# Appendix A

## Groundwater Analysis:
## Land Retirement Effects on Drainflow Volume and Area Requiring On-Farm Drainage Systems

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# A1 INTRODUCTION

HydroFocus, Inc. employed a transient, three-dimensional, regional groundwater-flow model to simulate changes in western San Joaquin Valley groundwater storage and water table depths under different water and land use scenarios. The U.S. Geological Survey developed the model for the San Joaquin Valley Drainage Program (Belitz et al. 1993). HydroFocus, Inc. (1998) evaluated model-projected groundwater levels and drainflow during the period 1989–97. They updated boundary conditions, recharge, and pumpage data and concluded model results are acceptable to evaluate long-term changes in water-table depth.

The groundwater model simulates hydrologic conditions in both the upper semiconfined and lower confined aquifer systems. It is spatially discretized into more than 550 square-mile model cells (Figure A-1), and represents about 212,500 acres of the approximately 604,000-acre Westlands Water District (Westlands)[1], and about 81,500 acres of the 97,400-acre Northerly Area[2].

# A2 METHODOLOGY AND ASSUMPTIONS

The analysis considered a representative In-Valley scenario, where drainage service is provided and the resulting drainwater is assumed treated and managed within the San Joaquin Valley. Results from the In-Valley scenario and additional scenarios that retired varying land acreages were considered to assess the effectiveness of land retirement as a drainage reduction strategy. Our land retirement scenarios focused on lands located within the San Luis Unit of the Central Valley Project. Common assumptions and model input are summarized below.

## A2.1 Recharge and Pumpage

The model utilizes mean annual recharge and pumpage data to project long-term annual changes in groundwater storage and water table depth. The model simulates water table recharge and groundwater pumpage within nine water budget subareas (Figure A-2). Most of the subareas correspond with individual water districts; however, Westlands is subdivided into three subareas based on depth to the water table (10 feet below land surface or less, 10 to 20 feet below land surface, and greater than 20 feet below land surface). Specified recharge and pumping rates are reported in Table A-1, and relevant data sources and assumptions are summarized below:

- For current conditions, annual district-wide recharge rates were estimated using information from Table 5 of Fraction of Deep Percolation by Irrigation Method in the San Luis Drainage Feature Re-Evaluation Source Control Memorandum (URS 2002). In Westlands, the estimated water table recharge (0.54 foot/year) is within 15 percent of the average deep percolation reported by Westlands (2002) for the period 1978–96. The 0.54 foot/year of water table recharge was spatially distributed using weighting factors based on the recharge distribution reported by Belitz et al. (1993). Hence, the simulated recharge rates in Westlands

[1] The model represents 110,080 of the 298,000-acre drainage-impaired area (DIA) within Westlands (37 percent).

[2] The model represents 42,880 acres of the 48,000 acres of on-farm drainage systems currently operated in the Northerly Area (89 percent).

range from 0.32 to 0.65 foot/year. The lowest recharge rates are specified in the areas having a water table within 10 feet of land surface (0.32 foot/year); whereas the highest rates are specified in the areas where the water table is greater than 20 feet from land surface (0.65 foot/year).

- Groundwater is a water supply within Westlands, but not within the Northerly Area. In Westlands, simulated annual groundwater pumping is maintained constant at 175,000 acre-feet per year (AF/year), which is equal to the average private supply reported in Westlands' Water Needs Assessment[3] (Bureau of Reclamation 2000). The distribution of semiconfined and confined zone pumping within Westlands was weighted based on the pumping rates reported by Belitz et al. (1993).
- Regional drainwater recycling continues in the Grassland Drainage Area and is assumed implemented in Westlands. Drainwater recycling displaces surface-water supplies and was assumed not to affect water table recharge. However, recycling increases irrigation-water salinity, which can influence water application rates and long-term changes in groundwater salinity. For example, growers may increase application rates to provide a greater leaching fraction in response to the increase in irrigation water salinity.

**Table A-1**
**Land Retirement, Recharge, and Pumping Conditions for the Screening Analysis**

| Water Budget Subarea | Model Area (acres) | | Water Table Recharge beneath Active Lands (foot/year) | Pumping from beneath Active Lands (foot/year) |
|---|---|---|---|---|
| | Active | Retired | | |
| **Northerly Area** | | | | |
| Firebaugh | 46,720 | 0 | 0.53 | 0.00 |
| Panoche | 30,720 | 0 | 0.70 | 0.00 |
| San Luis | 19,200 | 0 | 0.55 | 0.00 |
| Broadview | 0 | 10,240 | 0.55 | 0.00 |
| **Westlands** | | | | |
| WT < 10 | 35,200 | 26,880 | 0.32 | 0.48 |
| 10 < WT < 20 | 23,040 | 3,200 | 0.52 | 0.54 |
| WT > 20 | 123,520 | 0 | 0.65 | 0.32 |
| **Outside Study Area** | | | | |
| Tranquility | 19,840 | 0 | 0.81 | 0.38 |
| Mendota Wildlife Refuge | 14,080 | 0 | 0.00 | 0.00 |

[3] Because the model represents only a portion of Westlands, simulated pumpage was assumed equal to 40 percent of the annual local supply (70,000 AF/year).

