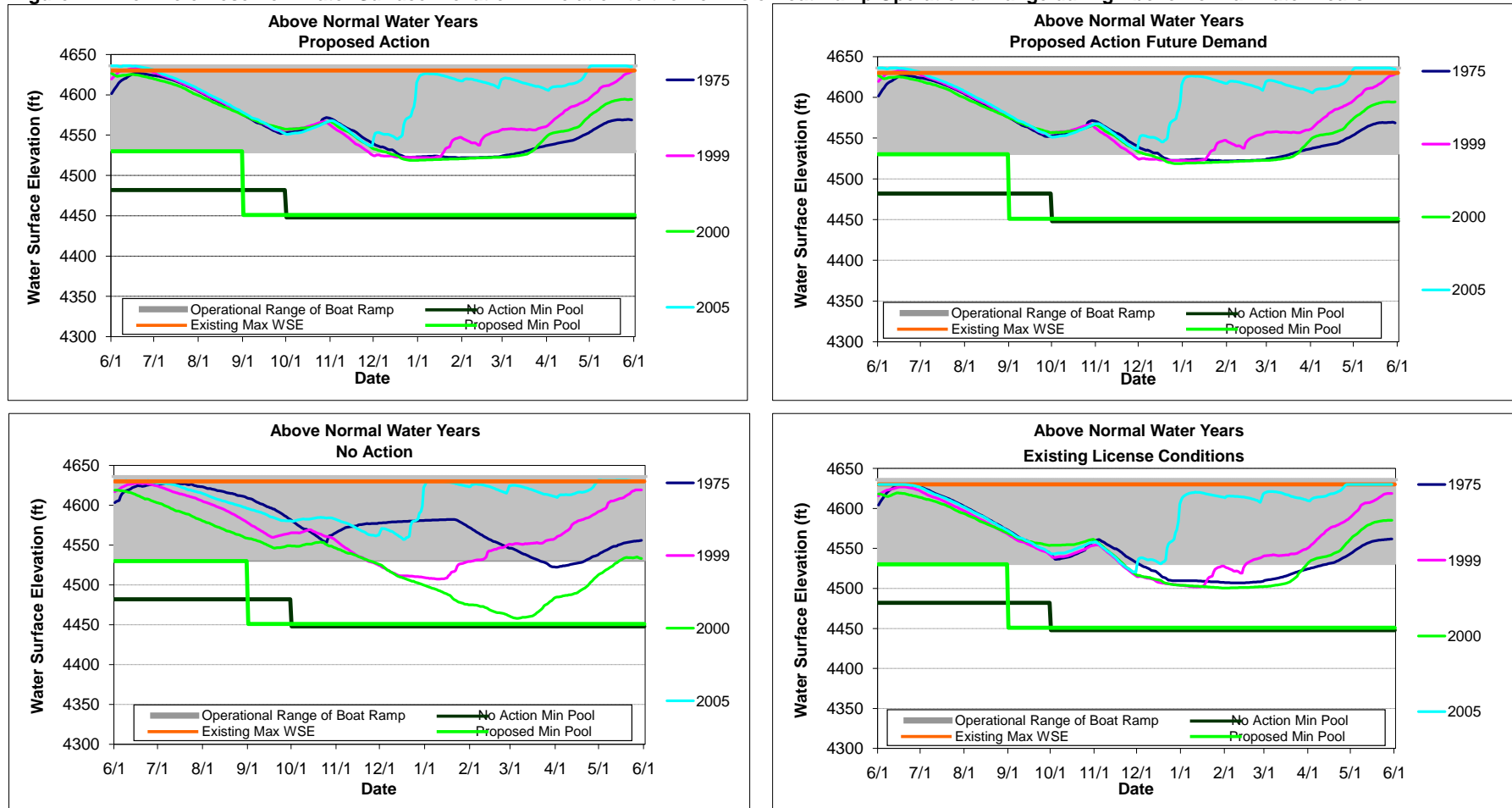


Figure B-3. Hell Hole Reservoir Water Surface Elevation in Relation to the Hell Hole Boat Ramp Operational Range during Below Normal Water Years.

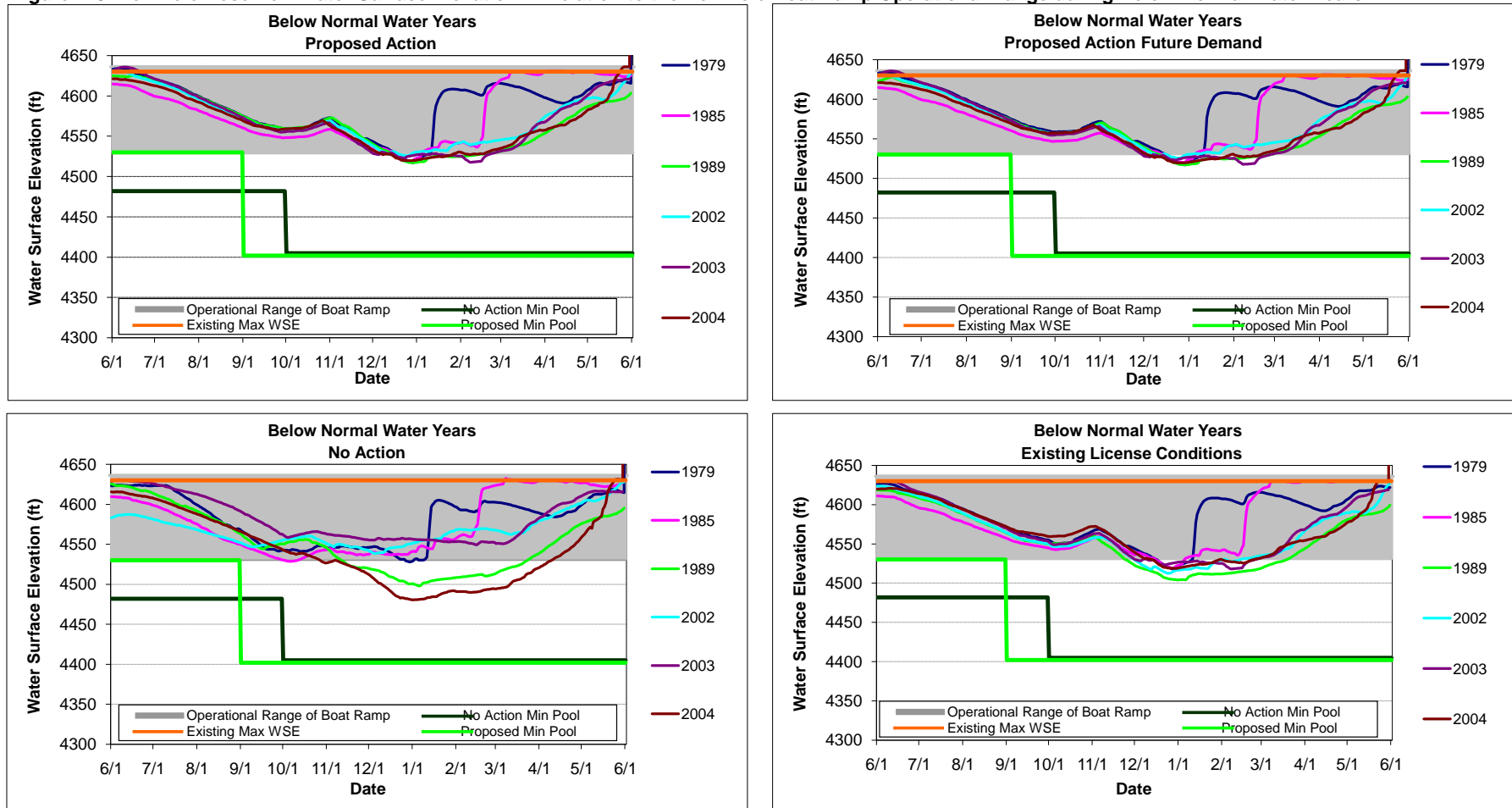


Figure B-4. Hell Hole Reservoir Water Surface Elevation in Relation to the Hell Hole Boat Ramp Operational Range during Dry Water Years.

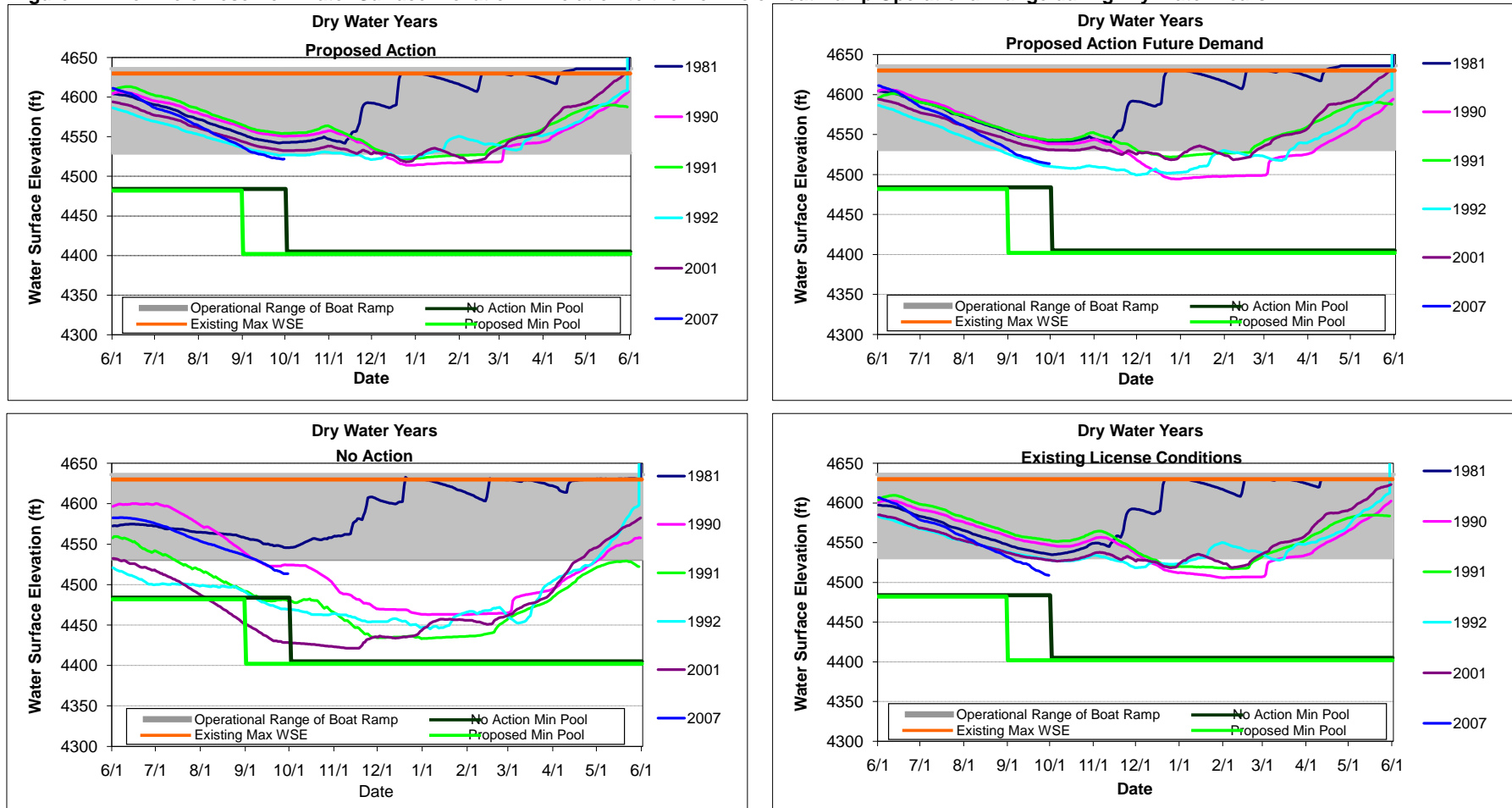


Figure B-5. Hell Hole Reservoir Water Surface Elevation in Relation to the Hell Hole Boat Ramp Operational Range during Critical Water Years.

