2022 Groundwater Quality Assessment Report

5-Year Update

PREPARED FOR

Sacramento Valley Water Quality Coalition

NCWA
Northern California Water Association

PREPARED BY

Luhdorff & Scalmanini
Consulting Engineers

September 2022

SEPTEMBER 2022

2022 GROUNDWATER QUALITY ASSESSMENT REPORT

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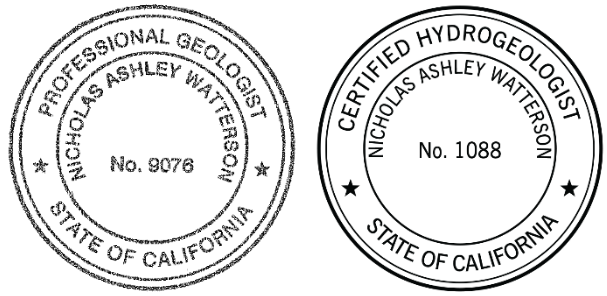
Signature Page



September 23, 2022

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
2022 GAR Update	Five-Year Groundwater Quality Assessment Report Update
BYS	Butte-Yuba-Sutter
CropScape2020	CS20
CVRWQCB (the Regional Board or Board)	Central Valley Regional Water Quality Control Board
DDW	State Board Division of Drinking Water
DL	Detection Limit
DPR	California Department of Pesticide Regulation
DWR	Department of Water Resources
EDF	electronic deliverable format
ENHD	Enhanced National Hydrography Dataset
EPA	Environmental Protection Agency
GAMA	Groundwater Ambient Monitoring and Assessment
GAR	Groundwater Quality Assessment Report
GIS	Geographic Information System
GQMP	Groundwater Quality Management Plan
GQTM	Groundwater Quality Trend Monitoring Program
GWPAs	Groundwater Protection Areas
HGVA	Hydrogeologically Vulnerable Areas
HSA	Hydrogeologically Sensitive Area
HVA	High Vulnerability Areas
ILRP	Irrigated Lands Regulatory Program
LIQ18	2018 Land IQ dataset
LLNL	Lawrence Livermore National Laboratory
MCL	maximum contaminant level
mg/L	milligrams per liter
NCWA	Northern California Water Association
NRCS	Natural Resources Conservation Service
PHVA	Preliminary HVA
PNSSNS	Placer-Nevada-South Sutter-North Sacramento
PWS	Public Water System
QA/QC	quality assurance/quality control
RL	Reporting Limit
SAGBI	Soil Agricultural Groundwater Banking Index
SI	Sensitivity Index
SSURGO	Soil Survey Geographic Database
SVWQC or Coalition	Sacramento Valley Water Coalition

SWRCB or State Board	State Water Resources Control Board
THVA	Tentative High Vulnerability Area
UCD	University of California Davis
UFRW	Upper Feather River Watershed
Ug/L	micrograms per liter
USGS	U.S. Geological Survey
WDR	Waste Discharge Requirements

1. INTRODUCTION

In accordance with the requirements of the Waste Discharge Requirements General Order R5-2014-0030 for Growers within the Sacramento River Watershed that are Members of a Third-Party Group (WDRs or Order) (Central Valley Regional Water Quality Control [CVRWQCB], 2019), the Sacramento Valley Water Quality Coalition (SVWQC or Coalition) has completed this Five-Year Groundwater Quality Assessment Report Update (2022 GAR Update). The watershed of the Sacramento River covers approximately 18.2 million acres of which about 4.4 million acres are within the Sacramento Valley.

1.1. Changes to Coalition Boundary and Valley Floor Analysis Area

Until 2020, the California portion of the Goose Lake hydrologic area, termed the Goose Lake Subwatershed in this and previous Coalition documentation, has been included in the Coalition region. This 245,552-acre region is located north of the Pit River Drainage Area, extending to the Oregon border. Approximately two-thirds of the Goose Lake drainage area is in Oregon. As of August 2021, the Goose Lake Subwatershed has been removed from the Coalition area by the CVRWQCB (also referred to as the Regional Board). The remaining 17.95 million acres of the Sacramento River Watershed make up the Coalition as described in this 2022 GAR Update (**Figure 1**).

Additionally, in the 2016 GAR and the 2021 documentation (LSCE, 2021) submitted initially for this 2022 GAR Update, the Sacramento Valley was defined by the Sacramento Valley Groundwater Basin[1]. The San Joaquin Valley Groundwater Basin was not considered part of the Sacramento Valley for the purpose of designating the high vulnerability area. However, the Regional Board has subsequently required the inclusion of the Cosumnes Subbasin of the San Joaquin Groundwater Basin in the high vulnerability area analysis. The Cosumnes Subbasin area encompasses the towns of Wilton, Ione, and Galt and is bordered by the Sacramento-San Joaquin County border in the south, the Cosumnes River on the northwest edge, and the uplands along the Valley's eastern side. This 2022 GAR Update presents updated analyses to reflect this change in the acreage, nitrate data, and crops' data analyzed for the purpose of determining the extent of the high vulnerability area throughout the valley floor of the Coalition.

1.2. Changes to HVA Delineation Methods

This 2022 GAR Update includes a refined approach to delineating the high vulnerability area (HVA) presented in the initial Groundwater Quality Assessment Report (GAR; CH2M, 2016), that was conditionally approved by the CVRWQCB on September 16, 2016.

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[1] The Sacramento Valley Floor area for the 2016 GAR and the 2021 GAR Update (LSCE, 2021) is referred to as the 2016-2021 valley floor definition. This 2022 GAR Update expands the valley floor analysis to include the Cosumnes Subbasin area.

The only element of the GAR that requires review every five years is the review and confirmation or modification of the GAR vulnerability designations, including review of publicly available groundwater quality data. Most other elements of the initial GAR relate to documentation of the hydrogeologic setting in the Coalition region and, therefore, do not need to be updated on a regular basis.

This 2022 GAR Update presents the results of the refined groundwater vulnerability designations for HVAs for the valley floor portions of the Sacramento River Watershed and provides recommendations for future review of new groundwater data (particularly nitrate) and ongoing assessment of potential groundwater vulnerability. Analyses conducted for this Update were based on data obtained from public sources in late 2020 and early 2021.

1.3. HVA Outside of Sacramento Valley Floor

The 2016 GAR did not establish any HVA outside of the Sacramento Valley. Because of limited available data on nitrate in groundwater in many of the upland areas of the Coalition region, a review of potential HVA outside the valley floor will be conducted in 2023, after completion of the first year of Drinking Water Well Monitoring in the Coalition. Land use and nitrate data currently available for the upper subwatersheds are discussed in **Section 6.** A simplified method for preliminarily establishing HVA in the Lake County Subwatershed, which has some agricultural characteristics that differ from other upper subwatersheds, is presented in **Section 6.1**.

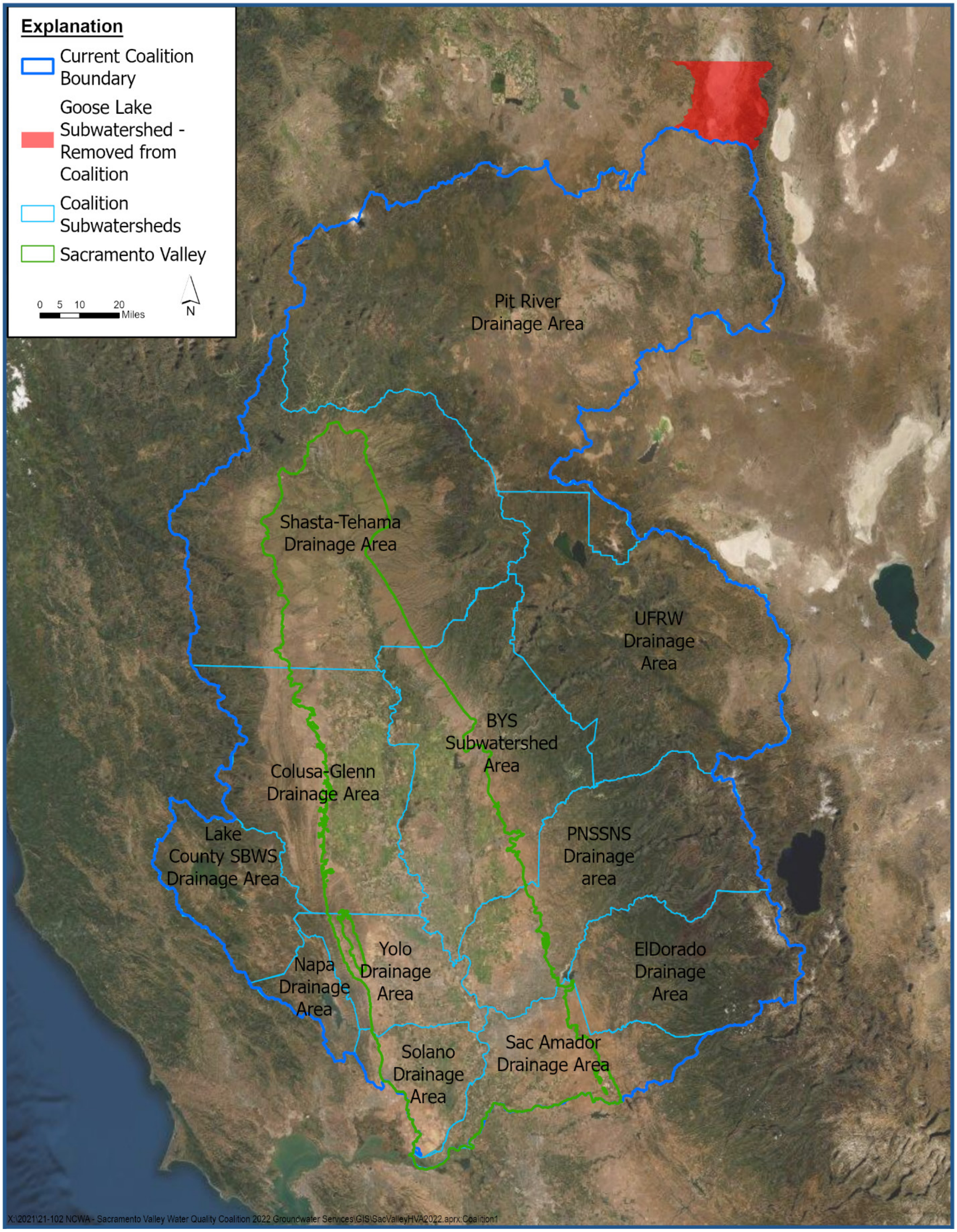

Figure 1: Coalition Subwatersheds as of August 2022

1.4. Waste Discharge Requirements and Groundwater Quality Protection

The Sacramento River Watershed WDRs provide important context for the protection of groundwater quality where discharges from irrigated agricultural operations may potentially impact groundwater quality. While large areas of the Sacramento River Watershed may have hydrogeologic or physical characteristics that are conducive to recharge and beneficial effects on groundwater quality, including lower constituent concentrations due to low mineral content recharge waters, these lands are not sensitive to irrigated agricultural impacts unless such overlying land use exists. Below are key WDR excerpts that emphasize the significance of linking irrigated agricultural land use to known or potential groundwater quality impacts when designating HVAs.

The WDRs (2019) establish the importance of groundwater quality protection:

> "In some areas, nitrate from both agricultural and non-agricultural sources has resulted in degradation and/or pollution of groundwater beneath agricultural areas in the Central Valley. Available data (see Information Sheet and the PEIR) indicate that there are wells, including water supply and environmental monitoring wells, within the Sacramento River Watershed that have exceeded the MCL for nitrate. As established in the Basin Plan, groundwater in the Sacramento River Watershed has been designated, for drinking water (MUN) uses; therefore, the water quality objective of 10 mg/L for nitrate plus nitrite (as nitrogen) applies to groundwater in the Sacramento River Watershed. Where nitrate groundwater quality data are not available, information on the hydrogeological characteristics of the area suggest that portions of the Sacramento River Watershed may be vulnerable to nitrate contamination. Sources of nitrate in groundwater may include leaching of excess fertilizer, confined animal feeding operations, septic systems, discharge to land of wastewater, food processor waste, unprotected well heads, improperly abandoned wells, and lack of backflow prevention on wells."

One of the key objectives of the GAR that pertains to this 2022 GAR Update includes:

> "Provide an assessment of all readily available, applicable and relevant data and information to determine the high and low vulnerability areas where discharges from irrigated lands may result in groundwater quality degradation."

Additionally, as part of data review and analysis that are relevant to the 2022 GAR Update:

> "Determine where known groundwater quality impacts exist for which irrigated agricultural operations are a potential contributor or where conditions make groundwater more vulnerable to impacts from irrigated agricultural activities."

The WDR also establishes the particular concerns that should determine the extent of high/low vulnerability areas:

> "The third-party must review and confirm or modify vulnerability designations every five (5) years after Executive Officer approval of the GAR. The vulnerability designations will be made by the third-party using a combination of physical properties (soil type, depth to groundwater, known agricultural impacts to beneficial uses, etc.) and management practices (e.g., irrigation method, crop type, nitrogen application and removal rates, extent of implementation, etc.)."

High and low vulnerability areas are defined as follows (WDRs Attachment E):

> "High vulnerability area (groundwater) – Areas identified in the approved Groundwater Quality Assessment Report "…where known groundwater quality impacts exist for which irrigated agricultural operations are a potential contributor or where conditions make groundwater more vulnerable to impacts from irrigated agricultural activities." (see section IV.A.3 of the MRP) or areas that meet any of the following requirements for the preparation of a Groundwater Quality Management Plan (see section VIII.H of the Order): (1) there is a confirmed exceedance (considering applicable averaging periods) of a water quality objective or applicable water quality trigger limit (trigger limits are described in section VII of the MRP) in a groundwater well and irrigated agriculture may cause or contribute to the exceedance; (2) the Basin Plan requires development of a groundwater quality management plan for a constituent or constituents discharged by irrigated agriculture; or (3) the Executive Officer determines that irrigated agriculture may be causing or contributing to a trend of degradation of groundwater that may threaten applicable Basin Plan beneficial uses.
>
> "Low vulnerability area (surface water and groundwater) – are all areas not designated as high vulnerability for either surface water or groundwater."

1.5. 2016 GAR HVA

The Northern California Water Association (NCWA), on behalf of the SVWQC submitted the first draft GAR to the Regional Board in June 2014 (CH2M, 2014). The Regional Board provided extensive comments on the HVA analysis methods and requested several revisions to the GAR (CVRWQCB, 2015). Following the Regional Board's comment letter, a revised GAR was submitted in January 2016 that included a revised methodology to develop HVAs (CH2M, 2016). This method had been previously reviewed together with the Regional Board. Upon review of the revised GAR, the Regional Board conditionally approved the GAR (CVRWQCB, 2016); a few additional modifications were specified by the Regional Board for the final HVA map.

The resulting final 2016 HVA map (**Figure 2**) was submitted to the Regional Board in November 2016 as a Geographic Information System (GIS) shapefile. The final 2016 HVA map provided the basis for the development of the subsequent Comprehensive Groundwater Quality Management Plan (GQMP; CH2M, 2017). The final 2016 HVA covered 955,231 acres, including 1,500 sections (typically one square mile), which were chosen based on the presence of irrigated agriculture. When these sections are intersected with the extent of the Sacramento Valley, the total 2016 HVA in the valley is 946,748 acres. Based on analyses conducted to prepare the 2022 GAR Update, it became apparent that the 2016 HVA included areas of the valley floor that are not hydrogeologically sensitive to nitrate contamination and other areas that are not now and have not been irrigated agriculture.

The WDR requires the HVA to include all wells in areas of irrigated agriculture that have exceeded the nitrate maximum contaminant level (MCL) of 10 mg/L as nitrogen (N.) In the years since the 2016 HVA was finalized, the State Water Resources Control Board (State Board) has improved access to nitrate data, and new datasets have become available. As the coverage of nitrate data in the Coalition has improved, more wells with exceedances have been identified, providing an opportunity for a systematic approach to fulfilling the requirements. Similarly, Department of Water Resources (DWR) is providing access to statewide land use data, which allows for a higher-resolution approach to assessment of the agricultural status of lands in regions with wells exceeding the nitrate MCL.

A review of the 2016 HVA, including new nitrate datasets and land use data indicated that many wells with nitrate MCL exceedances and located in irrigated agricultural areas were not captured by the 2016 HVA. Of the 183 wells with nitrate exceedances in the most recently available dataset and located in areas dominated by irrigated agriculture, the 2016 HVA captured 122 of the exceedance wells. Within the Sacramento Valley portion of the Coalition region, based on the most recent available data, there are 97 wells with nitrate exceedances prior to 2016, located near significant agricultural lands, of which the 2016 HVA captures 60 (**Figure 3**). The availability of the complete pre-2016 nitrate dataset at the time of development of the 2016 GAR is unknown.

The California Department of Pesticide Regulation's (DPR's) Groundwater Protection Areas (GWPAs; DPR, 2018) were included in the 2016 HVA at the request of the Regional Board, (**Figure 4**). Of the 183 wells identified with agricultural land uses and with nitrate exceedances, the GWPA captures 19.

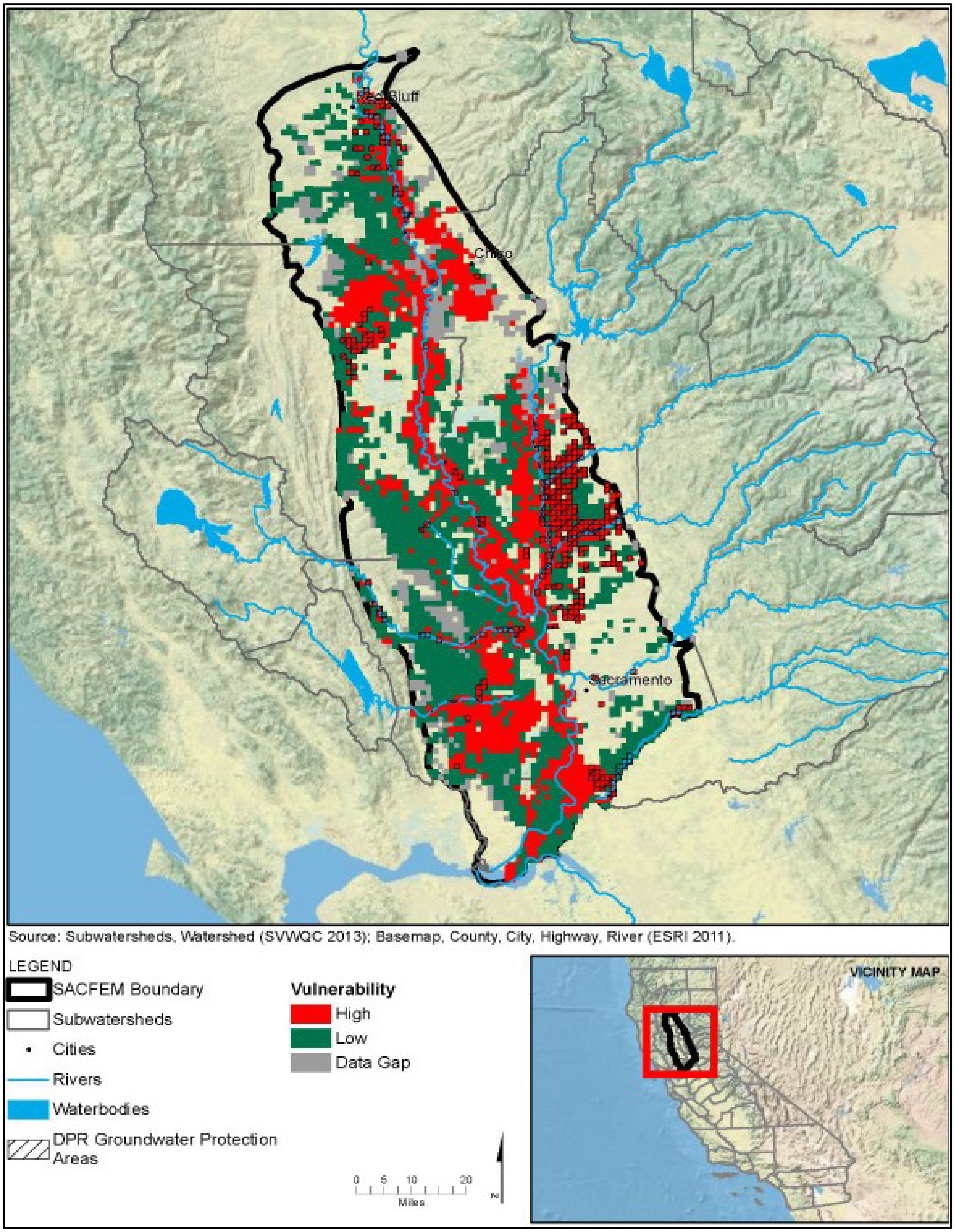

Figure 2: Final Vulnerability Designations, 2016 HVA (CH2M, 2017)

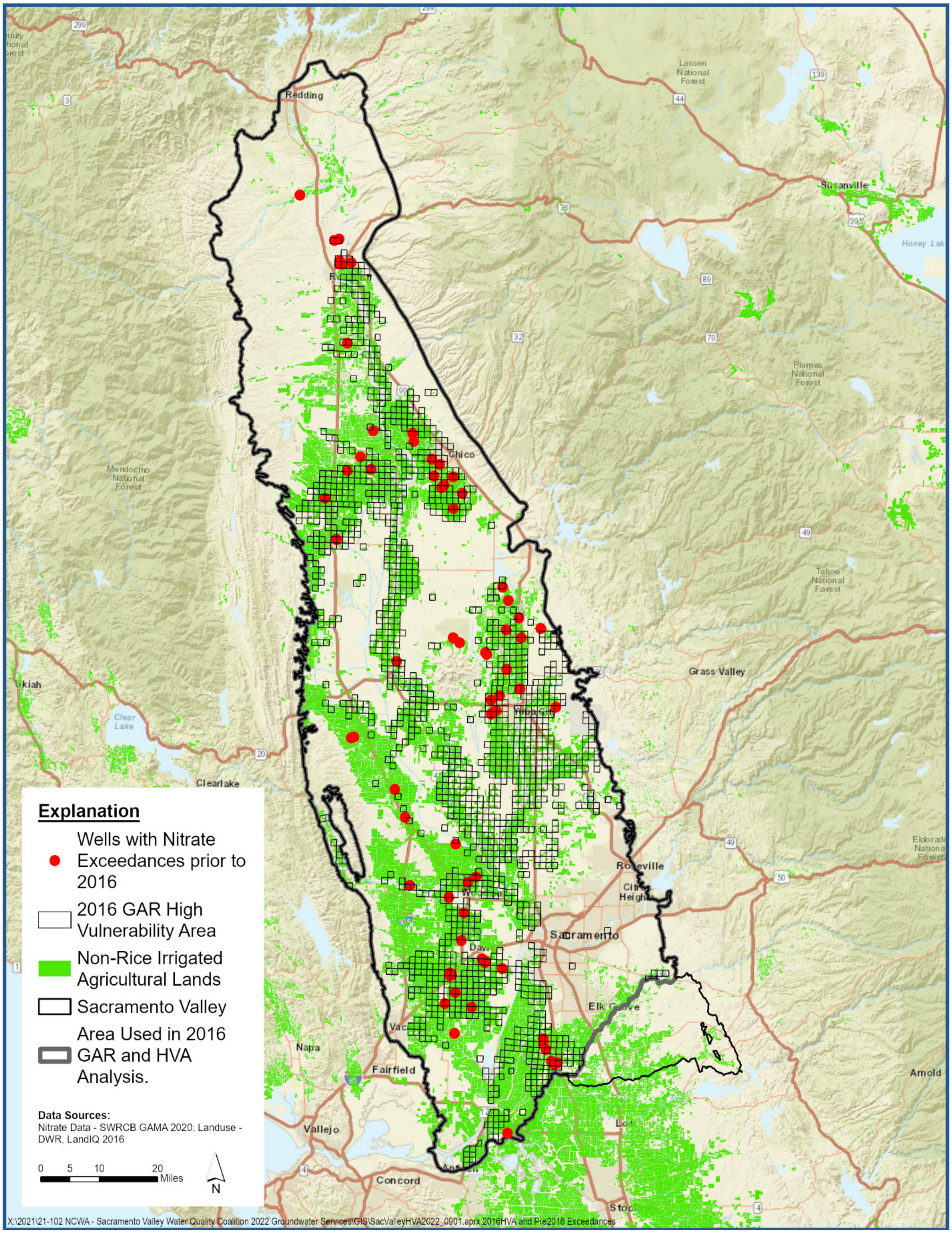

Figure 3: 2016 HVA and Pre-2016 Nitrate Exceedance Wells within the Sacramento Valley

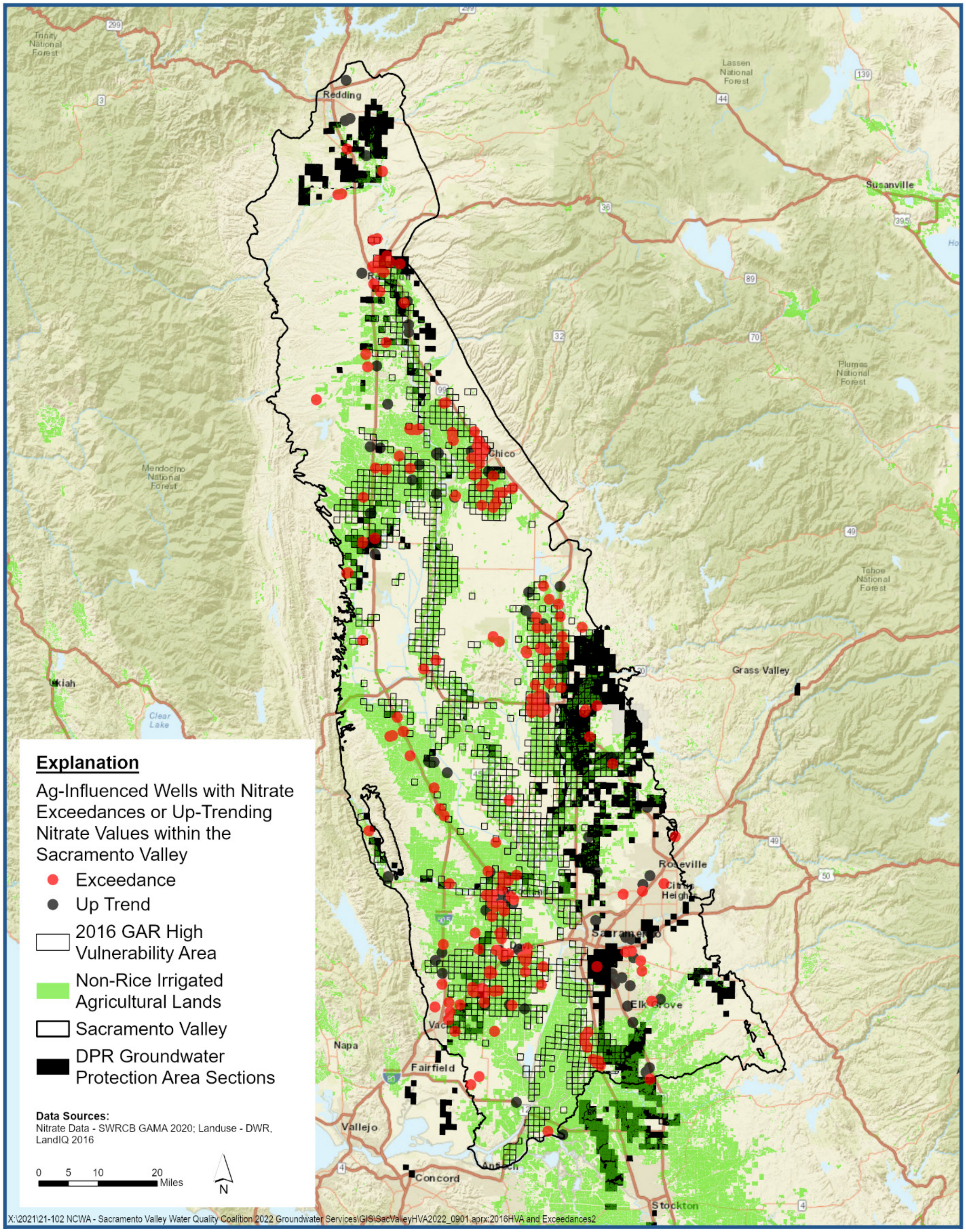

Figure 4: 2016 HVA and DPR GWPA Sections with Nitrate Exceedance and Uptrending Wells within the Sacramento Valley

2. DEVELOPMENT OF THE 2022 HIGH VULNERABILITY AREA

This 2022 GAR Update recognizes the over-designation of 2016 HVA acreage and the existence of nitrate exceedances outside the final 2016 HVA. By definition in the WDRs, the HVA is intended to include lands overlying groundwater resources that are vulnerable to nitrate contamination due to agricultural practices. Targeting all irrigated agriculture captures large regions of the Sacramento Valley that are not hydrogeologically susceptible to groundwater contamination. Likewise, targeting all lands that indicate sensitivity due to inherent physical characteristics of the geology and soils and underlying hydrogeologic and geologic conditions will capture large regions of the Valley where irrigated agriculture is neither present nor a source of contamination. The 2016 HVA is composed of sections that include irrigated agricultural land and is not discretized into specific agricultural parcels that may be vulnerable. As a result, the 2016 HVA includes 394,072 acres (based on the 2016 Land IQ land use data published by DWR; Land IQ, 2016) of non-agricultural, or rice-ag, land that does not meet the definition of vulnerability as defined by the WDRs.

