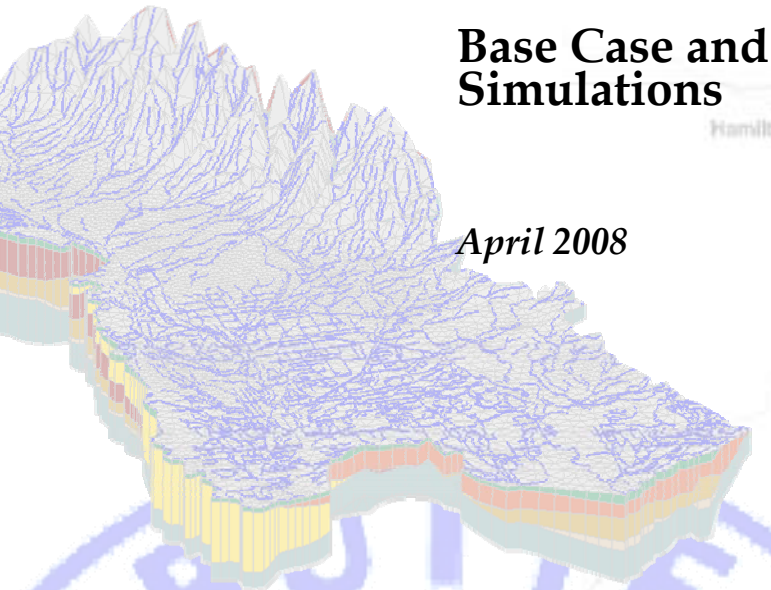
CDM

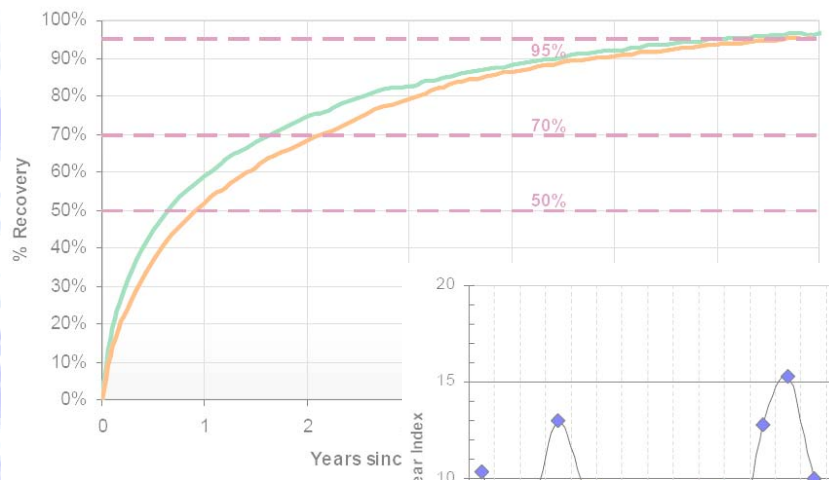
Butte County Department of Water and Resource Conservation

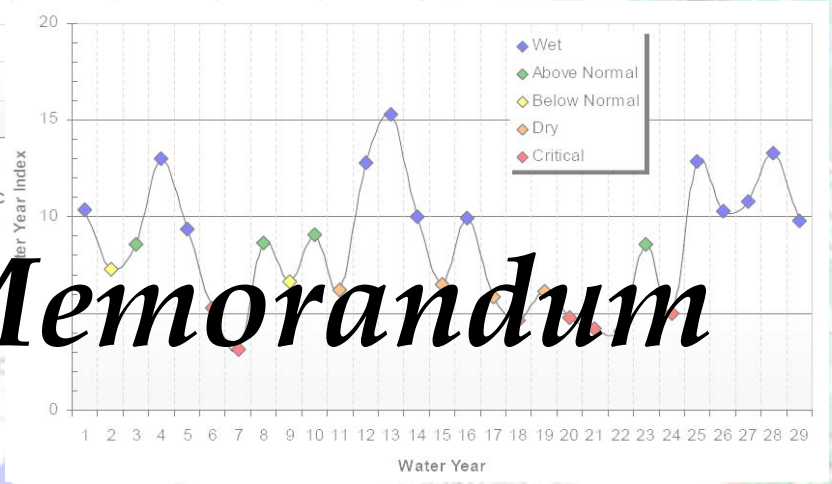
Butte Basin Groundwater Model Update

Base Case and Water Management Scenario Simulations

April 2008







Technical Memorandum

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Section 1
Introduction

This technical memorandum presents the results of 29 year base case and water management scenario simulations using the Updated Butte Basin Groundwater Model (CDM 2008). The inputs for the base case and water management scenario are briefly discussed and the simulated impacts to the water table due to changes in irrigation and groundwater pumping in the scenario are documented.

The Updated Butte Basin Groundwater Model was developed using California Department of Water Resources' (CA DWR) IWFM code and calibrated to the period of Water Year (WY) 1971 through WY 1999. Calibration and a detailed description of the model are presented in the *Butte Basin Groundwater Model Update Phase II Report* (CDM 2008).

Section 2
Base Case

The Updated Butte Basin Groundwater Model (CDM 2008) was developed to aid the county in assessing groundwater flow conditions and making sound decisions relating to the management of the county's water resources. The county can use the model to evaluate potential impacts (e.g. changes in groundwater levels) based on potential change in water resources practices in the county.

A base case was developed to serve as the basis of comparison to evaluate a proposed water management scenario. The base case simulation replaces all water demand and supply inputs in the calibrated model to represent a constant level of projected future development and a historical sequence of hydrologic conditions. Aquifer parameters that define the physical nature of the system (stratigraphy, aquifer properties, streambed properties, etc.) remain unchanged in the base case from the calibrated model.

Specifically, the base case is a 29 year simulation using the calibrated Updated Butte Basin Groundwater Model with alternate datasets for land use, urban pumping, and surface water diversions. Land use and groundwater pumping was updated to approximate 2030 conditions. Surface water diversions were approximated based on the historical surface water diversions and adjusted based on the hydrology (i.e. water year index). Precipitation data from October 1970 to October 1999 was used for the 29 year simulation.

Base Case Development

In the base case, agricultural land use was updated based on forecasts made in Butte County's *Agricultural Water Demand Forecast* (CDM 2003a). The crop acreage specified in the base case was calculated using the forecast changes for the year 2030. Based on the reported information, total irrigated agricultural acreage is forecast to decrease approximately 10% by 2030 as compared the agricultural acreage in 1998/1999. Figure 1 shows the total crop acreage in 1998/1999 and 2030. Irrigation efficiency was also adjusted as reported in the demand forecast report.

In addition to changes in agricultural land use, an increase in urban water use and acreage is expected by the year 2030. Butte County's *Urban Water Demand Forecast Technical Memorandum* (CDM 2003b) provides estimates of changes in urban water use. These values were used to adjust both urban water use and urban land use for the base case simulation. Table 1 shows the percent change in urban water use and land use for each community. As shown in Figure 1, the urban and agricultural land use changes were compensated for by a reduction in native/idle land acreage.

Table 1 ***Change in Urban Water Use by Community***	
Community	***Percent Increase in Urban Water Use***
Biggs	44%
Biggs/Gridley	37%
Chico	96%
Gridley	34%
Live Oak	20%
Marysville	20%
Oroville	77%
Paradise	11%
Yuba City	20%
Unincorporated Areas in Butte County	17%
Unincorporated Areas in Other Counties	17%

Averages of the historical diversions for the last five years of the calibration simulation were used to assign the diversions for the base case simulation. The base case diversions were adjusted annually based on historical records and correlation to CA DWR's Water Year Hydrologic Classification Index (Figure 2) for each subregion. The adjustment factors were developed using the 29 year diversion record from the calibration simulation. Diversions were also adjusted in proportion to the expected decrease in agricultural land discussed above.

The historical hydrology (e.g. precipitation pattern, stream inflows) from October 1970 through October 1999 is used in the base case simulation without any modification. Using historical hydrology allows for the assessment of water resources conditions based on a known range of hydrology, from wet to critical. Figure 2 shows CA DWR's Water Year Index for this period.