As part of the analysis, the effects of reduced recharge rates on simulated drainflow were also considered. Table A-2 summarizes the three recharge levels simulated in the model.[4]

**Table A-2**
**Simulated 2005–2050 Water Table Recharge: Current Conditions and Moderate and Maximum Recharge Reductions**

| Water Budget Subarea | Water Table Recharge (foot/year) | | |
|---|---|---|---|
| | Current Conditions | Moderate Reduction[1] | Maximum Reduction[1] |
| **Northerly Area** | | | |
| Firebaugh | 0.53 | 0.43 | 0.33 |
| Panoche | 0.70 | 0.60 | 0.50 |
| San Luis | 0.55 | 0.45 | 0.35 |
| Broadview[2] | --- | --- | --- |
| **Westlands** | | | |
| WT < 10 | 0.32 | 0.27 | 0.25 |
| 10 < WT < 20 | 0.52 | 0.43 | 0.39 |
| WT > 20 | 0.65 | 0.55 | 0.50 |
| **Outside Study Area** | | | |
| Tranquility | 0.81 | 0.81 | 0.81 |
| Mendota Wildlife Refuge | 0.00 | 0.00 | 0.00 |

[1]Recharge reductions in the Firebaugh Water Budget Subarea were included after completion of the model simulations.
[2]Beginning in 2005, Broadview is retired and, therefore, simulated recharge is assumed zero.

## A2.2 Drainflow

Drainflow is the net result of water table recharge, evaporative losses from the shallow water table, and natural drainage (vertical downward movement of groundwater past the drain laterals); regional processes (water table recharge and pumping) influence the underlying distribution of hydraulic head and the resulting natural drainage.

Beginning in 2005, new subsurface drainage systems are installed in all areas of Westland's DIA having a simulated water table within 7.5 feet of land surface. After 2005, drainage systems are gradually installed within the remaining DIA when the simulated water table reaches a depth of 7.5 feet or less.

For each model cell having an active drainage system, drainflow is calculated as the product of a drain conductance term and the difference between the simulated water table elevation and

[4] Our modeling analysis considered recharge rate reductions in San Luis Unit areas only. After modeling was completed, it was decided to also reduce recharge in model areas located outside the San Luis Unit to reduce annual Northerly Area drainflows. The simulated drainflows discussed later in this appendix were, therefore, adjusted to reflect recharge reductions in and outside the San Luis Unit.

prescribed drain lateral elevation. Drain conductance was estimated from drain lateral density and estimated drain lateral conductivity. Drain conductance incorporates the effective conductivity of the drain/soil system and drain lateral density. The drain laterals are assumed spaced 400 feet apart and at an average depth of 7.5 feet below land surface. Soil textures are generally fine-grained, and an average value of 80 feet/year was assumed for the drain lateral conductivity in Westlands (Fio 1994).

Simulated drainflows were adjusted to account for processes not directly simulated by the regional groundwater flow model:

- Simulated drainflow was increased to account for Northerly and Westlands areas not represented by the model (Figure A-1). The model represents 42,880 acres of the 48,000-acre Northerly DIA and, therefore, simulated drainflow was multiplied by a factor of 1.12 to account for the DIA not explicitly represented by the model. Similarly, the model represents 110,080 acres of the 298,000-acre Westlands DIA, and simulated drainflow was multiplied by a factor of 2.71 to account for the DIA not explicitly represented by the model.
- Previous comparisons between simulated and reported Northerly Area drainflows suggest model results should be increased to account for temporal variability not explicitly represented by the model. The model utilizes annual stress periods to estimate average annual drainflow, but relatively greater volumes of drainwater are produced during and immediately following irrigation than are expected from annual drainflow conditions (Deverel and Fio 1991; Fio and Deverel 1991). Therefore, simulated annual drainflows for the Northerly and Westlands areas were multiplied by 1.5 to account for these processes in our drainflow estimates.[5]
- Simulated drainflow from the Northerly DIA was increased by 15,400 AF/year to account for uncontrolled discharges into the drainage systems (URS 2002). Potential reductions in uncontrolled discharge were assumed to be proportional to Northerly DIA recharge rate reductions.
- The relationship between the percent change in recharge within the San Luis Unit and the corresponding percent change in simulated Northerly Area drainflow was utilized to estimate the additional decrease in drainflow attributed to recharge reductions in Northerly Area lands located outside of the San Luis Unit. The relationship was linear and indicated that the reduction in drainflow is 39 percent greater than the corresponding reduction in recharge (i.e., the recharge reduction, expressed as a percent, is multiplied by 1.39 to determine the corresponding percent reduction in Northerly Area drainflow).