During the development of the 2021 GAR documentation (LSCE, 2021), submitted initially, and this 2022 GAR Update, meetings were held with the Regional Board to discuss the five-year GAR Update, including the opportunity to refine the HVA designation to better align with the purpose and definitions set forth in the WDRs. The SVWQC presented a new approach to the Regional Board that included:

- An assessment of the hydrogeologic sensitivity of the entire valley floor to existing and potential future land uses (these are hydrogeologically sensitive areas based on physical factors and not land uses); and
- Identifying the subset of the hydrogeologically sensitive areas that are known to or have the potential to degrade groundwater quality due to irrigated agriculture; this acreage that is determined to be vulnerable to irrigated agricultural operations comprises the HVA acreage.

2.1. Purpose of 2022 High Vulnerability Area

The HVA should cover any lands that may contribute to groundwater quality impacts due to nitrate leaching associated with irrigated agriculture. In addition, the HVA is required to encompass all wells with exceedances of the nitrate MCL that can reasonably be considered representative of agriculturally influenced groundwater. These exceedances are recorded in datasets from various public agencies, including DWR, State Board Division of Drinking Water (DDW), other data archived by the State Board, U.S. Geological Survey (USGS), and the Irrigated Lands Regulatory Program (ILRP) Groundwater Quality Trend Monitoring Program (GQTM). Due to the expansion of publicly available groundwater-sourced nitrate data over the last half-decade, improved land use and other GIS data quality, and using more refined GIS techniques, the expanded nitrate dataset provided an opportunity to refine the nitrate in groundwater spatial analysis for the 2022 updated HVA designation.

The set of wells with nitrate data is not evenly distributed across the Sacramento Valley. As a result, lands that share land use and hydrogeologic characteristics that can lead to groundwater contamination are not always associated with wells that might reveal nitrate effects on groundwater. Based on previous experience, sufficient nitrate data exist to characterize the relationships between hydrogeologic conditions, groundwater nitrate concentrations, and irrigated agricultural land use in the Sacramento Valley. Multiple regression analysis was used to identify hydrogeologic variables that predict nitrate in wells. Importance was placed more on the significance of the variables than on the regression coefficient because it was already understood that large regions of the landscape that exhibit physical sensitivity to nitrate effects on groundwater have no wells or nitrate data to fit the regression. Through discussions with the SVWQC and review of data collected for the GQTM and other public data sources, the HVA refinement approach identified Coalition lands that met both criteria for vulnerability (presence of agricultural influence and hydrogeologic sensitivity).

The 2016 HVA did not include lands outside of the Sacramento Valley. New groundwater nitrate data collected in the Coalition region for the Drinking Water Well Monitoring Program, which commenced in 2022, should provide additional data on the distribution of nitrate in the upper subwatersheds for evaluating vulnerability. As discussed with the Regional Board previously, a review of data related to the upper subwatersheds and potential HVAs in those areas of the Coalition region will be conducted in 2023. In **Section 6**, this 2022 GAR Update outlines how HVA in the upland subwatersheds may be established as part of the review to be conducted in 2023.

2.2. Conceptual Model for 2022 HVA Development in the Sacramento Valley

Review of available data on nitrate concentrations in groundwater in the Sacramento Valley suggest that areas in proximity to large surface water features tend to have lower nitrate concentrations, with fewer nitrate exceedances, than areas away from major surface water features.

The current HVA development process is founded on a conceptual model that considers the riparian corridors and near floodplains of major rivers separately from the uplands in the Sacramento Valley (**Figure 5**).

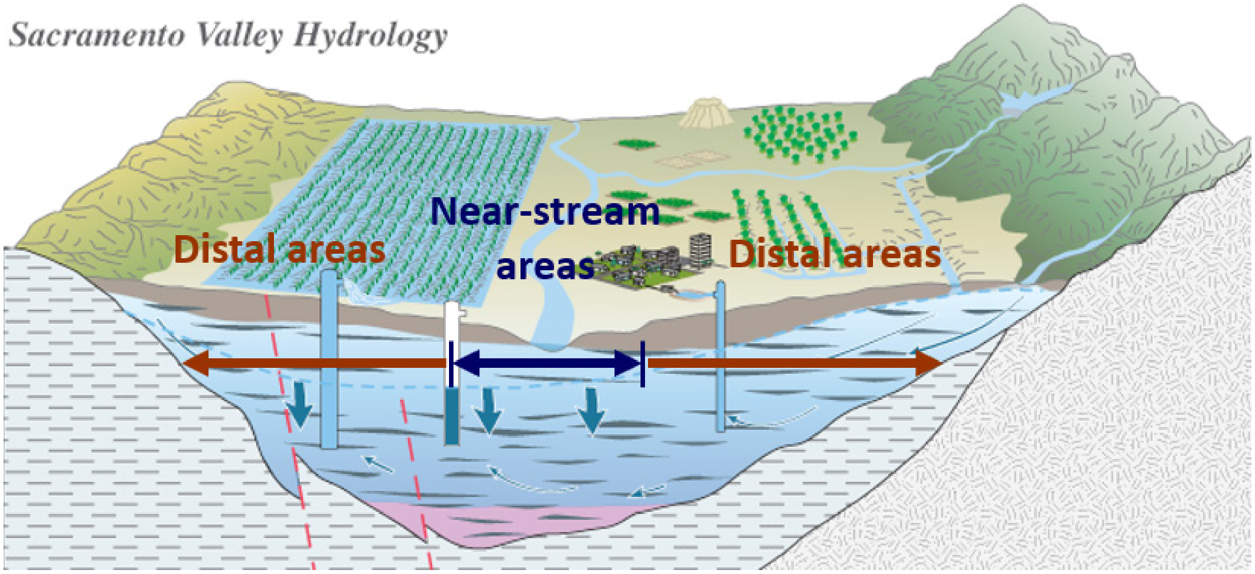

Figure 5: Conceptual Model of Land Use and Groundwater Hydrology in Near-Stream and Distal Areas of the Sacramento Valley

Recharge from high-quality surface water results in dilution of nitrate in groundwater when the flux is from the river to the local groundwater. The presence of a large volume of surface water dilutes nitrate in the nearby groundwater in the presence of relatively coarse substrates when the stream is contributing water to the local groundwater.

Conversely, when the flux is from groundwater to the river, the water that moves into the stream is the shallowest water in the groundwater system. Thus, the fraction of groundwater with the highest likelihood of elevated nitrate from surface activities is discharged to the stream, reducing the loading of nitrate into the deeper aquifer. Nitrate in streams is preferentially absorbed by aquatic macrophytes and algae and removed through denitrification in sediments (Prenier et al., 2020; Desmet et al., 2011). Whether gaining or losing, large streams produce a mitigating impact on local groundwater nitrate contamination. For this analysis, large streams are defined as streams of 8th-order or above (using the Shreve Order[2] method, see **Figure 6**). Based on observations of the spatial distribution and other characteristics of 8th order streams in the Sacramento Valley in relation to nitrate concentrations, these streams have significant annual flows and also tend to have lower nitrate concentrations in areas adjacent to the surface water features.

[2] Strahler Stream Order increases by 1 point when 2 streams of the same order join. Shreve Stream Order assigns the sum of the tributary orders to the reach below each confluence ().

Consistent with this conceptual model, two key assumptions underlie the development of the 2022 HVA. These include:

1. Lands that are vulnerable to groundwater degradation with nitrate due to agricultural influences have been subjected to those influences for long enough and at high enough intensity to produce spatial and temporal trends in the nitrate data that are detectable in wells.
2. Groundwater nitrate trends in riparian areas respond to land use practices substantially different from upland areas due to the influence of large streams on nearby groundwater quality.

Two separate empirical models were developed to represent the sensitivity of lands to influences from agricultural practices. One model addressed conditions, characteristics, and mechanisms occurring in the near-stream areas where major surface water features play a large role in groundwater quality conditions and another model addressed areas that are less influenced by surface water features.

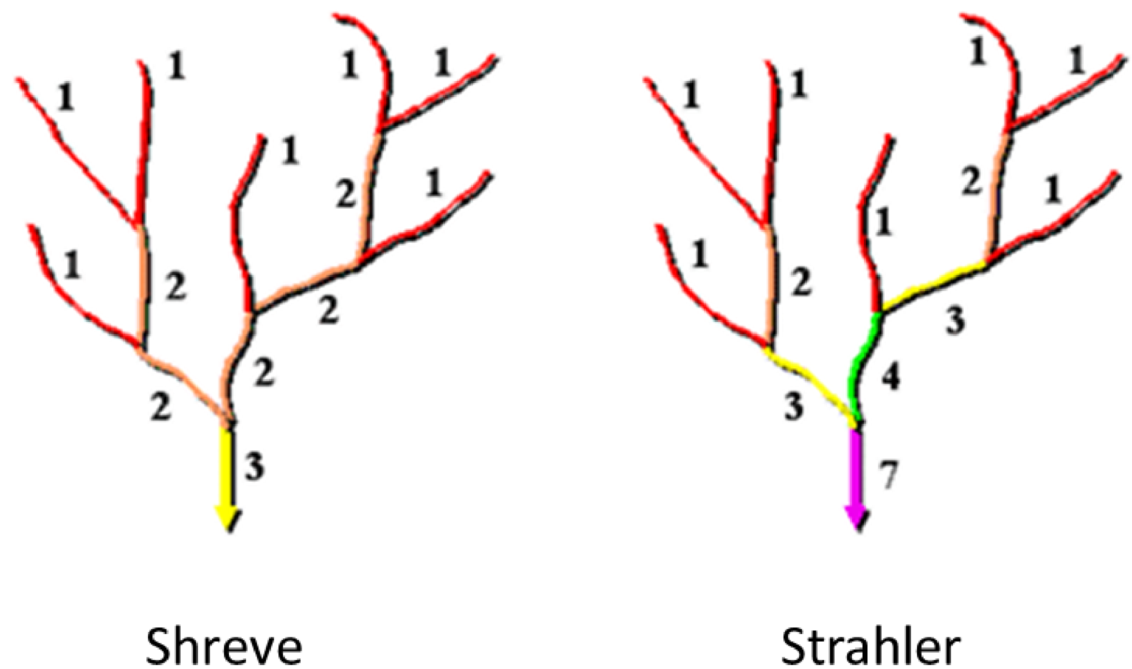

Image Credit: ESRI (https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-stream-order-works.htm)

Figure 6: Strahler vs Shreve Stream Order

3. 2022 HYDROGEOLOGICALLY SENSITIVE AREA DEVELOPMENT

The hydrogeologically sensitive area (HSA) is the area of the Sacramento Valley that has hydrogeologic characteristics rendering it sensitive to nitrate contamination of groundwater due to land uses on the surface. The HSA does not describe vulnerability to nitrate contamination, only the potential for such contamination based on hydrogeologic characteristics. The HSA was developed in the following steps:

1. Obtain, collate, and verify quality of nitrate data for regression analysis;
2. Identify appropriate independent hydrogeologic variables;
3. Conduct regression analysis based on GIS overlays of all selected variables; and
4. Select optimal threshold for nitrate exceedance well capture.

A multiple regression analysis was conducted to identify the most powerful hydrogeologic variables for predicting nitrate concentrations in wells, with nitrate concentrations in groundwater used as a proxy indicator for sensitivity to water quality influences from irrigated agricultural practices. All nitrate results were used, including non-detectable results. Although the target of the HVA development was to encompass all relevant exceedances, the entire set of available nitrate data was used to evaluate statistical relationships between key hydrogeologic characteristics and observed nitrate concentrations during the HSA development.

3.1. Overview of Multiple Regression Analysis

In a multiple regression analysis, multiple independent variables are compared with a single dependent variable to find the best-fit equation that uses all the independent variables to explain the dependent variable. In the analysis discussed here, well nitrate results are the dependent variable, and several hydrogeologic variables mapped over the landscape are the independent variables tested. The result of the regression analysis is a polynomial equation consisting of the independent variables at every location where a well nitrate datapoint exists multiplied by their respective coefficients and summed to produce a predicted value of the dependent variable. The comparison of the predicted value against the known value at each well location provides measures of the utility of the set of independent variables to correctly predict the dependent variable: the significance of the independent variables (p-value), and the coefficient of determination (R^2).

3.1.1. Significance of Independent Variables (p-value)

The significance of the relationship between hydrogeologic (independent) variables and nitrate concentrations (dependent variable) in wells determines the likelihood that the observed relationship within the sample set is a true relationship in the population. The p-value is the probability that the identified relationship between two variables in the sample data is not just by chance. Low p-values suggest that the relationship between an independent variable, such as hydraulic conductivity, and the dependent variable of nitrate concentration found within the sample set is a true relationship that holds throughout the study area and very unlikely to be result of chance. Low p-values imply that the independent variable in question is a good predictor of nitrate concentrations in groundwater.

3.1.2. Coefficient of Determination (R^2)

R^2 values, in contrast, explain the tightness of the relationship identified. The R^2 value represents the fraction of the variability in the dependent variable (nitrate) that is explained by the variation in the independent variable (for example, hydraulic conductivity). The power of a variable to explain the response is a function of factors such as:

- distribution of wells;
- presence of confining layers above well screens;
- variability in groundwater depth, flow direction, and flow magnitude;
- changes in land use practices;
- depth, material, and integrity of sanitary seals of the wells.

The R^2 values were also considered, although these values were not expected to be very high due to known heterogeneity in depth to groundwater and subsurface water chemistry, different well depths, variable pumping and nitrogen application rates over time and space, and non-uniform distribution of samples (wells), among other sources of error.

3.1.3. Selecting the Appropriate Multiple Regression Model

For the purpose of developing the HSA, the significance of the relationships between the independent variables and nitrate concentrations in wells (as measured by the p-value) is more important than the power of the regression to predict all nitrate values (the R^2 value) because wells are not available to provide nitrate data across all the land that is hydrogeologically sensitive, and other confounding limitations exist in the available data. As the number of independent variables increase (including independent variables without a statistically significant correlation with the dependent variable), the R^2 of the regression equation will also increase because of the additional information available to predict nitrate concentrations. However, this does not mean that all variables included in the regression equation have a significant correlation with nitrate concentrations. Identifying hydrogeologic characteristics consistent with the conceptual model for sensitivity that have statistically significant correlations to nitrate concentrations was the primary objective in the regression analyses. Sensitivity is not determined by the presence of wells but by the hydrogeology of the area. The regression equation should include those hydrogeologic variables exhibiting a statistically significant correlation to nitrate concentrations that can then be used to estimate hydrogeologic sensitivity across all areas, including even where no nitrate data exist. Given that there are not comprehensive and well-distributed well nitrate data throughout the study area, the HSA should capture areas with hydrogeologic character similar to the areas with high nitrate values – even though not all of these hydrogeologically similar areas have high nitrate values.

3.2. Dependent Variable Data

Mean nitrate concentration by well was used as the dependent (response) variable for multiple regression analyses used in assessing hydrogeologic sensitivity in the Coalition region. The regression data compiled for the regression modeling include 69,529 nitrate samples collected throughout the SVWQC from 8,346 wells since 1935 (49,870 samples from 5,437 wells in the area of the Coalition within the Sacramento Valley) (**Table 1**). The regression model used the mean nitrate concentrations because the maximum nitrate concentration results were found to have too many examples of outliers and anomalies to be reliable. The p-values (a measure of strength of a statistical relationship, discussed in **Section 3.1.1**, above) indicate a more significant relationship between the mean nitrate concentration and the independent variables chosen than that between the maximum nitrate and the same independent variables. The 2022 HSA also captures more of the exceedance wells when mean nitrate is used. The fit of the regression line to the data was better in all regression analyses using mean nitrate as the dependent variable, which integrates samples over years and thus reduces influence of data outliers and errors.

Although mean nitrate concentrations were ultimately used as the dependent variable in regression analyses for assessing hydrogeologic sensitivity, maximum values were not ignored in the development of the 2022 HVA. The highest value in any given well was used to determine if a well was a nitrate exceedance well, and thus required by the WDR to be included within the HVA.

3.2.1. Compilation of Data for Nitrate in Wells

The well nitrate data were obtained from the State Board Groundwater Ambient Monitoring and Assessment (GAMA) data clearinghouse for all nitrate results in wells in the Coalition area, except for shallow wells specifically installed to monitor spills, leaking tanks, and other cleanup sites. These data were retrieved from the State Board GAMA website in November 2020. All maps and analyses presented in the 2022 GAR Update are based on this data download.

The wells consist of municipal, domestic, irrigation, and monitoring wells, but nearly half of the wells in the Sacramento Valley are of unknown type (**Figure 7**). These data are compiled on GAMA from State Board Division of Drinking Water and GAMA Domestic Wells Survey wells; DWR monitoring wells; USGS monitoring and Priority Basins wells; ILRP monitoring wells; and wells sampled in studies conducted by UC Davis (UCD) and Lawrence Livermore National Laboratory (LLNL) (**Table 1**, **Figure 8**).

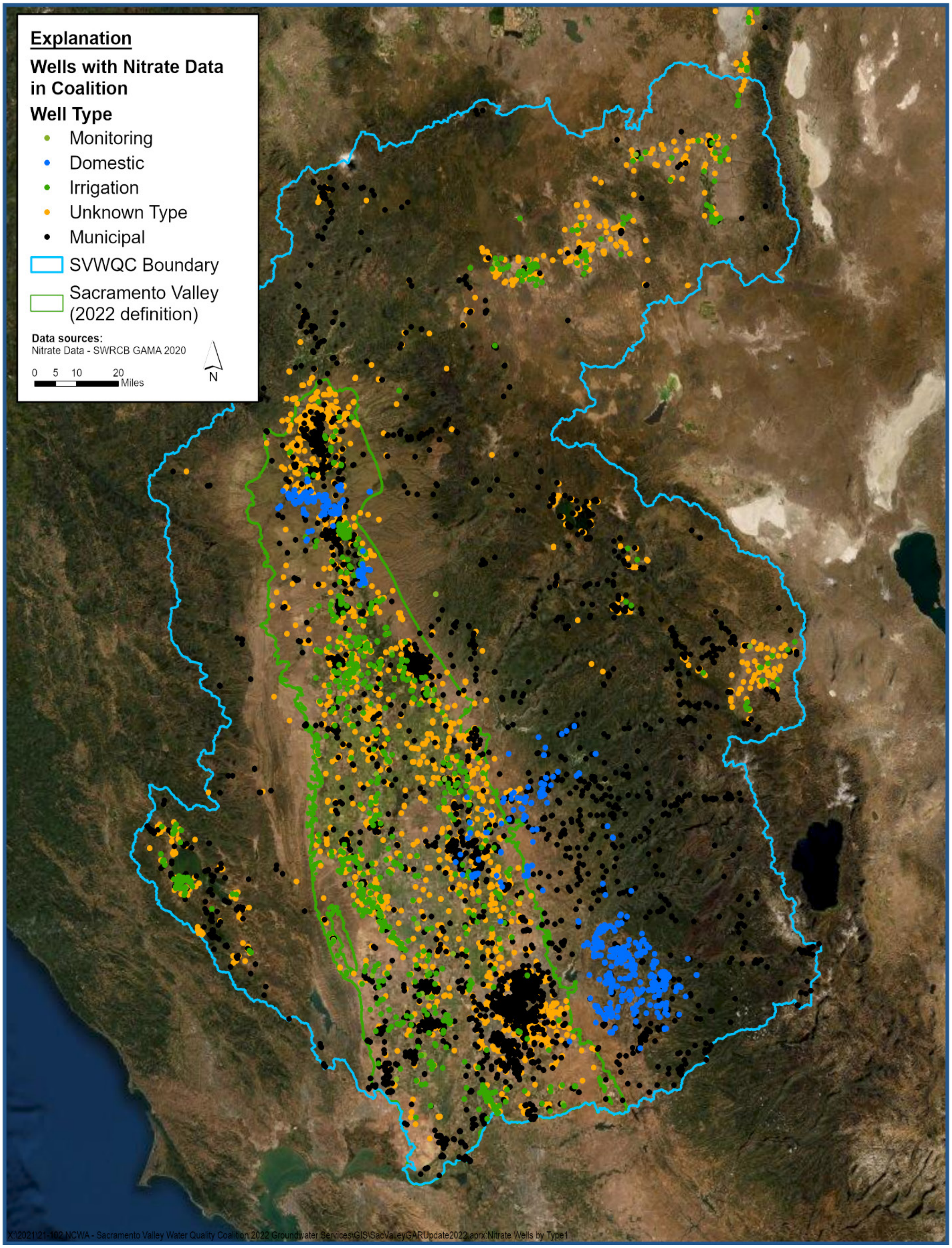

Figure 7: Wells with Nitrate Data by Well Type

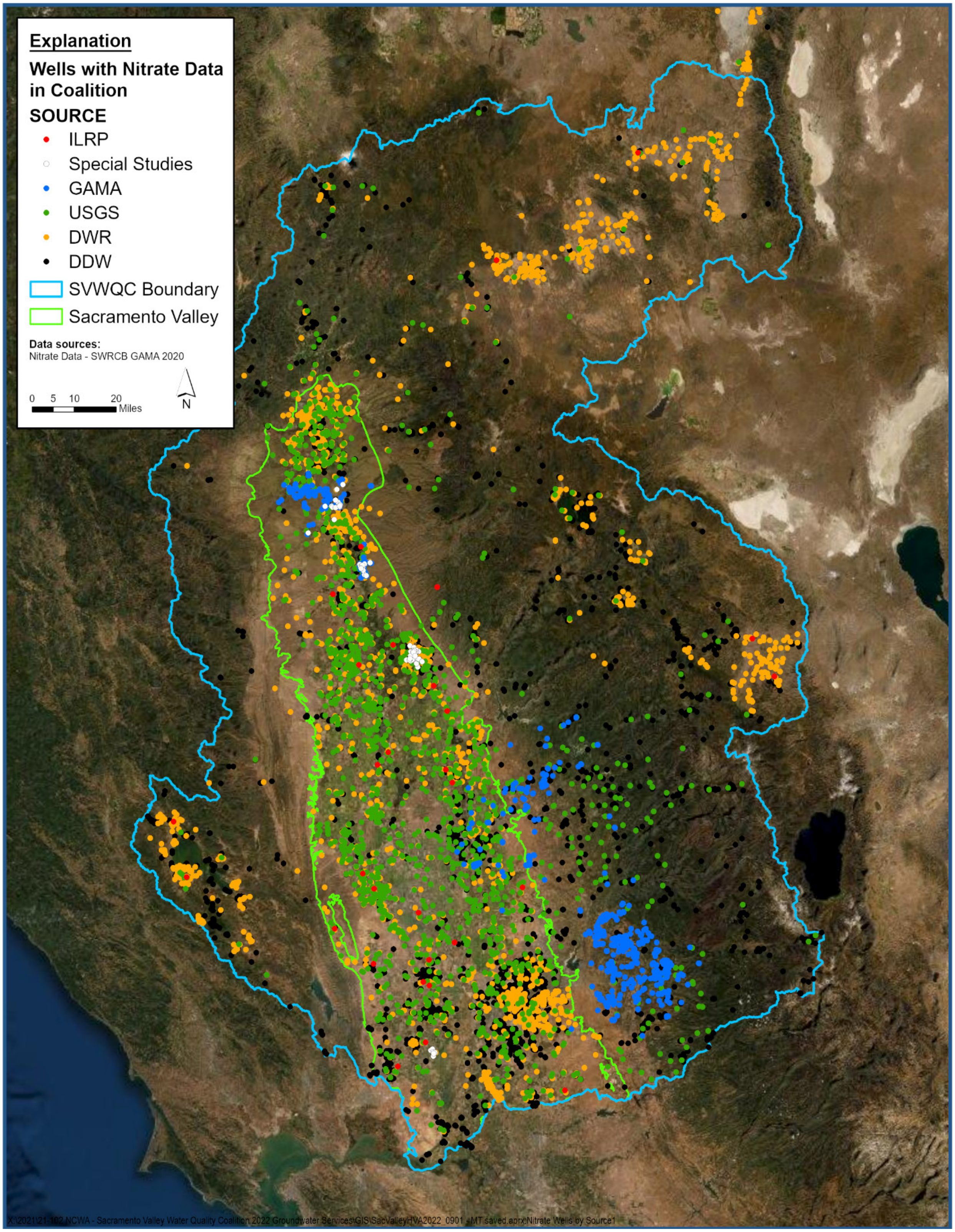

Figure 8: Wells with Nitrate Data by Data Source

Table 1: Nitrate Data Sources in the Coalition and Valley Floor (1935 to Present)					
Data Source	Count of Wells in Sacramento Valley	Count of Wells in Sacramento Valley with Depth Data	Count of Nitrate Samples in Sacramento Valley	Count of Wells in Coalition	Count of Nitrate Samples in Coalition
State Board-DDW	1,877	610	40,708	3,170	56,855
State Board-GAMA Domestic Wells	264	0	488	749	1,378
DWR	1,579	338	5,472	2,228	7,252
USGS	1,633	1,338	3,103	2,107	3,934
Special Studies (UCD, LLNL)	62	0	65	62	65
ILRP	23	18	41	30	53
TOTAL	**5,437**	**2,304**	**49,870**	**8,346**	**69,529**
Note: The GAMA data set does not include use of the regulated facility monitoring wells.					