Section 3
Water Management Scenario

A water management scenario is a modification of the base case simulation that can be used to assess the impacts due to a specific change in water management activities. Butte County's Department of Water and Resource Conservation determined that the simulation of impacts due to a cutback in State Water Project (SWP) surface water deliveries to Western Canal Water District (WCWD) and the Joint Water Districts (JWD) during selected dry years would serve as the first water management scenario to be simulated. As part of the scenario, the cutbacks in surface water deliveries are made-up through a combination of agricultural land fallowing and increased groundwater pumping. The specific year(s) when cutbacks occur and percent changes in surface water supply, fallowed acreage, and groundwater pumping were required as part of the water management scenario definition.

Water Management Scenario Development

The model subregions representing WCWD and JWD are outlined on Figure 3. WCWD is represented by subregions 12, 13 and 15 in the Updated Butte Basin Groundwater Model (CDM 2008). The JWD includes subregions 16, 18, 20, 24 and 26. The JWD also includes areas outside of the model domain. Diversions for the base case were reduced to the WCWD and JWD subregions for simulation water years 7, 21 and 22. These water years represent critical hydrologic conditions which followed years of dry and critical conditions according to the CA DWR water year index shown in Figure 2- Figure 2 shows that there are seven years that can be classified by CA DWR as "critical."

The settlement contracts between WCWD/JWD and CA DWR specify that cutbacks cannot exceed 50%of the settlement delivery in any given year and not more than a total of 100% over a 7 year period. The settlement delivery is a subset of the total surface water delivery to these districts. Surface water deliveries to these districts have been cut three times during the settlement agreement period in water years 1977, 1991, and 1992 For each cutback year, DWR exercised the maximum cutback of 50% per year. Therefore, the county decided to simulate the impacts using the historical cutback pattern of the 50% per year during the years with simulated hydrology equivalent to these years. Table 2 shows the base case surface water deliveries, the settlement delivery used to calculate the cutback, and the model simulated surface water deliveries used for the scenario.

Table 2 ***Simulated Surface Water Deliveries, Groundwater Pumping, and Fallowing for Scenario***		
	Western Canal Water District	***Joint Water Districts***
Base Case Surface Water Delivery	258 TAF	385 TAF
Settlement Delivery	131 TAF	382 TAF
Cutback (50% of Settlement Delivery)	65 TAF	191 TAF
Scenario Surface Water Delivery (Base Case Delivery minus Cutback)	192 TAF	194 TAF
Allocation of Cutback Quantity		
Additional Groundwater Pumping (60% of Cutback)	39 TAF	115 TAF
Fallowed Land in lieu of Water Supply (40% of Cutback)	26 TAF	76 TAF

For the scenario, the reduction in surface water supply to these districts is specified to be made-up through a combination of agricultural land fallowing and increased groundwater pumping. The county specified that 40% of the cutback quantity should be accounted for through land fallowing. Groundwater pumping would make up the remaining 60% of the cutback quantity. This quantity of groundwater is the amount which the districts indicated could be pumped based on existing or planned infrastructure. The quantities pertaining to additional groundwater pumping and agricultural land fallowing are shown in Table 2.

The crop acreage needed to result in a 40% reduction in water use was based on the average acre-feet of water used in the subregion divided by the acres of agricultural land. Each crop type was reduced by the percentage of total acres to be fallowed shown in Table 3. A comparison of the total acreage during cutback years in the base case and the water management scenario for the WCWD and JWD is shown in Figure 4.

Table 3 ***Percentage of Crop Land to be Fallowed during Cutback Years by Subregion***	
Subregion	***Percent of Agricultural Acreage Fallowed***
Western Canal Water District (WCWD)	
12	9.8%
13	10.3%
15	10.5%
Joint Water Districts (JWD)	
16	18.0%
18	23.4%
20	27.5%
24	17.9%
26	27.8%

In the water management scenario, groundwater pumping was specified in the WCWD and JWD subregions during cutback years. Groundwater pumping in other subregions was determined by IWFM. Figure 3 shows the elements where the groundwater pumping for agricultural use is applied for the water management scenario. For WCWD and JWD, groundwater pumping specified in the scenario was

determined for simulation water years 7, 21, and 22 by summing the basecase groundwater pumping and additional groundwater pumping needed to make-up for 60% of the cutback as shown in Table 2.

All other properties and inputs to the IWFM model remained unchanged from the base case as described in Section 2.

Section 4
Results

To assess the groundwater level impacts of the water management scenario, the results of the water management scenario simulation were compared to the results of the base case simulation. Differences between the base case and scenario simulations are due to the changes in surface water supply, agricultural land acreage, and groundwater pumping discussed in Section 3. Groundwater level impacts were evaluated by comparing hydrographs of water table levels at selected locations and the spatial extent of changes in the groundwater table.

A comparison of groundwater levels in the base case and scenario provides information on how the groundwater system will respond due to the increased groundwater pumping and decreased irrigated agricultural land specified in the scenario. The drawdown in the water management scenario is defined as the base case water table minus the scenario water table.

Groundwater Level Impacts

Impacts to groundwater levels were evaluated by comparing base case and scenario groundwater levels at selected locations and over the impacted subregions at times of maximum drawdown. Twelve locations were selected, shown in Figure 5. The locations were selected to spatially cover the area of impacted water levels and do not represent specific wells. Locations 1 through 3 are in WCWD. Locations 4 through 12 are in the subregions which constitute the JWD.

Figures 6, 7 and 8 show the drawdown at each location over the 29 year simulation period. The amount of drawdown varies at each location, but the maximum drawdown occurred at the end of the cutback years (simulation water years 7, 21 and 22).

Groundwater levels dropped as a result of the water management scenario as expected. The scenario specifies that additional groundwater is pumping with respect to the base case. This water is applied as irrigation in the same subregions where it was pumped. Some water is lost due to evapotranspiration, while some is recharged to the aquifer. Fallowing of agricultural land in response to the surface water cutbacks also reduces recharge because of reduction in total irrigation.

Maximum Drawdown

The drawdown at each node within the WCWD and JWD subregions were used to compute maximum and average drawdown of the water table. The maximum drawdown refers to the maximum at any node within the WCWD and JWD subregions. The average drawdown is the sum of the drawdown at each IWFM model

node within the WCWD and JWD subregions divided by the total number of nodes within the WCWD and JWD subregions.

The simulated maximum drawdown occurred at the end of the growing season for each year with cutbacks. The average and maximum drawdown after one year of pumping was similar for both water years 7 and 21, shown in Table 4. During the entire 29 year simulation period, the maximum drawdown occurred at the end of simulation water year 22. The increased drawdown from year 21 to year 22 was due to combined impacts of two consecutive years of increased pumping during the growing season.

Table 4
Average and Maximum Drawdown in WCWD and the JWD

Cutback year	Average Drawdown (feet)	Maximum Drawdown (feet)
WY 7	4.1	11.2
WY 21	4.2	11.2
WY 22	7.0	15.5

Timing of Drawdown and Recovery

As shown in Figures 6, 7, and 8, simulated drawdown began during the growing season when the cutback water was replaced by groundwater pumping and land fallowing. Drawdown increased until the end of the water year when cutbacks ended. Groundwater levels rebounded over the years following the cutback. The magnitude of the increase in drawdown for each cutback year is similar. During simulation water year 22 the water levels recovered an average of 37% at the hydrograph locations during the winter months just prior to the beginning of a second year of cutbacks.

Recovery times for water levels after cessation of groundwater pumping are shown in Figure 9. The rate of recovery is based on both the magnitude of the drawdown and the precipitation in the subsequent years. Recovery time is based on the average percentage recovery of water levels at the twelve hydrograph locations. After one year, the average recovery was approximately 50% as shown in Figure 9. Seventy percent of recovery was achieved at around two years after maximum drawdown. Groundwater levels had recovered to approximately 95% of the pre-cutback values after six years. Figures 6, 7, and 8 show the more detailed drawdown vs. time results in the affected region.