[5] HydroFocus Inc. (1998) compared simulated and reported drainflow from the Northerly DIA. The average reported drainflow from areas represented by the model was 1.03 AF/acre, whereas simulated drainflow for the corresponding area was 0.50 AF/acre. Approximately 30 percent of the reported drainflow, or 0.30 AF/acre, can be attributed to uncontrolled discharges not represented by the model (URS 2002). Hence, the remaining observed flow (0.73 AF/acre) was about 67 percent greater than simulated by the model. Therefore, simulated drainflow was multiplied by a factor of 1.5.

## A2.3 Evaporation from the Shallow Water Table

The model employs a linear function to calculate evaporation from the shallow water table. The evaporation rate is assumed zero when the water table is more than 7 feet below land surface, and a maximum evaporation rate of 1 foot/year is simulated for water-table depths 4 feet and less below the land surface.

## A2.4 Land Retirement

This analysis investigated the hydrologic effects due to mandatory retirement of various land areas. Beginning in 2005, the lands were assumed to be retired instantaneously and the annual changes in groundwater storage and water table depths were simulated up to 2050. As a result of land retirement, irrigation ceases on the retired lands and, consequently, groundwater pumpage and surface-water deliveries are discontinued. The surface water is assumed reallocated to other actively farmed lands within the district. The simulated recharge rate beneath the retired lands becomes zero and the recharge rate beneath active lands is assumed to remain the same. The simulated pumping rate beneath retired lands also becomes zero, but the pumping rate beneath active lands is increased to maintain a constant pumping rate of 175,000 AF/year within Westlands (Table A-3).

**Table A-3**
**Simulated 2005–2050 Pumping Rates for Different Westlands Land Retirement Levels**

| | Minimum Retired* | | In-Valley | | 198,000 | | 298,000 | |
|---|---|---|---|---|---|---|---|---|
| Water Budget Subarea | Area Retired (acres) | Pumping Rate from Irrigated Lands (foot/year) | Area Retired (acres) | Pumping Rate from Irrigated Lands (foot/year) | Area Retired (acres) | Pumping Rate from Irrigated Lands (foot/year) | Area Retired (acres) | Pumping Rate from Irrigated Lands (foot/year) |
| **Northerly Area** | | | | | | | | |
| Firebaugh | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Panoche | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| San Luis | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Broadview | 10,240 | 0.00 | 10,240 | 0.00 | 10,240 | 0.00 | 10,240 | 0.00 |
| **Westlands** | | | | | | | | |
| WT < 10 | 1,280 | 0.41 | 26,880 | 0.48 | 60,800 | 0.69 | 62,080 | 0.00 |
| 10 < WT < 20 | 0 | 0.47 | 3,200 | 0.54 | 21,120 | 0.76 | 26,880 | 0.00 |
| WT > 20 | 0 | 0.26 | 0 | 0.32 | 3,840 | 0.54 | 21,120 | 0.68 |
| **Outside Study Area** | | | | | | | | |
| Tranquility | 0 | 0.38 | 0 | 0.38 | 0 | 0.38 | 0 | 0.38 |
| Mendota Wildlife Refuge | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |

*The "Minimum Retired" scenario is not associated with a land retirement or drainage alternative being considered. Rather, this scenario was considered to provide end member values for the simulation results and to define a relationship from which drainflow and drainage area values could be interpolated over a range of feasible acreages that could be retired.

A substantial land area is retired under the In-Valley scenario. These retired lands are common to most of the scenarios considered:

- About 34,100[6] acres of land is retired under the Sumner Peck Ranch et al. settlement. About 88 percent (30,080 acres) of these lands are geographically located within the model boundaries, and the remaining land areas are located south of the model boundary. It was assumed these lands were all retired in 2005.
- As of 2002, 2,091 acres of land had been permanently retired under the CVPIA land retirement program. About 61 percent (1,280 acres) of these lands are located within the model boundaries, and the remaining 811 acres are located south of the model boundary.
- Broadview was assumed to be retired in 2005, which removed 10,240 acres of irrigated lands from the Northerly Area. The existing drainage systems were de-activated upon retirement and, therefore, no drainflow was simulated from Broadview after retirement.