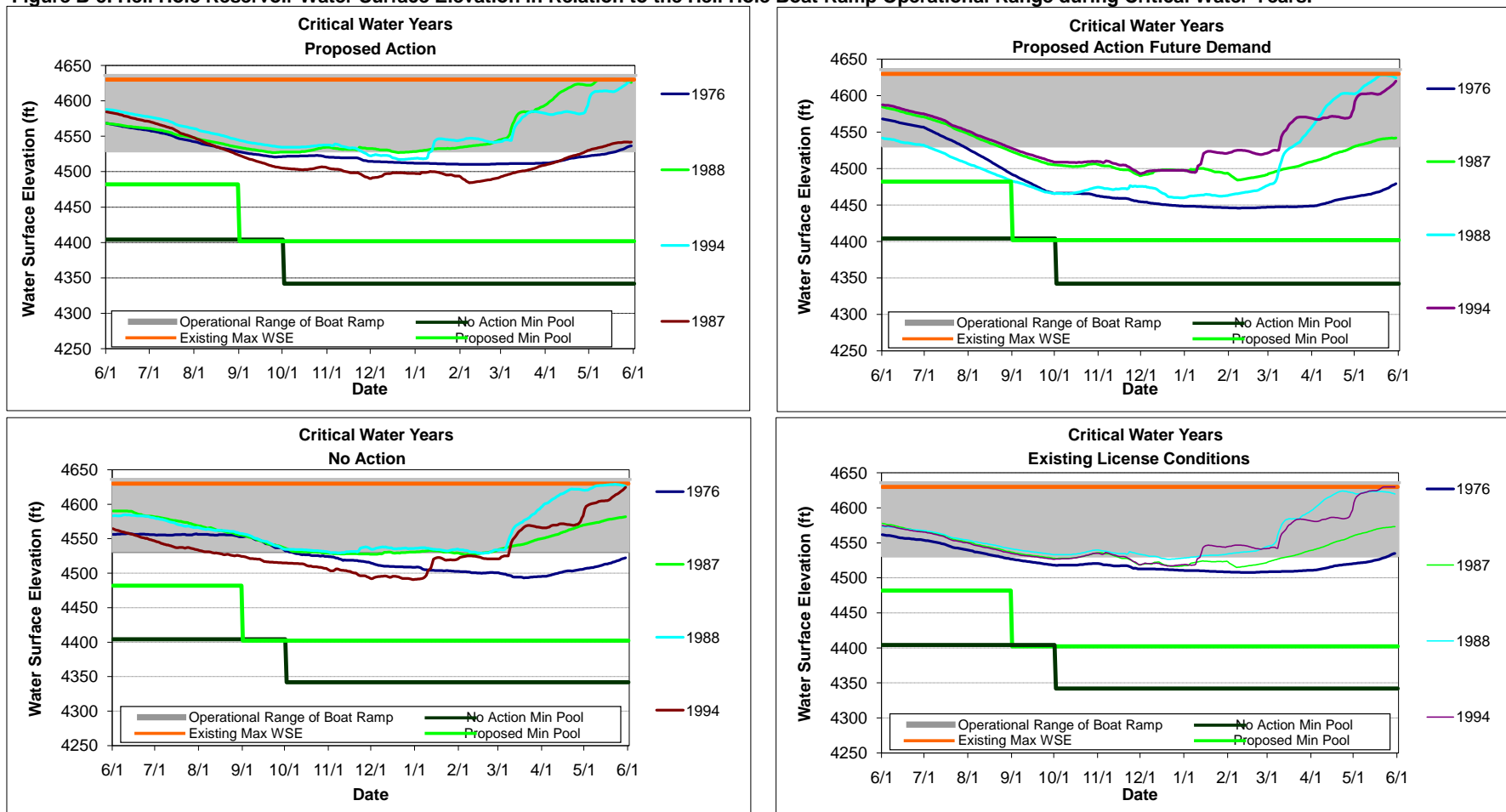


Figure B-6. Hell Hole Reservoir Water Surface Elevation in Relation to the Hell Hole Boat Ramp Operational Range during Extreme Critical Water Years.

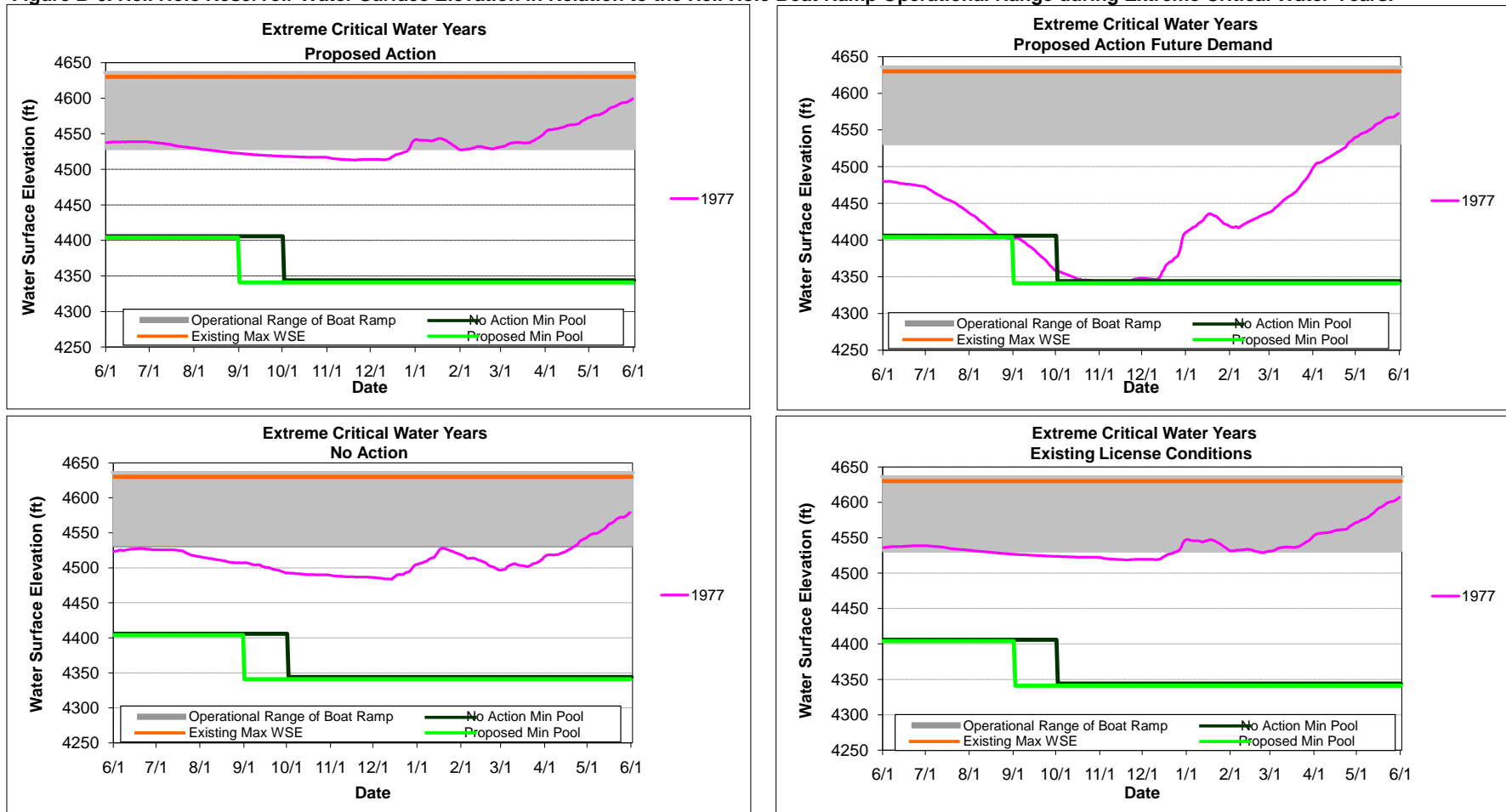


Figure B-7. French Meadows Reservoir Water Surface Elevation in Relation to the French Meadows Boat Ramp Operational Range during Wet Water Years.

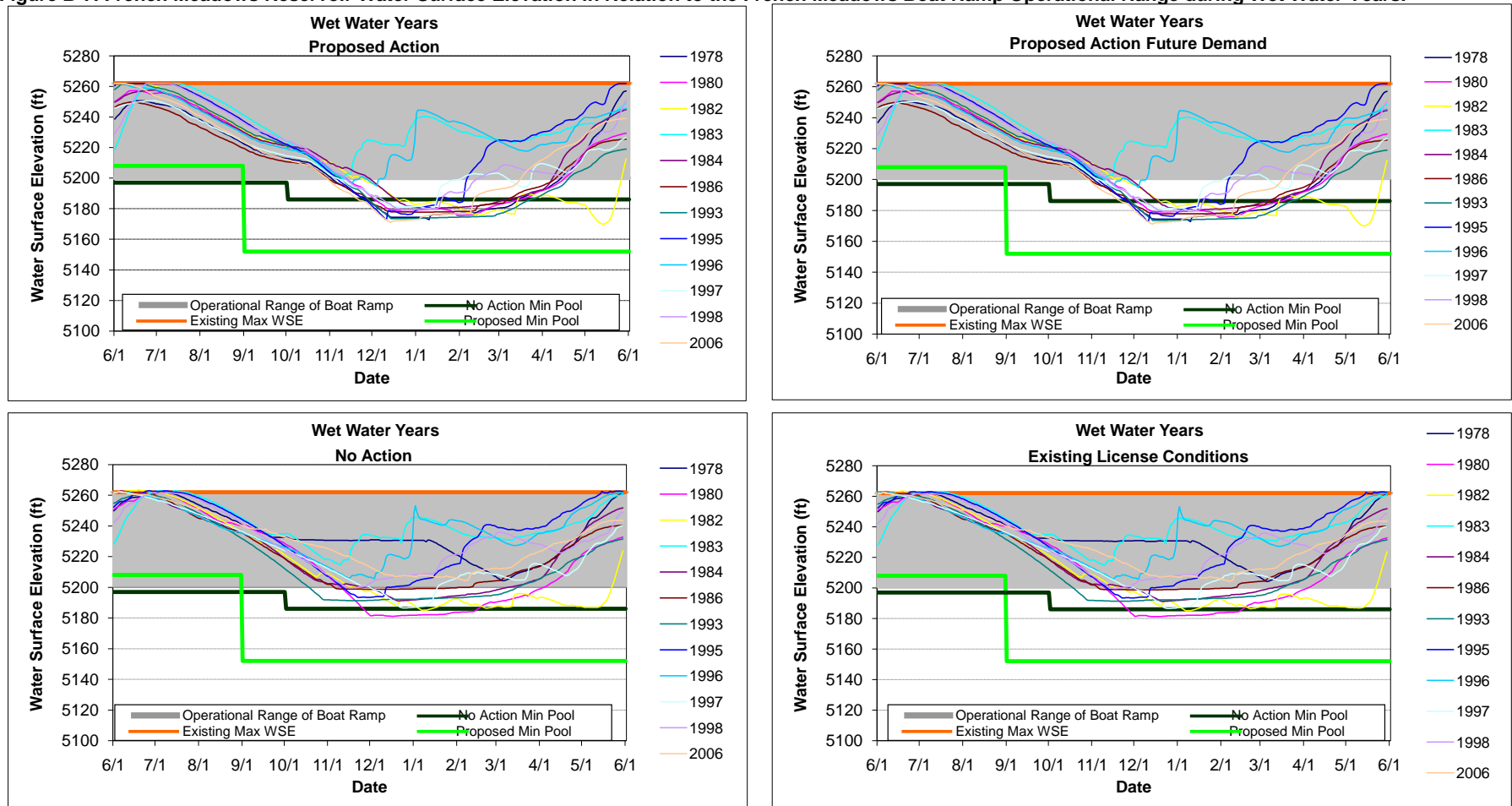


Figure B-8. French Meadows Reservoir Water Surface Elevation in Relation to the French Meadows Boat Ramp Operational Range during Above Normal Water Years.