Spatial Extent of Drawdown

Figure 10, 11, and 12 present the spatial extent of water table drawdown as a result of the water management scenario. The drawdown is calculated as the difference between the simulated water table elevation in the base case and scenario simulations. As mentioned previously, the base case was developed expressly as a point of comparison. These figures show the drawdown at the end of water years 7, 21 and 22

respectively. These years represent the water years in which cutbacks were simulated. As mentioned in Section 3, these years correspond to the historical hydrology of water years 1977, 1991, and 1992. The extent of drawdown at the end of the water year generally represents the maximum drawdown because peak agricultural pumping has ended. Overall, drawdown of greater than 2 feet was mostly limited to areas with increased groundwater pumping. Elements with assigned groundwater pumping are shown in Figure 3.

Section 5
References

CDM 2003a. *Agricultural Water Demand Forecast Technical Memorandum.* October 2003.

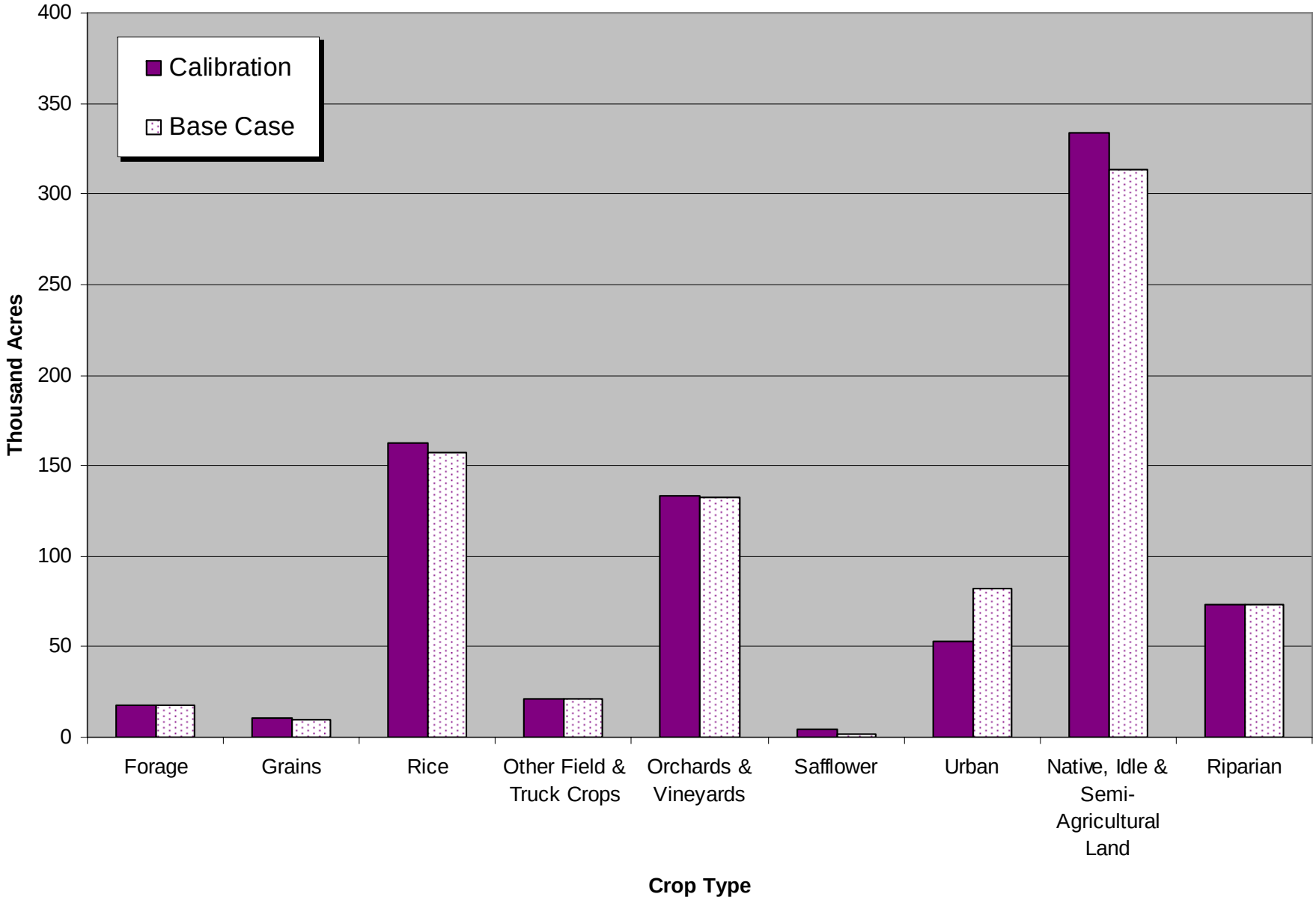
CDM 2003b. *Urban Water Demand Forecast Technical Memorandum.* October 2003.

CDM 2008. *Butte Basin Groundwater Model Update Phase II Report.* March 2008.

CA DWR 2007. *IWFM Version 2.4.1b Simulation Modeling Code.* Provided by California Department of Water Resources Hydrology Development Unit Modeling Support Branch Bay-Delta Office. Model code revision date of April 20, 2007.

CA DWR. *California Department of Water Resources Water Year Hydrologic Classification Index.* Available at http://cdec.water.ca.gov/cgi-progs/iodir/wsihist

Figures

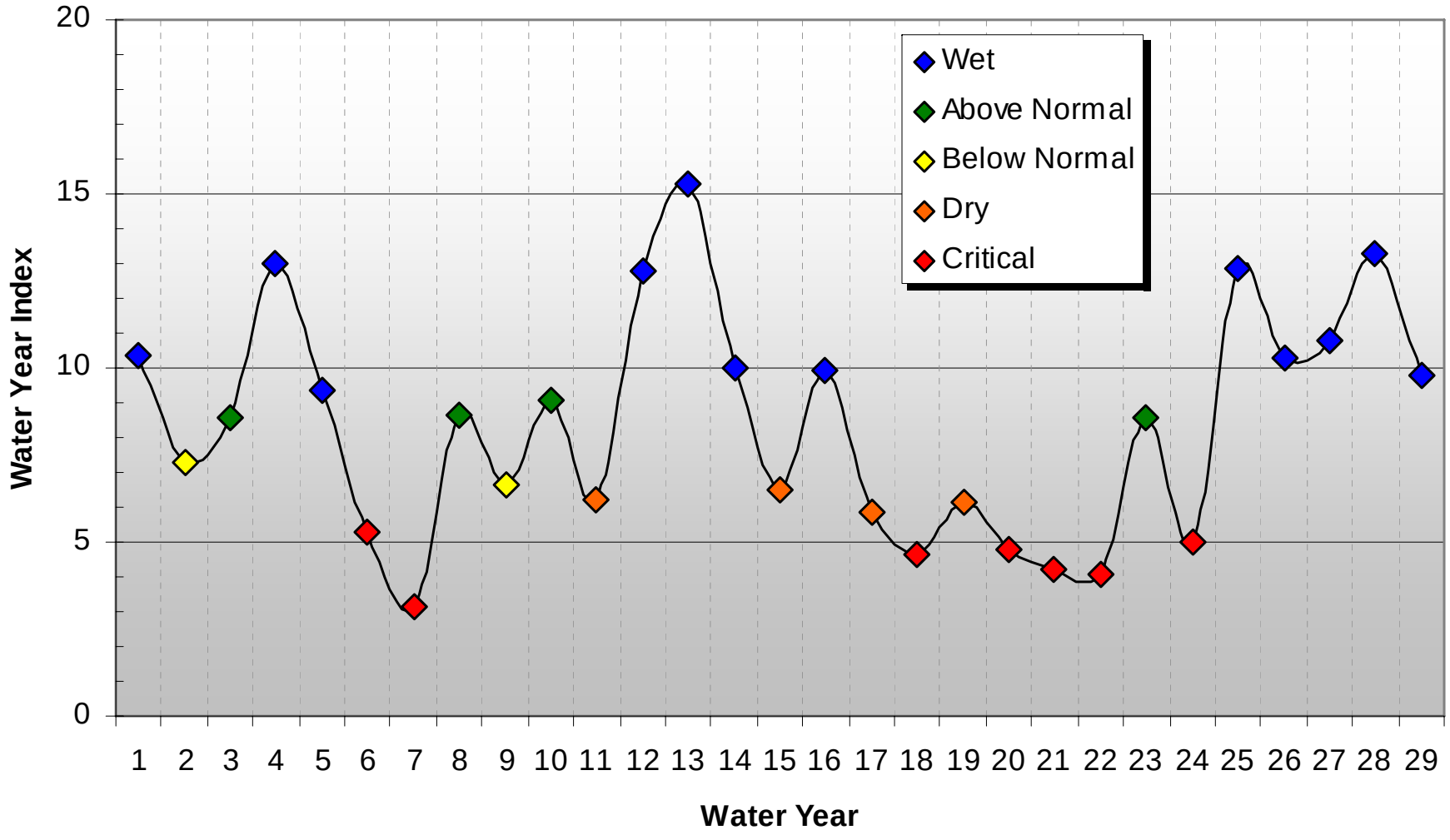


Acreage values represent the entire model area.