### A2.5 Simplifying Assumptions Relative to Draft EIR

Several assumptions were made to simplify model input data set development and construction. These assumptions relax some of the approaches employed for previous analyses of the In-Valley Alternative. Most of these simplifications are common to all the scenarios we assessed for this land retirement analysis. The key simplifications are summarized below:

- Drainage system installation and land retirement implemented instantaneously rather than phased in gradually over a 5-year period.
- Neglected water table recharge beneath reuse facilities and evaporation ponds.
- Neglected seepage control measures in the Northerly Area. Seepage control measures reduce water table recharge in the Northerly Area 4,200 AF/year.
- Neglected 3,007 acres of new drainage systems planned for installation in the Northerly Area.
- Assumed all new drainage systems are conventional in design; however, 25 percent of the new drainage systems planned for Westlands and 10 percent of the new drainage systems planned for the Northerly Area are assumed to be designed to manage shallow groundwater (for example, using closer drain lateral spacing and shallower drain lateral depths).

## A3 RESULTS

Several scenarios that varied land retirement area and recharge rates were completed. Simulated drainflow and drainage system area were then plotted against the fraction of DIA irrigated within the model. Figure A-3 shows the relationship between simulated drainflow and irrigated area

[6] Portions of the Sumner Peck lands (3,170 acres referred to as the “Britz” lands) were not retired in the model. Most of these lands (2,715 acres) are located within the model boundaries, and the remaining 455 acres are located south of the model boundary. This was not a problem for the analysis as the general relationship between varying land retirement areas and drainage conditions was being investigated. Model simulations to estimate the absolute effects of retiring these lands need to explicitly include these acreages.

within the Westlands DIA; simulated drainflow decreases as the area retired increases (i.e., the irrigated area decreases). Figure A-4 shows the relationship between simulated area requiring drainage systems and irrigated area within the Westlands DIA; the simulated area requiring drainage systems decreases as the area retired increases (i.e., the irrigated area decreases). Furthermore, Figures A-3 and A-4 show that drainflow and the area requiring drainage systems decrease as the volume of water table recharge is reduced.

The relationships on Figures A-3 and A-4 provide an empirical estimate of drainflow and drainage system area for any land retirement configuration considered. These relationships were employed to estimate drainflow and area requiring drainage systems for four representative land retirement scenarios within Westlands:

- In-Valley (57,141 acres): retires land as a result of Sumner Peck and Britz settlements, CVPIA land retirement program, and lands needed for drainage facilities.
- Groundwater Quality (88,578 acres): Includes lands retired in the In-Valley scenario, Westlands-acquired lands, and remaining lands underlain by shallow groundwater having selenium concentrations greater than 50 parts per billion.
- Water Needs (185,000 acres): Includes lands retired in the In-Valley scenario and additional lands as necessary to free up adequate surface water to meet irrigation demand within the Northerly and Westlands DIAs.
- Maximum Retired in Westlands (298,000 acres): Retires all land within Westlands DIA.

Similar drainflow relationships were developed and employed for the Northerly DIA[7] (not shown on Figures A-3 and A-4). The results for the Westlands and Northerly areas under the above retirement scenarios are reported in Table A-4.

**Table A-4a**
**Simulated 2050 Drainflow – Current Recharge**

| Scenario | Retired (Westlands) | | 2050 Westlands Drainflow (AF/yr) | | 2050 Westlands Collector System Area (acres) | | 2050 Drainflow (AF/tiled acre) | |
|---|---|---|---|---|---|---|---|---|
| | Acres | Fraction of DIA Irrigated | Model | Scaled | Model | Scaled | Westlands | Northerly* |
| In-Valley | 57,141 | 0.81 | 9,989 | 40,562 | 62,083 | 168,066 | 0.24 | 0.55 |
| Groundwater Quality | 88,578 | 0.70 | 8,573 | 34,811 | 52,147 | 141,169 | 0.25 | 0.55 |
| Water Needs | 185,000 | 0.38 | 4,441 | 18,035 | 25,116 | 67,993 | 0.26 | 0.53 |
| Maximum Retired | 298,238 | 0.00 | 0 | 0 | 0 | 0 | 0.00 | 0.47 |

*Northerly Area drainflow rate does not include the approximately 15,400 AF of uncontrolled discharge. The total drainflow volume is, therefore. equal to the drainflow rate multiplied by 48,000 plus the uncontrolled discharge.

[7] Simulated Northerly Area drainflow is sensitive to land retirement within the approximately 110,000-acre northerly portion of Westlands (the area of Westlands represented by the model shown on Figure A-1). Hence, simulated drainflow for the Northerly Area reported in Table A-4 is relative to the fraction of DIA irrigated in the 110,000-acre northerly portion of Westlands only.