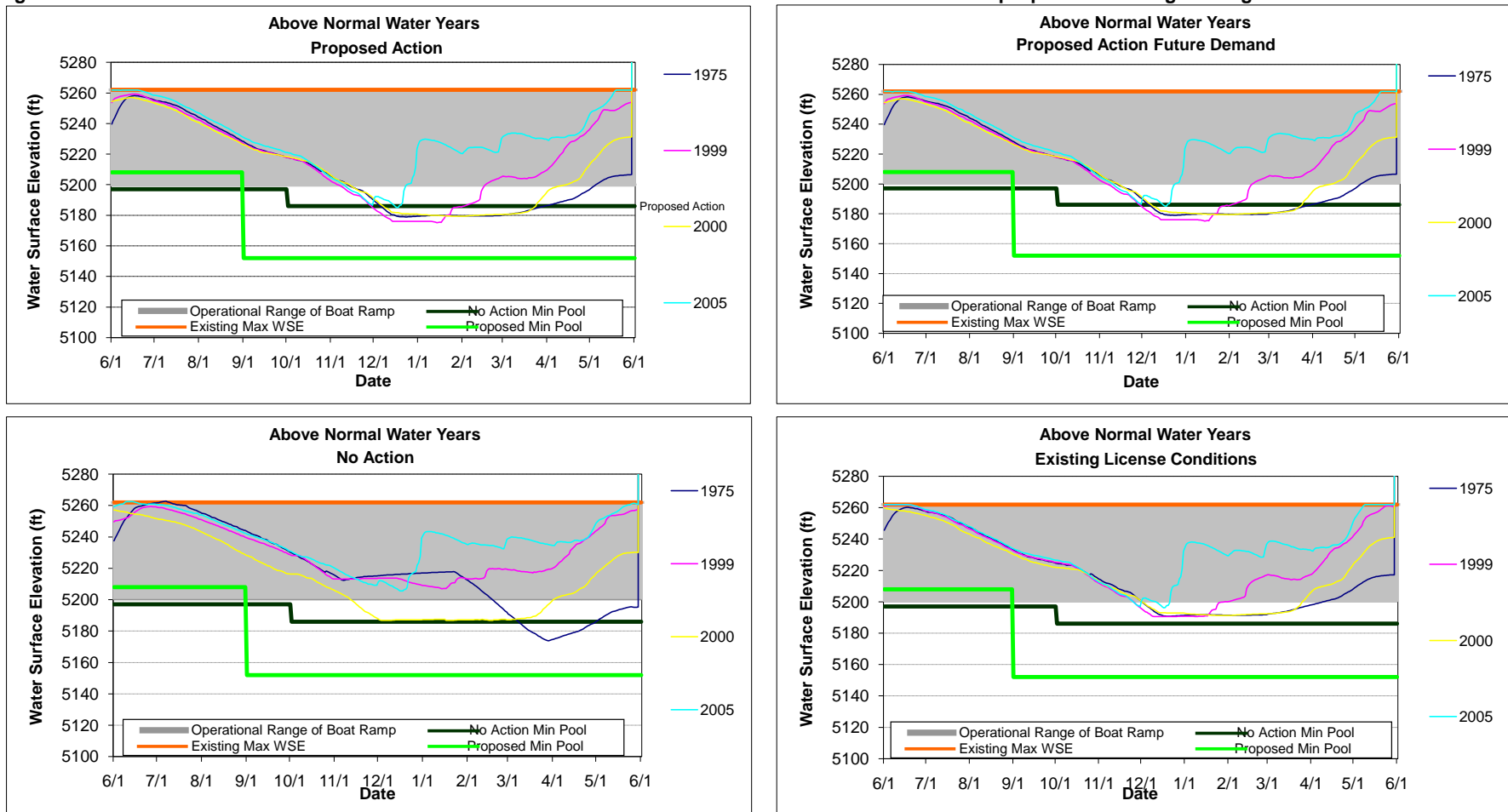


Figure B-9. French Meadows Reservoir Water Surface Elevation in Relation to the French Meadows Boat Ramp Operational Range during Below Normal Water Years.

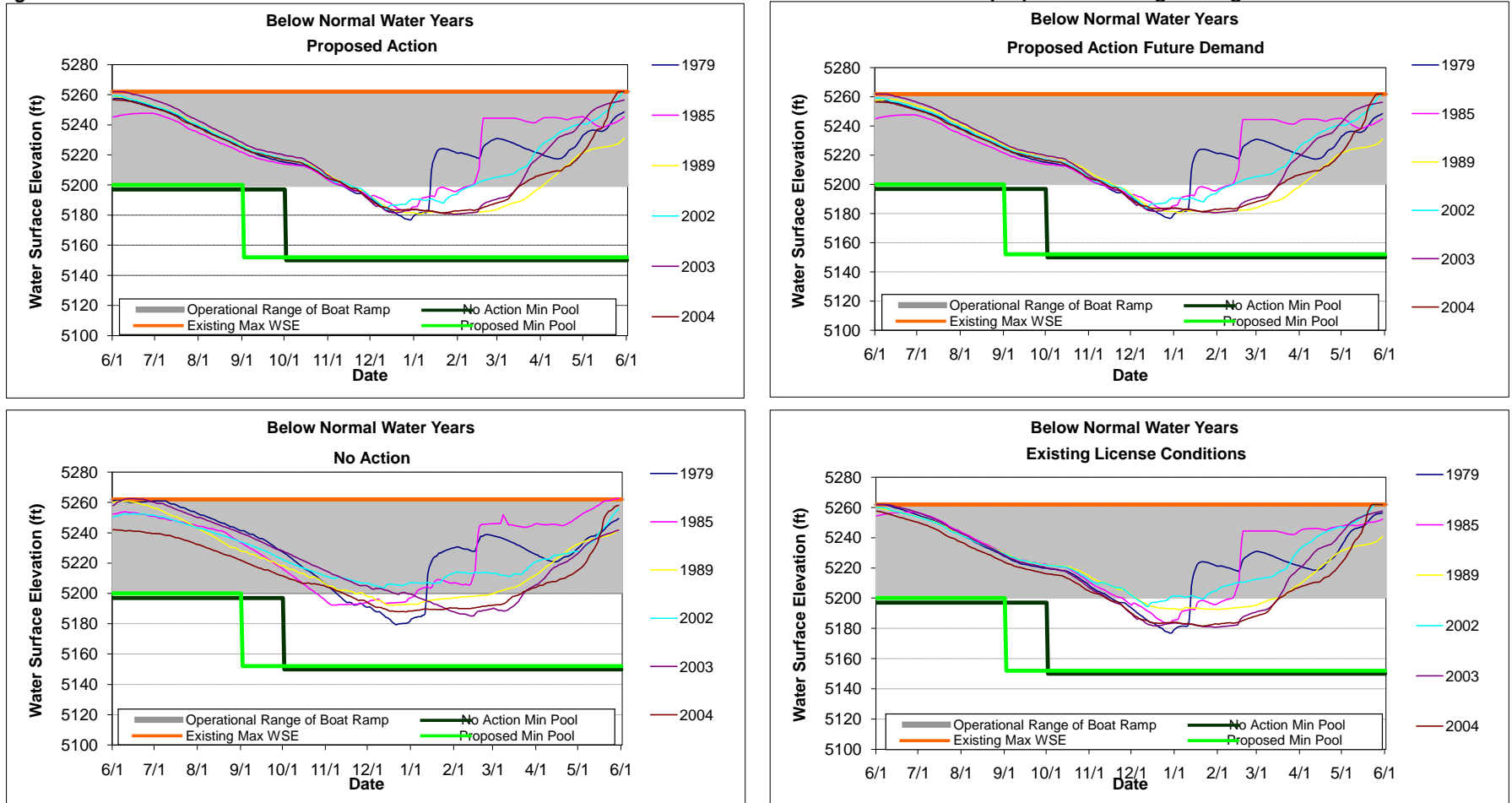


Figure B-10. French Meadows Reservoir Water Surface Elevation in Relation to the French Meadows Boat Ramp Operational Range during Dry Water Years.

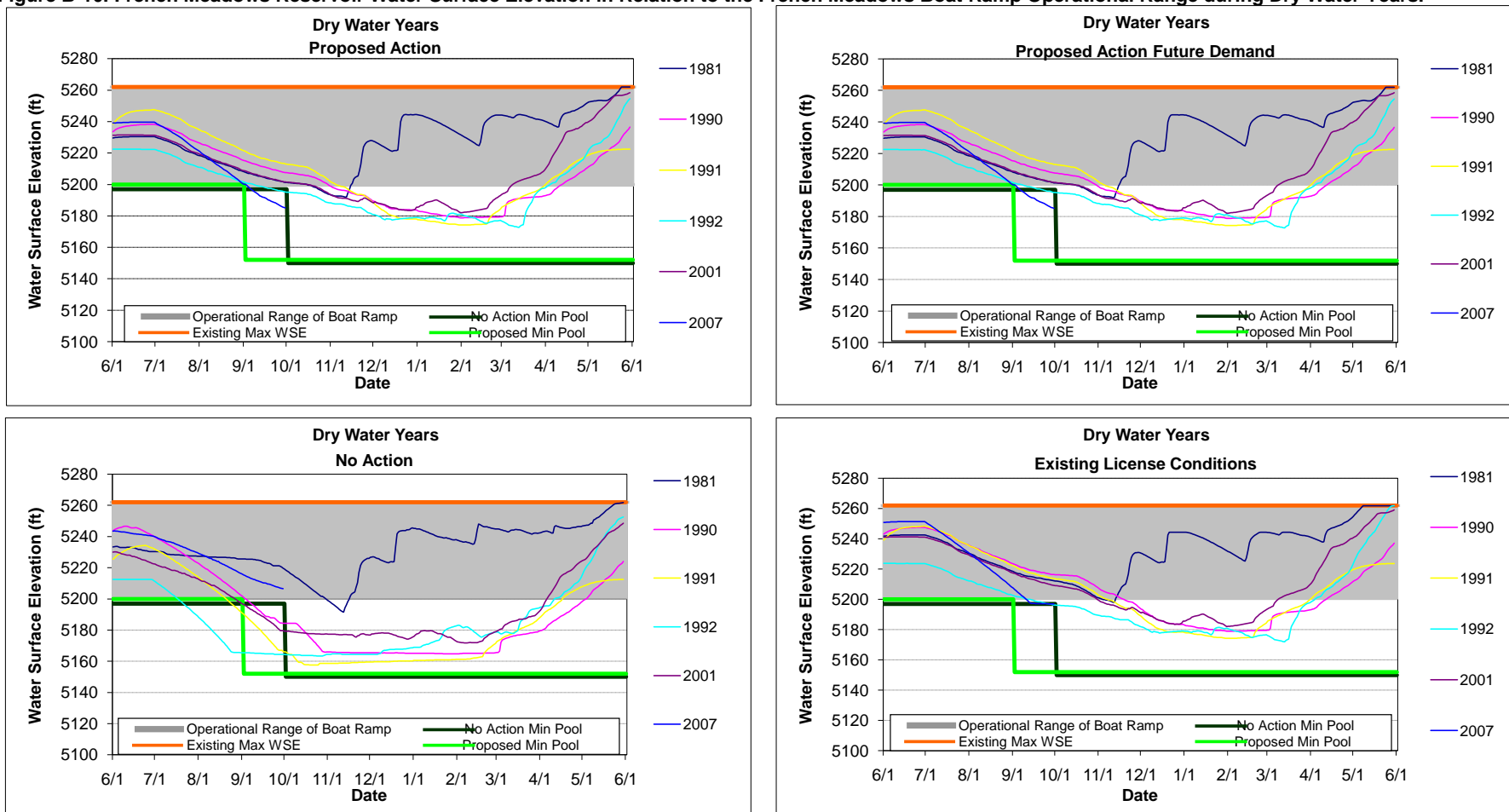


Figure B-11. French Meadows Reservoir Water Surface Elevation in Relation to the French Meadows Boat Ramp Operational Range during Critical Water Years.