Figure 1
Comparison of Land Use – Calibration and Base Case Simulations

CDM

Butte Basin Groundwater Model Update
Basecase and Scenario



The Water Year Index corresponds to historical hydrologic record for water years 1971 through 1999.

Figure 2
Water Year Index

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Butte Basin Groundwater Model Update
Basecase and Scenario

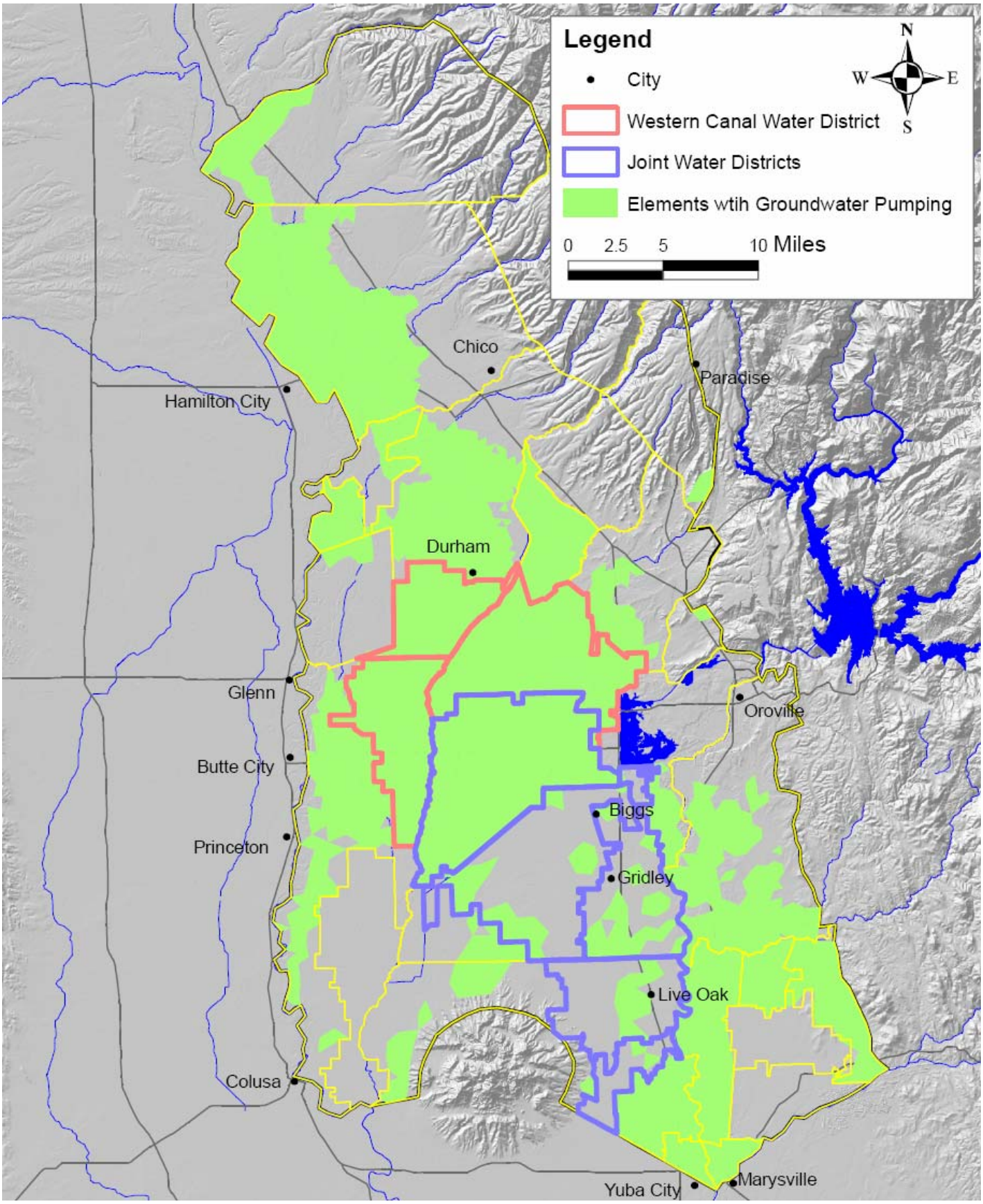
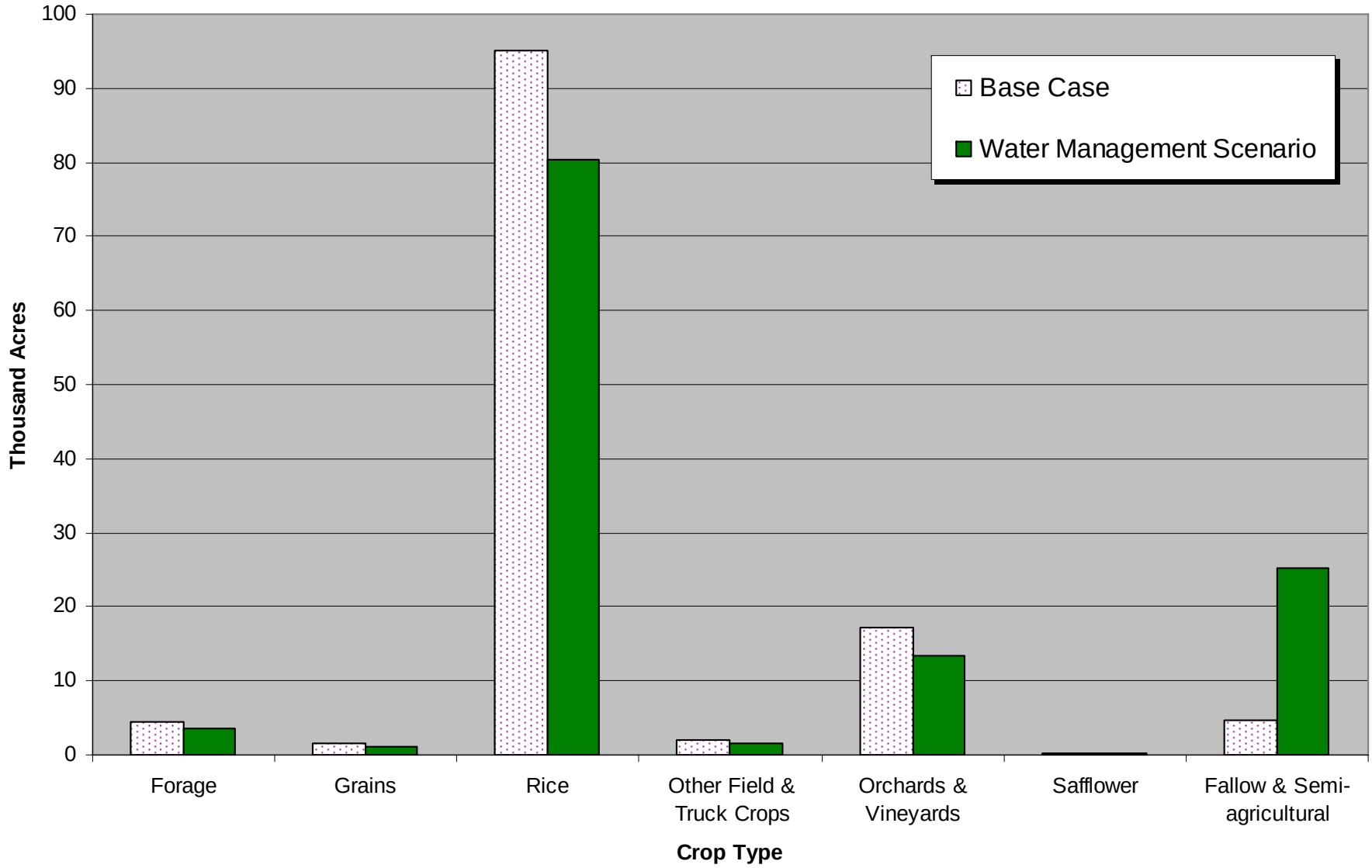


Figure 3
Subregions with Cutbacks and
Agricultural (Element) Pumping in Scenario

CDM

Butte Basin Groundwater Model Update
Basecase and Scenario



Acreage values represent the Western Canal Water District and Joint Water Districts.