Most samples (around 85%) collected for nitrate have been collected from Public Water System (PWS) wells sampled for compliance with State Board Division of Drinking Water permit requirements (**Table 1**). These are wells located in or near populated areas. The data collected from these wells are generally reliable due to strict rules governing the quality of drinking water served to the public.

Table 2: Nitrate Data Sources and Well Types in the Coalition						
Data Source	Domestic	Irrigation	Monitoring	Municipal	Unknown	Total
State Board-DDW				3,170		3,170
State Board-GAMA	749					749
DWR		592			1,636	2,228
USGS		227		538	1,342	2,107
Special Studies		5		56	1	62
ILRP			30			30
TOTAL	**749**	**824**	**30**	**3,764**	**2,979**	**8,346**

PWS wells do present some potential problems for analysis. Due to the MCL requirements imposed on PWS wells, when a PWS well starts to produce water with nitrate concentrations approaching or exceeding an MCL, it is often replaced with a deeper well, resulting in discontinuities in the datasets. If an increasing trend in nitrate causes the well's use to be discontinued, then its sampling regime is also discontinued. If the trend in nitrate concentrations continues in the local groundwater, but testing is not continued in the well that can detect it, that trend may appear to end, or the level of exceedances may be underestimated.

3.2.2. Historical Record of Nitrate Data Collection

The data discussed here include all available data from the data sources described above up to the date of retrieval in November 2020. Nitrate data in the Coalition area have been collected for over 85 years. Prior to 1950, very few tests exist, and the likelihood of influence from irrigated agriculture is quite low. For this reason, only wells with samples collected from 1950 or later were used in the regression analysis described below. This removed 9 wells. Wells with samples as early as 1935 were retained. The majority of samples in the publicly available data record have been collected since 2000.

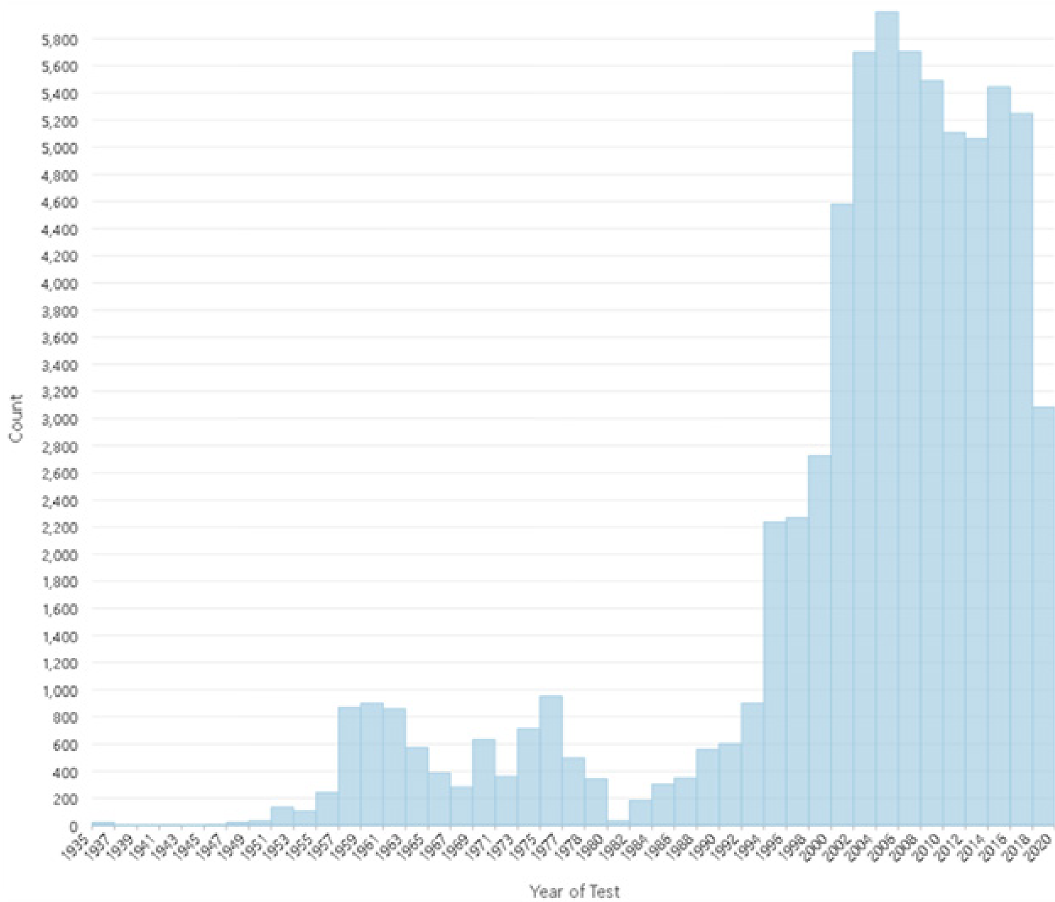

Figure 9: Distribution of Sample Collection Dates for the SVWQC Region

3.2.3. Spatial Distribution of Nitrate Sampling Data

Nitrate has been analyzed for samples from wells throughout much of the Sacramento Valley and in many of the Coast Range and Sierran valleys. These wells are not evenly distributed, with much higher densities of wells sampled in areas with higher populations than in the more rural areas. Maximum nitrate concentrations in wells within the Coalition region (**Figure 10**) were used to determine if the well had ever exceeded the nitrate MCL.

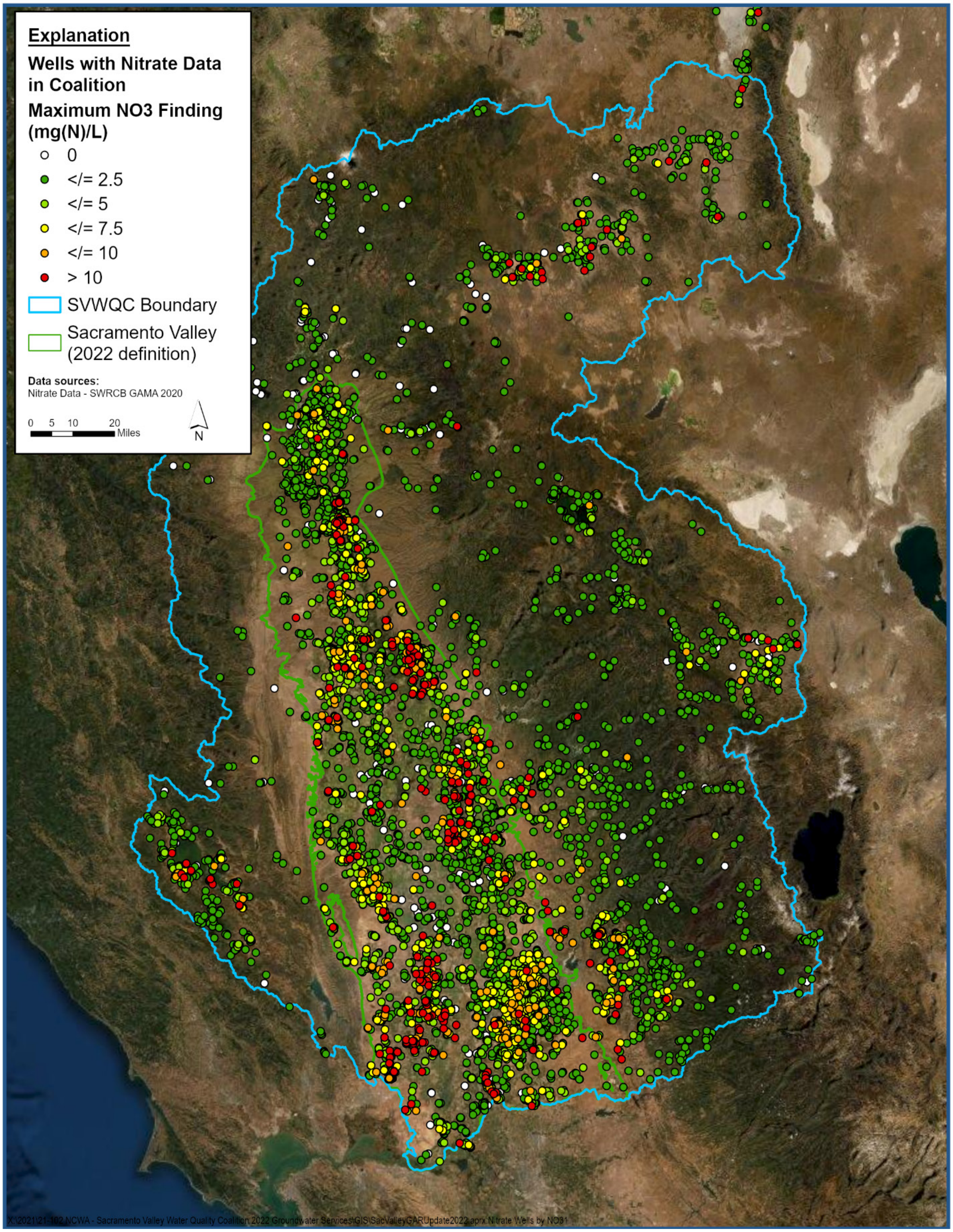

Figure 10: Maximum Nitrate (as Nitrogen) Concentrations in Wells

3.3. QA/QC and Potential Sources of Error in Nitrate Data

All data were obtained from the State Board GAMA website, but not all the data available at the GAMA website were used in this analysis, as discussed in **Section 3.3.1**, below. The GAMA data are all subjected to quality control prior to upload. Further quality assurance/quality control (QA/QC) analyses were performed on the data prior to inclusion in the HSA development process. Certain nitrate sample result errors were noted and corrected. Well depth availability was investigated, and the decision was made not to limit the dataset by the absence of well depth or availability of such information.

3.3.1. Exclusion of Cleanup Site Monitoring Wells

GAMA includes data from regulated facility monitoring wells (identified as electronic deliverable format or "EDF" on the GAMA tabular download webpage) associated with spills, underground storage tanks, and other contaminant sources. These wells are often shallow wells that sample first encountered water. EDF wells are not included in the set of wells used in this analysis.

3.3.2. Reporting Limits and Detection Limits

Most laboratories list the Reporting Limit (RL) of their test method on their results, and these are supposed to be recorded with the data on the test results. However, many of the GAMA data do not correctly report RLs. The RL is the lowest value that the test can detect and report. Where a RL was reported, but the result was listed as a value lower than the RL, the RL was substituted.

The GAMA data do not report Detection Limits (DLs), but the "Qualifier" attribute lists "ND" for non-detect for 6,140 results. All but 46 of these report "0" as the test result. Those 46 results range from 0.01 to 1.6 milligrams per liter (mg/L) nitrate as N. In the cases where a DL was reported, but the result was reported as "0", the DL was substituted. In cases where no DL was reported, a DL of 0.1 mg/L (nitrate as N) was assumed.

3.3.3. Nitrate Reporting Standards

There are several different data reporting protocols that have been utilized over the decades. The Environmental Protection Agency STORET protocol (unique codes that identify an analyte and a method used to test that analyte) for reporting water quality parameters has three different reporting standards for nitrate that have been used in California. These three standards are used for all PWS data reporting. In addition, the GAMA website that houses much of the PWS water quality data has used a separate standard, whereby all nitrate results are labeled as "NO3", with no distinction between the source data reporting standards. Until recently, it was not clear if the data reported on GAMA were reported in units of nitrate as nitrate or nitrate as nitrogen. Starting in 2016, the state of California required all nitrate reporting to be recorded as mg/L as nitrogen.

The three STORET standards are described here. The 71850 standard reports nitrate as nitrate in mg/L. As such, when these data are reported on GAMA, they should be converted to nitrate as nitrogen (N) values. This has resulted in errors with a factor of 4.5, the ratio of the mass of a nitrate molecule to a nitrogen atom. Typically, the error results in a reported value of nitrate-N that is 4.5 times higher than it should be.

The 00618 STORET standard reports nitrate as N in ug/L, and this has also led to confusion, with data reporting off by a factor of 0.001, when a finding is reported as if in mg/L but recorded with the units of ug/L. This standard is used less frequently than the 71850 standard, and the 4.5 times error has been found in data under this standard as well. This occurs when the investigator reports a value as if it were in nitrate-nitrate, but it is recorded as nitrate-N.

The A-029 STORET standard reports nitrate-plus-nitrite as N, in ug/L. This standard is rarely used in California, and LSCE staff have found that the data recorded under this standard are unreliable. Records using this standard were not included in this analysis.

In addition, the GAMA data have been found to contain errors that appear to be due to misreporting of dilution results. While these errors are difficult to identify, they typically result in over-estimation of the nitrate value by 5 or 10 times. When a laboratory dilutes a sample that is out of range (too high) for the selected analytical method, they typically report the results as the true concentration, but due to some confusion among data users and uploaders, the dilution factor has sometimes been applied to this previously corrected data, resulting in reported nitrate concentrations equal to the true value multiplied by the dilution factor.

Well nitrate data within the Coalition area were reviewed for consistency and some examples of these errors were noted. Only sample results that exceeded the 10 mg/L as N threshold were checked for errors. In cases where a well showed an atypical increase in nitrate concentration of 4.5 times (nitrate-nitrogen reported as nitrate-nitrate) or 1000 times (ug/L reported as mg/L) previous sampling results, this was assumed to indicate a unit error, and these were fixed. Similarly, results that seemed to be off trend by a factor of 5 or 10 times were assumed to be dilution errors. The nitrate values were adjusted for 43 results of 36 wells in this way. Only the most obvious examples of these types of errors were corrected. These were identified by visual inspection of the time series on several hundred wells with elevated nitrate. When a single data point was visually off trend, and there were at least two on-trend results prior and two on-trend results after the out-of-trend datapoint, the on-trend value that would be expected was calculated, and if the out-of-trend value was off by one of the factors (4.5, 1000, 10, or 5) described above, it was corrected.

3.3.4. Well Depth Availability

Of the 69,529 samples collected throughout the SVWQC, 44,646 samples are associated with wells that do not have depth information (27,977 of 49,870 samples in the Sacramento Valley). In terms of wells, there are 2,754 wells with depth data available out of 8,346 wells in the SVWQC, and 2,304 of 5,437 wells in the Sacramento Valley (**Table 3**, **Table 4**).

Although this is a source of uncertainty for the current analysis, it is unlikely to be significant due to the comparative time of travel for surface-applied water to groundwater and the time period of widespread irrigated agricultural practices. The time of travel for surface-applied water is dependent on the depth to groundwater, not the depth of wells. Depths to groundwater in the Sacramento Valley are rarely greater than 200 feet, as shown in **Figure 11**. The Fall 2018 depth to groundwater map illustrates the annual deepest groundwater, which is a conservative estimate of groundwater depth for this purpose.

The time for irrigation recharge to reach relatively deep groundwater in the Sacramento Valley is on the order of 10 to 30 years, and irrigated agriculture has been widely distributed for over half a century. It is expected that any trends in nitrate levels in groundwater due to irrigated agriculture will be apparent in the data collected from these wells. As such, it was determined that the improvement of the analysis achieved by using all available nitrate data was more beneficial than limiting the analysis to only wells with well depths available, and all wells were used for the analysis.

Table 3: Depths of Wells with Nitrate Data in SVWQC

Max Depth in Feet Below Ground Surface	Count of Wells
No data	5592
200	1403
400	845
600	345
800	91
1000	50
1200	9
1400	7
Over 1400	4

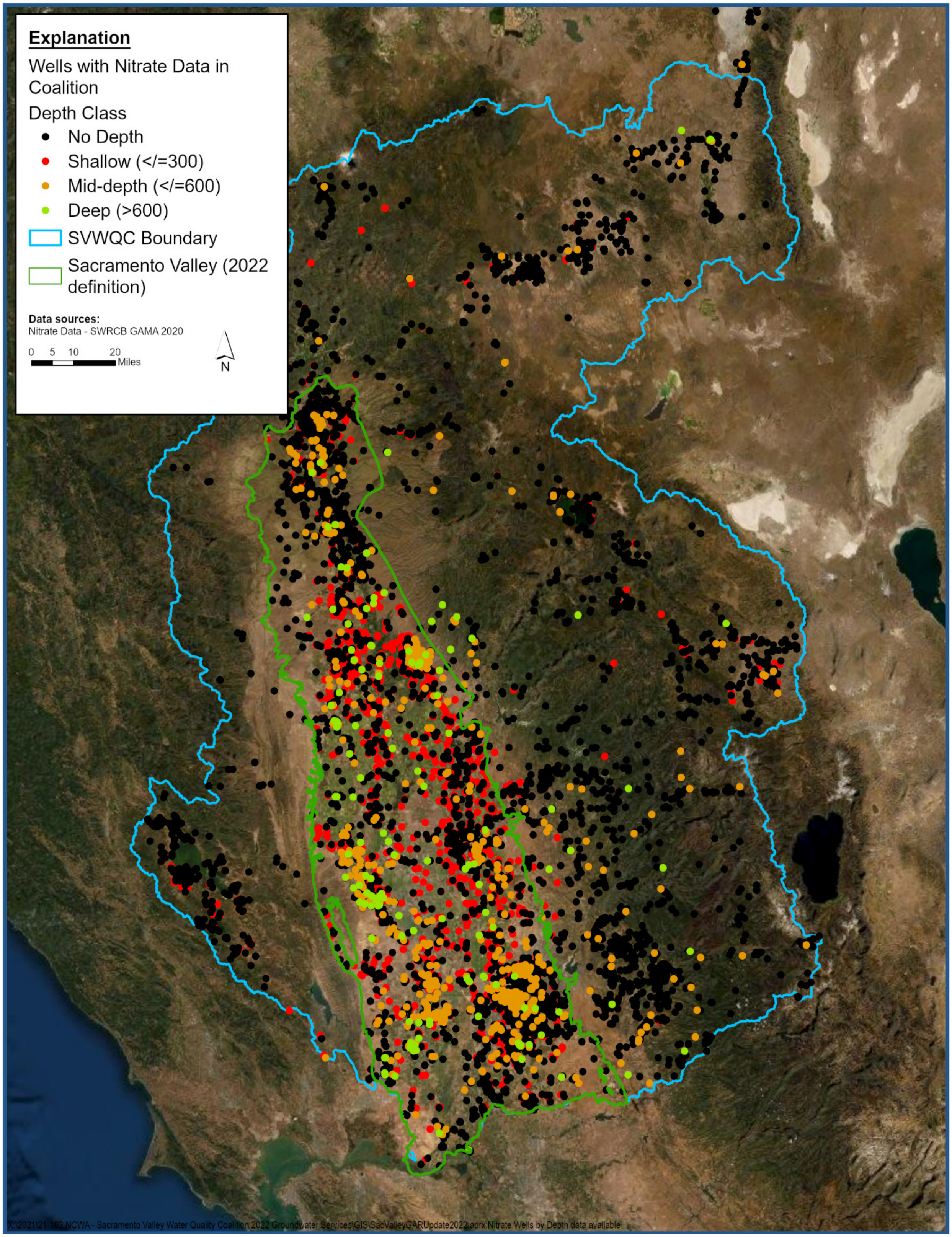

Figure 11: Wells with Nitrate Data by Depth Class

Table 4: Well and Sample Counts in the Coalition and Sacramento Valley			
Well and Sample Statistic	Entire SVWQC Area	Sacramento Valley Floor	Outside Valley Floor
Count of N results, all	69,529	49,870	19,659
Count of N results, depth known	20,747 (30%)	18,415 (37%)	2,332 (12%)
Count of wells, all	8,346	5,437	2,909
Count of wells, depth known	2,754 (33%)	2,304 (42%)	487 (15%)
Percent of samples collected from PWS wells [1]	84%	83%	85%
Count of wells, N exceedance	325	247	78
Count of wells, N exceedance, known or inferred as associated with irrigated agriculture	210	183	27

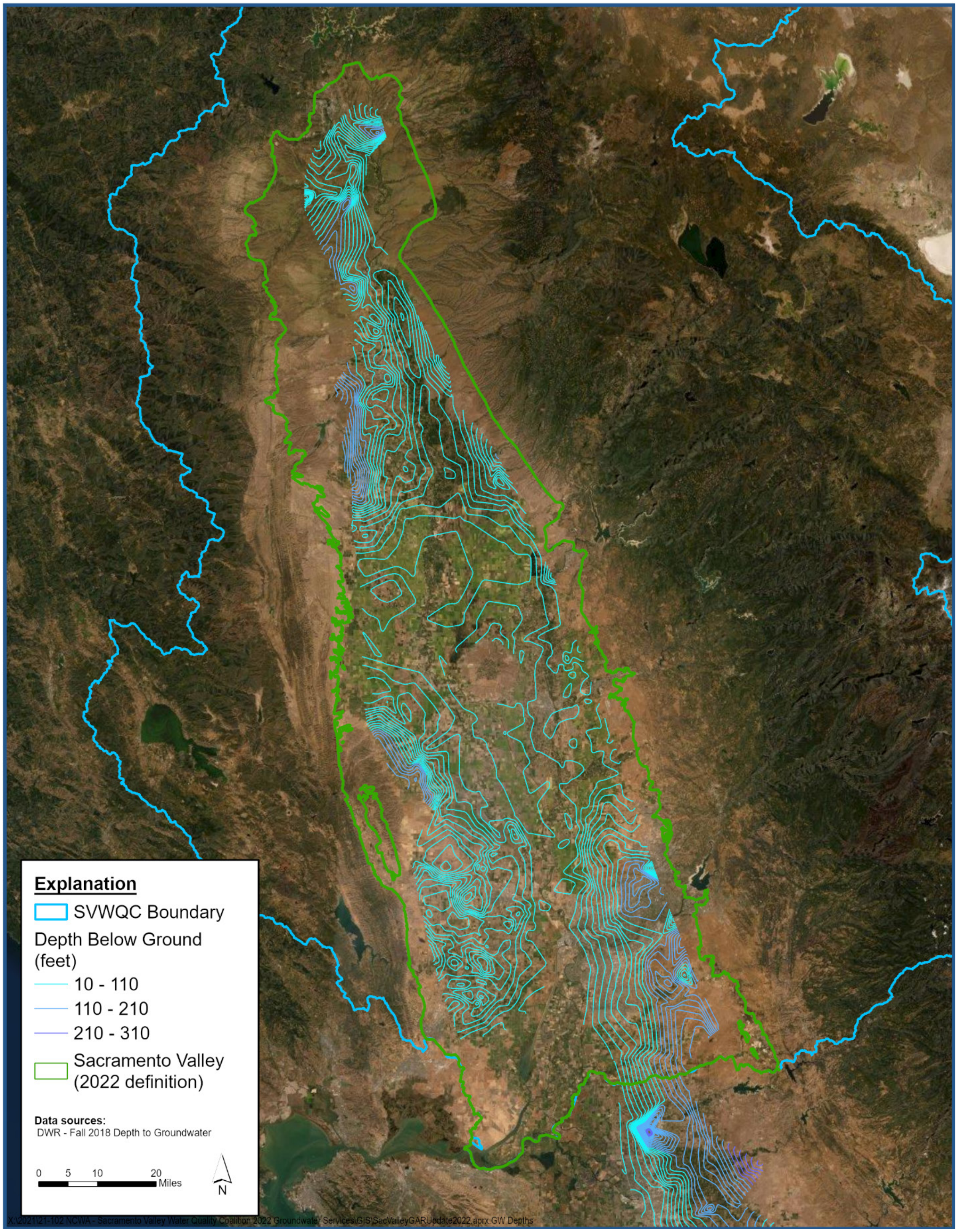

Figure 12: Fall 2018 Depth to Groundwater in the Sacramento Valley (DWR 2019)

3.4. Choice of Dependent Variable

Mean nitrate concentration by well was used as the outcome variable for the regression analysis. The data used in the model included 69,529 nitrate samples collected throughout the SVWQC from 8,346 wells (49,870 samples from 5,437 wells in the Sacramento Valley analysis area used in the original 2016 GAR) (**Table 4**). The regression is based on the mean nitrate concentrations because the maximum nitrate concentration results were found to have too many examples of outliers and anomalies to be reliable. The p-values (a measure of significance, discussed in **Section 3.1.1**) indicate a more significant relationship between the mean nitrate concentration and the independent variables chosen than that between the maximum nitrate and the same independent variables. The 2022 HSA also captures more of the exceedance wells when mean nitrate is used. The fit of the regression line to the data was better in all cases with mean nitrate, which integrates samples over years and thus smooths out outliers and errors.