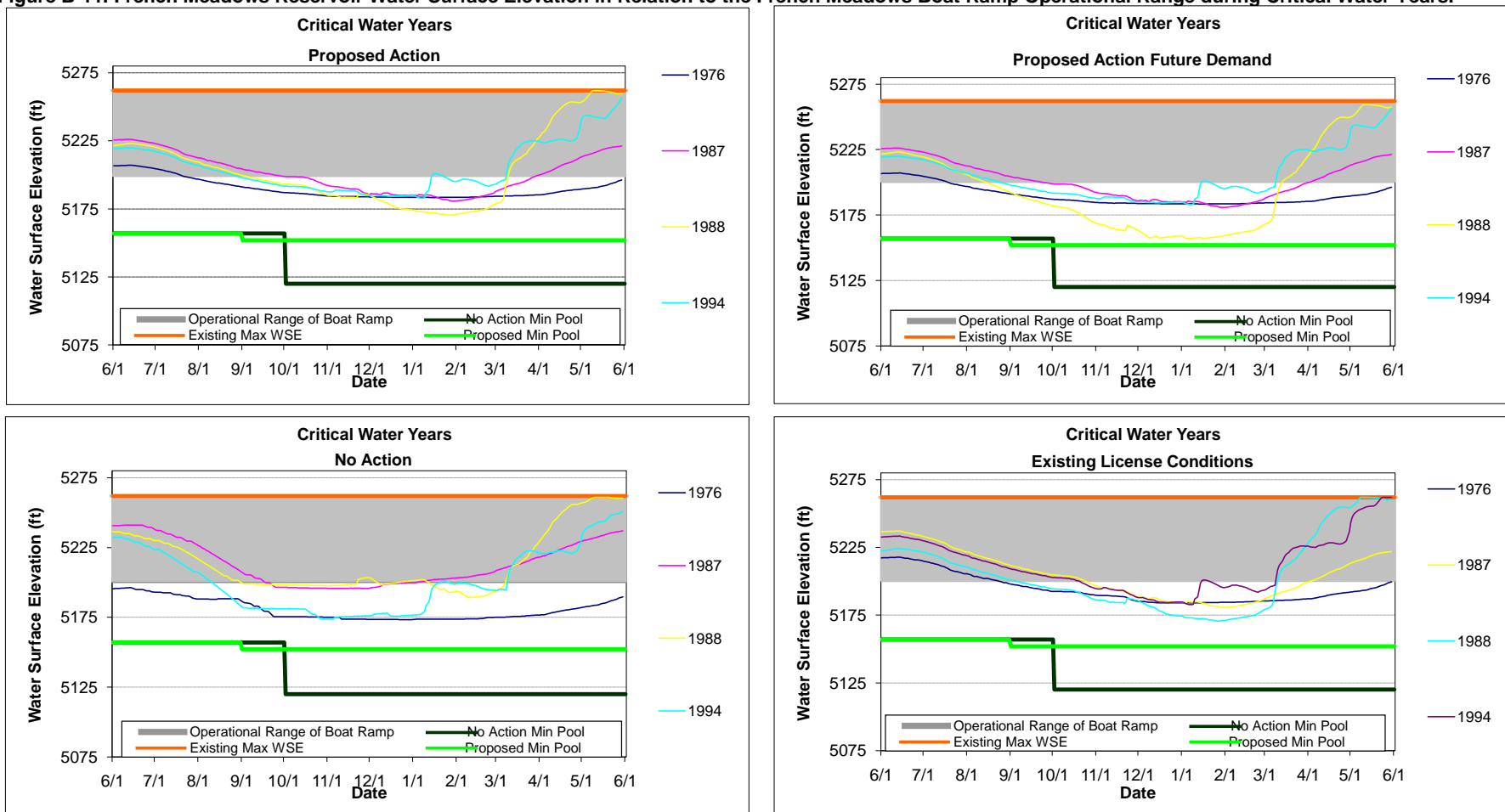
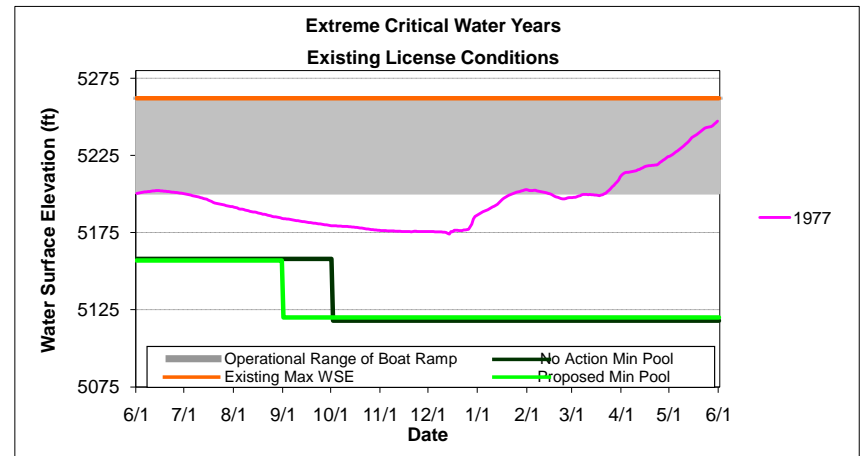
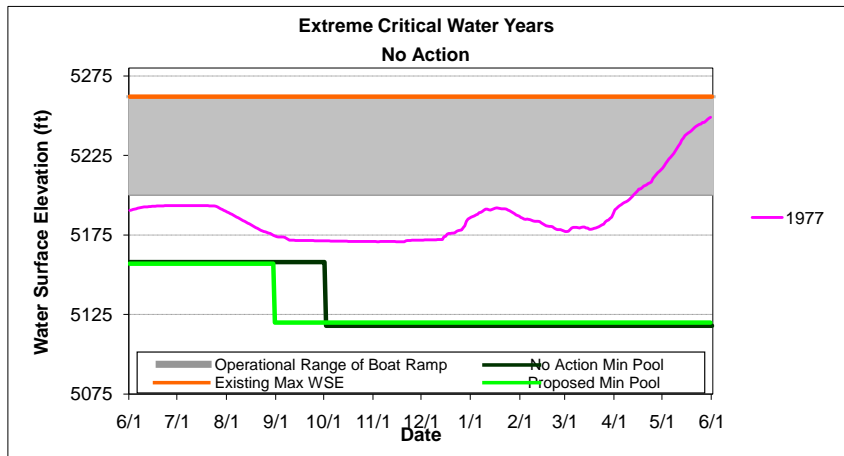
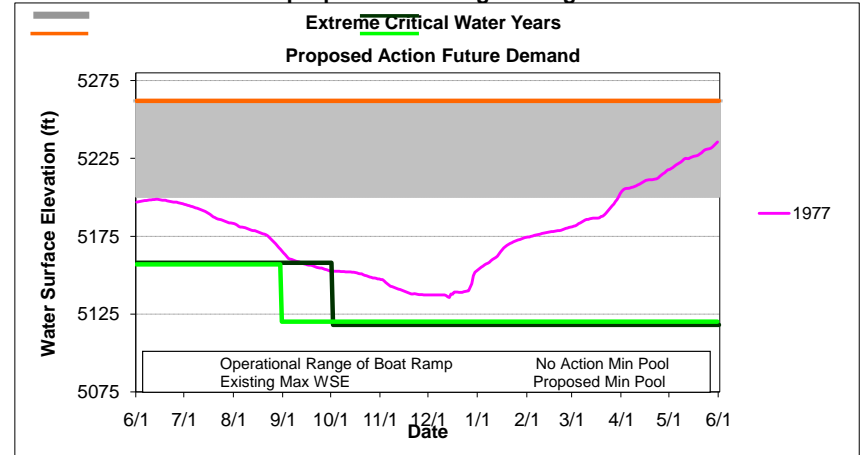
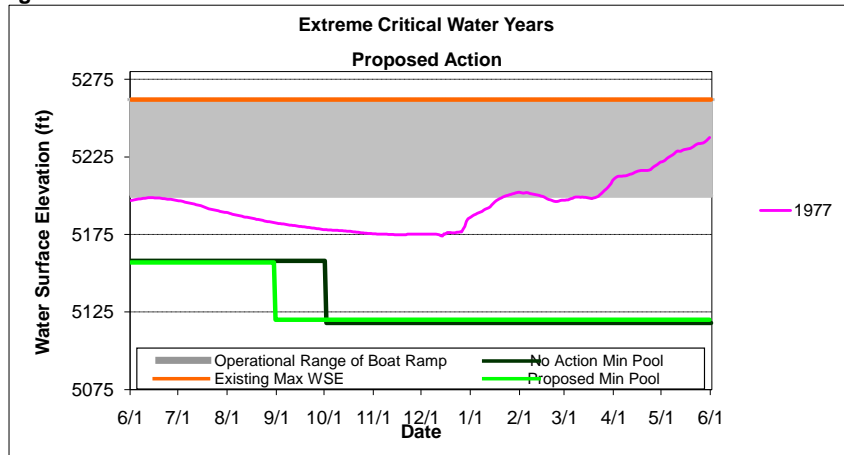


Figure B-12. French Meadows Reservoir Water Surface Elevation in Relation to the French Meadows Boat Ramp Operational Range during Extreme Critical Water Years.



APPENDIX C

Comparison of French Meadows Reservoir, Hell Hole Reservoir, and Ralston Afterbay Water Temperature and Dissolved Oxygen Profiles (2005–2008).

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Figures

Figure C-1. Comparison of French Meadows Reservoir Water Temperature Profiles at FM1 (2005-2008)¹.

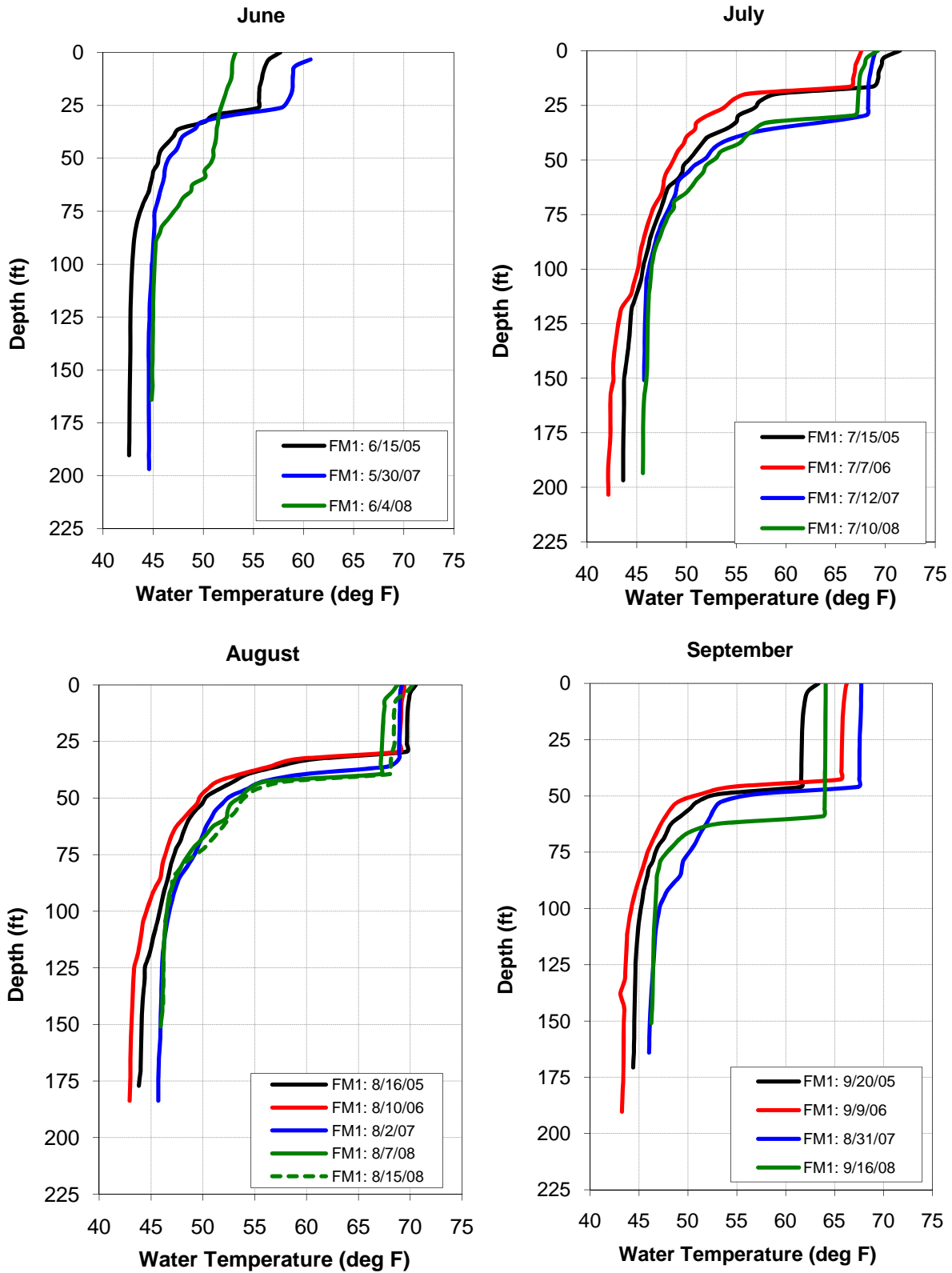
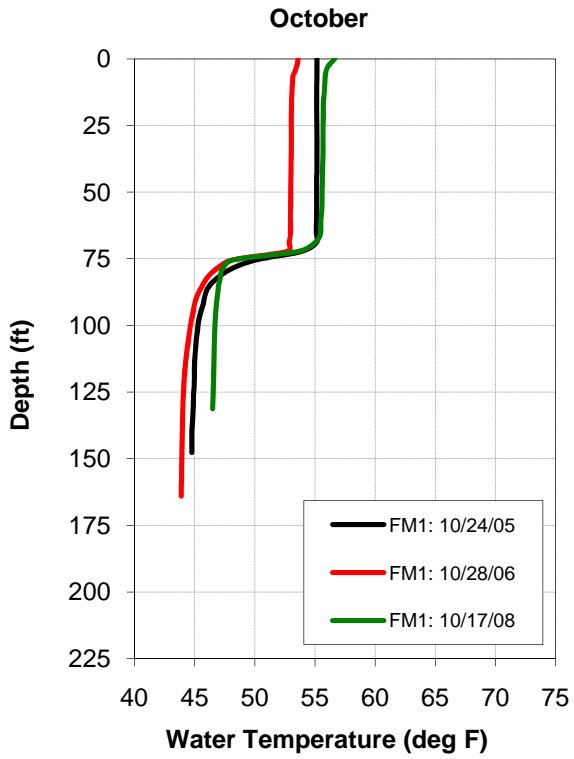


Figure C-1. Comparison of French Meadows Reservoir Water Temperature Profiles at FM1 (2005-2008) (continued).



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-2. Comparison of French Meadows Reservoir Water Temperature Profiles at FM2 (2005-2008)¹.