Figure 4
Change in Irrigated Crop Acreage for Cutback Years - Western Canal Water District and Joint Water Districts

Butte Basin Groundwater Model Update
Basecase and Scenario

CDM

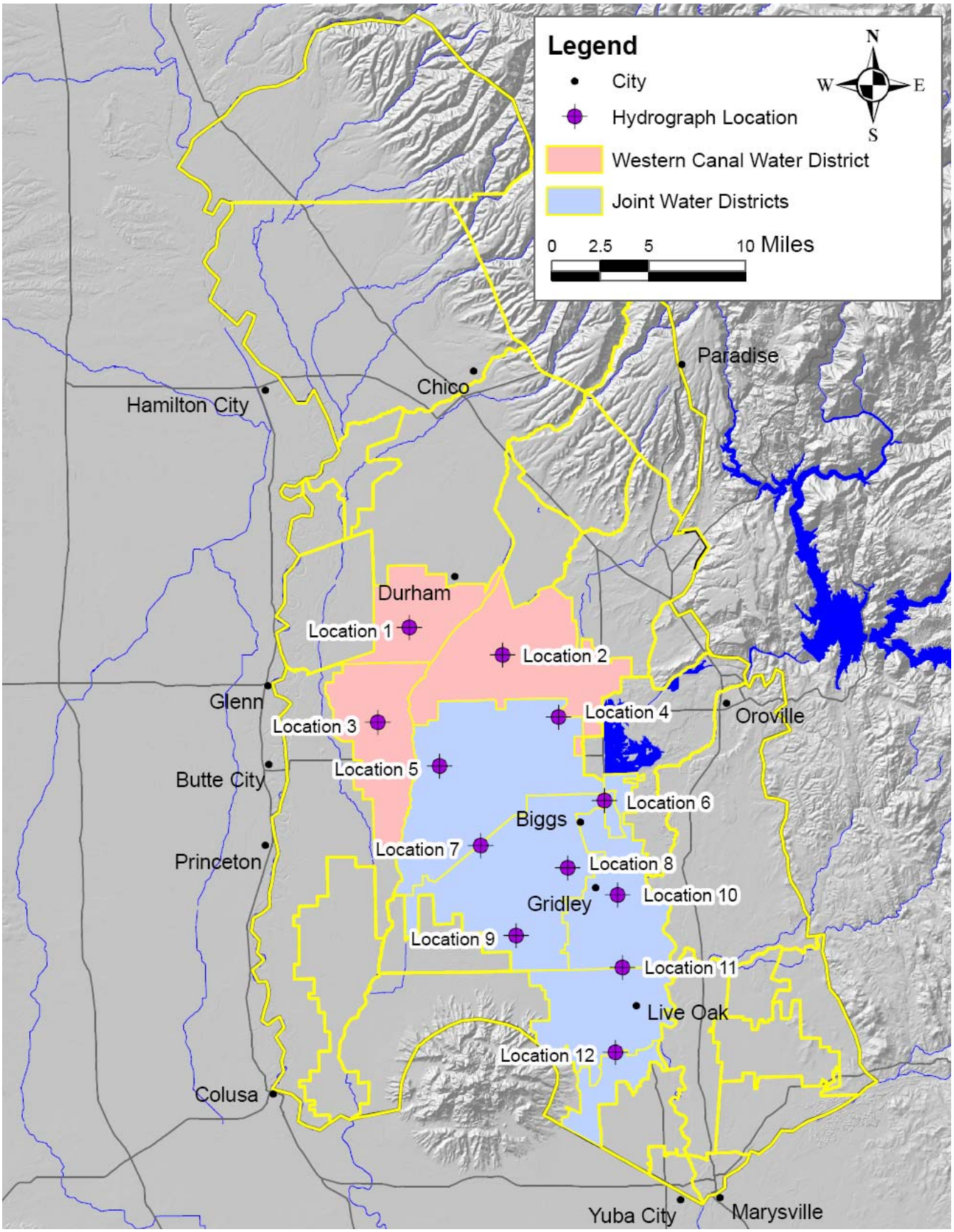


Figure 5
Locations of Hydrographs for Cutback Scenario

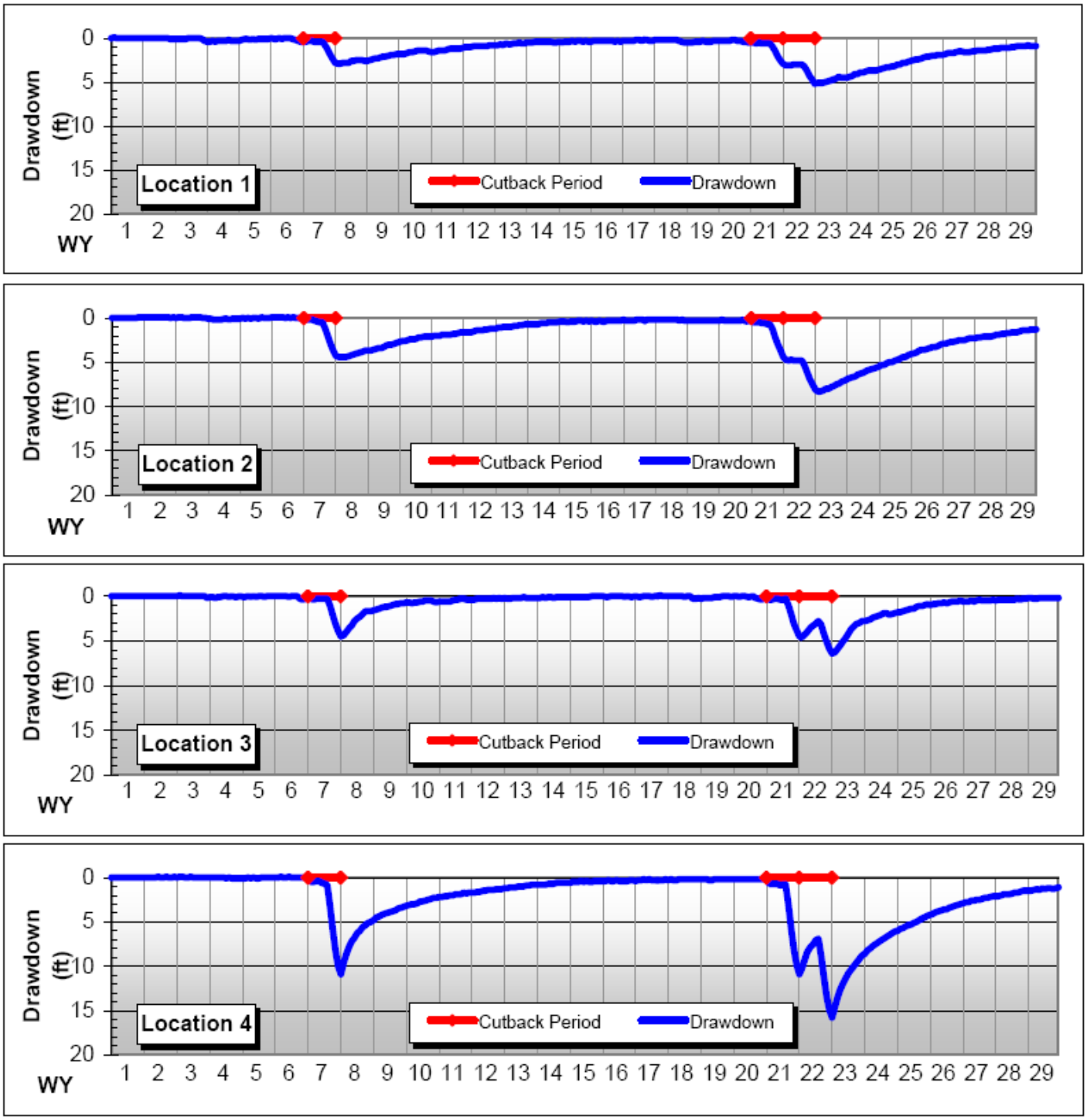


Figure 6