## Table A-4b
## Simulated 2050 Drainflow – Moderate Recharge Reduction

| Scenario | Retired (Westlands) | | 2050 Westlands Drainflow (AF/yr) | | 2050 Westlands Collector System Area (acres) | | 2050 Drainflow (AF/tiled acre) | |
|---|---|---|---|---|---|---|---|---|
| | Acres | Fraction of DIA Irrigated | Model | Scaled | Model | Scaled | Westlands | Northerly Area* |
| In-Valley | 57,141 | 0.81 | 5,085 | 20,647 | 41,276 | 111,739 | 0.18 | 0.42 |
| Groundwater Quality | 88,578 | 0.70 | 4,353 | 17,676 | 25,053 | 94,893 | 0.19 | 0.42 |
| Water Needs | 185,000 | 0.38 | 2,237 | 9,085 | 17,540 | 47,482 | 0.19 | 0.40 |
| Maximum Retired | 298,238 | 0.00 | 0 | 0 | 0 | 0 | 0.00 | 0.36 |

*Northerly Area drainflow rate does not include the approximately 14,000 AF of uncontrolled discharge. The total drainflow volume is, therefore, equal to the drainflow rate multiplied by 48,000 plus the uncontrolled discharge. Drainflow reduction due to recharge reductions in Northerly Area lands located outside of the San Luis Unit (i.e., Firebaugh Water Budget Subarea in Table A-2) were estimated using model results for simulated recharge reductions in lands located within the San Luis Unit land (i.e., the Panoche and San Luis Water Budget Subareas in Table A-2).

## Table A-4c
## Simulated 2050 Drainflow – Maximum Recharge Reduction

| Scenario | Retired (Westlands) | | 2050 Westlands Drainflow (AF/yr) | | 2050 Westlands Collector System Area (acres) | | 2050 Drainflow (AF/tiled acre) | |
|---|---|---|---|---|---|---|---|---|
| | Acres | Fraction of DIA Irrigated | Model | Scaled | Model | Scaled | Westlands | Northerly Area* |
| In-Valley | 57,141 | 0.81 | 3,218 | 13,067 | 30,836 | 83,476 | 0.16 | 0.29 |
| Groundwater Quality | 88,578 | 0.70 | 2,718 | 11,038 | 26,053 | 70,529 | 0.16 | 0.29 |
| Water Needs | 185,000 | 0.38 | 1,335 | 5,422 | 12,809 | 34,675 | 0.16 | 0.28 |
| Maximum Retired | 298,238 | 0.00 | 0 | 0 | 0 | 0 | 0.00 | 0.25 |

*Northerly Area drainflow rate does not include the approximately 12,600 AF of uncontrolled discharge. The total drainflow volume is, therefore, equal to the drainflow rate multiplied by 48,000 plus the uncontrolled discharge. Drainflow reduction due to recharge reductions in Northerly Area lands located outside of the San Luis Unit (i.e., Firebaugh Water Budget Subarea in Table A-2) were estimated using model results for simulated recharge reductions in lands located within the San Luis Unit land (i.e., the Panoche and San Luis Water Budget Subareas in Table A-2).