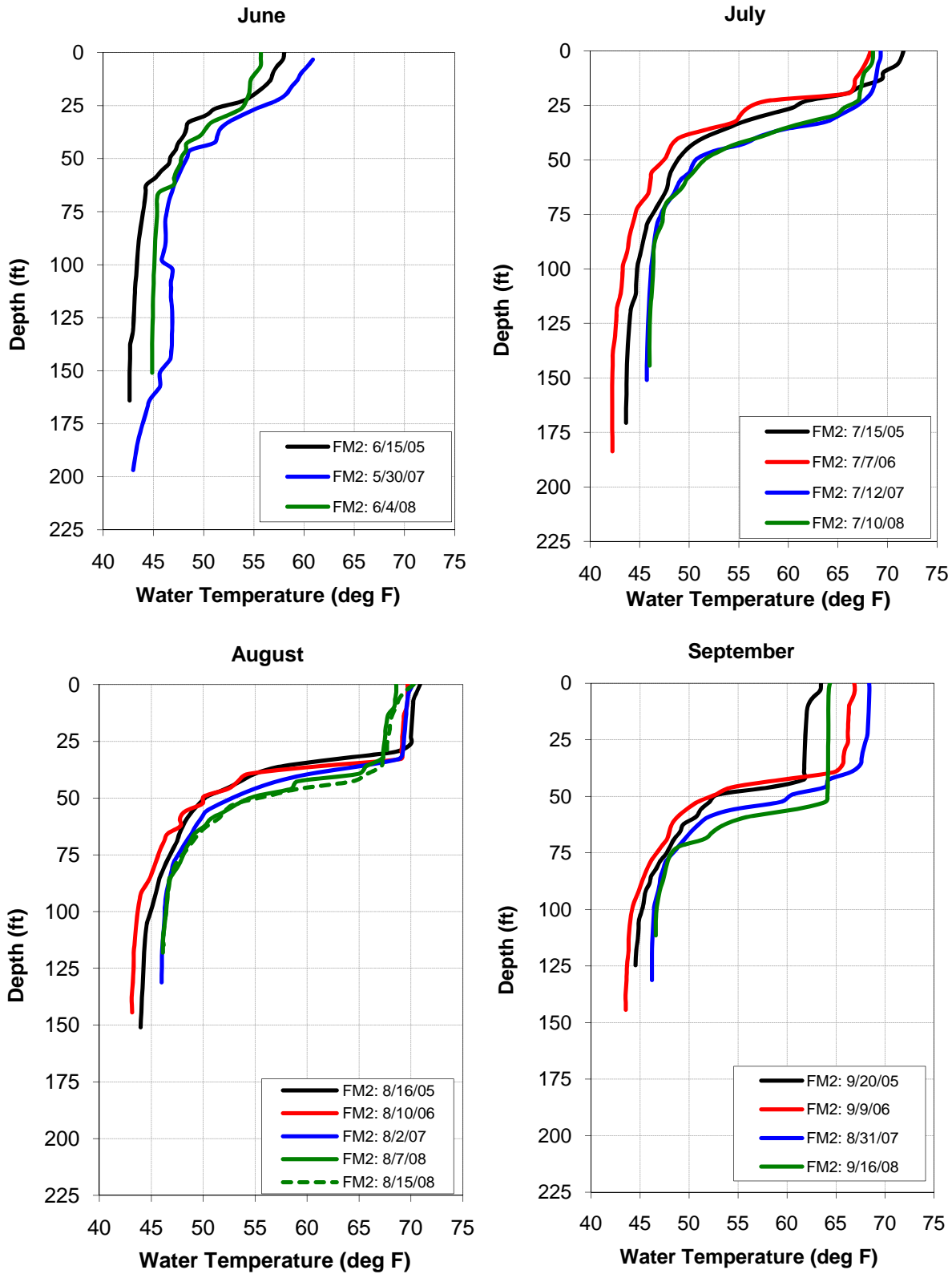
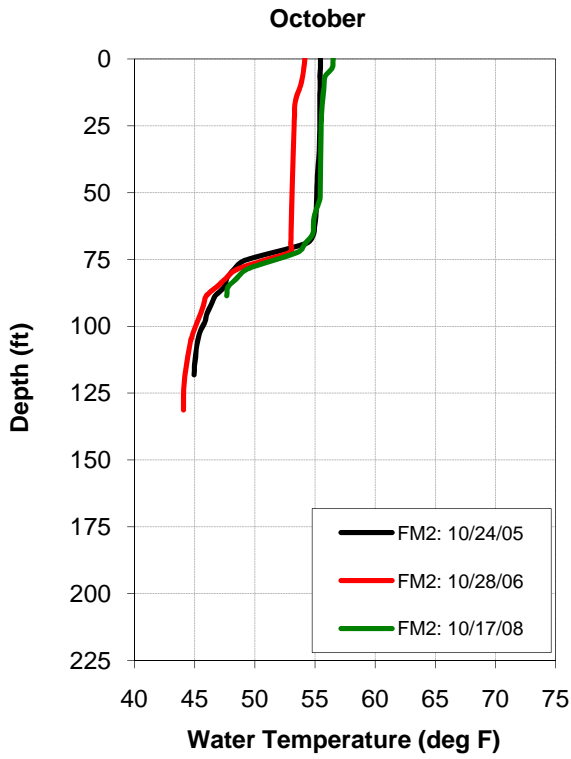
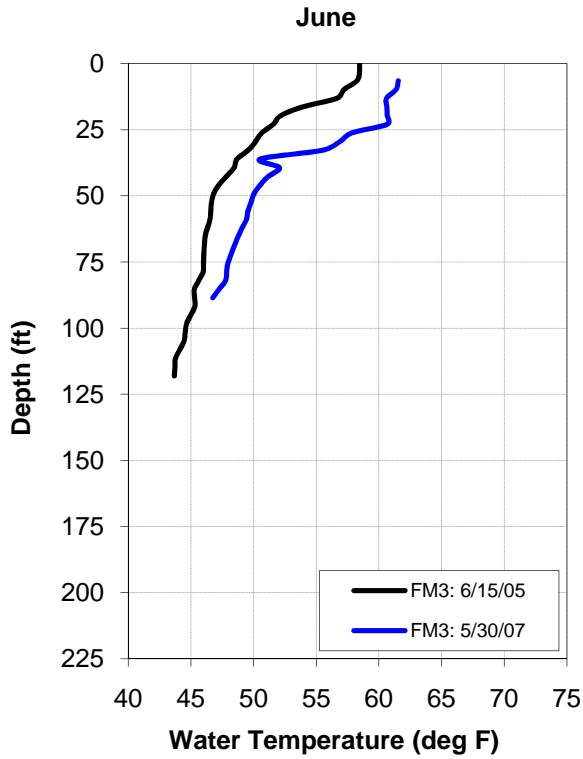


Figure C-2. Comparison of French Meadows Reservoir Water Temperature Profiles at FM2 (2005-2008) (continued).



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-3. Comparison of French Meadows Reservoir Water Temperature Profiles at FM3 (2005-2008)¹.



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-4. Comparison of French Meadows Reservoir Dissolved Oxygen Profiles at FM1 (2005-2008)¹.

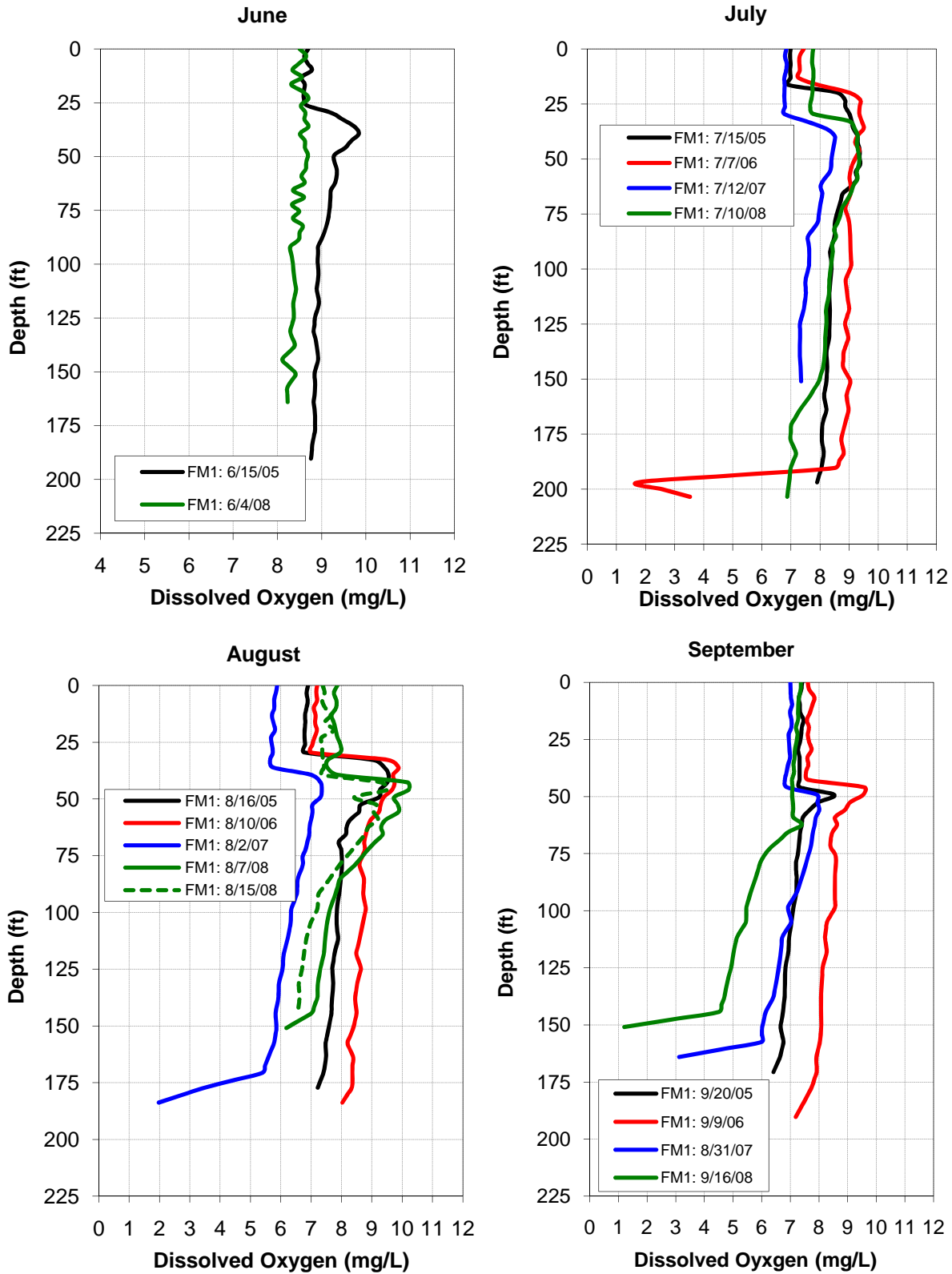
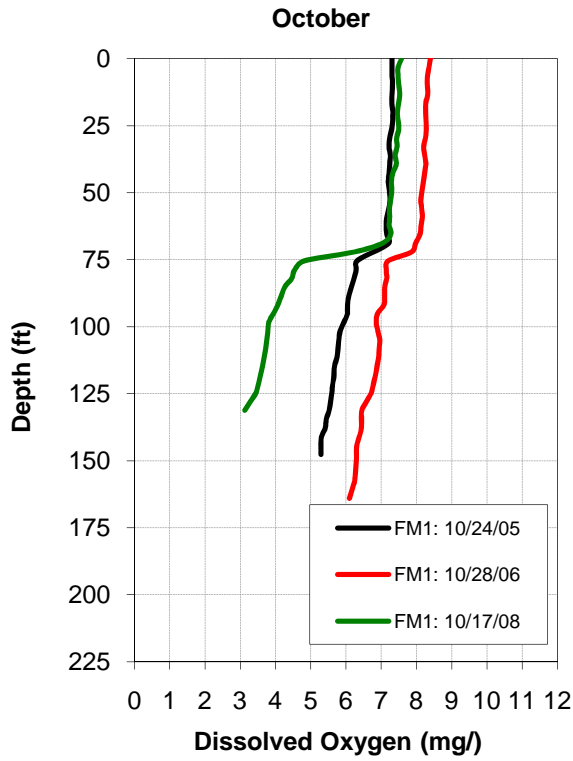


Figure C-4. Comparison of French Meadows Reservoir Dissolved Oxygen Profiles at FM1 (2005-2008) (continued).



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-5. Comparison of French Meadows Reservoir Dissolved Oxygen Profiles at FM2 (2005-2008)¹.