Hydrographs for Locations 1 through 4

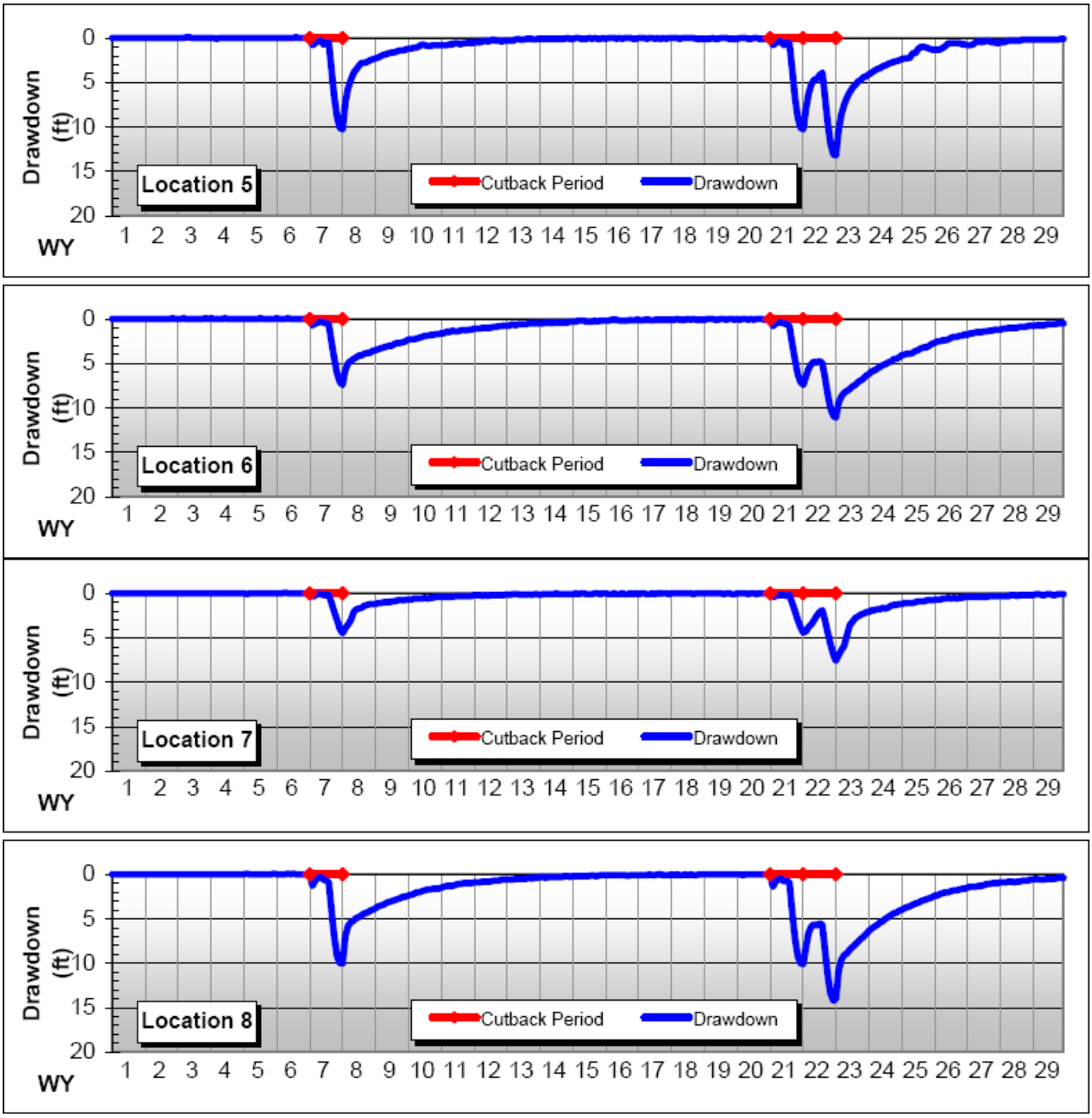


Figure 7
Hydrographs for Locations 5 through 8

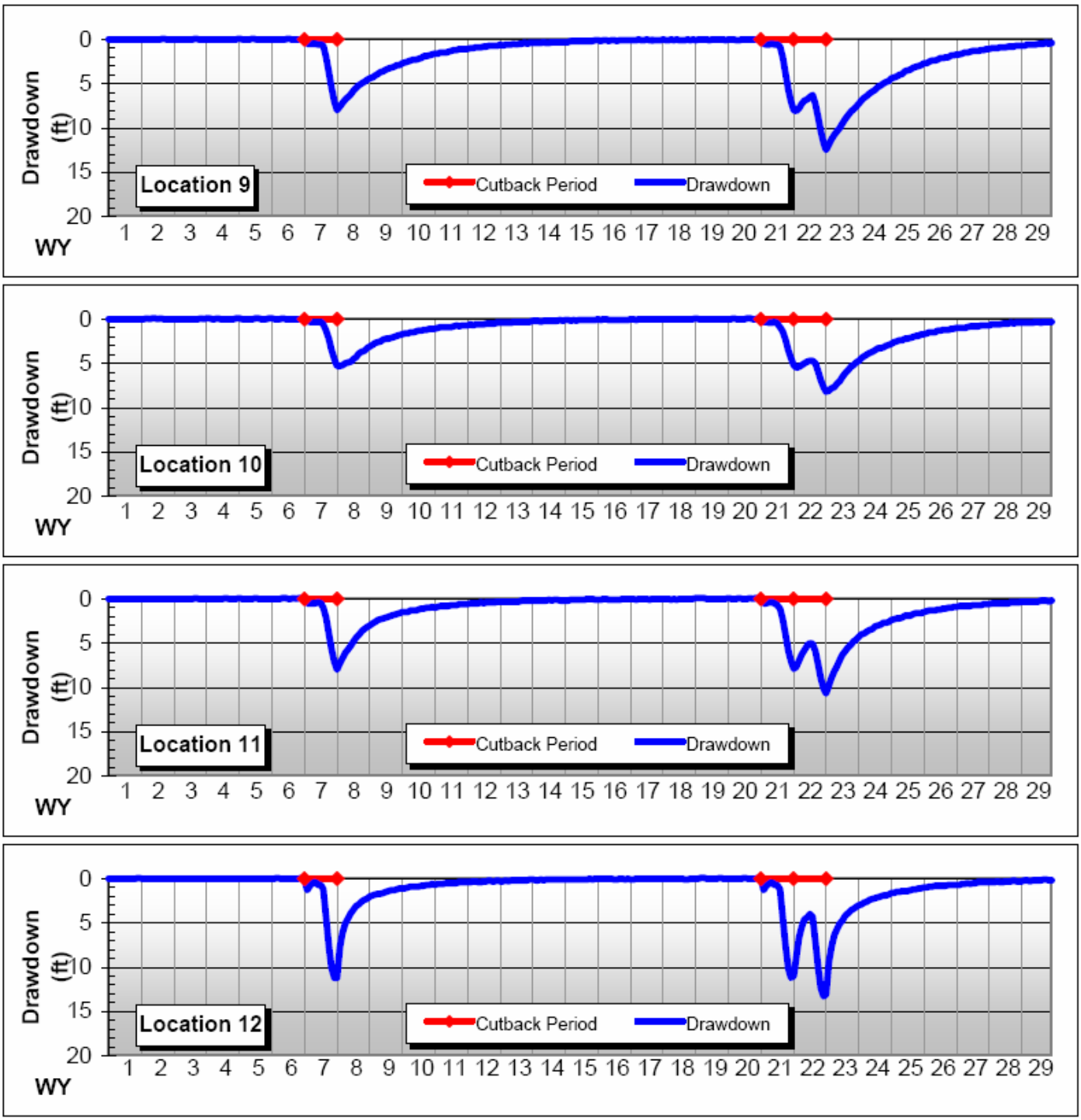


Figure 8
Hydrographs for Locations 9 through 12

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Butte Basin Groundwater Model Update
Basecase and Scenario