Maximum values were not ignored in the development of the 2022 HVA. The highest value in any given well was used to determine if a well was a nitrate exceedance well, and thus required by the WDR to be included within the HVA.

3.5. Hydrogeologic Variables

With consideration of the conceptual model for hydrogeologic sensitivity in the Coalition region as discussed in **Section 2.2**, six key hydrogeologic (independent) variables were analyzed in relation to historical nitrate concentrations in wells using multiple regression. The hydrogeologic variables included:

1. Saturated Hydraulic Conductivity from the Soil Survey Geographic Databases (SSURGO) of the Natural Resources Conservation Service (NRCS)
2. Distance to nearest stream of 8th order or larger
3. Density of 3rd order and larger streams
4. Depth to groundwater
5. Soil Agricultural Groundwater Banking Index (SAGBI) derived from soils data by University of California at Davis (O'Geen, 2015).
6. Deep percolation index from SAGBI

Various combinations of the six independent variables were tested to identify statistically significant correlations. In the original submittal of this GAR Update (LSCE, 2021), the Sensitivity Index was developed based on data within the Sacramento Valley region used in the 2016 GAR, which did not include any part of the San Joaquin Valley Groundwater Basin. In 2022, the Regional Board required the HVA to extend into the Cosumnes Subbasin of the San Joaquin Valley Groundwater Basin. The regression analysis was not reevaluated with this new extent. Instead, the input parameters for the sensitivity model were mapped for the added subbasin area, and the model developed in 2021 was evaluated to produce the Sensitivity Index for the entire valley floor, including the Cosumnes Subbasin, as required by the Board.

3.5.1. Regression Models Results and Significant Independent Variables

Important independent variables for use in assessing hydrogeologic sensitivity were selected based on the statistical significance of the relationships between independent variables and the dependent variable (nitrate concentrations). Increasing the number of independent variables always increases R^2 in a multiple regression, however, the additional independent variables may not have a statistically significant correlation with nitrate concentrations. The smallest set of independent variables with statistically significant correlations with high nitrate concentrations (low p-values) is believed to provide the most robust model for assessing sensitivity. The variables that were chosen for the region outside of one mile from the larger streams based on statistical significance were:

- SAGBI (see further discussion below),
- distance to 8th order and larger streams,
- density of 3rd order and larger streams, and
- depth to groundwater.

Within one mile of larger streams, SAGBI was the only variable used to predict vulnerability.

3.5.1.1. One-Mile Cutoff Discussion

The distance cutoff of one mile from an 8th order stream for the two regression models used in the analysis was chosen based on an assessment of the p-values for the independent variables at different model cutoff distances; it was also based on the expected range of riparian dominance over the groundwater system. For the first part, in the not-near-stream model, cutoff values between one-half mile and one mile produced similar p-values for the four independent variables used. In the near-stream model, the SAGBI p-value was much better at one mile than at lesser distances, or at greater distances. Even the highest p-values found were well below the one-tailed 99% confidence except for the near-stream model SAGBI variable at one- quarter mile cutoff. The p-values for all independent variables in the regression model are shown in **Table 5**.

As shown in **Table 5**, a cutoff distance of 1.75 miles would produce slightly better p-values in both the near-stream and not-near-stream models. However, the one-mile cutoff better reflects the extent of riparian influence on soils, particularly along the Sacramento River (**Figure 13**). Typical riparian corridor width for the largest streams in the Sacramento Valley is approximately one mile on either side of the stream (Warner and Hendrix, 1984).

Table 6 and **Table 7** show the results of the regression analysis for the two models, one for the region outside of one mile from large streams and the other for the region near large streams. The R^2 in both cases is around 0.2, meaning that 20% of the variability in the nitrate concentrations in wells is explained by the hydrogeologic variables used in the regression. This is reasonable, given the coverage of the wells available to predict hydrogeologic sensitivity relative to the total area of the Sacramento Valley.

More importantly, the p-values, expressing the likelihood that the relationships described by the listed coefficients do not represent relationships that are true within the entire landscape subsampled by the well data used, are very low. That is, the likelihood of a false positive is very low. These p-values imply that the relationships between the independent variables chosen and the nitrate in wells are representative of these relationships throughout the groundwater system represented by these wells.

The p-values, coefficients, and regression coefficients presented in **Table 6** and **Table 7** were developed based on regression analyses conducted on the area of the Coalition within the Redding and Sacramento Valley Groundwater Basins, which includes the entire Central Valley Floor portion of the Coalition with the exception of the Cosumnes Subbasin of the San Joaquin Valley Groundwater Basin. As described in Section 1.1, the Cosumnes Subbasin was excluded during the 2021 analysis (LSCE, 2021). After the 2021 submission, the Board notified the Coalition that the Cosumnes Subbasin should be included in HVA assessment. The Cosumnes Subbasin represents a relatively small area of the Coalition region within the Valley Floor (4.5 percent) and has only two historical nitrate exceedance wells. Therefore, although the Cosumnes Subbasin area of the Coalition was not included in the 2021 regression analyses, the hydrogeologic susceptibility and vulnerability of the area was evaluated using the statistical relationships and other assessment approaches developed for the Sacramento Valley.

Table 5: P-values of Independent Variables Used in Model of Nitrate Sensitivity at Various Cutoff Values of Distance from Nearest 8th - Order Stream

Distance from Eighth-Order Streams in Miles	2p10NS	2p10NNS				
	Mean SAGBI	Mean 3rd-Order-Plus Stream Density	Mean SAGBI	Mean of Means Depth to Water	Mean Distance to Nearest 8th-Order Stream	Mean p-value
0.25	3.7E-02	9.7E-08	8.0E-24	8.7E-09	6.7E-10	2.7E-08
0.5	7.3E-09	1.6E-07	4.3E-20	7.0E-10	9.7E-08	6.4E-08
0.75	2.8E-11	2.1E-07	7.4E-19	1.8E-09	1.5E-06	4.2E-07
1	2.6E-13	4.0E-07	1.1E-17	1.5E-09	1.2E-05	3.0E-06
1.25	2.1E-14	2.1E-06	3.6E-16	7.8E-10	1.2E-04	3.0E-05
1.5	1.3E-15	2.1E-07	2.7E-15	1.5E-09	7.2E-05	1.8E-05
1.75	1.5E-10	6.9E-11	4.2E-19	4.6E-10	2.2E-06	5.5E-07
2	1.9E-10	2.0E-10	3.7E-18	2.0E-09	1.8E-04	4.6E-05
Note: Better (lower) p-values are indicated with darker shading.						

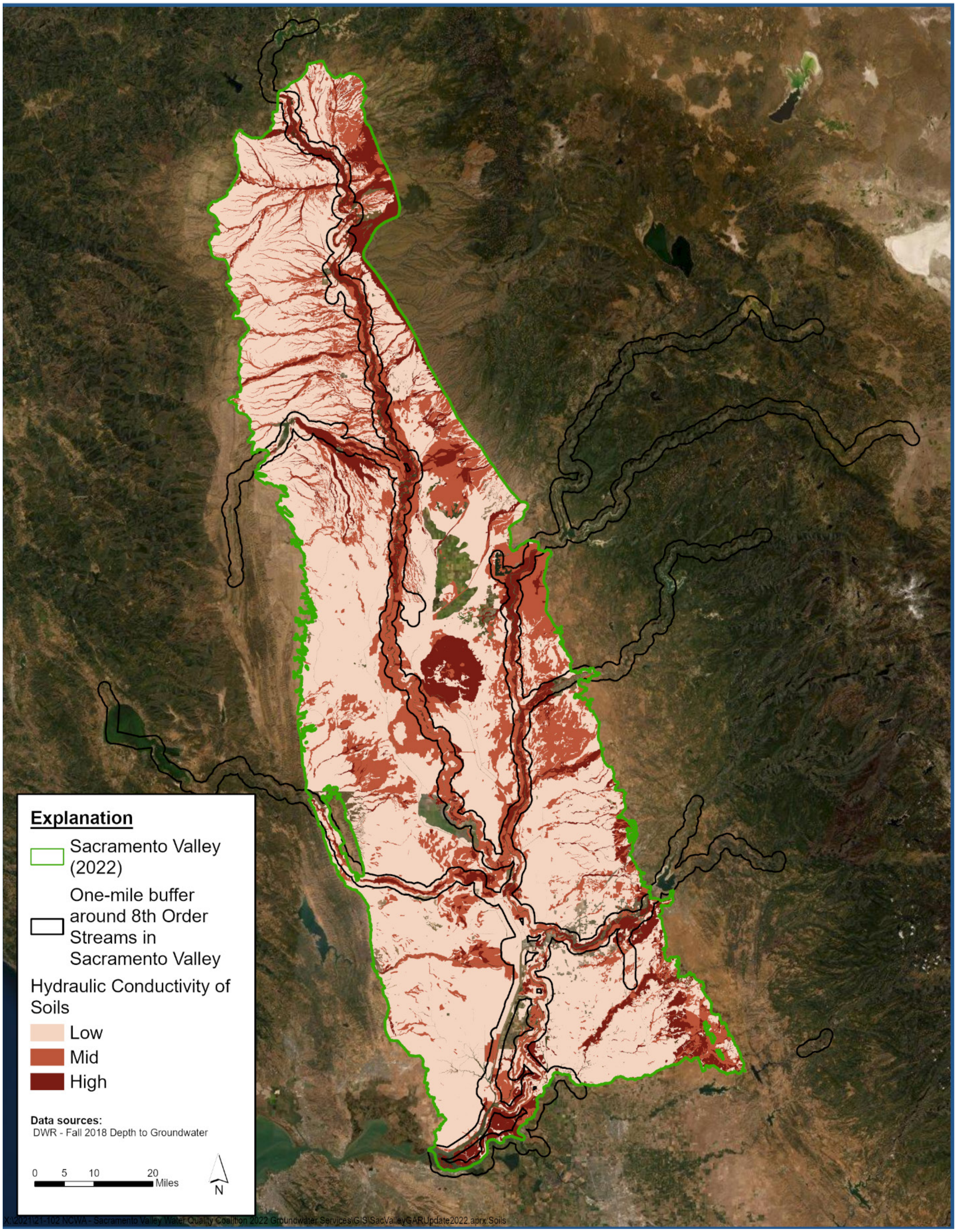

Figure 13: Soil Hydraulic Conductivity Along Large Streams in the Sacramento Valley

Table 6: Regression Results for the Not-Near Stream Region of the Sacramento Valley		
Sensitivity Model 2p10: Beyond One Mile Submodel Multiple R Square: 0.19		
Independent Variable	Coefficient	p-value
Soil Agricultural Groundwater Banking Index	0.01939	1.1E-17
Distance from nearest 8th-order Stream (feet)	1.229E-05	1.2E-05
Miles of Streams per square Mile	-9.281	4.0E-07
Mean Spring Depth to Water (2015-2018) (feet)	-0.008150	1.5E-09
Note: Based on mean nitrate result in all wells (excepting EDF wells), from all years since 1950, in the Sacramento Valley. Each well buffered by 1/2 mile to derive values for the independent variables listed.		

Table 7: Regression Results within One Mile of Large Streams in the Sacramento Valley		
Sensitivity Model 2p10: Within One Mile Submodel R Square: 0.20		
Independent Variable	Coefficient	p-value
Soil Agricultural Groundwater Banking Index	0.02088	2.6E-13

3.5.1.2. SAGBI

The SAGBI was developed by University of California at Davis researchers (O'Geen et al., 2015) to provide researchers, farmers, and regulators a means to quickly assess the potential for land to absorb recharge. It is based largely on the soil survey data hosted by the NRCS. The version of SAGBI used here is the version discussed in O'Geen et al. (2015) that was modified to account for deep ripping of certain fields. The higher the SAGBI, the more potential the soils in that area have for transmitting water through the root zone to groundwater.

The SAGBI compounds five factors to arrive at an index score. These are:

- Deep Percolation
    - based on saturated hydraulic conductivity (direct relationship)
- Root Zone Residence Time
    - based on saturated hydraulic conductivity (direct relationship)
- Topographic Limitations
    - based on slope of the land surface (inverse relationship)
- Chemical Limitations
    - based on soil salinity (inverse relationship)

- Surface Condition
  - based on soil erosion factor, a measure of the tendency of a surface soil to be eroded (inverse relationship)
  - sodium adsorption ratio, a measure of the tendency of the soil to form crusts (inverse relationship)

SAGBI is based on five factors, weighted as follows: Deep percolation (27.5%), root zone residence time (27.5%), topographic limitations (20%), chemical limitations (20%) and surface condition (5%). Factors with greater relevance to groundwater recharge were weighted more heavily, while factors that may be modified by management, such as surface condition, were given a lower weight (O'Geen et al., 2017). Of the five variables that are inputs to the index, deep percolation and root zone residence time are direct outputs of hydraulic conductivity, which is largely a function of soil coarseness. These two factors are weighted to produce 55% of the SAGBI. The topographic limitations factor is based on slope, and this also correlates with soil coarseness, due to the depositional nature of the valley floor. This factor accounts for another 20% of the SAGBI. Thus, 75% of the SAGBI is strongly related to soil coarseness, and this is a commonly understood factor that may influence the effects of land surface operations on groundwater.

SAGBI has been calculated for the Central Valley and some agricultural regions in the Sierra and Coast Ranges. The data are available from the University of California at Davis California Soil Resource Laboratory.

3.5.1.3. Distance to 8th Order and Higher Streams

As discussed with regards to the conceptual model for development of the HSA, the largest streams in the Sacramento Valley provide a protective benefit to their riparian regions, such that as the distance from the stream increases, the land becomes more sensitive to nitrate impacts from surface inputs.

The 2018 Enhanced National Hydrography Dataset (ENHD) includes an attribute for the Shreve stream order of each stream in the dataset. Streams of 8th and higher Shreve Order were used as input for a simple Euclidean distance operation in GIS. The output of this operation is a raster surface of distances from the nearest linear feature, in this case, streams of 8th and higher order, over the extent of the Sacramento Valley.

3.5.1.4. Density of 3rd Order and Higher Streams

As with very large streams, very high densities of smaller streams can have a protective effect on local groundwater. This metric uses the same ordering method as above, the Shreve method. However, rather than treating each stream as a source of dilutant or a sink for shallow groundwater, this metric integrates these effects due to many smaller streams. Very small streams, those of 1st and 2nd order, are not considered, as these are typically too small to move a significant amount of water, and are often ephemeral or discontinuous, and thus do not provide a protective function.

The 2018 ENHD was used as the input for a Line Density GIS operation. This operation generates a raster surface of Length (in miles of streams) per Area (in square miles of the study region).

3.5.1.5. Depth to Groundwater

Depth to groundwater is perhaps the most commonly noted risk factor for water quality degradation. Shallow depths to groundwater increase the potential for effects from land surface operations.

For the analyses conducted here, the Spring 2015, 2016, 2017, and 2018 groundwater depth surfaces generated by DWR, retrieved from the California Natural Resources Agency Open Data Platform, were used. Regression calculations were tested on each year individually, the mean of all four years, and the minimum and maximum of all four years. The mean depth to water for the four fall datasets was found to perform the best.

3.5.2. Mapping Sensitivity Scores

The significant variables identified from the two regression models were used to create a Sensitivity Index (SI). Each variable (depth to water, stream density, distance to stream, and SAGBI) was mapped within the valley on a 100-foot by 100-foot grid (**Figure 14**) and then multiplied by the respective variable coefficient from the regression (see **Table 6** and **Table 7**). The resulting values were summed to produce a sensitivity score - a weighted estimate of the sensitivity of the groundwater to nitrate applications from surface activities across the entire Sacramento Valley portion of the Coalition region. The value of this score indicates the relative sensitivity of the local hydrogeologic setting to nitrate contamination in groundwater from surface activities.

This estimate of relative sensitivity was mapped to land area to produce a histogram of the land area included as the score decreased. This land area value was then used to normalize the sensitivity score from 0% of the landscape to 100% of the landscape to produce an area-normalized SI. Higher SI indicates higher hydrogeologic sensitivity. The relationships between SI, land area (acres), and nitrate exceedance wells for the two different sensitivity models are displayed in **Figures 15** and **16**. Most nitrate exceedance wells fall within or near to the area that scores relatively high on this index (**Figure 17**).

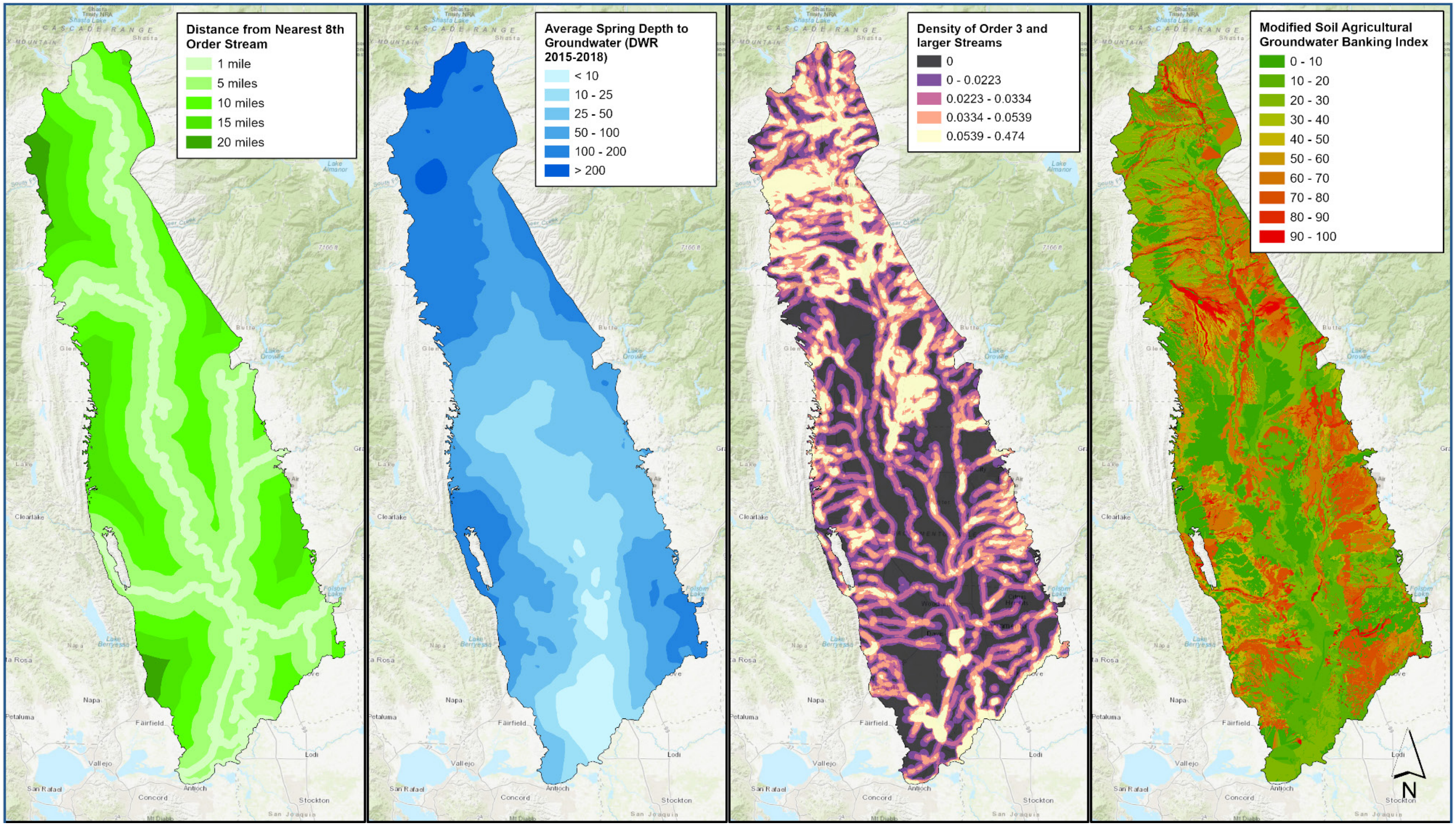

Figure 14: Independent Variables in Regression Model

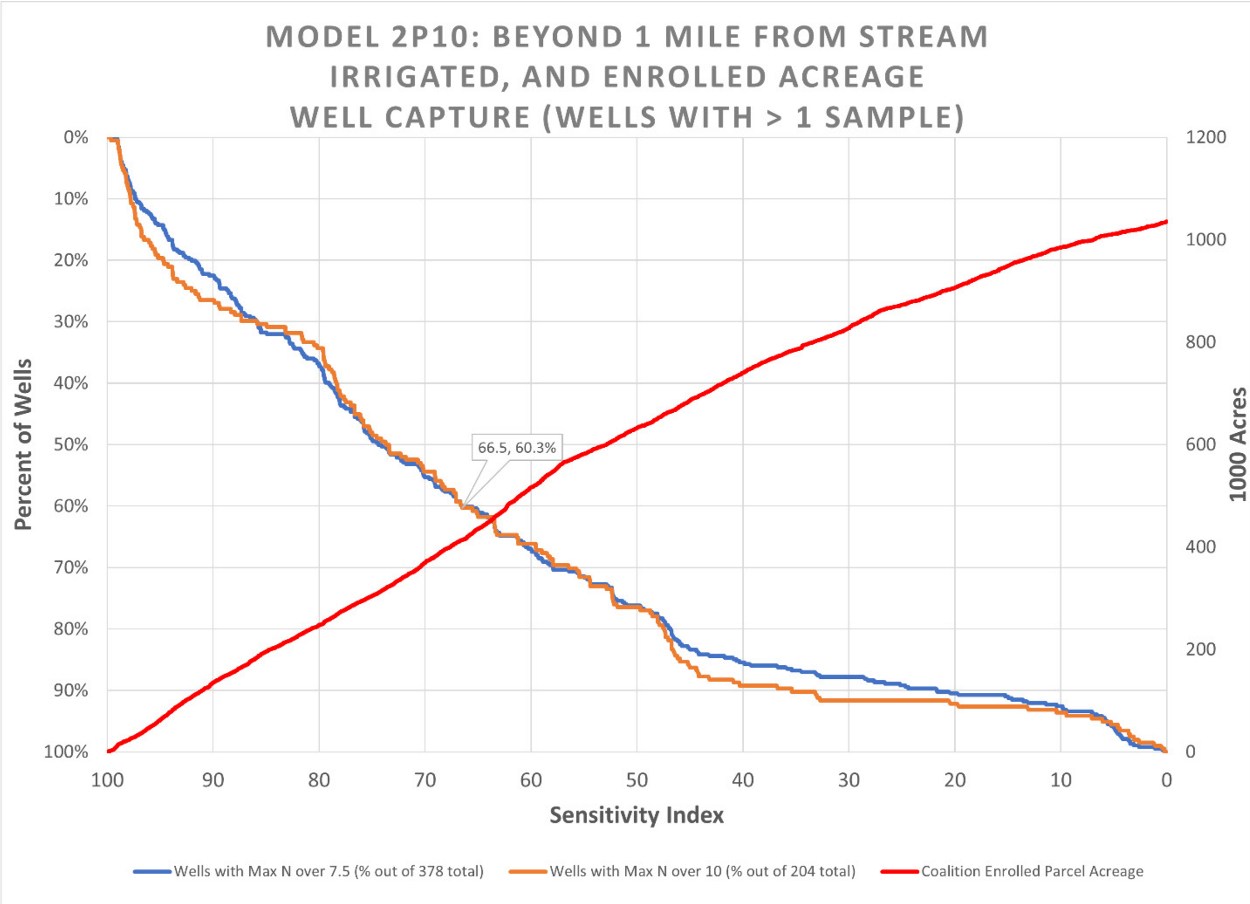

Figure 15: Sensitivity Index and Capture of Exceedance Wells in the Not-Near-Stream Model

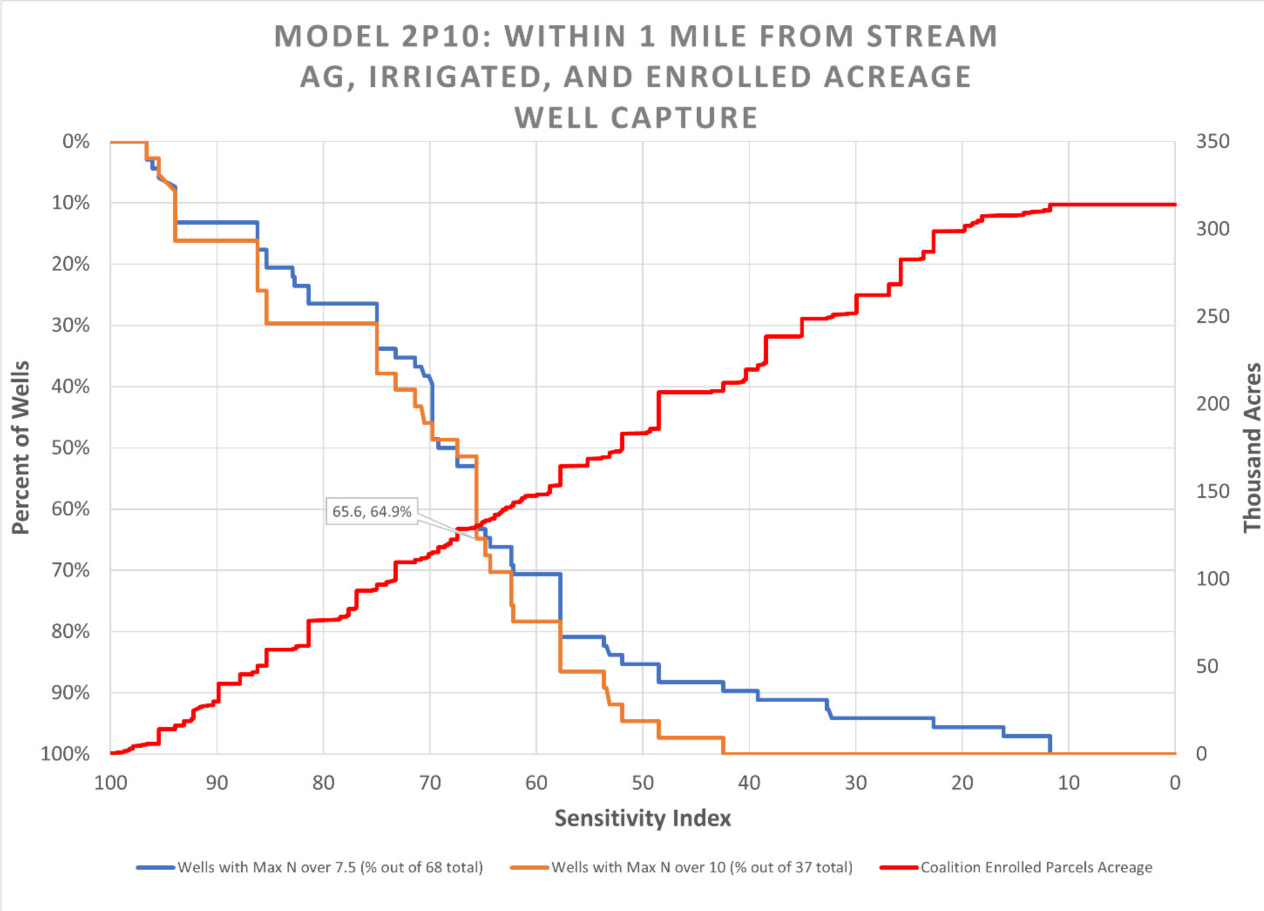

Figure 16: Sensitivity Index and Capture of Exceedance Wells in the Near-Stream Model

3.5.3. Selection of SI Cutoff Values for the 2022 HSA

The WDR requirements for the HVA includes all wells exhibiting nitrate MCL exceedances associated with agricultural operations. This requirement drives the determination of the cutoff between lands that should be considered hydrogeologically sensitive or not. Sensitivity to nitrate impacts is a function of the hydrogeologic conditions and not land use. Land use only comes into consideration when vulnerability is assessed. Vulnerable lands are hydrogeologically sensitive lands that are influenced by agricultural practices and have the potential to affect groundwater quality.