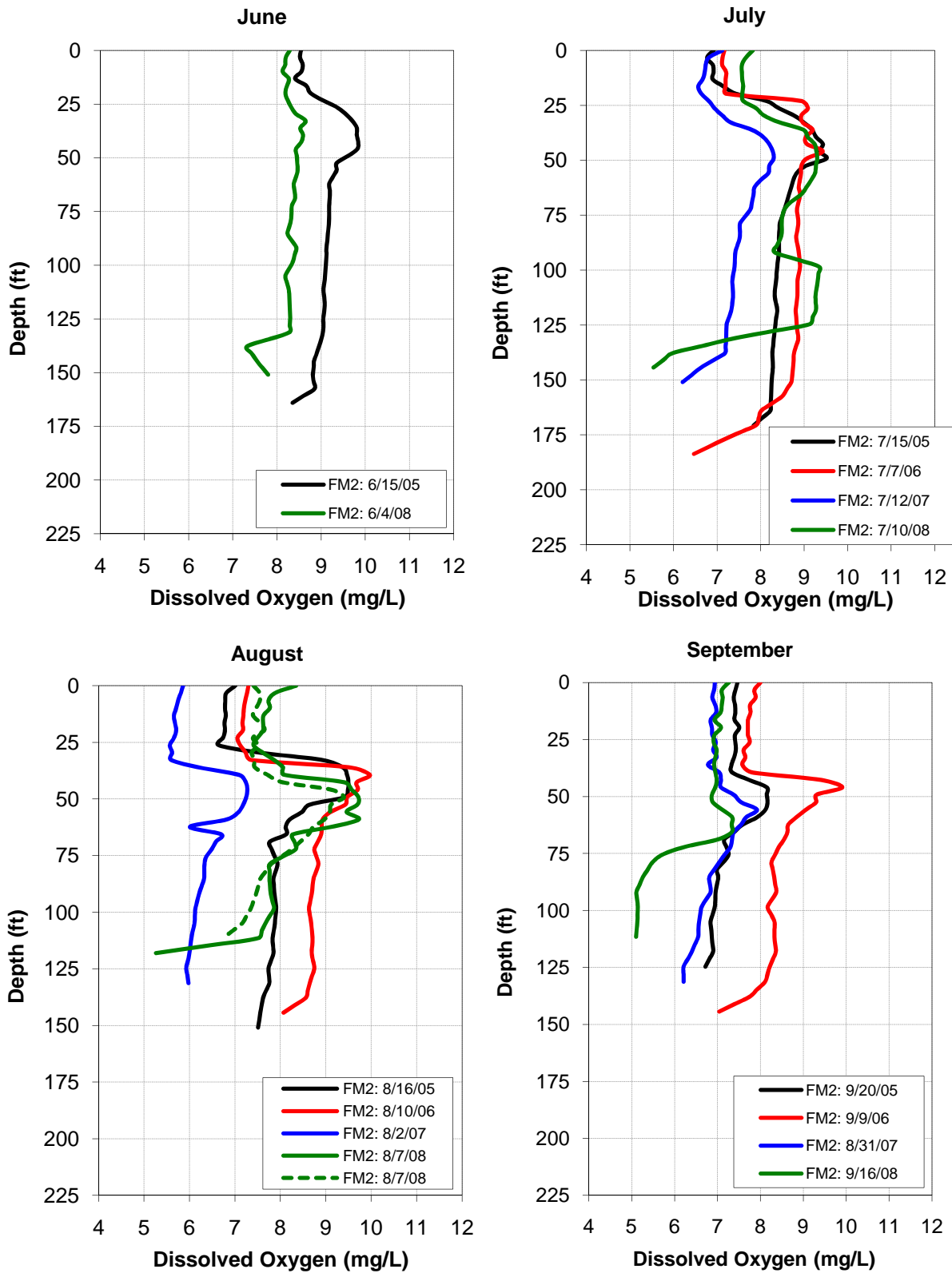
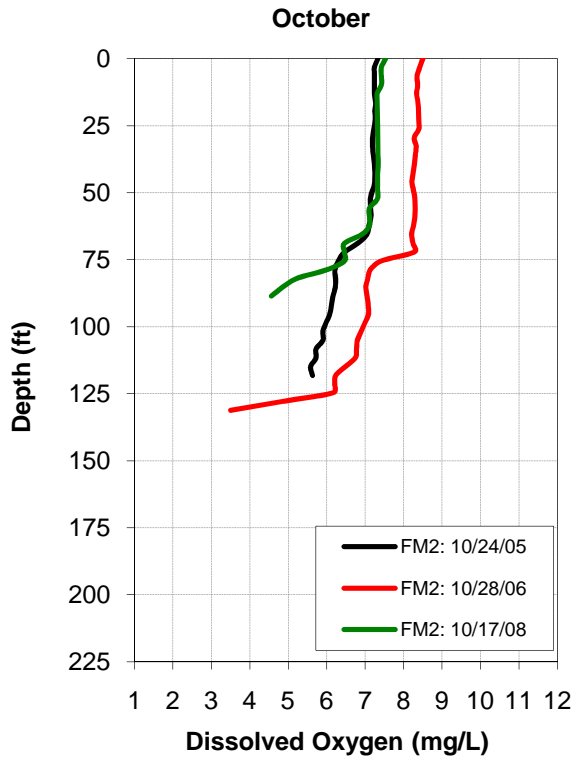


Figure C-5. Comparison of French Meadows Reservoir Dissolved Oxygen Profiles at FM2 (2005-2008) (continued).



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-6. Comparison of Hell Hole Reservoir Water Temperature Profiles at HH1 (2005-2008)¹.

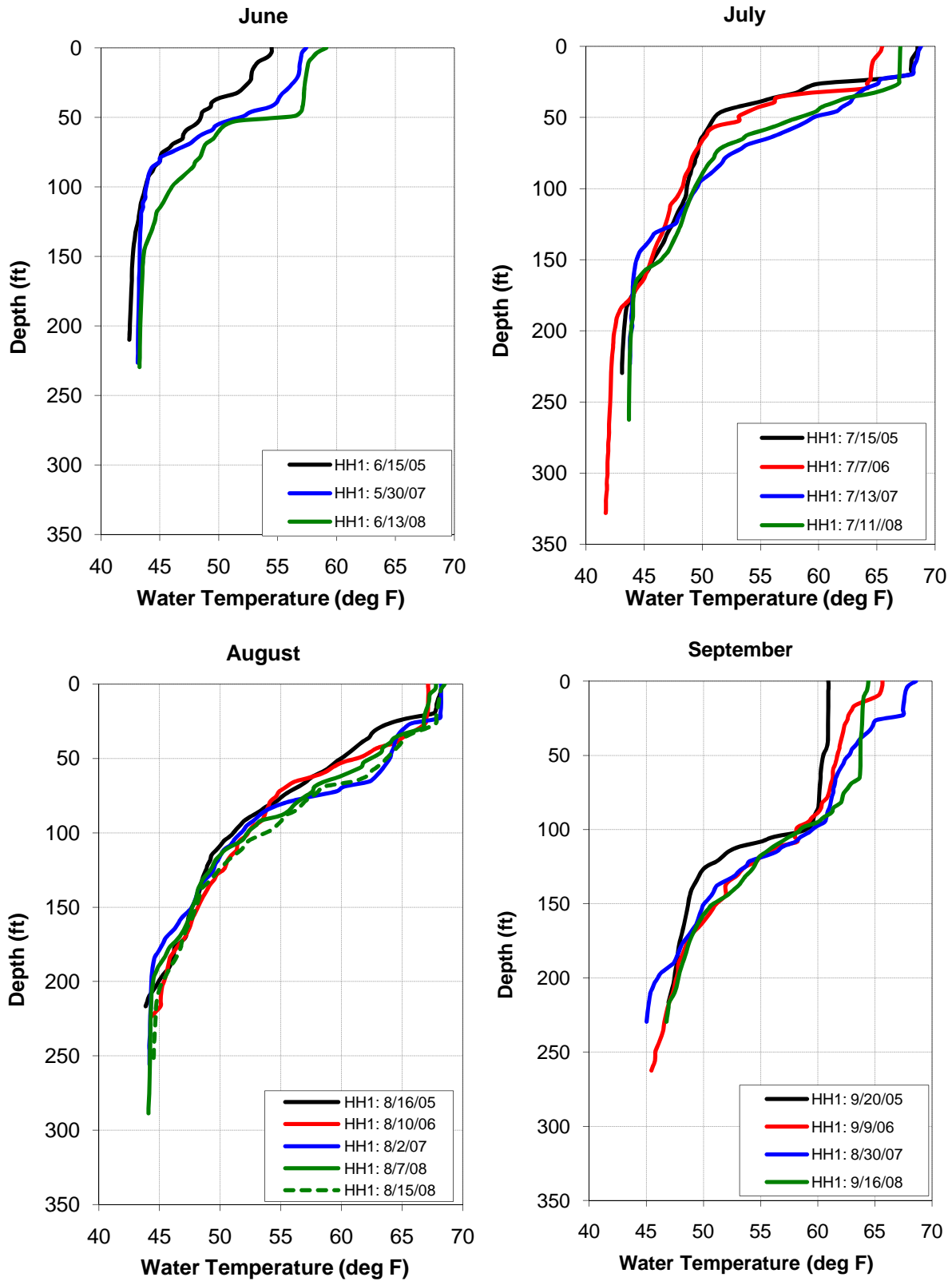
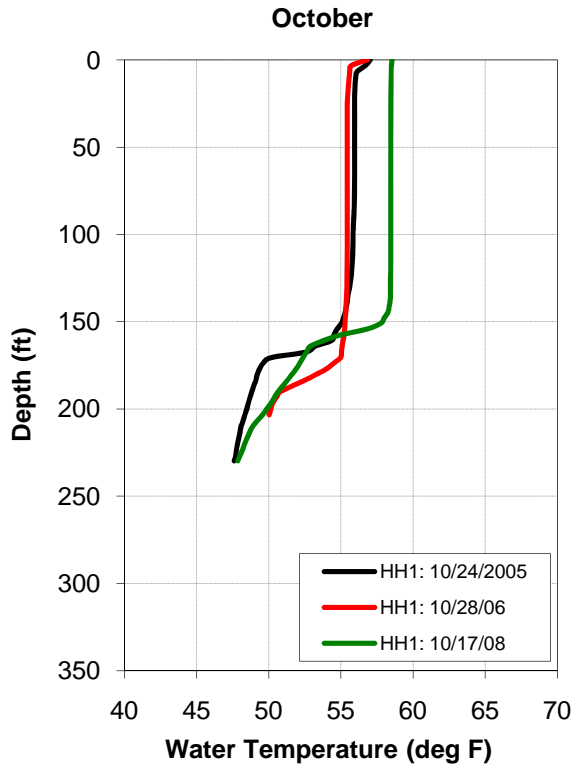


Figure C-6. Comparison of Hell Hole Reservoir Water Temperature Profiles at HH1 (2005-2008) (continued).



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-7. Comparison of Hell Hole Reservoir Water Temperature Profiles at HH2 (2005-2008)¹.