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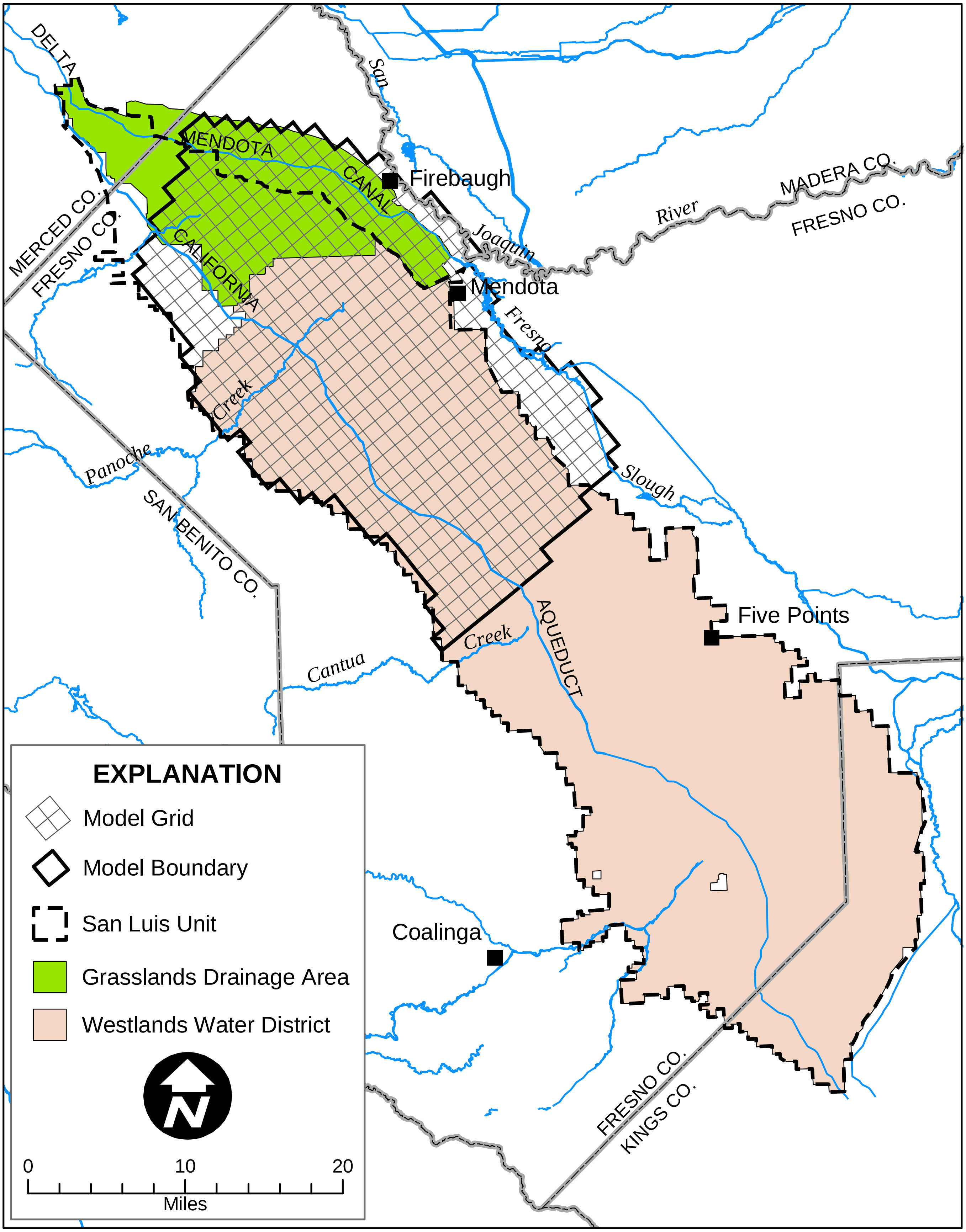


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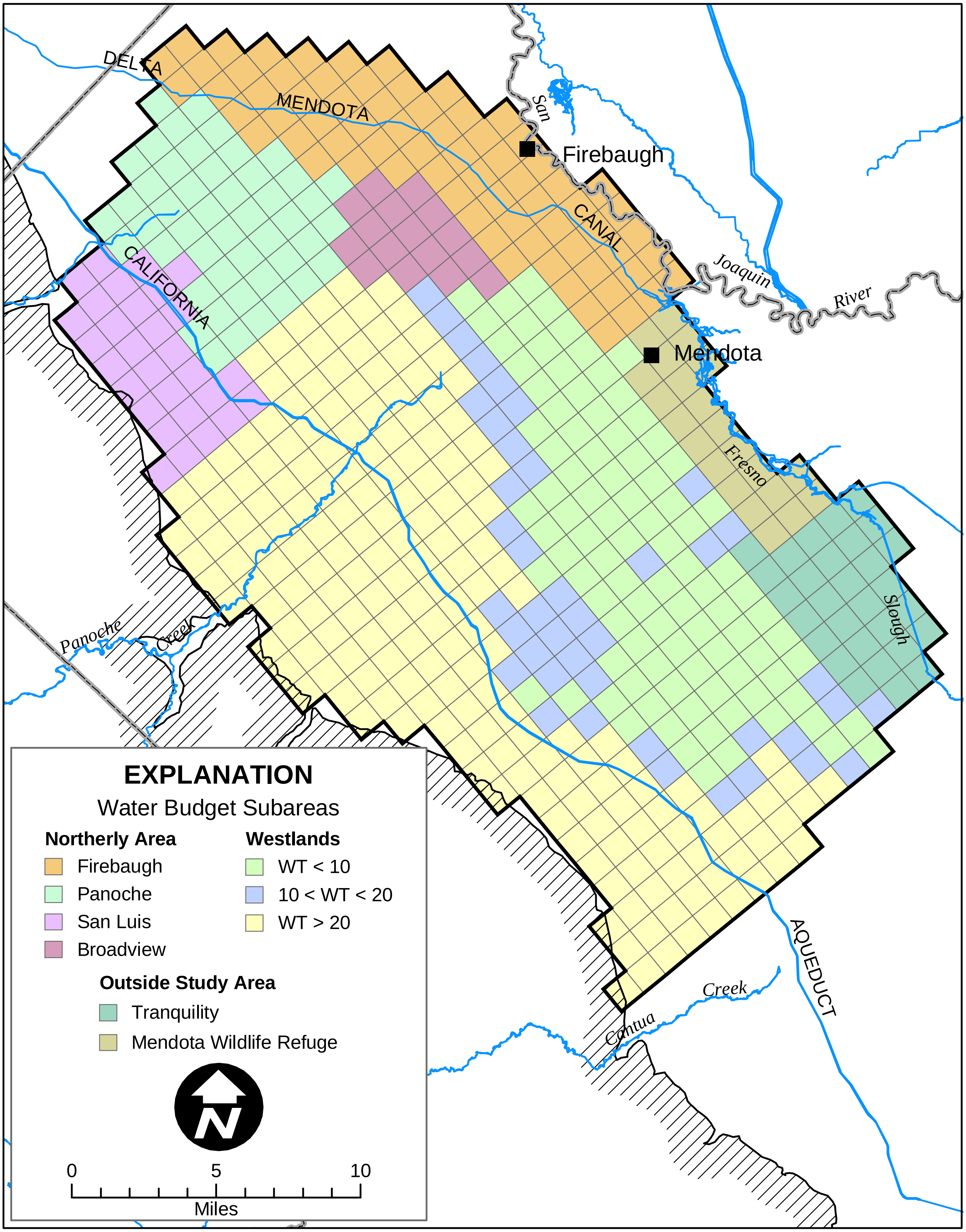
| PROJECT: 5017 | DATE: 4/22/04 | |