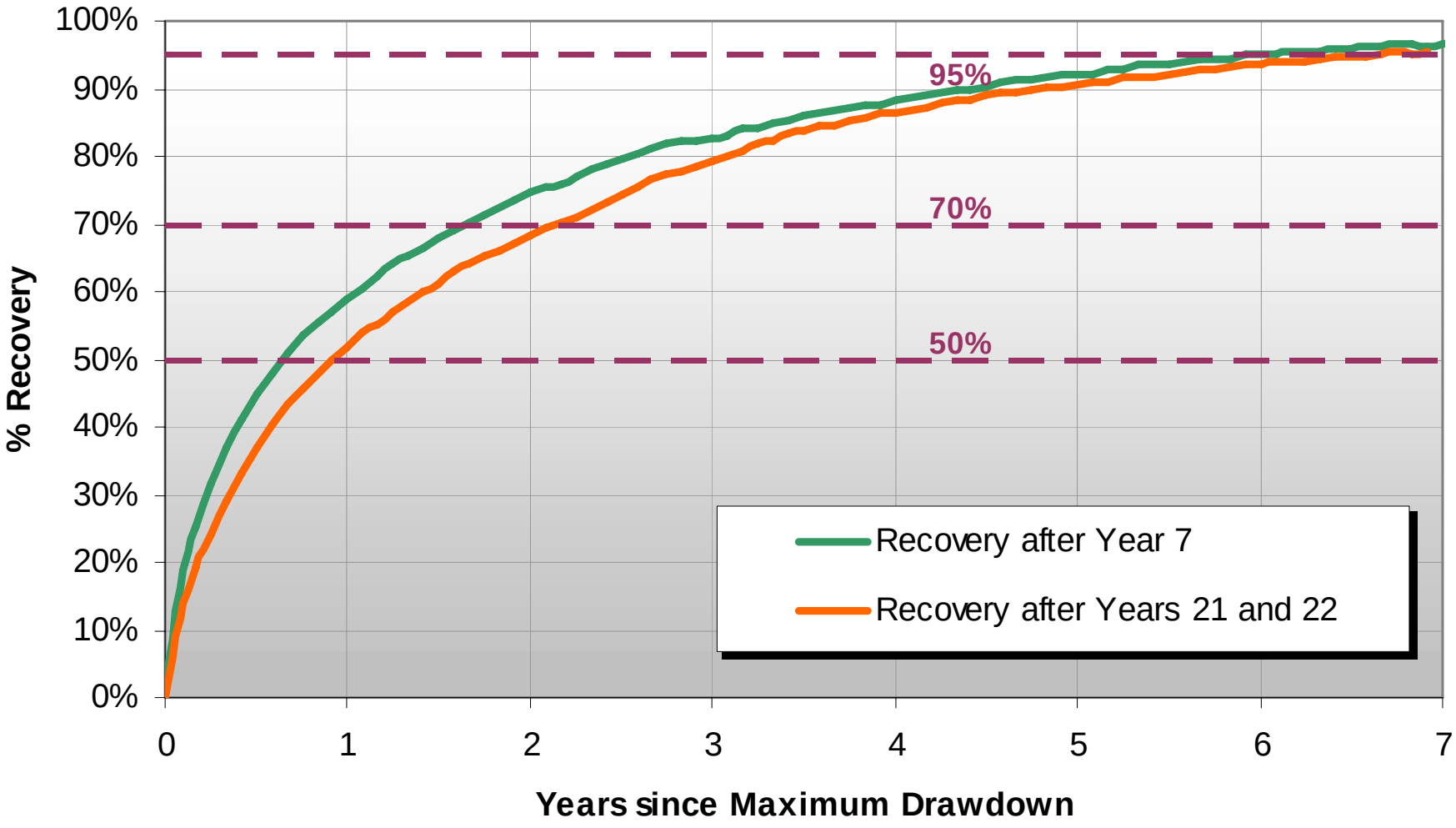

Figure 9
Average Recovery of the Groundwater Table from Pumping due to Cutbacks
Average for 12 Hydrograph Locations

Butte Basin Groundwater Model Update
Basecase and Scenario

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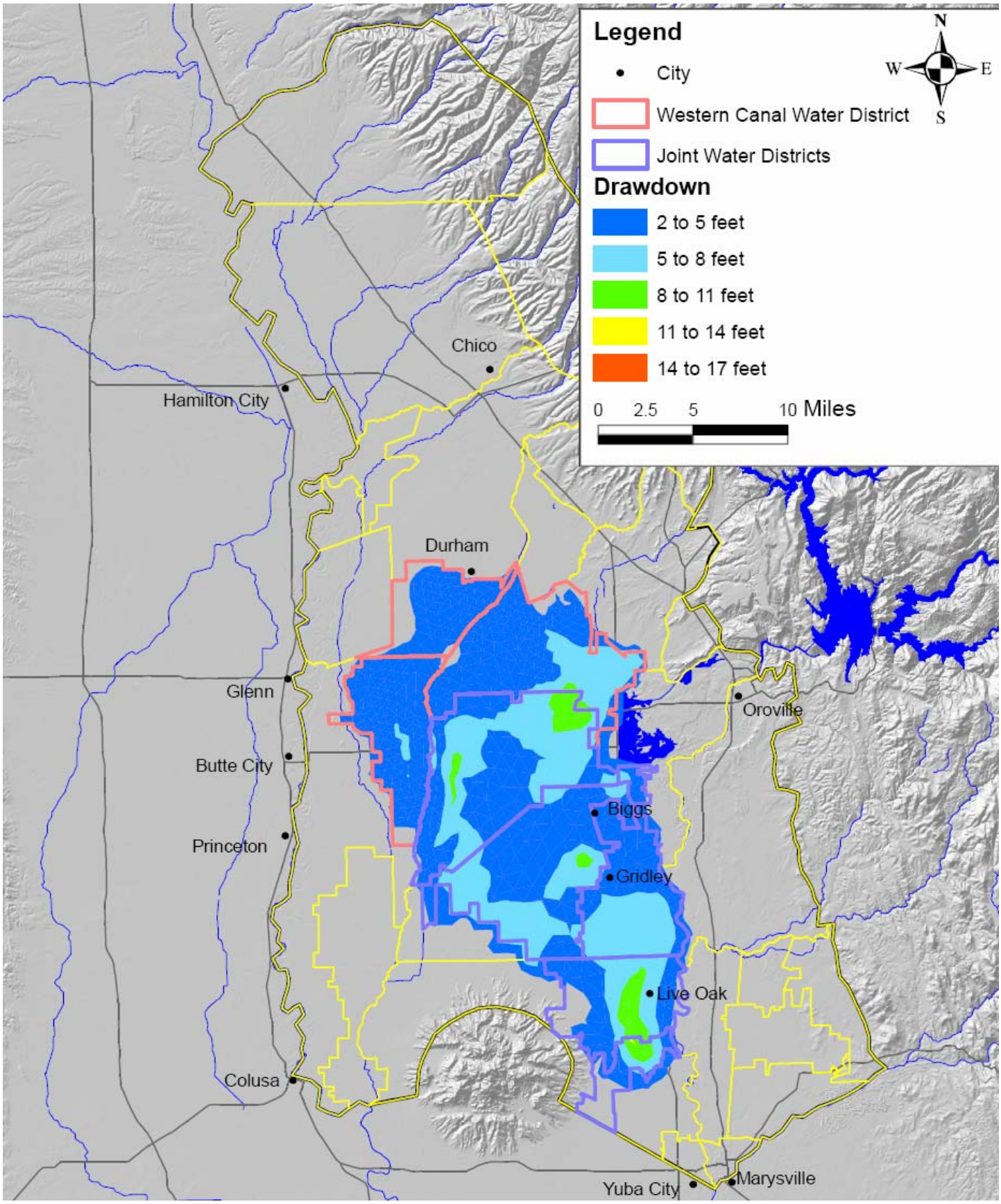