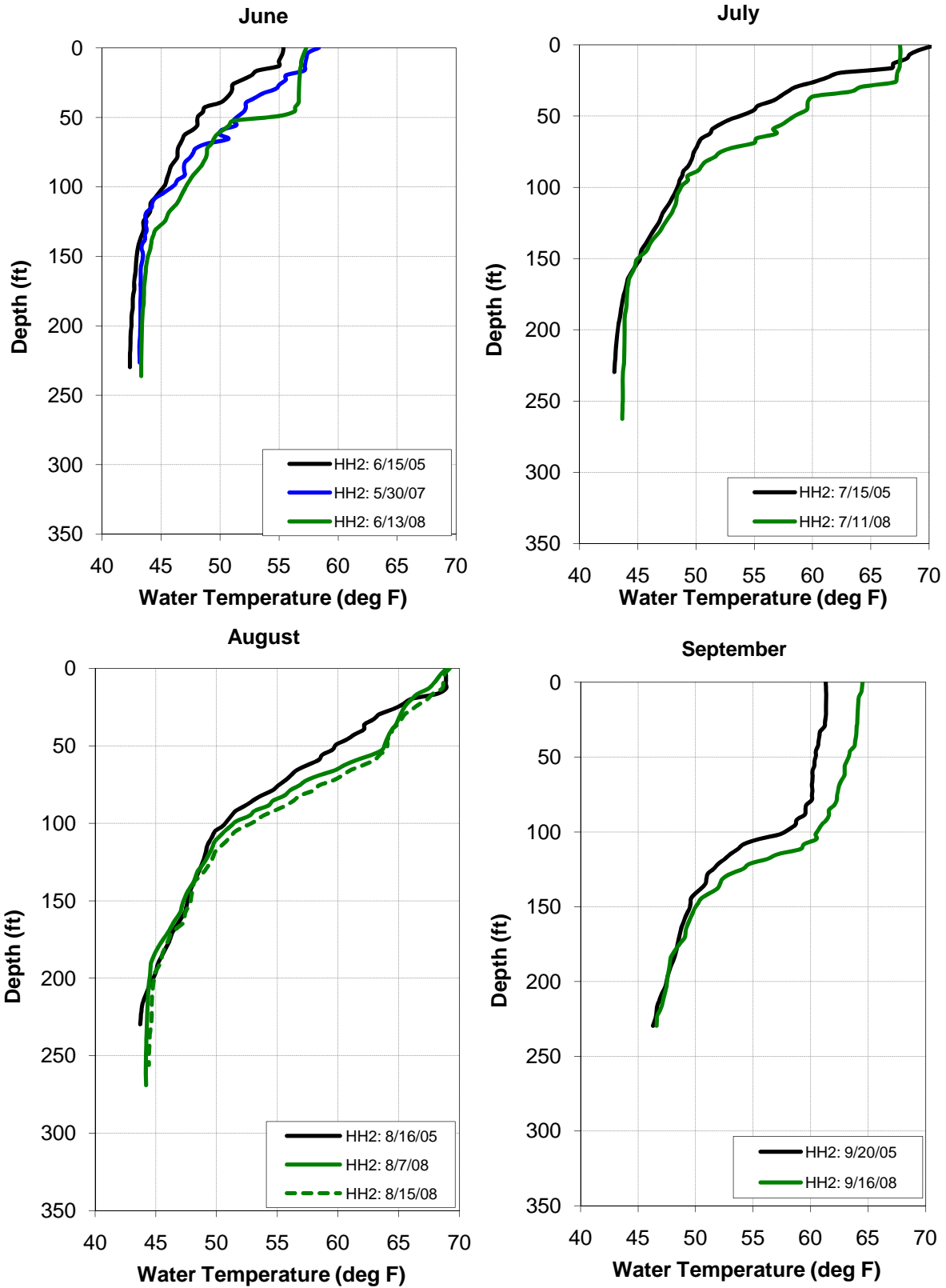
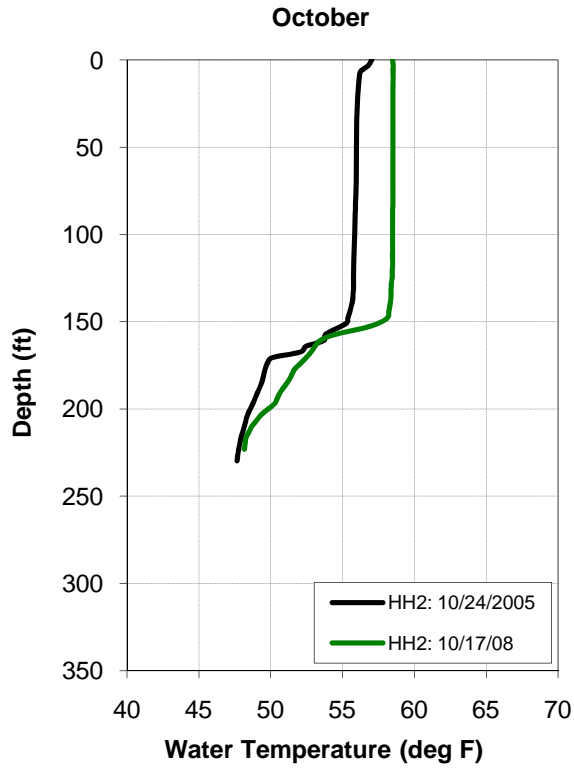
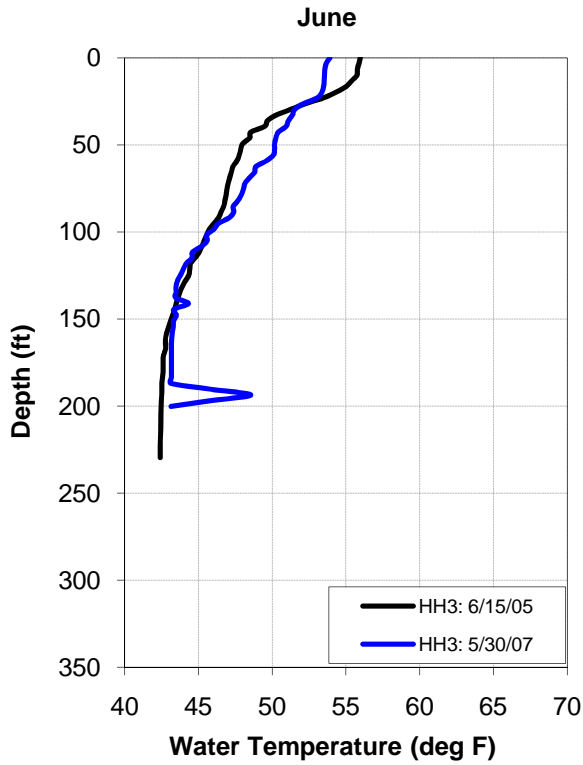


Figure C-7. Comparison of Hell Hole Reservoir Water Temperature Profiles at HH1 (2005-2008) (continued).



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-8. Comparison of Hell Hole Reservoir Water Temperature Profiles at HH3 (2005-2008)¹.



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-9. Comparison of Hell Hole Reservoir Dissolved Oxygen Profiles at HH1 (2005-2008)¹.

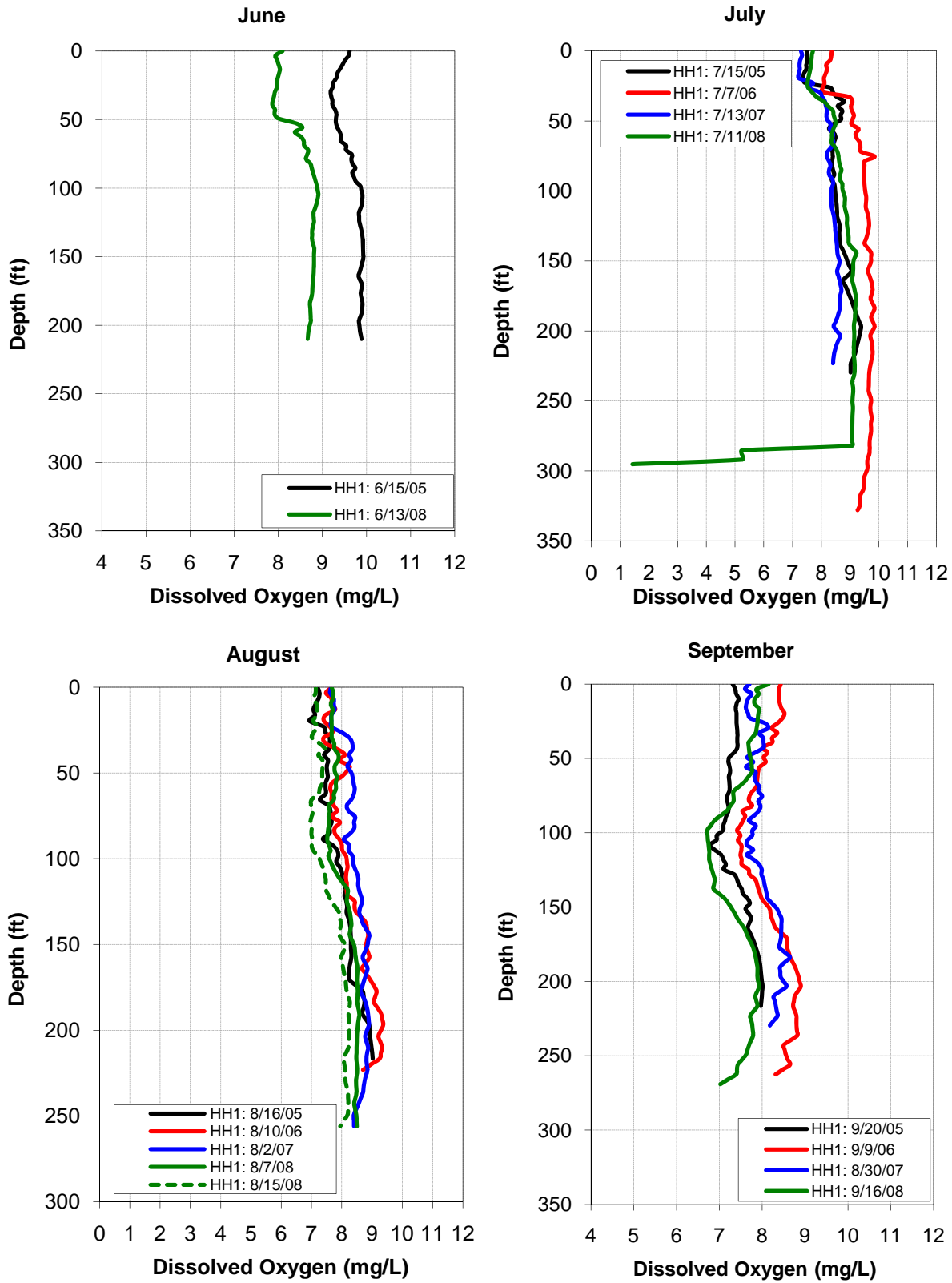
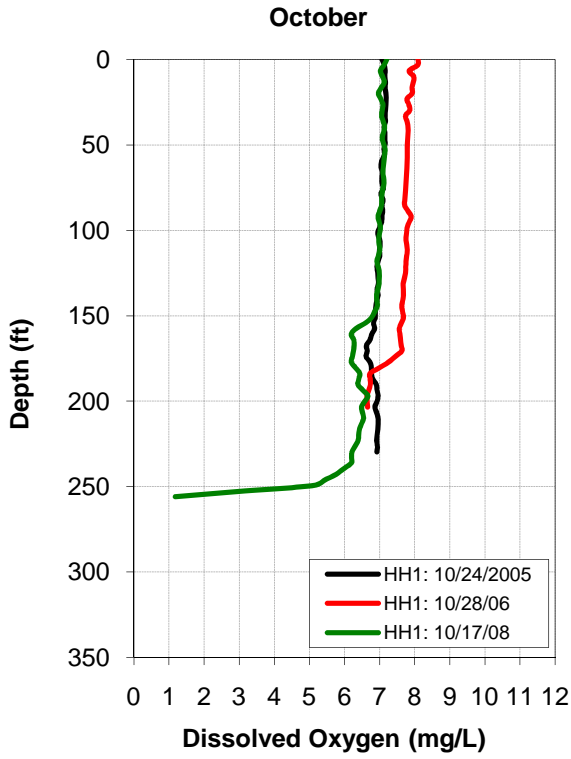


Figure C-9. Comparison of Hell Hole Reservoir Dissolved Oxygen Profiles at HH1 (2005-2008) (continued).



¹ Additional dates and locations were sampled during some years. If the locations were not sampled during more than one year at the same time period, the data were not graphed for comparison purposes. All the data are available in Excel format.

Figure C-10. Comparison of Hell Hole Reservoir Dissolved Profiles at HH2 (2005-2008)¹.