In each of the modeled zones, values of SI were chosen that captured roughly 65% of the wells with nitrate MCL exceedances. This capture rate was chosen based on changes in the capture rate along the SI curve and proximity of the remaining exceedance wells to the resulting HSA (**Figure 15**, **Figure 16, Figure 17**). For each model, the value chosen represents a point on the curve such that as the SI decreases beyond this point the number of new exceedance wells captured per unit decrease of the SI (and per unit of increasing area encompassed by the resulting HSA) decreases. Once a cutoff value was chosen, the area of land with SI equal to or above that score was designated hydrogeologically sensitive (**Figure 18**).

For the near-stream model, covering lands within one mile of 8th Shreve Order and larger streams, the cutoff was chosen at 65.6. Any modeled area with a score equal to or greater than 65.6 is considered HSA for that model. For the model beyond one mile from these large streams, the cutoff was chosen at 66.5. The curves presented in **Figure 15** and **Figure 16** reflect the results for a comparison of SI within the Redding and Sacramento Valley Groundwater Basins portion of the Coalition, although SI was also generated for the Cosumnes Subbasin and used in the identification of HSA and HVA in the Coalition (**Figure 17**).

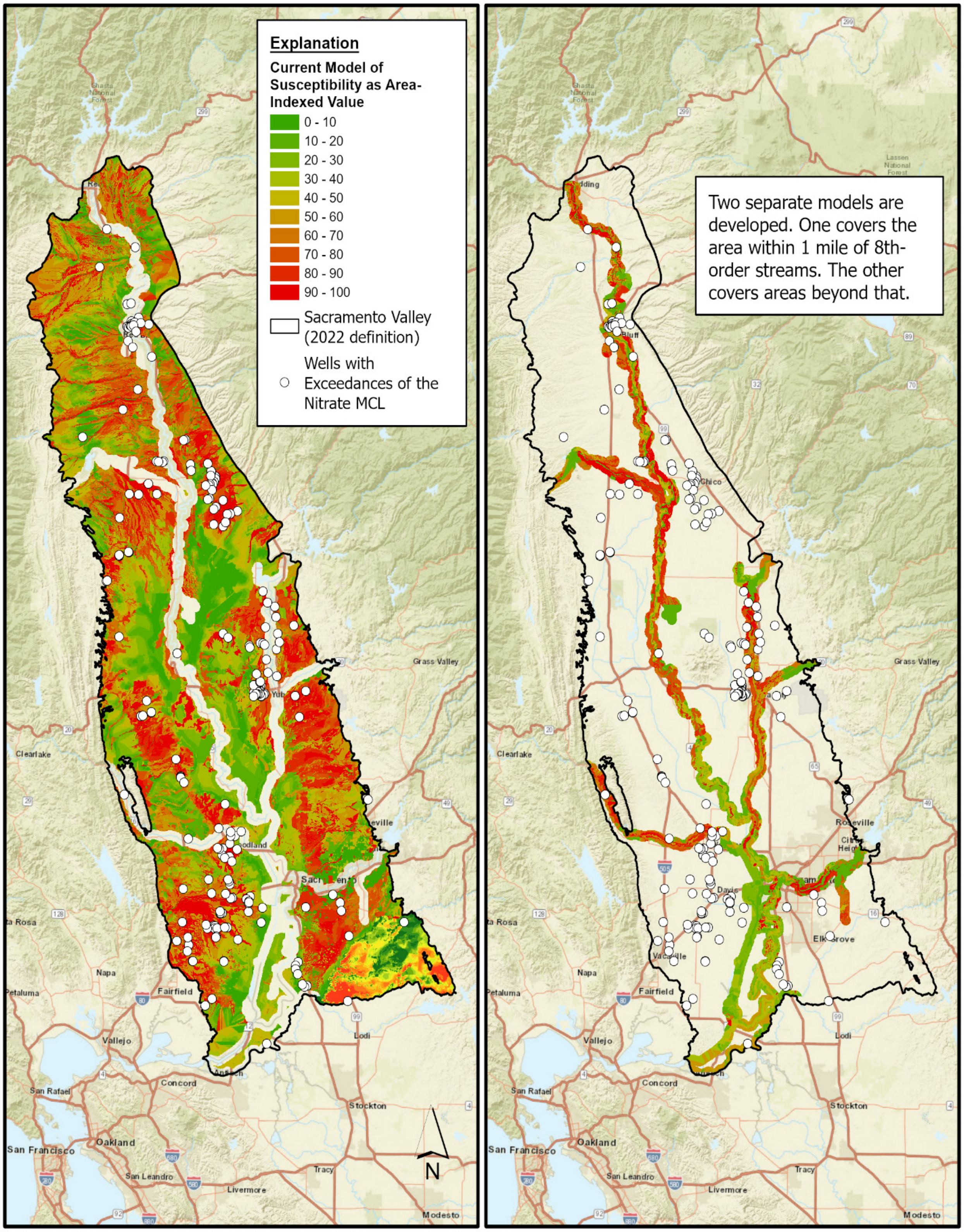

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Figure 17: Sensitivity Scores for Near- and Not-Near Stream Models

3.5.4. Final Delineation of Hydrogeologically Sensitive Area (HSA)

The combination of the selected areas from the two models results in a complete model of sensitivity over the Valley Floor portion of the Coalition region based on hydrogeologic factors The model identifies lands that overlie groundwater expected to be most sensitive to surface nitrate applications from irrigated agriculture.

This HSA does not explicitly consider land use. Rather, the sensitivity is defined as a measure of the likelihood that surface inputs of nitrogen or nitrate, should they exist, can directly impact the underlying groundwater resource. The primary drivers of this sensitivity, as evaluated here, are proximity of the groundwater to the land surface, the tendency of water to infiltrate to the saturated zone, and the extent of interaction with surface water bodies.

The 2022 HSA covers 1,478,472 acres, or 34% of the Sacramento Valley floor. As shown in **Figure 18**, the HSA tends to cover lands that are influenced by flowing surface waters, but not immediately adjacent to those water bodies, and areas dominated by alluvial fan deposits, but not steeply sloped.

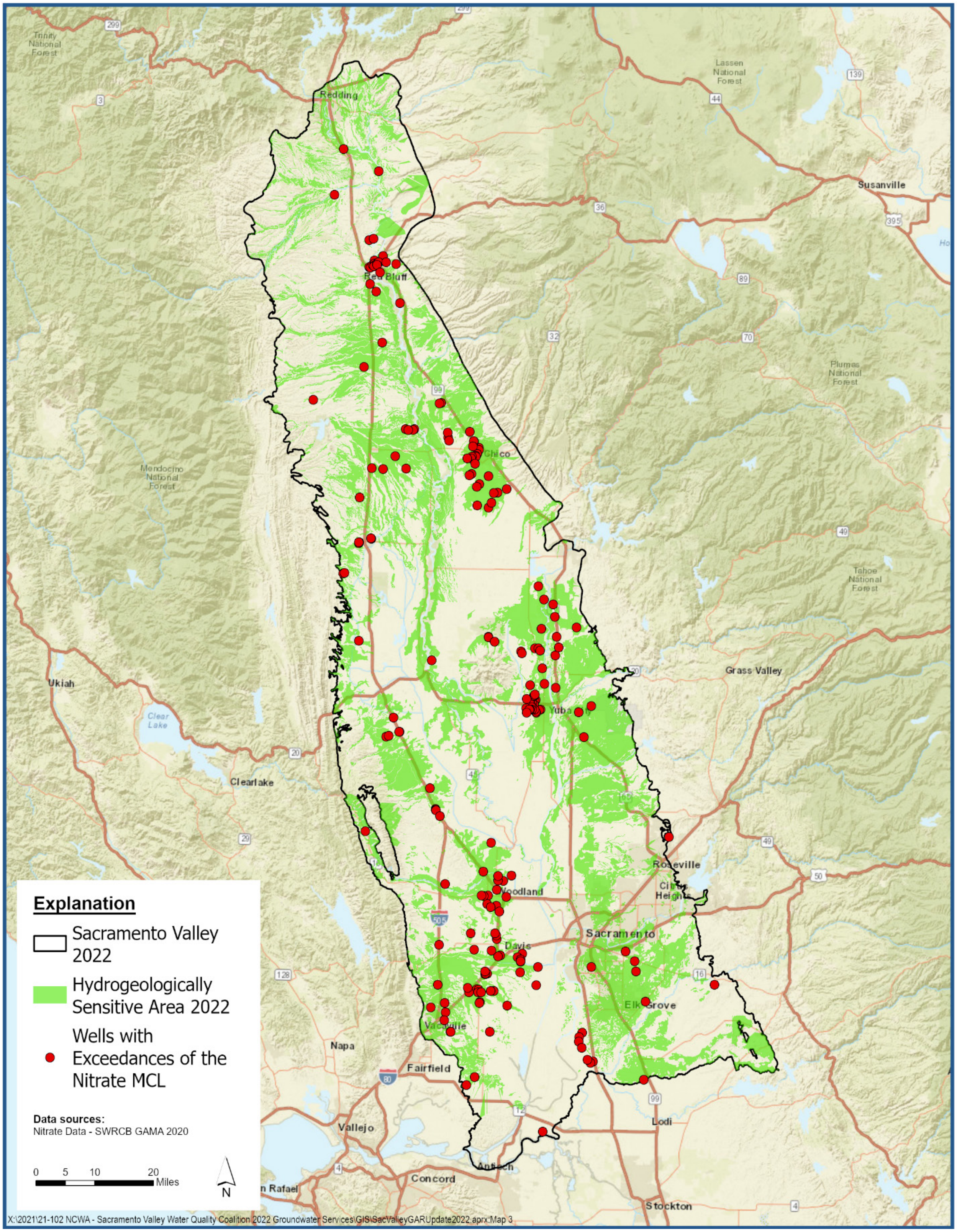

Figure 18: 2022 HSA and Nitrate MCL Exceedances

4. DELINEATION OF 2022 HVA

The HVA is the intersection of all irrigated non-rice agricultural land and the HSA developed above, with additional land added to encompass any nitrate exceedance wells not already captured, as required by the WDR. Additionally, the HVA was further expanded to encompass wells with a maximum nitrate concentration of 5 mg/L or higher and which have statistically significant increasing trends in nitrate (uptrending) at rates higher than 0.1 mg/L/year.

All irrigated non-rice agricultural lands in the Sacramento Valley were considered in the HVA development, regardless of their enrollment status in the Coalition. Thus, all enrolled irrigated agricultural lands that intersect the HSA are considered HVA. Enrollment status does not influence the HVA status of agricultural lands because all irrigated lands, whether enrolled or not, are considered. Future updates of the HVA will also consider all irrigated lands, including all enrolled irrigated lands.

4.1. Identifying Irrigated Lands

There is no current public dataset that specifically delineates irrigated lands in the Sacramento Valley. Land use data identifying crops and fields can provide an estimate of irrigated land coverage. The 2018 Land IQ land use dataset (LIQ18) published by DWR, and the 2020 CropScape (CS20) land use dataset published by NRCS, along with a Digital Elevation Model of the Sacramento Valley extracted from the USGS National Elevation Dataset and the 2016 National Hydrography Dataset of streams were used to delineate irrigated lands within the Sacramento Valley. These data represent the best and most recently available spatial datasets for delineating the extent of the current irrigated area within the Coalition region. The details of this analysis are presented in **Appendix A**.

4.1.1.1. Overview of the 2018 Land IQ Data

The LIQ18 land use data published by DWR were developed through a combination of remote sensing data and ground truthing with land use and crop type defined by parcels or fields. For the purpose of defining the extent of irrigated area in the Coalition, land use designations in the dataset were reviewed and categorized according to irrigated or not irrigated, to the extent possible.

Altogether, among classes designated as agricultural, there are three pasture classes (P3, P4, and P6), two Grain classes (G, and G6), and one Unidentified class (X) in the LIQ18 dataset that include some significant fraction of non-irrigated lands. Only the Native Pasture (P4) class appears to be entirely non-irrigated. In addition, the Urban (U) class is considered non-irrigated for the purpose of this analysis.

4.1.2. Discussion of the 2020 CropScape Dataset

The 2020 CropScape data, produced from remote sensing for NRCS, are a much less refined. This dataset includes many small errors due to the remote sensing nature of the input data, compared to the LIQ18 data. The CS20 GIS data is a raster-based dataset, not feature-based. Rather than polygons designating fields or other areas on the map, the CS20 data consists of 100 by 100 foot cells, each with a crop type assigned. These cells are not aligned with any particular feature on the landscape. Visually, crop fields can be identified where they are different crop types from neighboring areas, but errors in the remote-sensed data produce anomalies in the resulting raster data. Within any given field apparent from examination of the CS20 data, it is typical to see cells of one or more incongruous crop types scattered throughout the field. Examination of aerial imagery consistently shows that these are errors in the data. Thus, rather than accepting that every cell of the CS20 data represents the correct crop type, areas must be evaluated based on the most common crop type represented.

However, despite the spatial errors, the CS20 land use classification includes more discretization of crop types in the grazing lands and rangelands classes. For example, CS20 parses the P3, P6, G, and G6 fields in the LIQ18 data into several specific crops each, allowing for a better differentiation between irrigated and non-irrigated crops within those LIQ18 designations. To take advantage of the better distinctions in CS20, along with the better spatial consistency in LIQ18 data, the CS20 data were evaluated over the crop fields in the LIQ18 dataset.

Table 8: CropScape2020 Non-Irrigated Land Uses	
Land Uses	Acres in the Sacramento Valley
Barley	10,454
Oats	10,082
Open Water	69,587
Perennial Ice/Snow	12
Developed/Open Space	184,723
Developed/Low Intensity	123,071
Developed/Med Intensity	145,589
Developed/High Intensity	42,198
Barren	24,275
Deciduous Forest	2,052
Evergreen Forest	9,134
Mixed Forest	3,463
Shrubland	460,946
Grassland/Pasture	930,565
Woody Wetlands	35,809
Herbaceous Wetlands	80,765
Triticale	20,341

Table 9: Land IQ 2018 Non-Rice Irrigated Agricultural Land Use Categories in the Sacramento Valley 2022 Definition	
Land Use Category	Irrigated Acres
Citrus	27,237
Deciduous Orchard	537,094
Field Crops	156,016
Grain Crops	139,614
Pasture	189,492
Truck	98,179
Vineyard	60,522
Young Perennial	42,212
Unidentified	71,635
Total	**1,322,001**

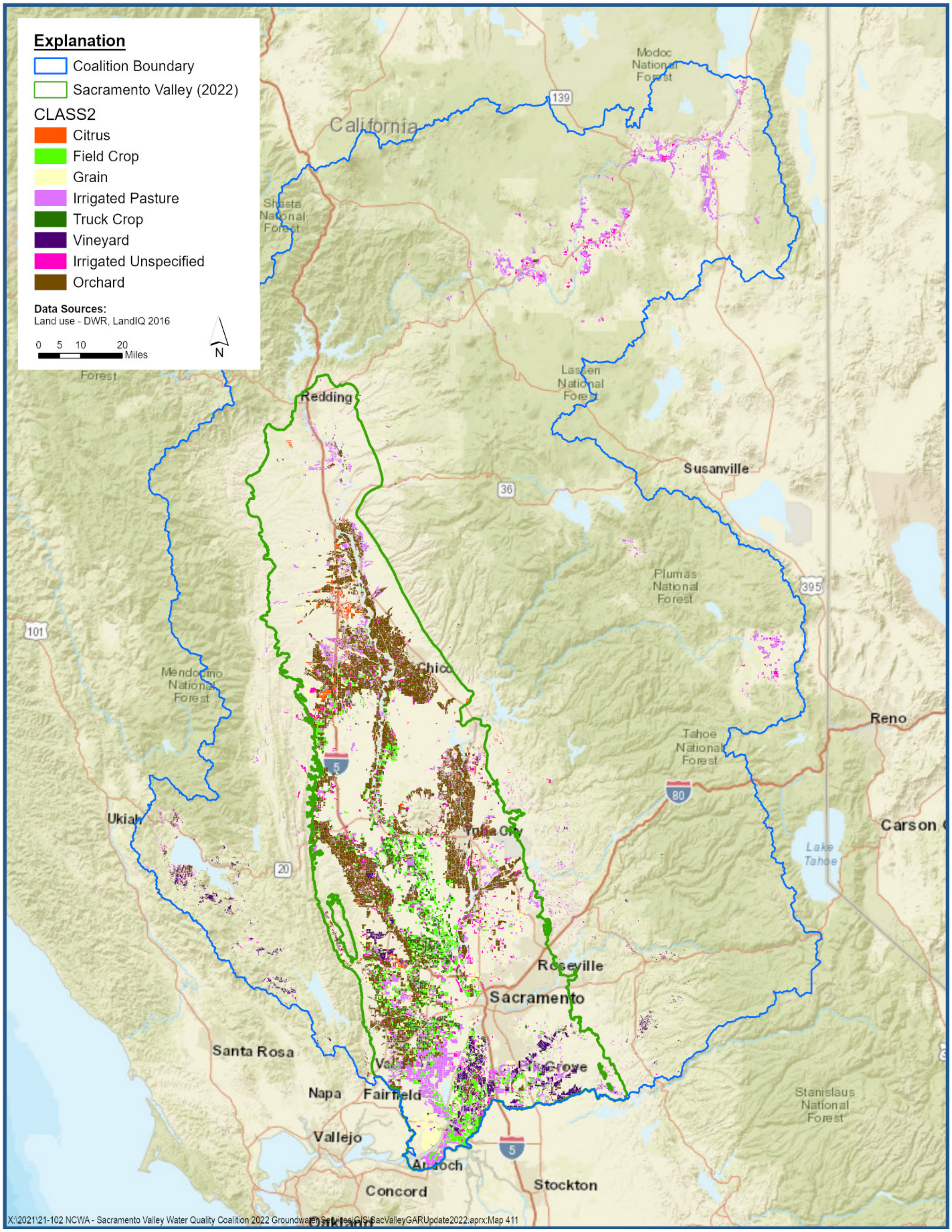

Figure 19: Irrigated Non-Rice Agricultural Lands in Coalition

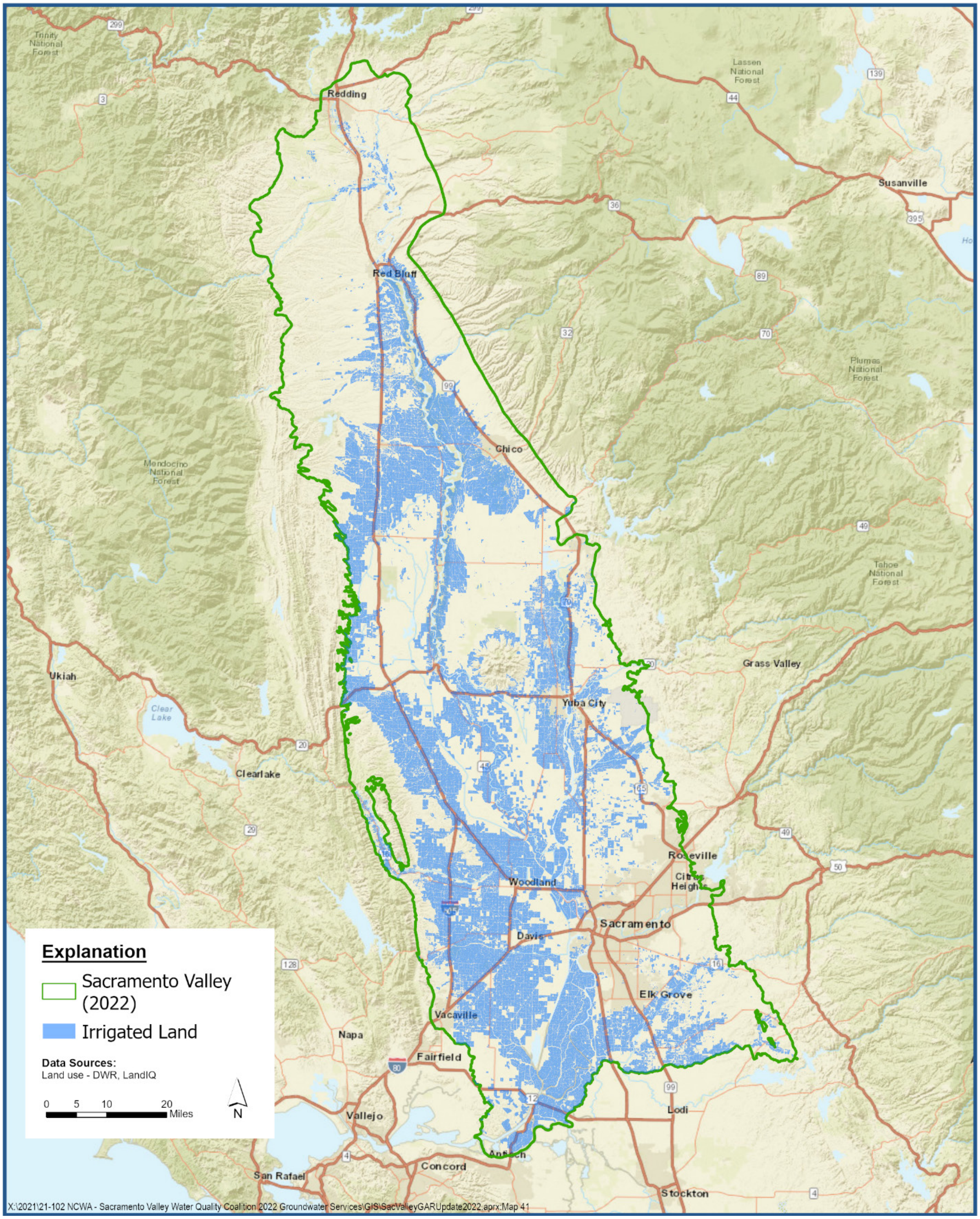

Figure 20: Irrigated Non-Rice Agricultural Lands in Sacramento Valley

4.1.3. Final Irrigated Lands Delineation

As detailed in **Appendix A**, there were many crop fields in the land use data that were not reasonable to consider as irrigated agriculture for purposes of this analysis. After all these fields were removed from consideration, there were 46,935 fields left, covering 1,322,001 acres of irrigated land (**Figure 19, Figure 20**). All non-rice irrigated land uses in the Sacramento Valley were included (**Figure 19**).

4.2. 2022 HVA Development Process

The irrigated lands within the Sacramento Valley, including the Cosumnes Subbasin of the San Joaquin Groundwater Basin, as shown in **Figure 20,** were intersected with the has described in **Section 3** to produce a preliminary HVA (PHVA, **Figure 21**) that was expanded slightly to include certain wells with nitrate exceedances or uptrends that were not already captured.

4.2.1. Identifying Agriculturally Influenced Wells

In communications during the HVA development the Regional Board expressed that the HVA must include all agriculturally influenced wells with a historical exceedance of the nitrate MCL and wells with elevated nitrate concentrations exhibiting a statistically significant increasing trend (uptrending wells). Although the HSA was developed from the available nitrate data, due to confounding effects such as lateral movement of groundwater, variability in land use activities and other characteristics, the HSA and related PHVA do not capture the locations of all exceedance wells. The HSA is intended to identify ground that is relatively more sensitive to groundwater quality impacts from surface activities, not necessarily the locations of all groundwater quality impact (e.g., nitrate exceedances). Additionally, available geospatial land use data have high spatial resolution and precision, so designated irrigated lands often exclude the exact locations of many wells even if they are surrounded by agriculture. To address this, the PHVA was expanded to include exceedance wells in agriculturally dominated areas that were not captured by the PHVA.

For this analysis, a nitrate exceedance well is defined as any well, except for monitoring for a regulated facility (environmental contamination cleanup site), that has one or more nitrate sample results over the MCL. This can include wells that have not been sampled recently but does ensure that all locations with historical results of nitrate above the MCL are included in the HVA. Based on these criteria, 215 nitrate exceedance wells are present in the Sacramento Valley.

Not all wells in the Sacramento Valley are influenced by agricultural land uses. Following development of the PHVA, the area around each of the 215 nitrate exceedance wells was reviewed to assess whether the well was in an area where agricultural activities might be likely to influence groundwater quality. Wells where the land within one mile of the well was less than 20 percent agriculture (31 wells) were considered to have a low likelihood of the exceedance being a result of agricultural activities and were excluded from the set of exceedance wells to be encompassed within the HVA. One additional well, (Well 32 on **Figure 22**, and **Table 10**) located on an island in Seven Mile Slough, was also excluded as it is most likely to be influenced primarily by land use activities occurring outside of the Coalition region.

The nitrate data for all wells, including those with an exceedance, were included in the regression analysis, as the relationship between nitrate concentrations beneath any lands in the Sacramento Valley still contributes to the understanding of hydrogeologic sensitivity and not to land use.

Of the 215 wells in the Valley with exceedances of the nitrate MCL, 183 exceedance wells are considered agriculturally influenced (**Figure 21**).