Figure 10
Maximum Drawdown Contours due to Cutbacks in Simulation Year 7

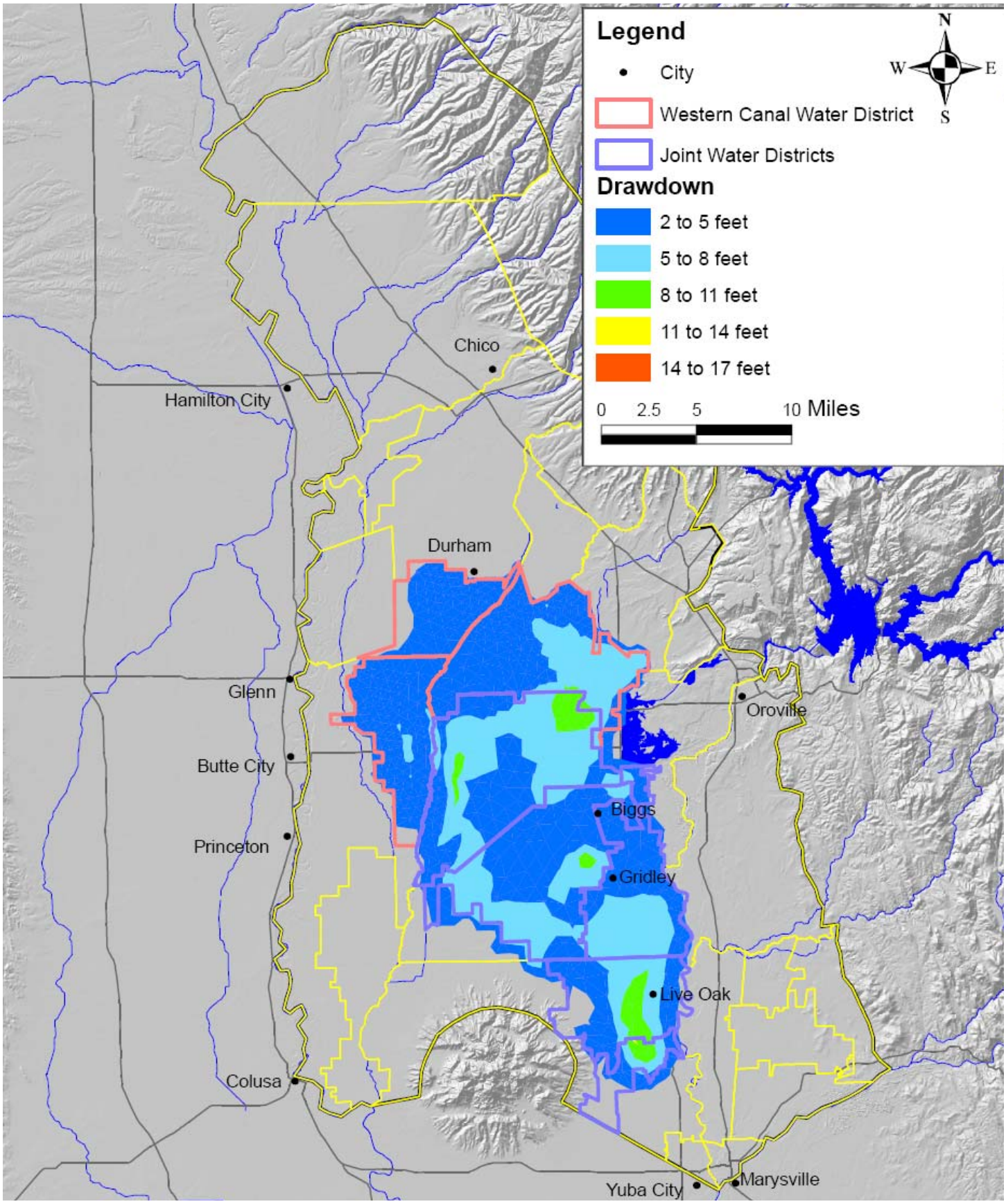

Figure 11
Maximum Drawdown Contours due to Cutbacks in Simulation Year 21

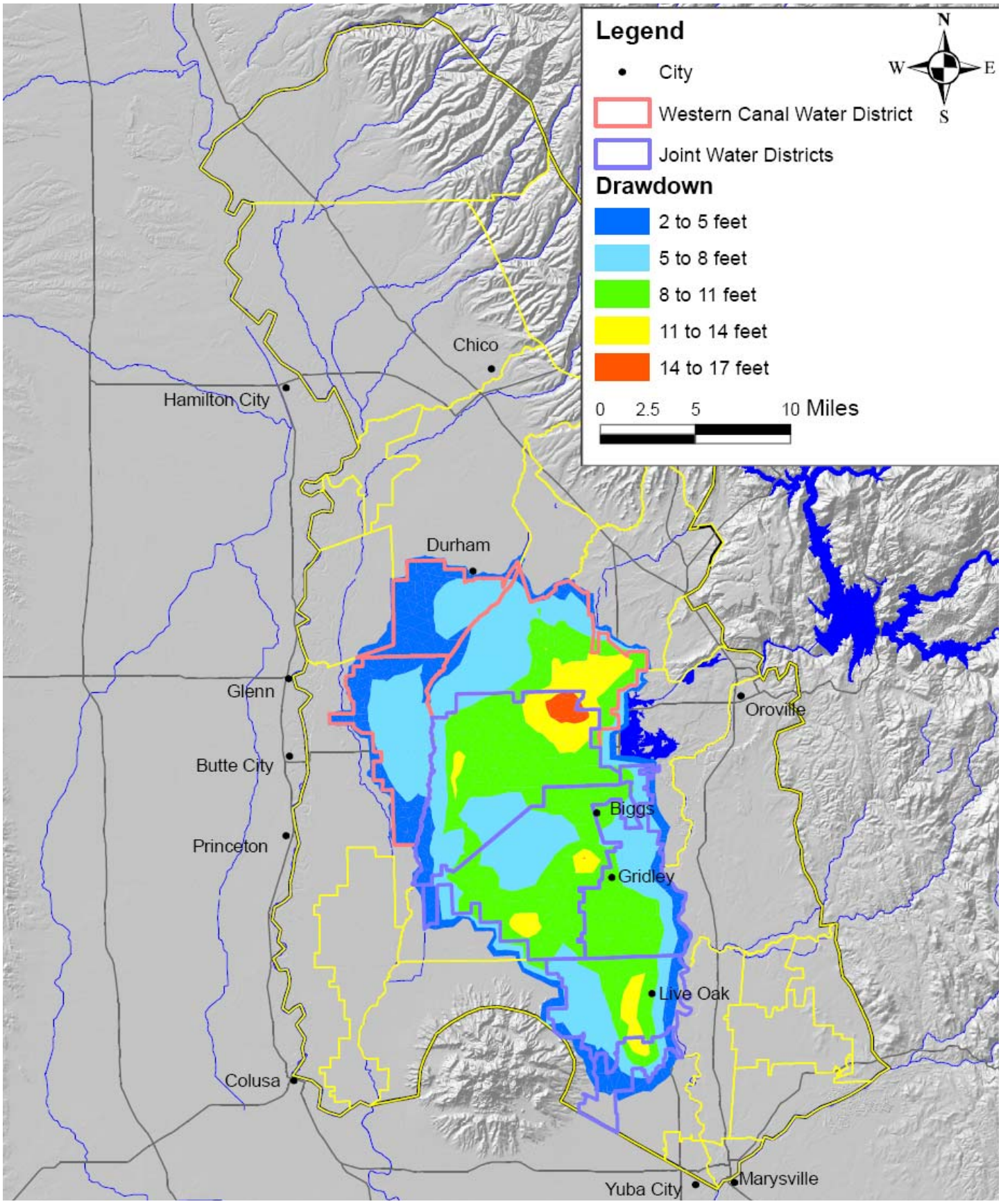

Figure 12
Maximum Drawdown Contours due to Cutbacks in Simulation Year 22