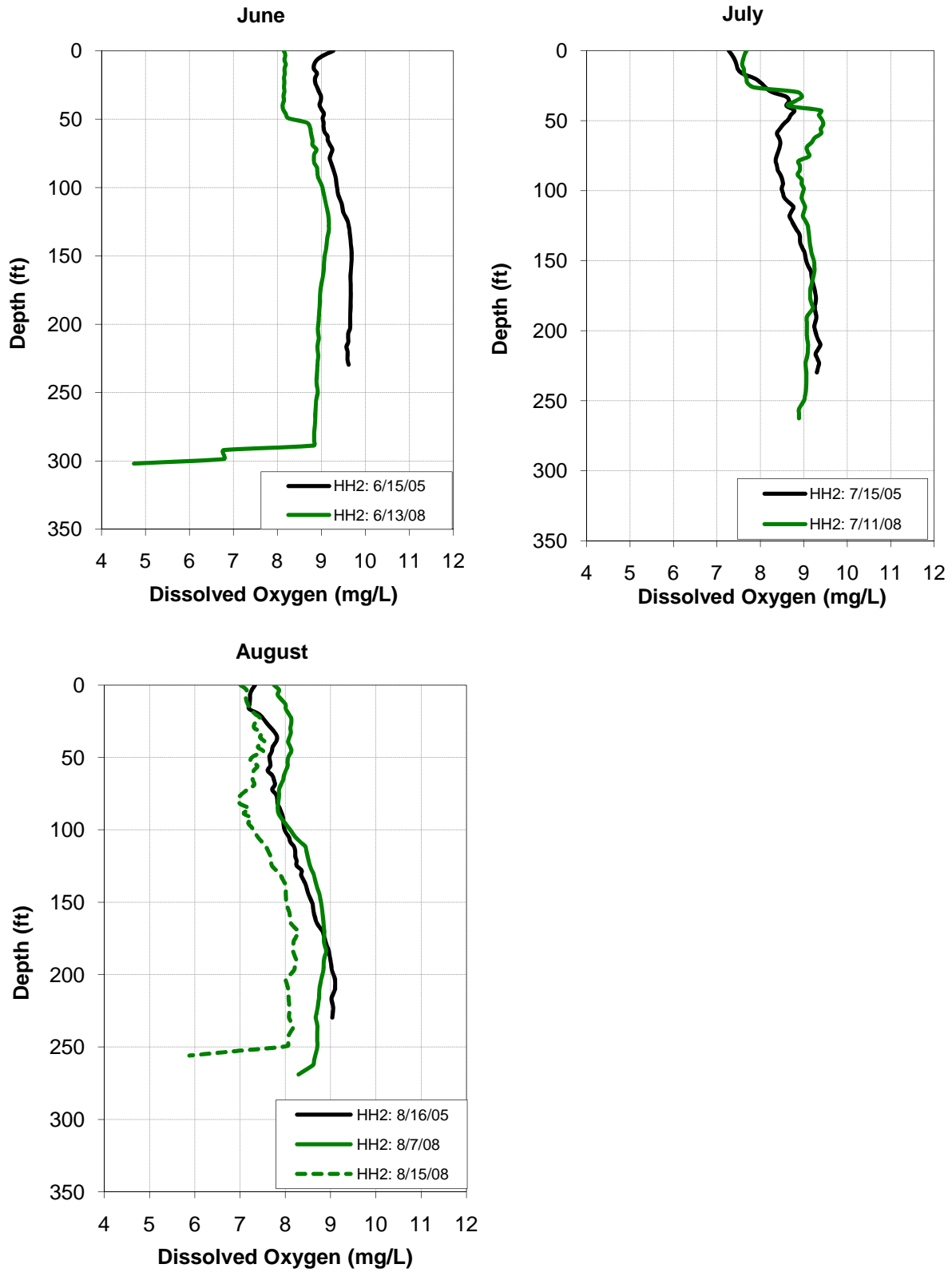


Figure C-11. Comparison of Ralston Afterbay Water Temperature Profiles at RA1 (2005-2008).

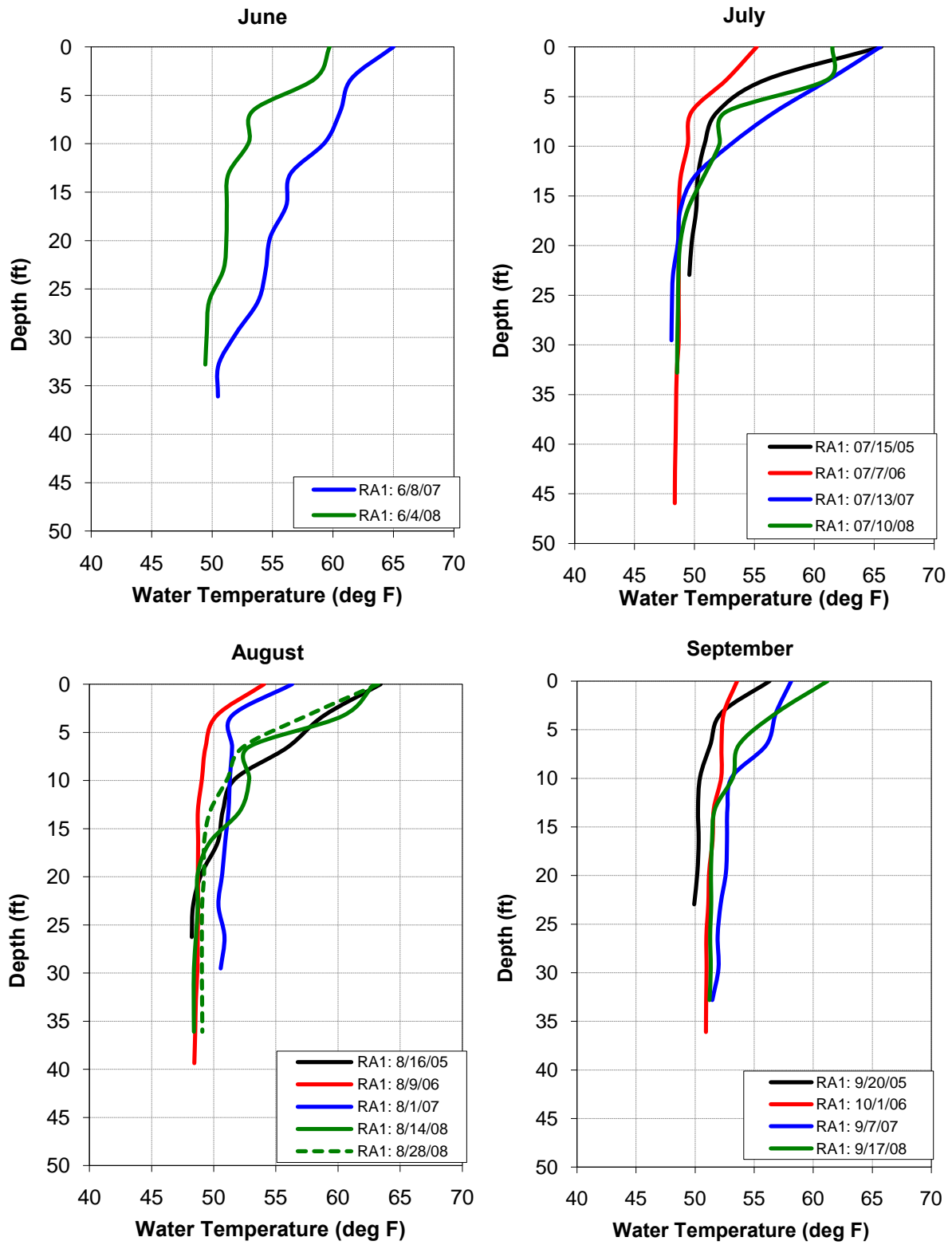


Figure C-11. Comparison of Ralston Afterbay Water Temperature Profiles at RA1 (2005-2008) (continued).

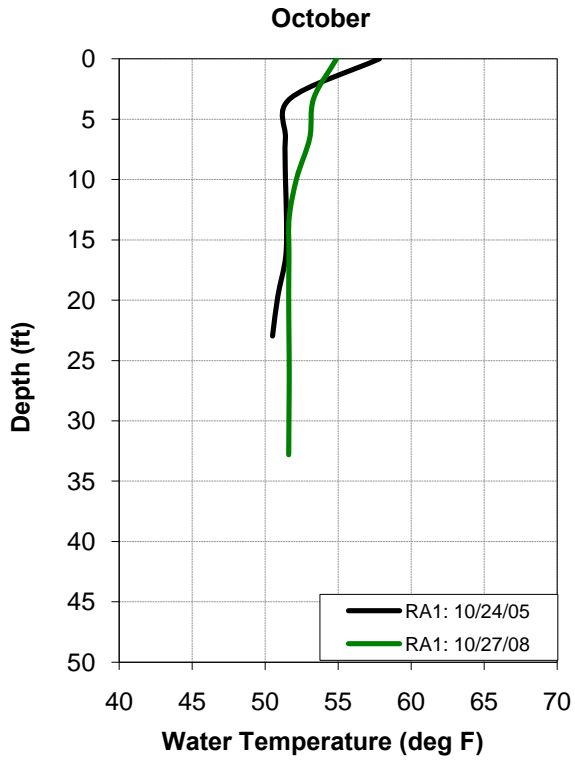


Figure C-12. Comparison of Ralston Afterbay Dissolved Oxygen Profiles at RA1 (2005-2008).

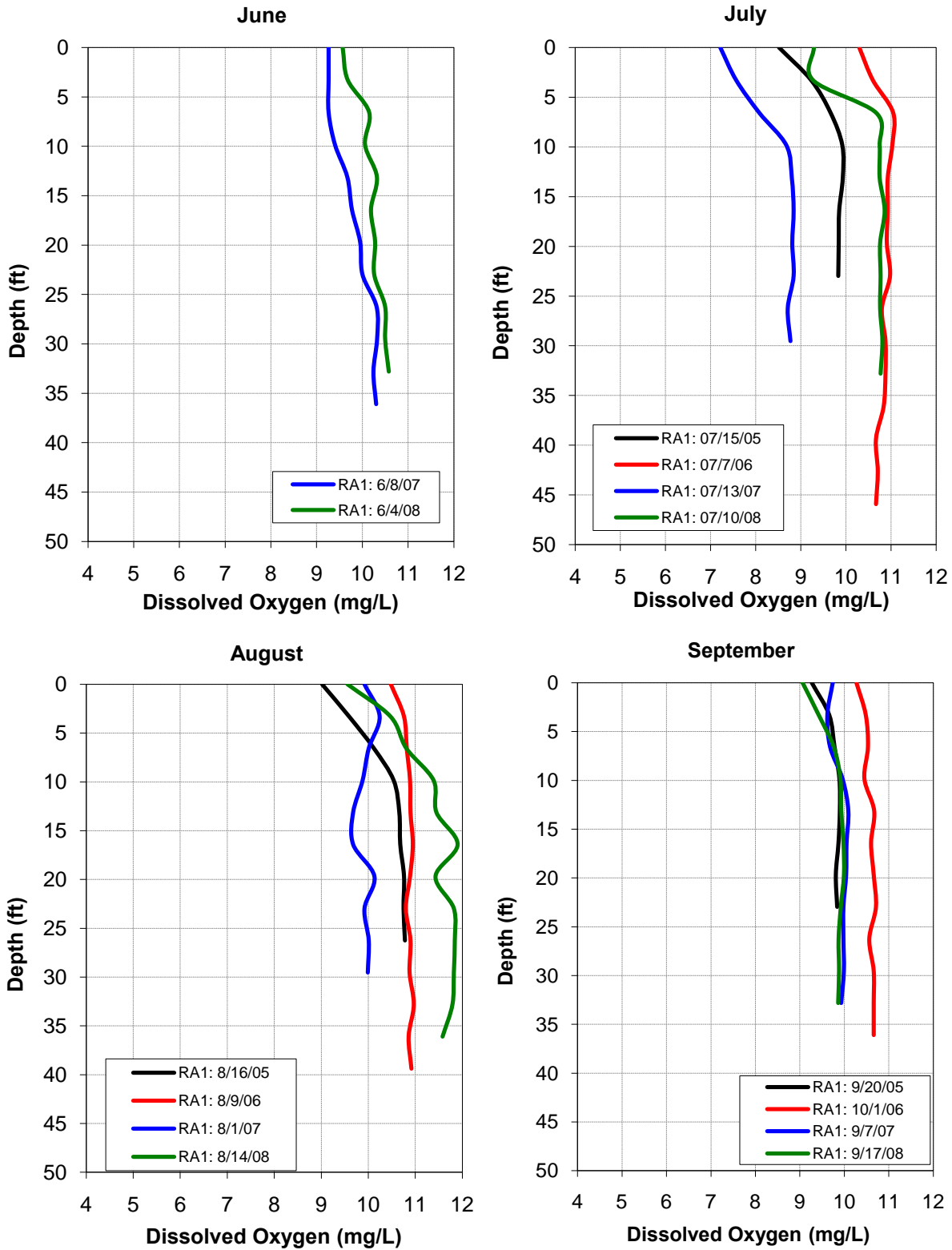
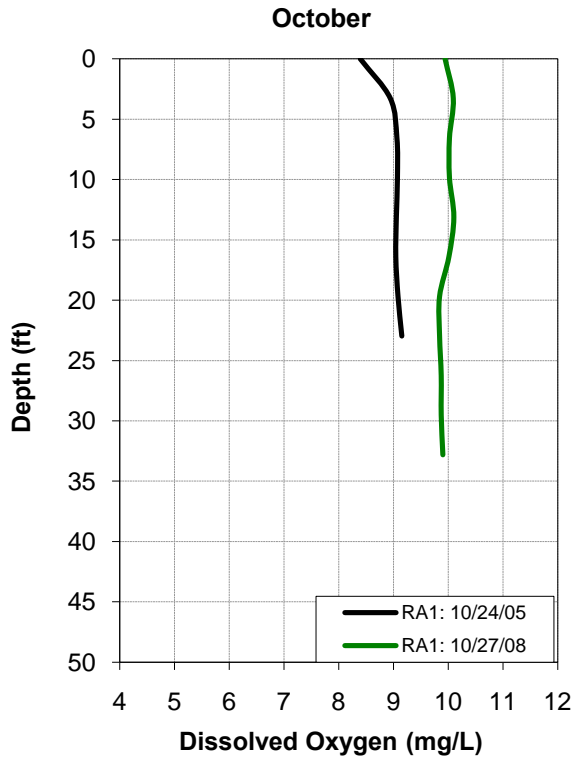


Figure C-12. Comparison of Ralston Afterbay Dissolved Oxygen Profiles at RA1 (2005-2008) (continued).



Maps