4.2.2. Preliminary HVA

The HSA delineated in **Section 3** was intersected with all non-rice irrigated agricultural land in the Valley as identified in **Section 4.1**. All non-rice irrigated land overlapping the HSA was designated PHVA (**Figure 21**). This PHVA encompasses 593,436 acres of irrigated agriculture within the Sacramento Valley representing about 45 percent of the 1,322,001 acres of irrigated agricultural (non-rice) lands in the Sacramento Valley. The PHVA balances the requirement to include nitrate exceedance wells with a focus on actual irrigated lands that are vulnerable.

The modeled HSA identifies lands that are sensitive to surface inputs by correlating hydrogeologic variables with well nitrate data, and then capturing lands with similar hydrogeologic character to those lands that demonstrate sensitivity based on those well nitrate data. The PHVA extracts from those sensitive lands the area that can be considered vulnerable to irrigated agricultural nitrogen impacts because of the presence of irrigated agriculture.

The PHVA is the result of the overlap of the HSA and irrigated non-rice agriculture. Because available land use data and locations of wells with nitrate data typically have very high spatial resolution and precision and because wells are not typically situated directly in an irrigated field, even irrigation wells are typically located off the field along an access road or in a cleared area. Most exceedance wells do not fall within the exact boundaries of the PHVA; 21 of the 183 agriculturally-influenced exceedance wells are mapped within the PHVA.

Of the remaining 162 agriculturally-influenced exceedance wells, 96 percent of the wells are within 0.5 mile of the PHVA. Just over half (89) of the wells are mapped within 0.1 mile of the PHVA; another 48 wells are within 0.25 mile; and another 19 wells are within 0.5 mile. The final HVA was developed to include these 162 wells not directly within the PHVA (See **Section 4.2.3**).

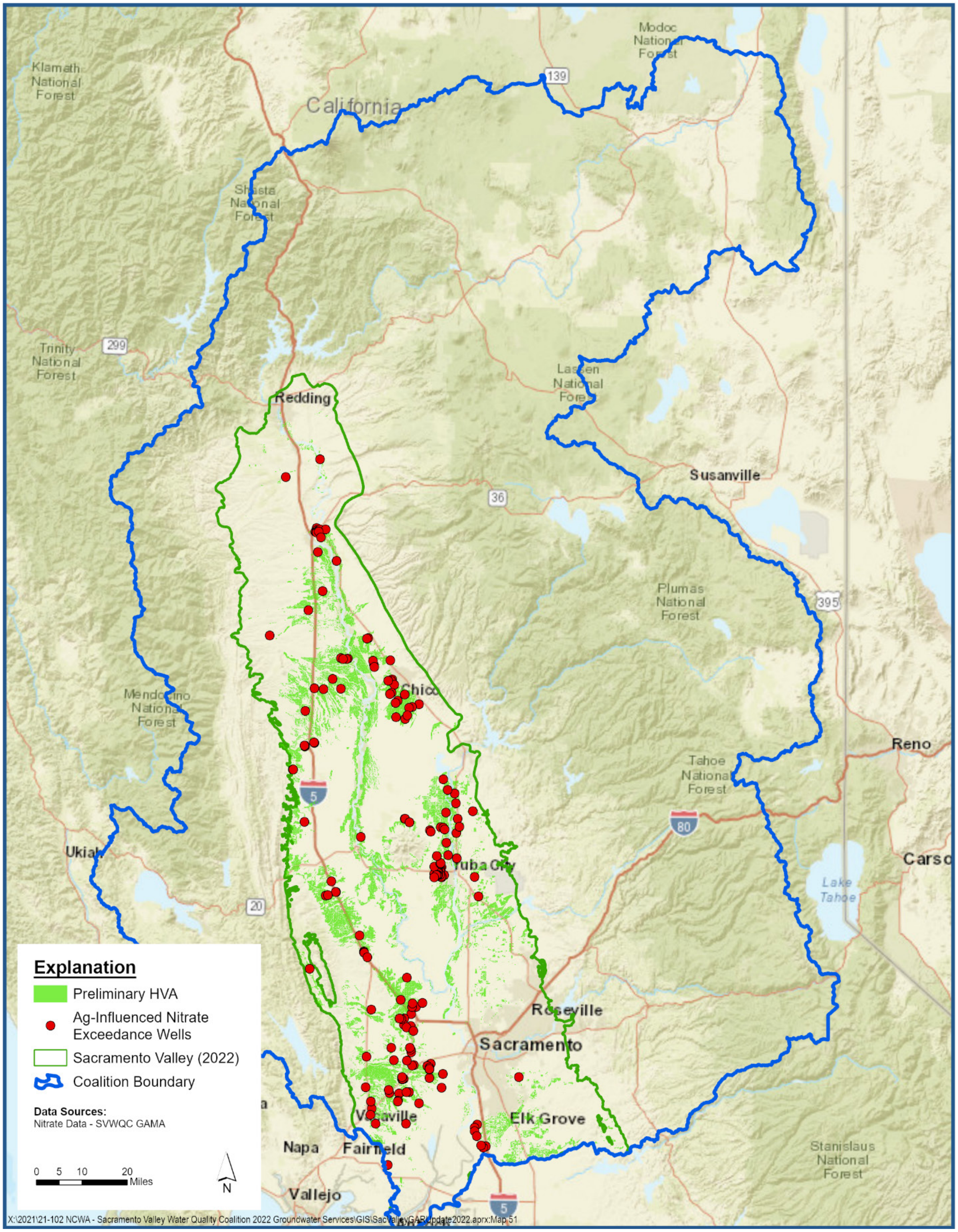

Figure 21: Preliminary High Vulnerability Area

Table 10: Exceedance Wells Not Included in the 2022 HVA								
Map ID	Well ID	Well Type	Data Source	Max NO3 Result (mg(N)/L)	Nitrate Samples Collected	Last Year Sampled	Fraction Urban within 1 Mile	Fraction Non-Rice Ag within 1 Mile
1	3910005-049	MUNICIPAL	DHS	10.5	141	2020	0.51	0.03
2	3900702-002	MUNICIPAL	DHS	11.8	40	2020	1.00	0.00
3	05N01E35B001M	UNK	DWR	16	8	1978	0.00	0.01
4	103014	MUNICIPAL	LLNL	13.7	1	2005	0.99	0.01
5	4800821-001	MUNICIPAL	DHS	20	10	2001	0.77	0.01
6	103013	MUNICIPAL	LLNL	15.5	1	2005	0.99	0.01
7	3410010-045	MUNICIPAL	DHS	16	133	2018	0.94	0.02
8	USGS-394430121513701	UNK	USGS	27.1	1	1975	0.97	0.03
9	27N02W18F00?M	UNK	DWR	44.1	1	1963	0.00	0.05
10	0410002-055	MUNICIPAL	DHS	14	60	2012	0.91	0.06
11	5700745-001	MUNICIPAL	DHS	14	20	2009	0.90	0.07
12	27N03W11D002M	UNK	DWR	42.5	1	1936	0.00	0.07
13	3400419-001	MUNICIPAL	DHS	12	44	2020	0.07	0.07
14	USGS-390822121285701	UNK	USGS	61	1	1976	0.06	0.08
15	5000005-001	MUNICIPAL	DHS	16.2	1	1992	0.52	0.09
16	0400036-001	MUNICIPAL	DHS	10.7	71	2020	0.78	0.09
17	22N01E09N001M	UNK	DWR	31.4	9	1965	0.74	0.10
18	0400037-001	MUNICIPAL	DHS	16	31	2007	0.87	0.10
19	4810002-006	MUNICIPAL	DHS	10.583	310	2017	0.86	0.10
20	3400399-001	MUNICIPAL	DHS	10.6	5	2019	0.55	0.12
21	5200546-001	MUNICIPAL	DHS	11.4	30	2017	0.51	0.12
22	TEH 773	DOMESTIC	GAMA	14	2	2005	0.06	0.12
23	4810002-004	MUNICIPAL	DHS	10.706	217	2019	0.85	0.12
24	5200525-001	MUNICIPAL	DHS	13.6	55	2020	0.19	0.13
25	103005	MUNICIPAL	LLNL	12.4447	1	2005	0.77	0.14
26	3410011-009	MUNICIPAL	DHS	10.1	5	1997	0.36	0.14
27	5100128-001	MUNICIPAL	DHS	12.4	9	2003	0.80	0.15
28	4810002-001	MUNICIPAL	DHS	14	2	1990	0.80	0.15
29	TEH 833	DOMESTIC	GAMA	11	2	2005	0.07	0.18
30	07N08E10K001M	UNK	DWR	13	1	1971	0.02	0.19
31	5200600-001	MUNICIPAL	DHS	11.7	5	2015	0.52	0.19
32*	3901210-001	MUNICIPAL	DHS	14.8	21	2010	0.00	0.56

Note: Well number 32 is located on an island in Seven Mile Slough, immediately adjacent to the main stem of the San Joaquin River and is not considered influenced by Sacramento valley agricultural operations.

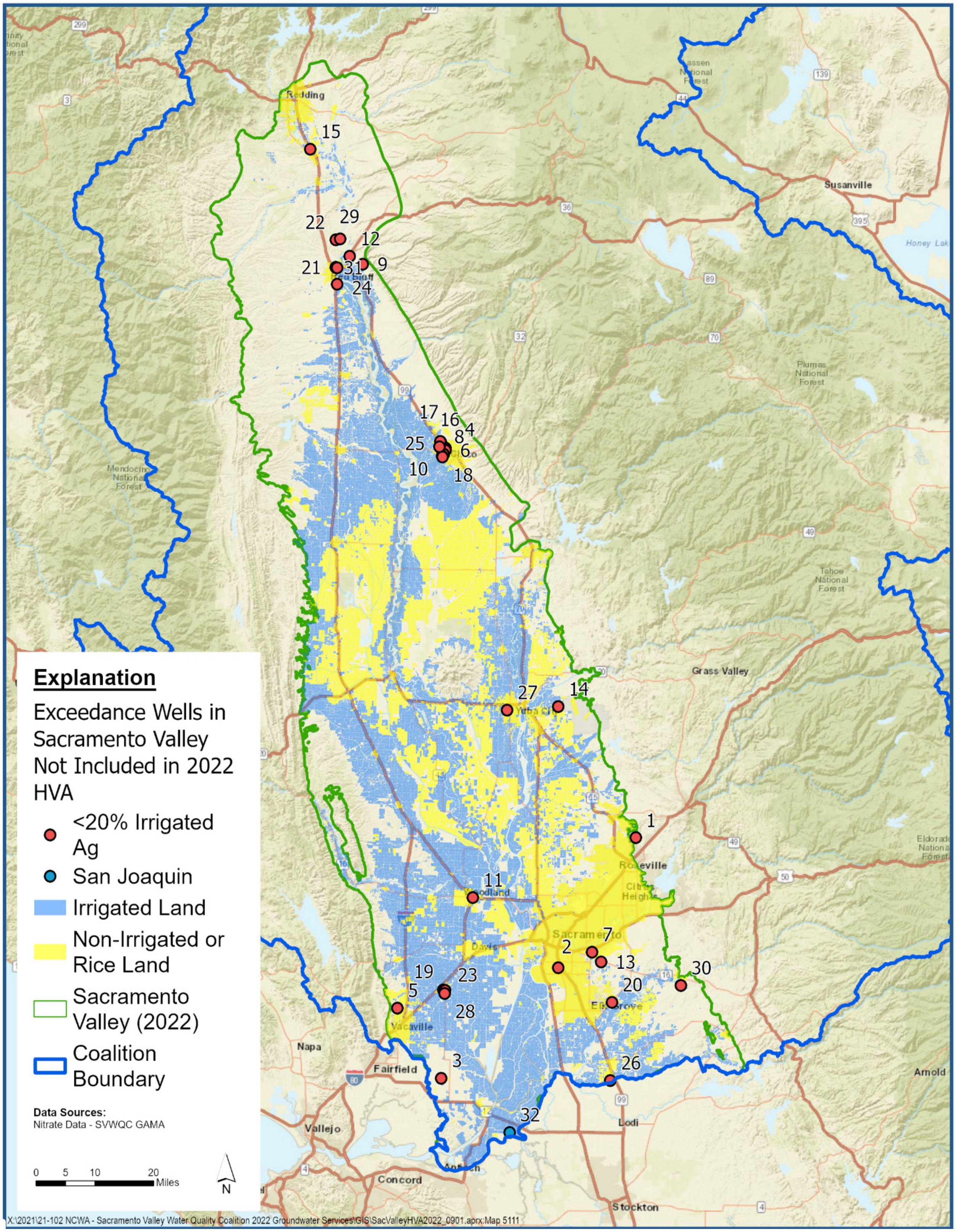

Figure 22: Excluded Exceedance Wells in the Sacramento Valley

4.2.3. Extension of PHVA to Include Exceedance Wells and Uptrending Wells

4.2.3.1. Exceedance Wells

To encompass all agriculturally influenced nitrate exceedance wells within the HVA, a simple approach relying on an assumption of approximate contributing area for wells was applied to establish reasonable HVA buffers around exceedance wells that were not directly within the PHVA. Wells in the nitrate dataset used in this GAR Update varied from small monitoring or domestic wells to large municipal or irrigation wells. Typical domestic well contributing areas are estimated at around a half an acre, while larger wells can have contributing areas of hundreds of acres (Horn and Harter, 2008; Lockhart et al., 2013; Friesz et al., 2021). Since well use data are lacking for most of the datasets used here, data sources were assumed to be indicative of the well type, and therefore size of the contributing area. All DDW wells are assumed to be larger wells; all GAMA domestic well program and dedicated monitoring wells are assumed to be smaller; and approximately one quarter of USGS and DWR monitoring wells are assumed to be smaller, while the other three quarters are considered larger wells, since these entities typically monitor existing irrigation and municipal wells. From this, a weighted average contributing area of approximately 280 acres was assumed, corresponding to a buffer (circle) with a radius of about 1,870 feet, or 0.35 mile, around each well. These buffered areas around all 183 agriculturally influenced exceedance wells were added to the PHVA and included as part of the HVA. Although some of the wells were already included within the PHVA, they were still buffered by the full 1,870 feet, to ensure that the true location of each was well within the HVA.

4.2.3.2. Uptrending Wells

To ensure that all agriculturally influenced wells with elevated nitrate concentrations exhibiting increasing nitrate trends (uptrending wells) were included in the HVA, all wells with a historical nitrate concentration over 5 mg/L (as N) and statistically significant trends of increasing nitrate concentration were also added to the HVA, using the same 1,870 feet buffer as used for the exceedance wells. A total of 40 wells met these criteria.

The entire nitrate dataset for the HSA area was reviewed to identify trends where sufficient historical data exist. The Mann-Kendall test for trend analyses was used to identify significant trends in nitrate concentrations and estimate the slope of any trend.

Wells that were identified as exhibiting increasing nitrate trends at a rate of 0.1 mg/L/year or higher (with 90% confidence, based on a p-value of 0.1 or less), and that had a maximum nitrate concentration in their record of greater than 5 mg/L, were considered to be uptrending wells. There were 147 wells that met these criteria, and of those, 131 wells are located within the Sacramento Valley. Fifty-one (51) of the 131 wells are already included in the HVA as they are exceedance wells. Of the remaining 80 wells, 40 wells met the criteria for agricultural influence.

All 40 of these uptrending wells were within 0.5 mile of the HVA after it was extended to reach the exceedance wells. The HVA was further extended to encompass these 40 wells in the same manner as described for the exceedance wells.

The final HVA, extended to cover all agriculturally-influenced exceedance and uptrending wells within the Valley floor covers 621,689 acres (**Figure 23**).

4.3. 2022 HVA Summary

The final extent of the 2022 HVA (**Figure 23**) consists of 621,689 acres of irrigated agriculture and adjacent lands. The 2022 HVA lies within the valley floor of the Coalition area and is based on an assessment of the hydrogeologic sensitivity of the valley floor and the potential vulnerability of groundwater to impacts from nitrate associated with irrigated agricultural operations. The 2022 HVA captures all wells that are likely influenced by irrigated agricultural practices and that have exceeded the nitrate MCL or that have exceeded half the MCL and have increasing trends in nitrate concentrations.

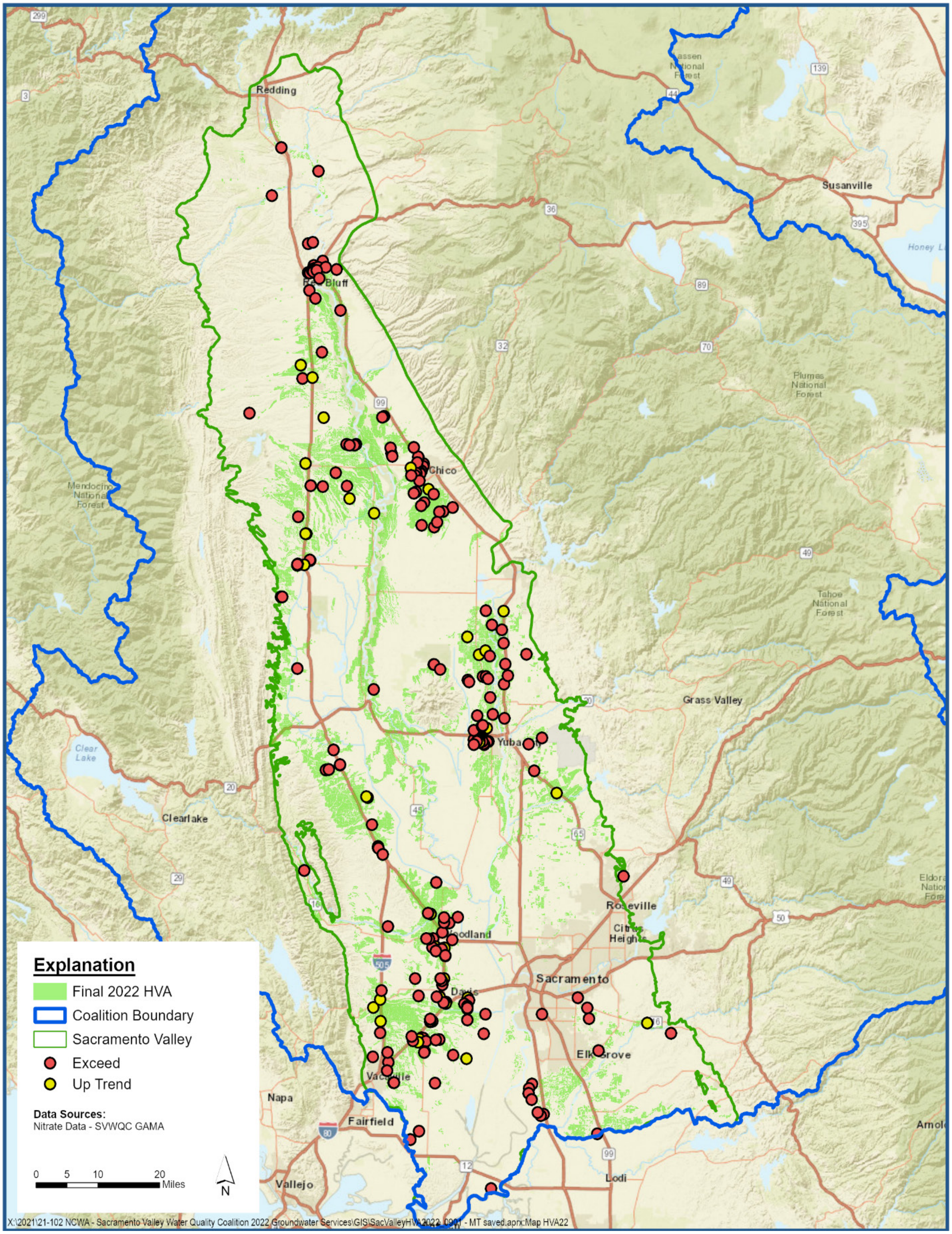

Figure 23: Final 2022 HVA with Exceedance and Uptrending Wells

5. COMPARISON OF 2022 HVA WITH PREVIOUS VULNERABILITY ASSESSMENTS

Several previous assessments of groundwater vulnerability in the Sacramento Valley have been conducted using various methods and data sources. The key assessments conducted previously and considered during the development of the 2022 HVA include the 2016 HVA, Groundwater Protection Areas identified by the Department of Pesticide Regulation, Aquifer Risk Assessment by the State Board, and Hydrogeologic Vulnerability Areas delineated by the State Board. Comparisons of the 2022 HVA to these other assessments are summarized below.

5.1. 2016 HVA

The proposed 2022 HVA overlaps much of the previous 2016 HVA (**Figure 24**), but about half of the 2016 HVA irrigated land acreage is not included in the 2022 HVA, although other agricultural land in the Sacramento Valley previously not included in the 2016 HVA were designated part of the 2022 HVA (**Table 11**). The 2016 HVA captures 122 (67%) of the nitrate exceedance wells and 22 (55%) of the nitrate uptrending wells.

5.2. DPR Groundwater Protection Areas

The DPR produced an assessment for consideration in pesticide application in 2000. DPR (Troiano et al., 2000) published a soils-based analysis describing their development and mapping of the GWPAs (**Figure 25**). The GWPAs are designed to prioritize areas for regulatory oversight and mitigation efforts for pesticide contamination of groundwater. The DPR GWPA assessment differentiates between areas where runoff is high and could result in inputs to streams that influence groundwater quality, and areas where runoff is low and infiltration rates are high. The DPR GWPA captures few of the nitrate exceedance wells (**Table 11**). The GWPA captures 19 (10.4%) of the nitrate exceedance wells and 7 (17.5%) of the nitrate uptrending wells.

5.3. State Board Aquifer Risk

The State Board Aquifer Risk (SWRCB, 2022) assessment was developed to meet the requirements of Senate Bill 200, signed into law in 2019. The Aquifer Risk map is based on depth-filtered well nitrate data, domestic well density, and state small water systems' locations. It is designed to provide regulators and others a measure of the risk that individuals may be drinking well water with high nitrate outside of PWS (where it would be brought to the attention of state regulators). The Aquifer Risk assessment does not produce a particular area, instead the assessment categorized Water Quality risk into "Low", Medium", and "High" regions. For the purpose of comparison with the 2022 HVA, the regions of "Medium" and "High" risk, within the Sacramento Valley, were used (**Figure 26**). This region encompasses 631,304 acres (245,806 irrigated acres) within the Valley. The region captures 54% of the wells with nitrate exceedances, and 65% of the wells with uptrending nitrate concentrations that are considered agriculturally influenced in the Sacramento Valley (**Table 11**).

5.4. State Board Hydrogeologic Vulnerable Area

The State Board has also produced (SWRCB, 2000) a map of Hydrogeologically Vulnerable Areas (HGVA), in response to Executive Order D-5-99 (1999). The WDR calls for the HGVA to be considered in development of the GAR and HVA, though no specific requirement is made for the inclusion of the HGVA acreage in the HVA for the GAR. The HGVA designated areas are based on DWR and USGS well data and were primarily designed to assess vulnerability to constituents associated with fuel contamination (**Figure 27**)**.** The HGVA captures 72 (39.3%) of the exceedance wells, and 15 (37.5%) of the uptrending wells (**Table 11**).

5.5. Consideration of DPR GWPA Sections in 2022 HVA

In the 2016 GAR, the Regional Board required the DPR GWPA sections to be added into the HVA. The 2022 HVA does not include all the GWPA sections; although, in accordance with the WDR, the GWPAs were considered during development of the 2022 HVA. The Coalition considered the GWPA sections throughout the Sacramento Valley and evaluated the performance of the 2022 HSA model and the 2022 HVA in comparison with sections not designated GWPA. No bias in the HSA or HVA was found in relation to the GWPA sections, meaning that GWPA sections are equally likely to be included in the HSA or the HVA as non-GWPA sections. Importantly, GWPA sections underperform relative to non-GWPA sections in identifying areas with elevated nitrate concentrations. Therefore, the GWPA sections should not be specifically excluded from the HVA, but they also should not be categorically included.

Table 11: Comparison of 2022 HVA with Previous Vulnerability Assessments							
Vulnerability Schema	Uptrending Wells Captured		Exceedance Wells Captured		Acreage in the Sacramento Valley		Acres Overlap with 2022 HVA (%)
	Number	Percent	Number	Percent	Total	Irrigated Ag	
2022 High Vulnerability Area	**40**	**100**	**183**	**100**	**621,689**	**601,891**	**-**
2016 GAR High Vulnerability Area	22	55%	122	67%	946,748	552,297	284,543 (45.8%)
SB Aquifer Risk (Medium and High Water Quality Risk Region) (2022)	26	65%	98	54%	631,304	245,806	135,592 (22%)
SB Hydrogeologically Vulnerable Areas (2000)	15	37.5%	72	39.3%	830,582	403,850	241,591 (38.9%)
DPR Groundwater Protection Area (Leaching & Runoff)	7	17.5%	19	10.4%	434,044	115,588	63,682 (10.2%)
Note: All values in Table 11 are reported for areas within the Sacramento Valley floor.							