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| HYDROFOCUS INC. Solutions for Land and Water Resources | Water Budget Subareas | Figure A-2 |
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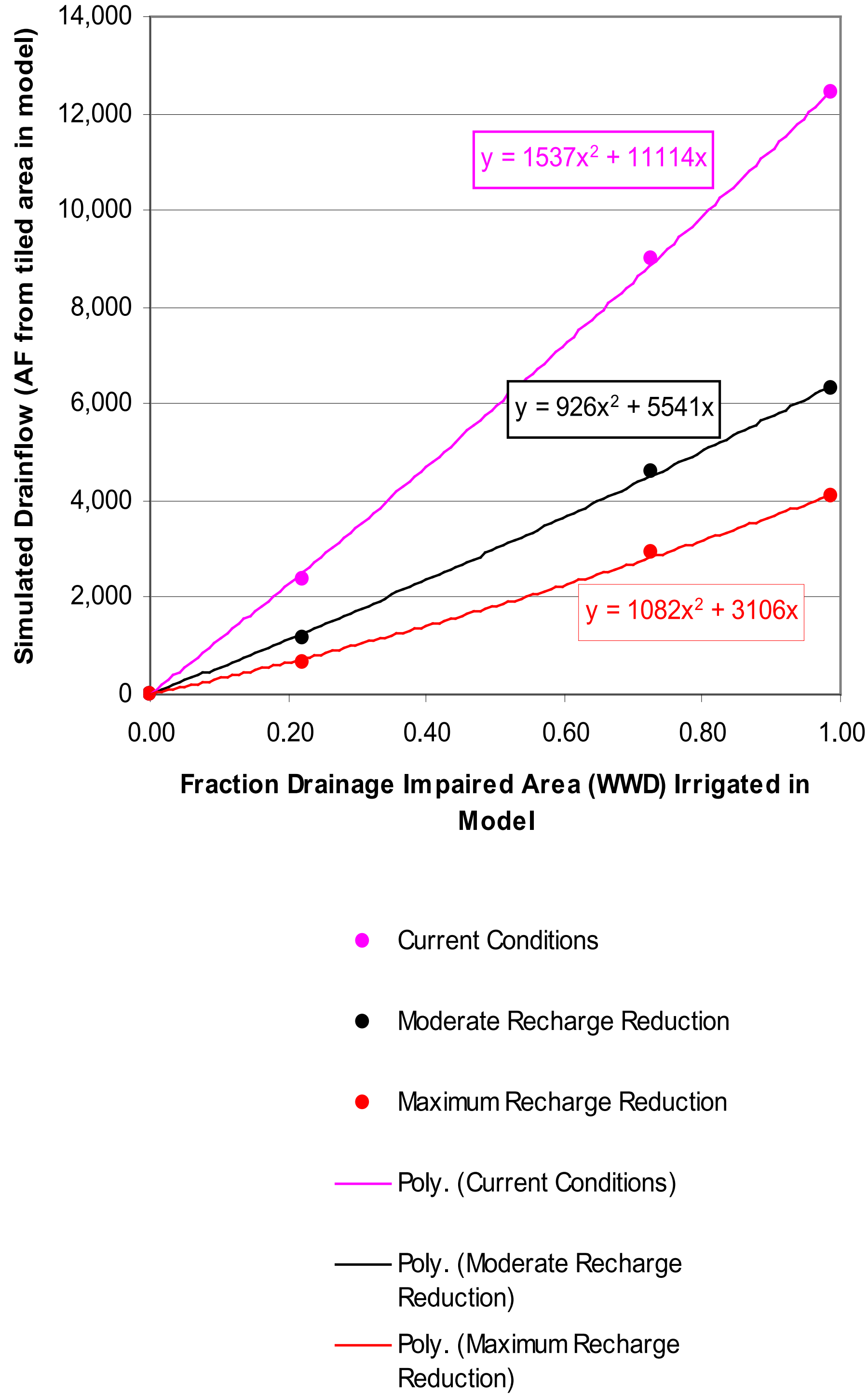