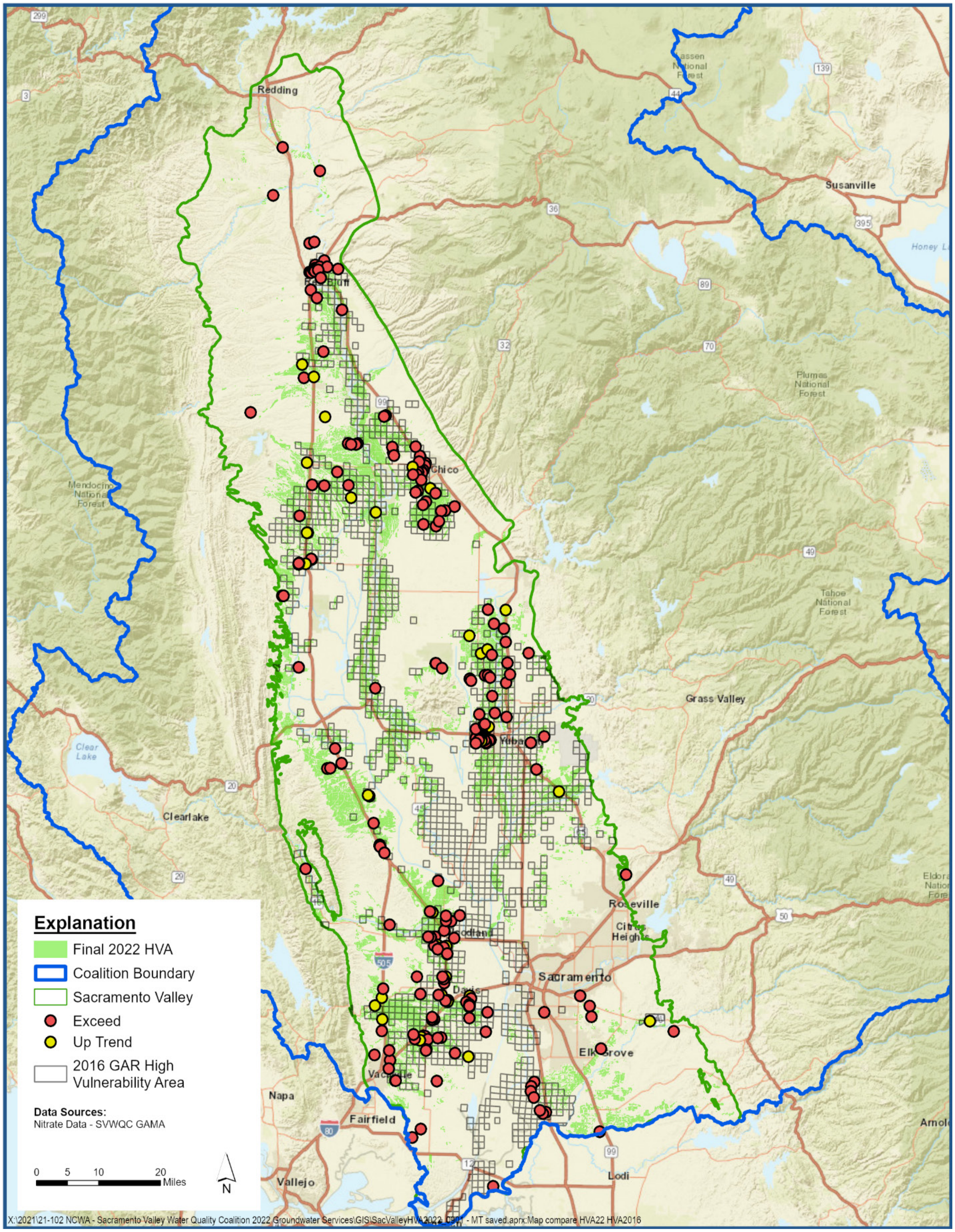

Figure 24: Comparison of 2022 HVA with 2016 HVA

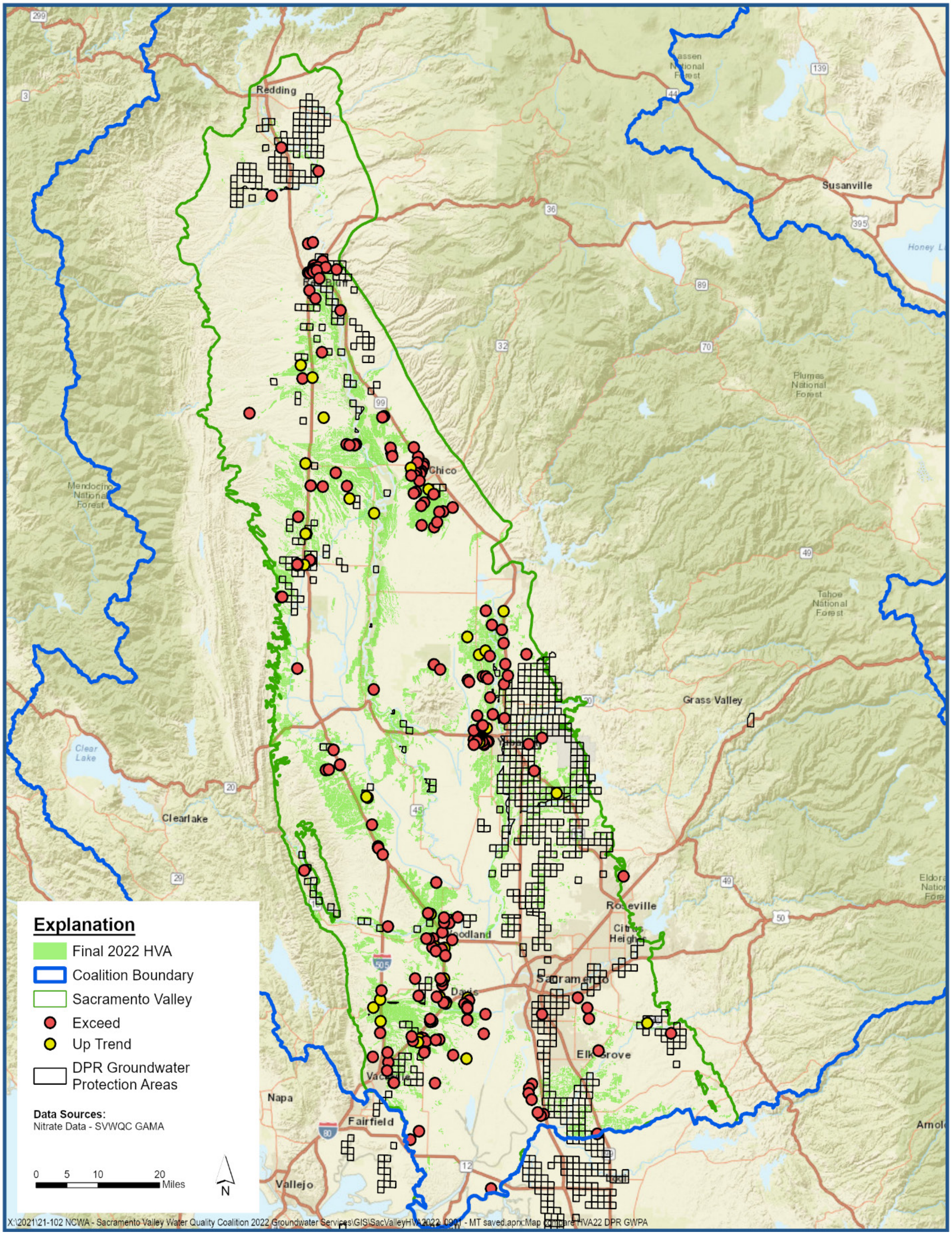

Figure 25: Comparison of 2022 HVA with DPR GWPA

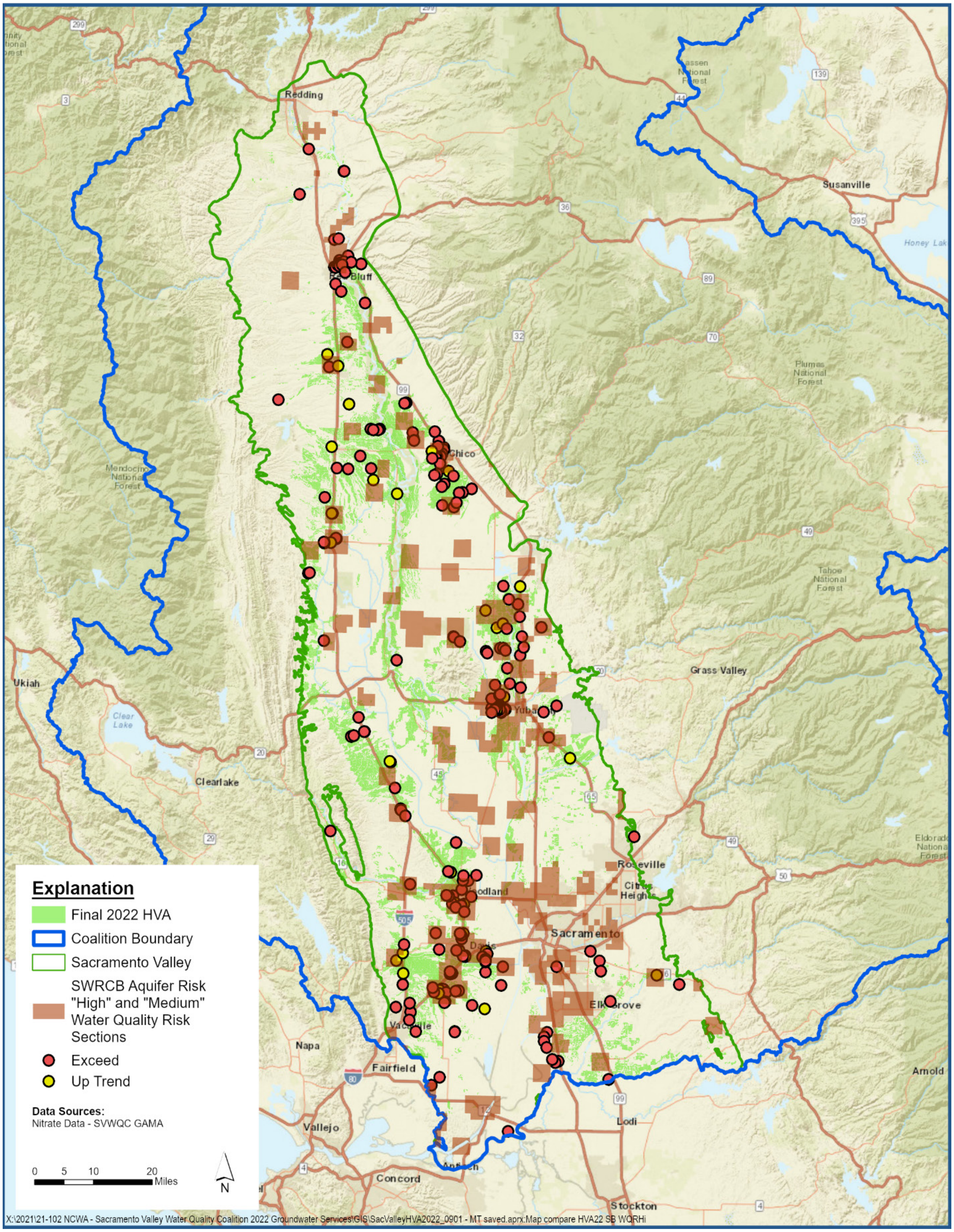

Figure 26: Comparison of 2022 HVA with State Board Aquifer Risk Map

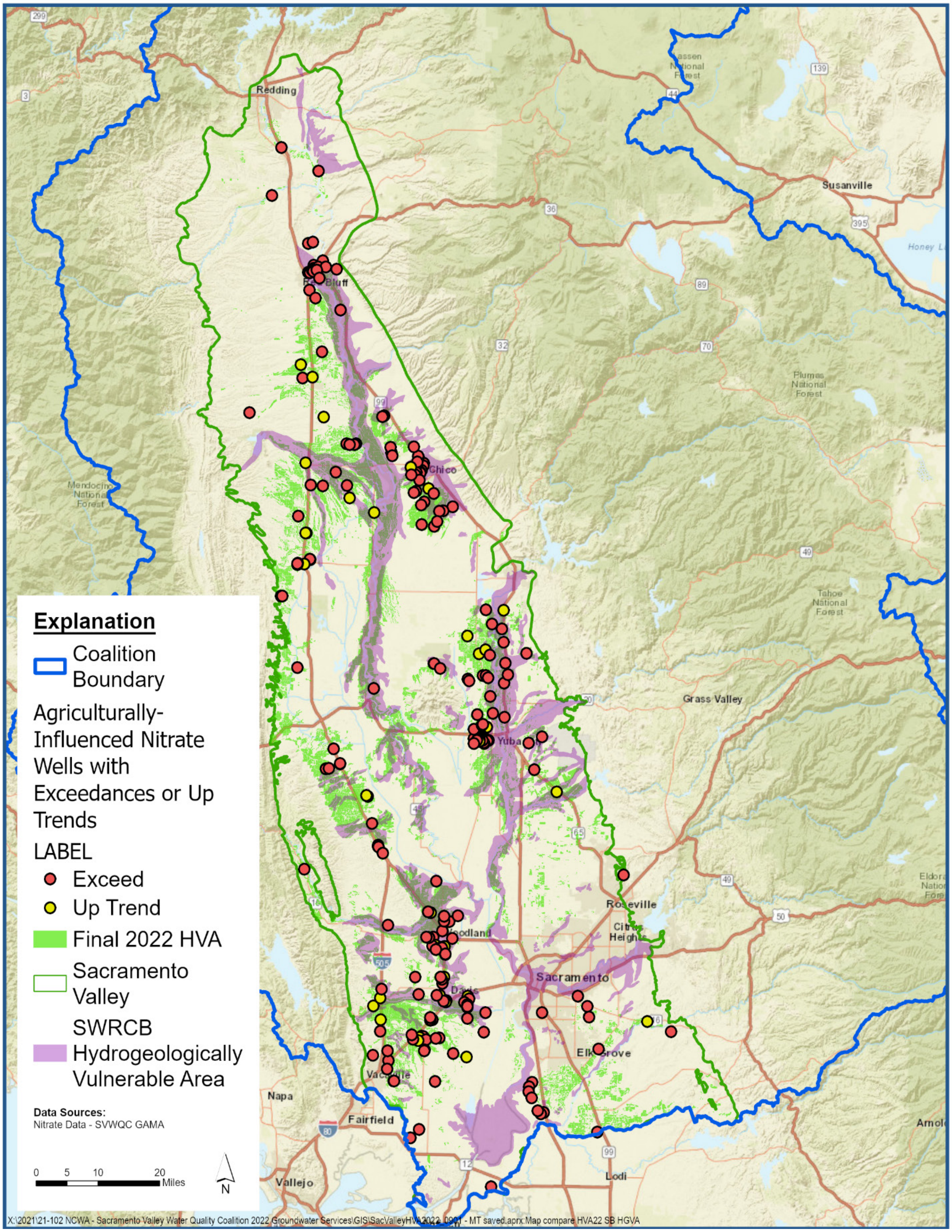

Figure 27: Comparison of 2022 HVA with State Board HGVA

6. HVA OUTSIDE OF THE SACRAMENTO VALLEY

The upper subwatersheds of the SVWQC region include Pit River, Upper Feather River, El Dorado, Napa, Lake County, and portions of Shasta-Tehama, Butte-Yuba-Sutter, Placer-Nevada-South Sutter-North Sacramento (PNSSNS), Sacramento-Amador, Solano, Yolo, and Colusa-Glenn Counties. Of the 18.2 million acres of the SVWQC region, 13.57 million are in upper subwatersheds, outside of the Sacramento Valley. Of the 13.57 million acres in the upper subwatersheds, only 178,339 acres (approximately one percent) are irrigated agriculture, although some of the area mapped as irrigated may include pasture acres that are not irrigated (**Table 12**).

Table 12: Upper Subwatershed Areas

Subwatershed	Out of Valley Acres	Out of Valley Irrigated Ag Acres
BYS Subwatershed Area	872,460	4,380
Colusa-Glenn Drainage Area	699,601	8,468
El Dorado Drainage Area	1,013,125	4,734
Lake County SBWS Drainage Area	652,539	27,076
Napa Drainage Area	231,074	5,598
Pit River Drainage Area	4,364,365	92,230
PNSSNS Drainage area	1,182,710	12,301
Sac Amador Drainage Area	234,351	4,987
Shasta-Tehama Drainage Area	2,009,584	2,132
Solano Drainage Area	42,656	2,249
UFRW Drainage Area	2,157,581	14,031
Yolo Drainage Area	113,303	153
Total	**13,573,349**	**178,339**

BYS = Butte-Yuba-Sutter; SBWS = Subbasin Watershed; USFW = Upper Feather River Watershed

The agricultural land in these upper subwatersheds is of mixed character, with some of the watersheds dominated by pasture, while others have large fractions of vineyards or orchards (**Table 13**). The Pit River Drainage Area has the largest area of land considered irrigated agriculture (**Table 12**), but the majority of its irrigated crop acreage is pasture, unclassified, or grains (**Table 13**). Further analysis of the Pit River agricultural acreage is warranted, as it is expected that large areas of these lands are neither irrigated nor fertilized. This analysis will be conducted when the results of the Drinking Water Well Monitoring Program are available, and the area is assessed for HVA in 2023. The Lake County Subwatershed, in contrast, has around a third as many irrigated acres, but this acreage is dominated by vineyard and orchard crops.

Table 13: Types of Irrigated Agriculture in Upper Subwatersheds							
Subwatershed	Agriculture in Subwatersheds, Outside of Sacramento Valley (Acres)						
	Irrigated Pasture	Vineyard	Irrigated Unclassified	Grains	Orchard	Field	Truck
BYS Subwatershed Area	2,218	204	267	25	259	0	23
Colusa-Glenn Drainage Area	1,974	54	2,637	1,896	1,772	100	16
El Dorado Drainage Area	464	2,519	425	35	916	0	325
Lake County SBWS Drainage Area	4,732	11,807	2,027	998	7,367	9	62
Napa Drainage Area	92	4,829	259	327	73	0	1
Pit River Drainage Area	69,045	1	14,321	8,346	15	0	502
PNSSNS Drainage area	9,770	682	623	40	503	0	410
Sac Amador Drainage Area	593	3,448	461	159	277	15	6
Shasta-Tehama Drainage Area	885	228	337	542	55	0	82
Solano Drainage Area	96	42	202	619	1,221	0	50
UFRW Drainage Area	9,809	0	2,115	2,085	20	0	3
Yolo Drainage Area	0	23	0	39	58	1	0
Total	**99,678**	**23,837**	**23,674**	**15,111**	**12,536**	**125**	**1,480**

The number and distribution of wells with nitrate data are limited in the areas outside the Sacramento Valley. This poor data distribution, combined with the highly variable hydrogeology and topography characterized by groundwater occurring in both fractured consolidated-rock geologic settings and alluvial basins, makes it very challenging or inappropriate to apply the same vulnerability assessment approach as was used for the Sacramento Valley.

Of the 8,346 wells with nitrate data in the SVWQC, 2,909 wells are located in the upper subwatersheds and not in the Sacramento Valley. Of those 2,909 wells, 26 wells with nitrate exceedances in the upper subwatersheds have more than 20 percent irrigated agriculture in the area within one mile of the well (**Table 14**, **Figure 28**); another seven wells with elevated nitrate concentrations and significant increasing trends in nitrate have more than 20 percent irrigated area within one mile.

Table 14: Exceedance and Uptrend Wells Near Agriculture in Upper Subwatersheds		
Subwatershed	Irrigated Ag > 20% Near Well	
	Exceedance Wells	Uptrending Wells
Butte-Yuba-Sutter Subwatershed Area	—	—
Colusa-Glenn Drainage Area	—	—
El Dorado Drainage Area	—	—
Lake County SBWS Drainage Area	4	4
Napa Drainage Area	—	—
Pit River Drainage Area	15	—
PNSSNS Drainage Area	—	—
Sacramento-Amador Drainage Area	—	—
Shasta-Tehama Drainage Area	—	—
Solano Drainage Area	—	—
UFRW Drainage Area	1	—
Yolo Drainage Area	—	—
Total	**20**	**4**

The hydrogeology and land use mix of the upper subwatersheds is different from the Sacramento Valley, so the hydrogeologic sensitivity model developed for the Valley is not appropriate for use in these upland areas. Compared with the Sacramento Valley, the hydrogeology of the upland areas is more complex, irrigation and fertilizer use are less widespread, and other sources of nitrogen, such as cattle ranching and septic or on-site wastewater systems, are more common.

As of Summer 2022, the Drinking Water Well Monitoring Program has been implemented in some parts of the Coalition. Coalition members subject to the requirements of this Program have until December 31, 2022 to comply with the required sampling and nitrate testing. It is expected that these nitrate results will be available by early 2023. The Coalition intends to review these new data, in conjunction with other data, in 2023 as part of evaluating the vulnerability of the upper subwatershed areas and delineation of HVA. Each of the upper subwatersheds has unique and diverse hydrogeologic and land use characteristics, and these unique characteristics will be considered during the evaluation of vulnerability for each of the upper subwatersheds.

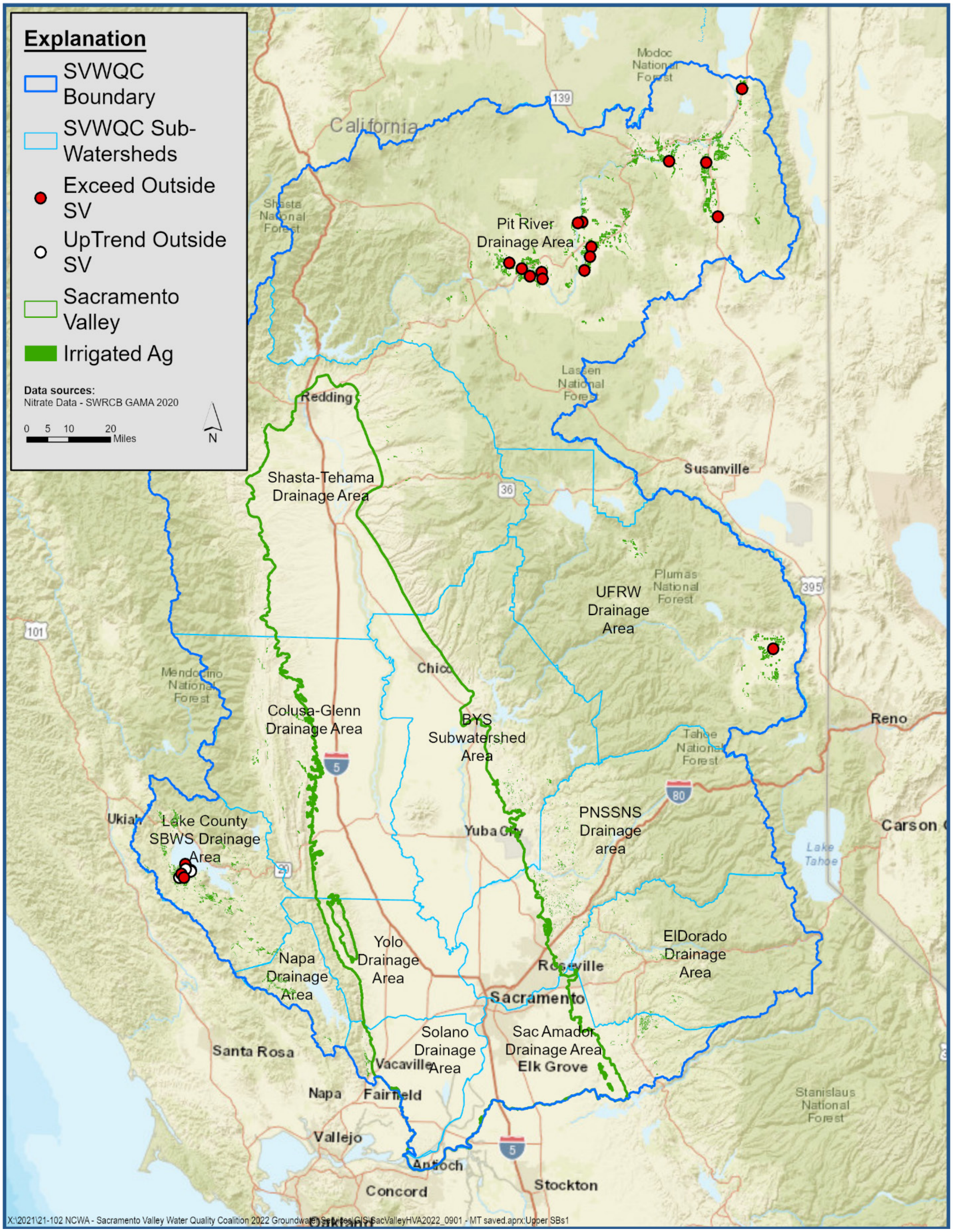

Figure 28: Exceedance Wells Near Irrigated Agriculture in Upper Subwatersheds

Of the upper subwatershed areas, the Lake County Subwatershed has a much higher fraction of cropped area that is not pastureland suggesting some higher potential for irrigated agricultural activities to affect groundwater quality, compared with other upper subwatersheds. The locations of exceedance and uptrend wells in the Lake County Subwatershed are generally clustered in and around the agricultural region of the Subwatershed. Considering this, the Lake County Subwatershed is examined in more detail in the following section, as an example of how HVA might be developed in these upper subwatersheds.

6.1. Lake County Subwatershed

In Lake County Subwatershed, all of the wells with exceedances or uptrending nitrate values are located near the town of Kelseyville (**Figure 29**). That area is the primary non-grazing land agricultural region of the Subwatershed, with a mix of different irrigated crop types (**Figure 30**). The nitrate exceedance and uptrending wells are located in agricultural areas dominated by a mixture of vineyard and orchard, with pasture, grain, field, and truck crops also present.

Application of the sensitivity model described in **Section 3** is not possible in this region due to the lack of data to describe the independent variables used by that model to predict sensitivity. Because of this, it is likely the Coalition will utilize an approach to defining HVA similar to the method used in the Valley for including exceedance and uptrend wells that do not naturally fall within the PHVA (described in **Section 4.2.3**) through establishing a buffer around exceedance and uptrending wells.

The Tentative High Vulnerability Areas (THVAs) delineated through this approach are presented in **Figure 31**. The THVAs cover approximately 1730 acres, with approximately 1006 acres (58%) of that land irrigated agriculture.