| HYDROFOCUS INC. Solutions for Land and Water Resources | Relationship Between Irrigated Area and Simulated Drainflow in 2050 for Different Recharge Rates | Figure A-3 |
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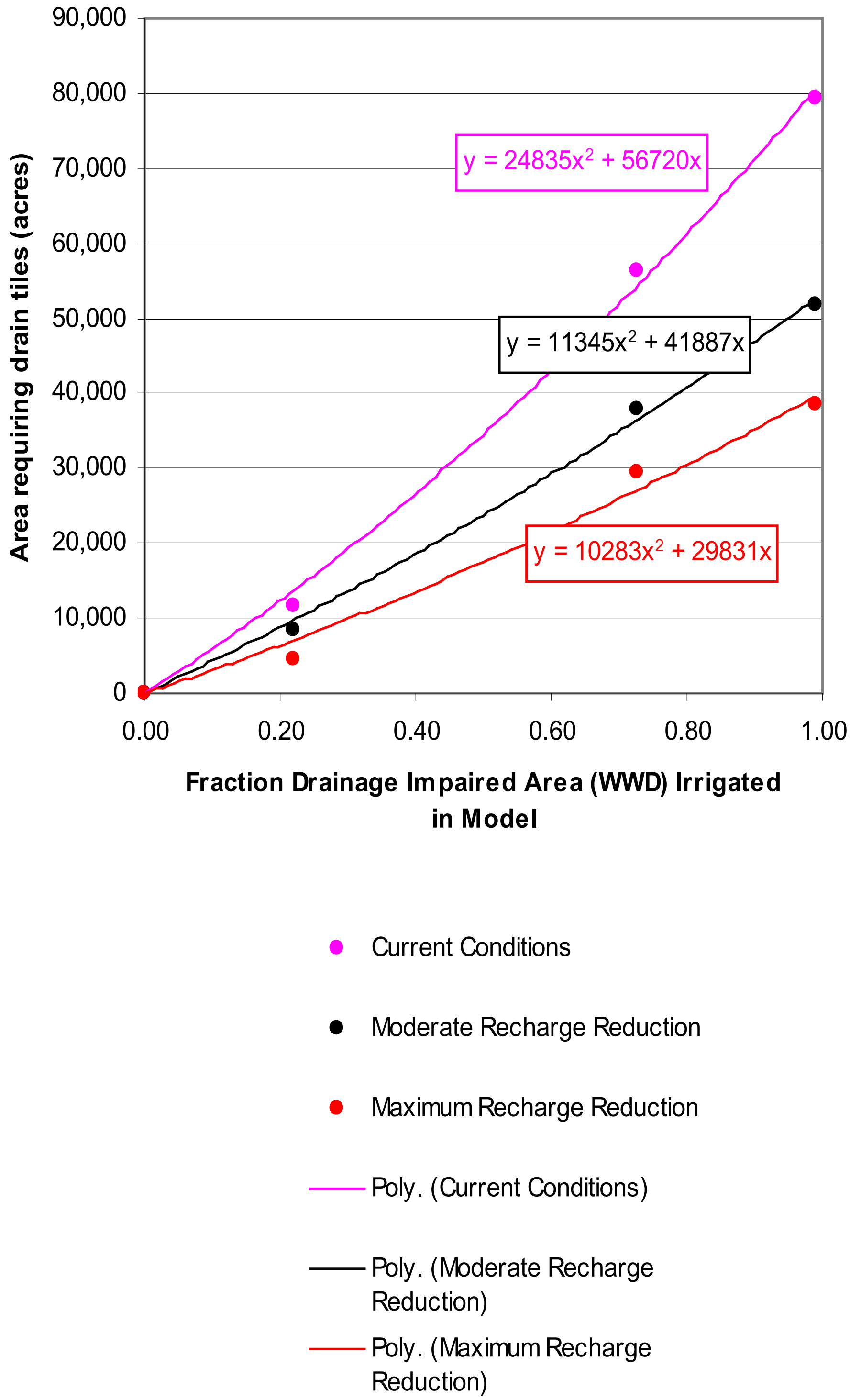


| HYDROFOCUS INC. Solutions for Land and Water Resources | Relationship Between Irrigated Area and Simulated Area Requiring Drainage Systems in 2050 for Different Recharge Rates | Figure A-4 |
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| PROJECT: 5517 | DATE: 4/22/04 | |