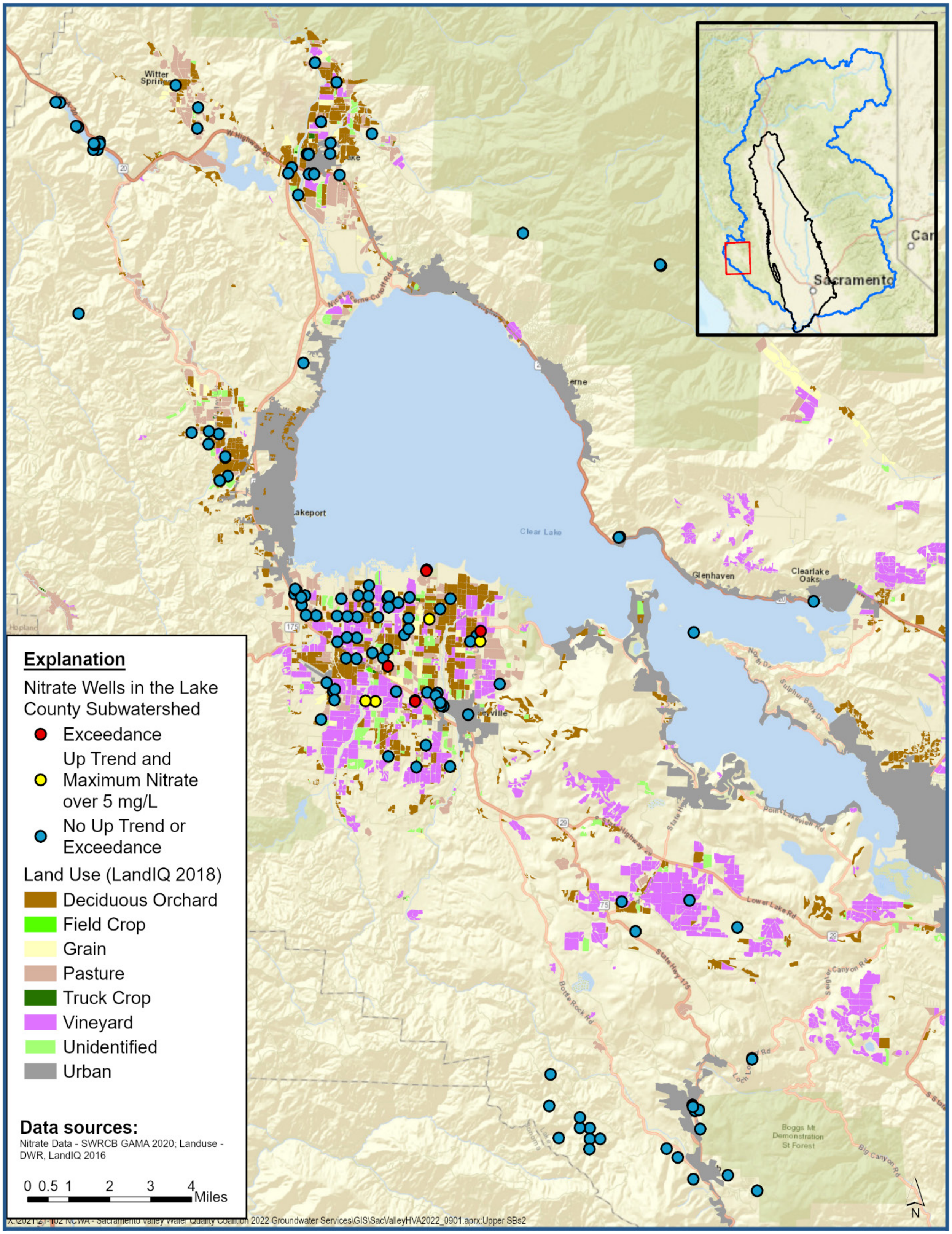

Figure 29: Lake County Wells Sampled for Nitrate, with Land Uses

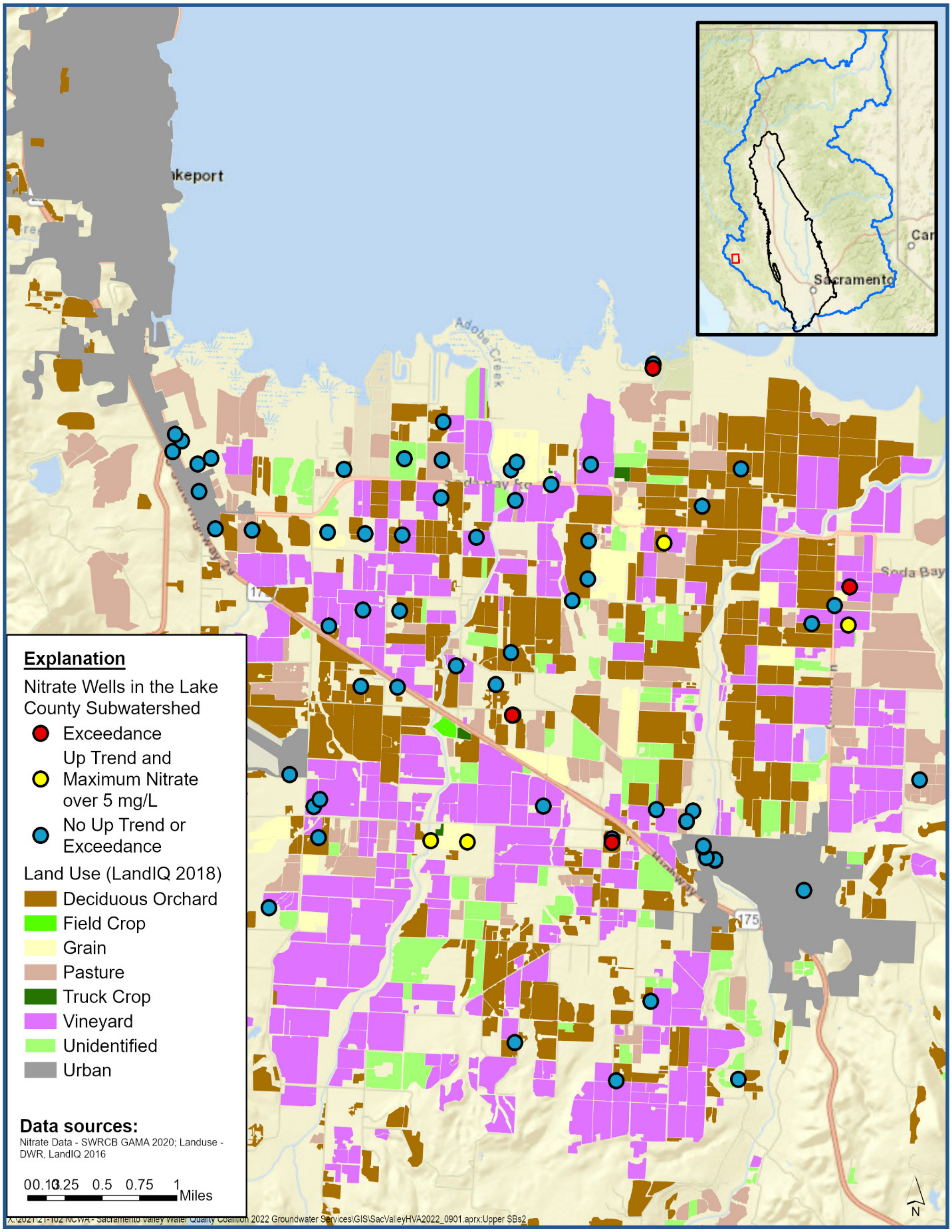

Figure 30: Lake County Near Kelseyville, Nitrate Wells and Land Uses

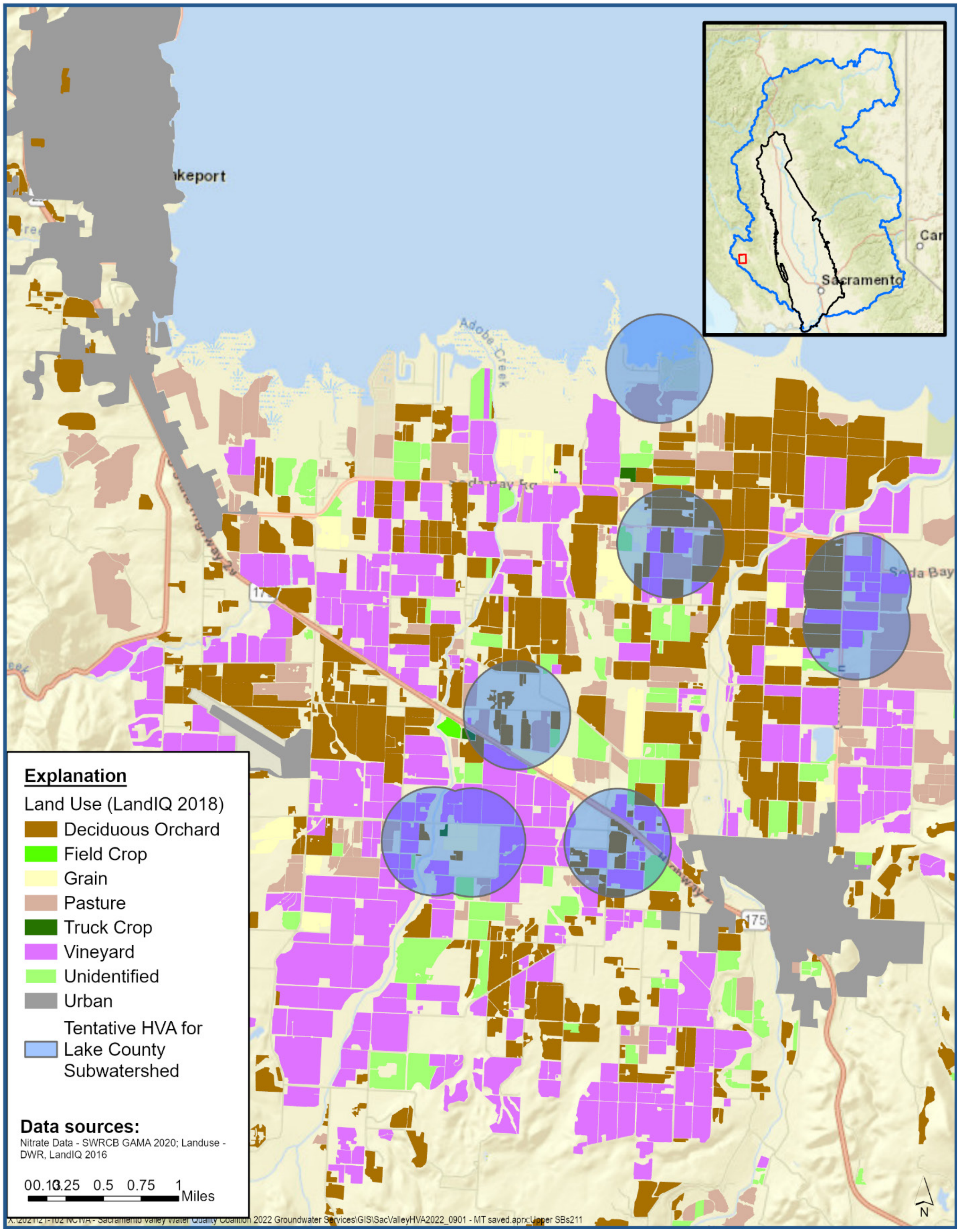

Figure 31: Tentative HVAs in Lake County Subwatershed

6.2. Pit River Drainage Area

Although some exceedance wells are near agriculture in the Pit River Drainage Area, that agriculture is predominantly Alfalfa and Alfalfa Mixtures, and Mixed Pasture, with Miscellaneous Grasses, and Miscellaneous Grain and Hay present as well, but very few fields of Field, Truck, or Orchard crops (**Figure 32**, **Figure 33**). Among these crops, Mixed Pasture, Miscellaneous Grasses, Miscellaneous Grain and Hay, and Alfalfa and Alfalfa Mixtures will generally be unfertilized.

Based on aerial imagery and the DWR county-by-county field survey data, hosted at (https://gis.water.ca.gov/app/CADWRLandUseViewer/), Mixed Pasture in the upper subwatersheds is nearly always unirrigated. Because the agricultural management practices associated with these crops have very low potential for causing nitrate impacts to groundwater, the exceedance wells in this area are not likely related to agricultural management practices.

In the Pit River Subwatershed, continued monitoring and periodic reassessment of the available data are recommended to determine if HVA should be considered in the future. The ILRP Drinking Water Well Monitoring Program, set to be completed at the end of 2022, will provide more data to evaluate the current conditions and establish a baseline from which future trends may be analyzed.

6.3. Upper Feather River Watershed Drainage Area

Agriculture in the UFRW Drainage Area is dominated by unirrigated and/or unfertilized crops. Only one well meeting the 20% agricultural land use within one-mile criteria in the UFRW Drainage Area has an exceedance of the nitrate as N MCL. This single well was last sampled in 1967 and is in an area where no drinking water wells exist. No other agriculturally influenced wells in the UFRW Drainage Area have either nitrate exceedances or samples over 5 mg/L with uptrending nitrate concentrations over time (**Figure 34**). No HVA is recommended in the UFRW Drainage Area.

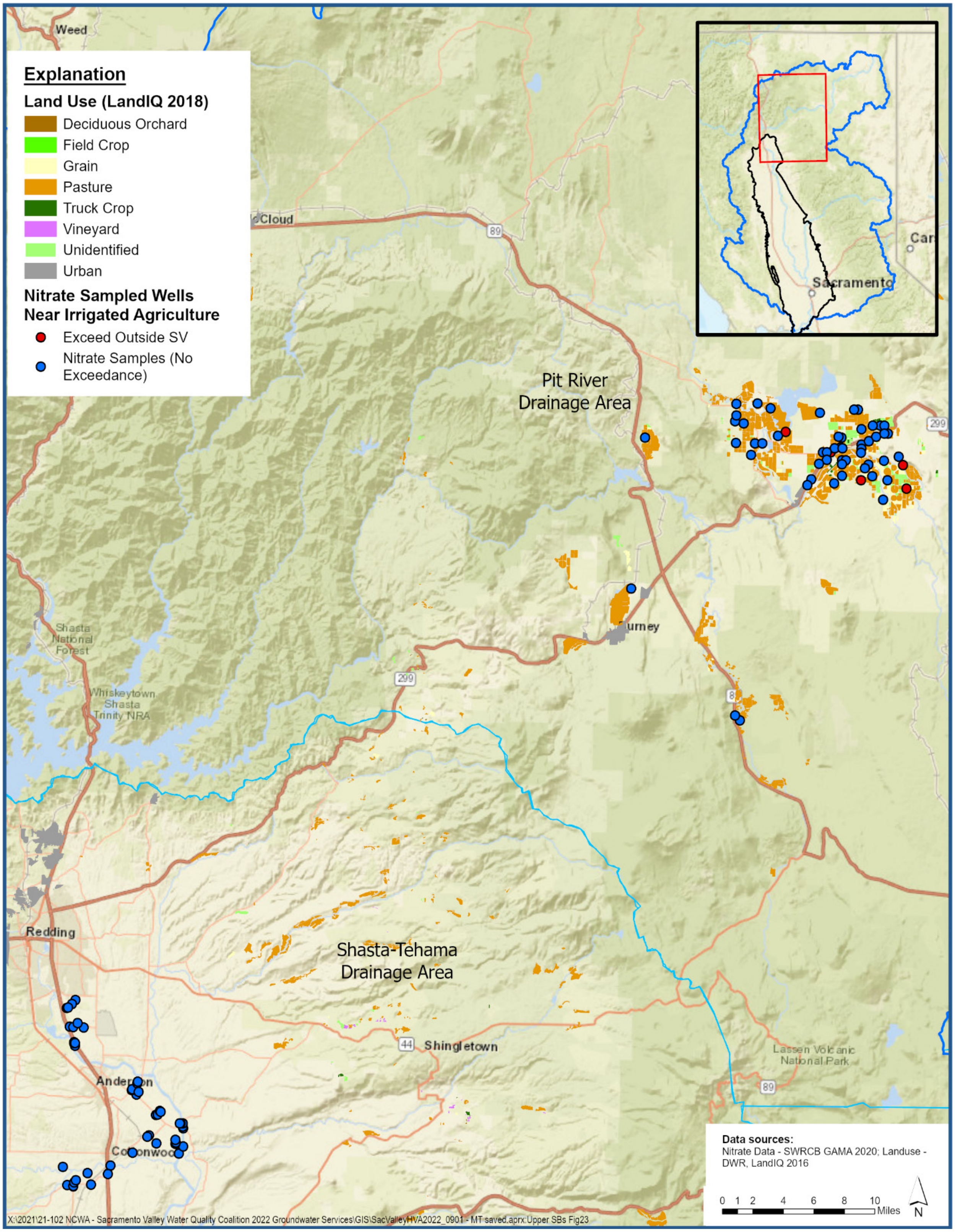

Figure 32: Pit River Near Fall River with Exceedance Wells and Crop Types

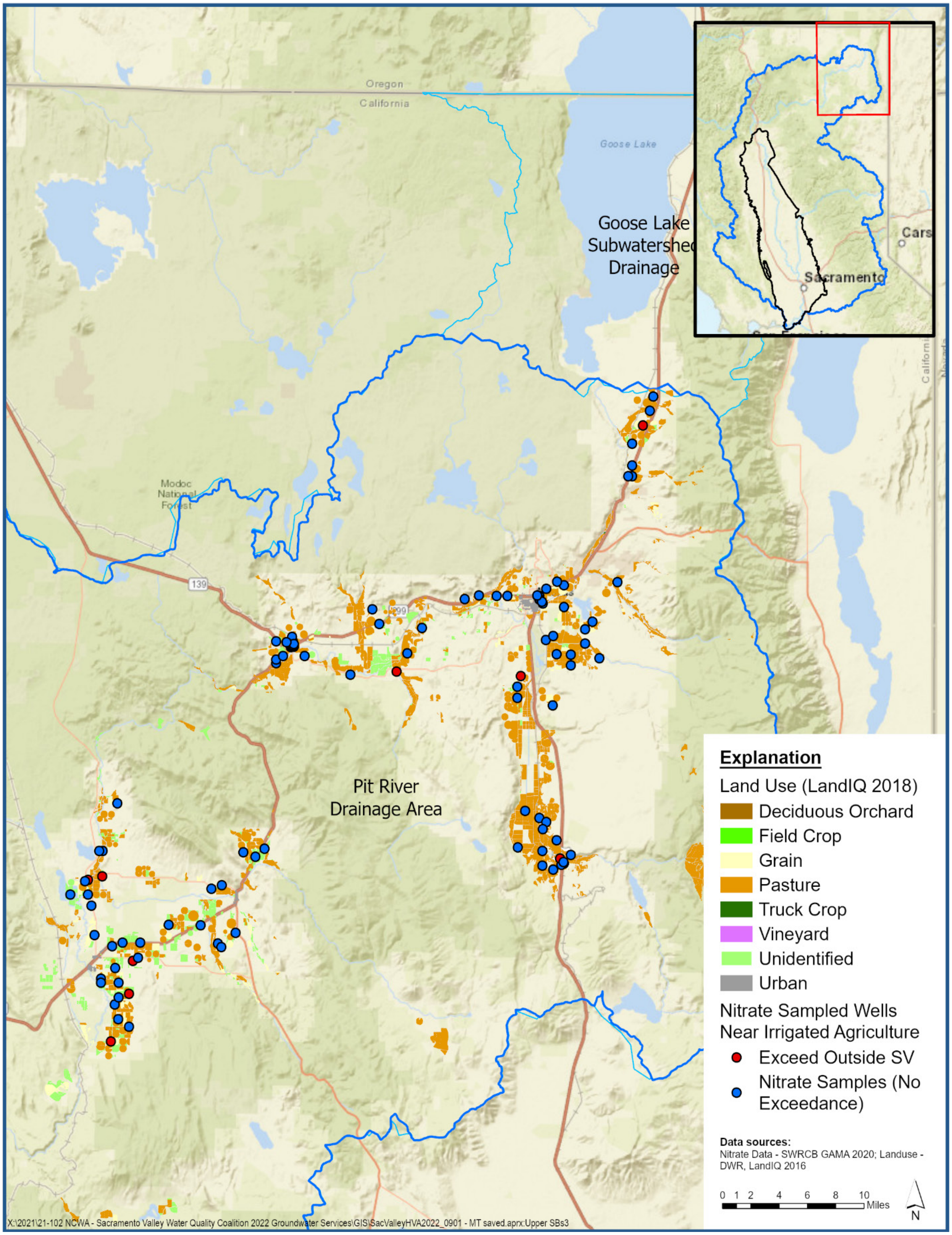

Figure 33: Pit River Near Alturas with Exceedance Wells and Crop Types

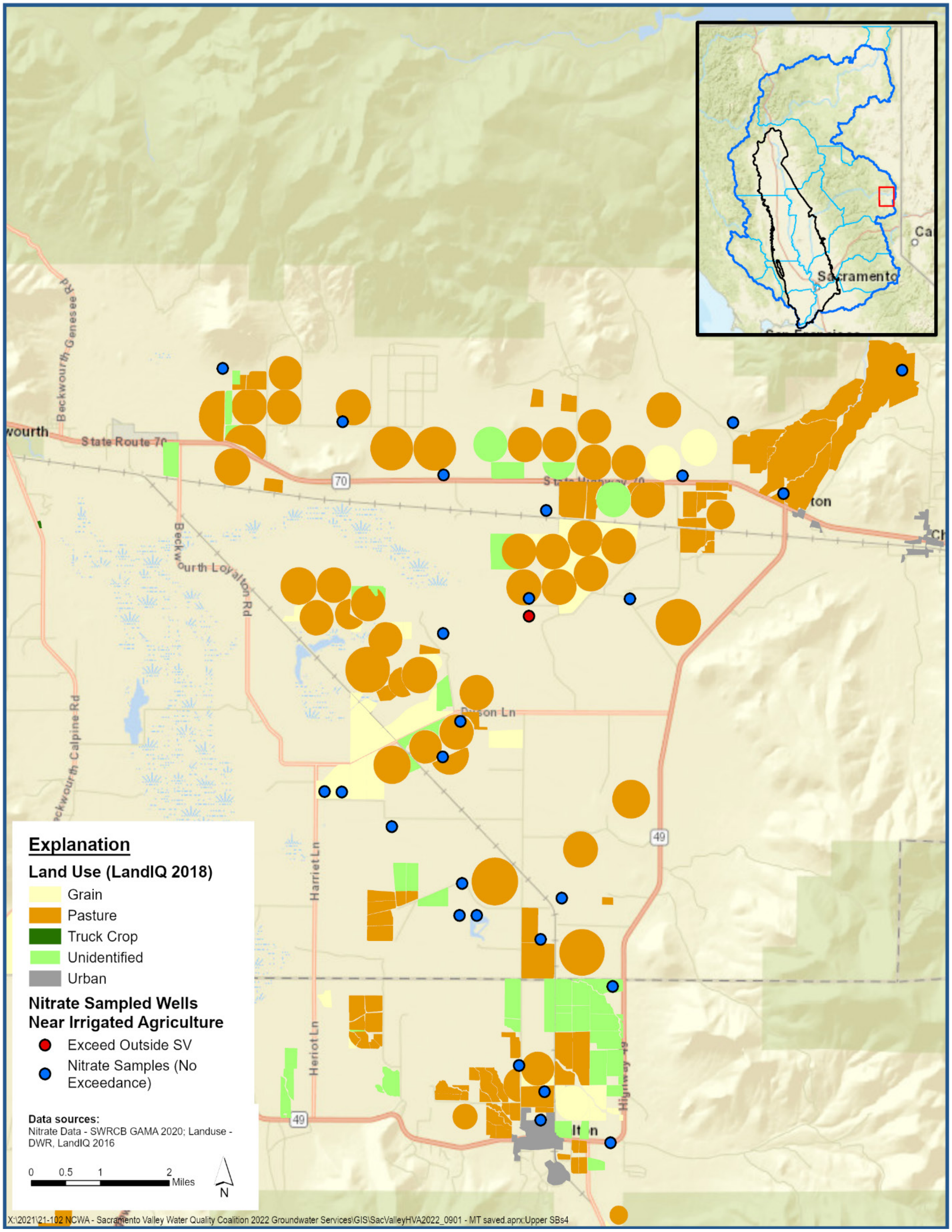

Figure 34: Upper Feather River Near Loyalton with Exceedance Well and Crop Types

7. PRIORITIZATION WITHIN THE HVA

In the 2016 GAR, the HVA lands were assigned priorities to help the Coalition focus outreach and implementation efforts to further the goals of the WDRs. These priority assignments are not applicable to most of the 2022 HVA as described here because of the differing coverage of these two HVAs. The Coalition recommends relooking at this prioritization process in the future due to the 2022 implementation of the Drinking Water Well Sampling Program required by the WDRs. This Program will produce hundreds of new datapoints that will be used in conjunction with the other datasets available from public sources to refine the priorities within the 2022 HVA.

8. FUTURE HVA UPDATES

Land uses change over time. As irrigated agricultural lands are retired or converted to other uses, the SVWQC should not continue to be responsible for those lands, particularly if the irrigated agriculture did not contribute to impacts on groundwater quality. Likewise, if new lands are brought into agricultural production by SVWQC existing or newly enrolled members, their irrigated lands may become part of the HVA. Any new lands brought into irrigated agricultural production will be compared with the HSA and if they overlap, then these lands will become HVA to protect groundwater quality in those areas. Annually, the Coalition will overlay the updated Participant List shapefile on the HSAs and add any new irrigated enrolled member acres to the HVAs where they overlay HSA. When newly enrolled irrigated agricultural lands that overlie HSA areas are designated HVA, these will be reported to the Regional Board as part of the Coalition's annual report and an updated HVA shapefile will be provided.

The WDRs require SVWQC members with domestic wells on enrolled parcels to test those wells for nitrate by the end of 2022. Where MCL exceedances occur, the HVA will be expanded to include those wells in a similar manner as with exceedance well. Since the Coalition will be preparing a five-year groundwater quality trend assessment in 2023, new data from the Drinking Water Well Sampling Program will be evaluated and, where MCL exceedances occur; the HVA will be expanded if those wells are not already located in the HVA.

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APPENDIX A

A 1. Land Use Data Processing Methods

Within each Land IQ (LIQ18) feature (crop field), the area of each CropScape2020 (CS20) land use type was calculated. In most cases, the two datasets agree, but in many of the pasture and rangeland fields, the CS20 data provide more information. Similarly, within each LIQ18 feature, the area of CS20 Irrigated Crops (those shown in the table below) was calculated.

Typically, a feature in the LIQ18 dataset, such as a crop field, will be overlapped primarily by CS20 cells of the same or a similar crop as that shown in the LIQ18 data. However, in most cases, the edges and sometimes portions of the interior of that LIQ18 feature will be characterized in the CS20 data as some other land use type, and these can be completely different from the dominant crop in that field. This does not mean that there are different land use types on the field. Rather, it is a result of the poor accuracy on the edges of fields, or in places where some temperature or other anomaly exits within a field, in the CS20 data.

Based on the crop types, each CS20 class was assigned to either irrigated or non-irrigated status. Non-irrigated CS20 land uses are listed here:

Table A1: Non-irrigated Crop Designations in CS20 Dataset in Sacramento Valley

CropScape2020 Non-Irrigated Land use	Acres in Sacramento Valley
Barley	10,454
Oats	10,082
Mustard	0.2
Open Water	69,587
Perennial Ice/Snow	12
Developed/Open Space	184,723
Developed/Low Intensity	123,071
Developed/Med Intensity	145,589
Developed/High Intensity	42,198
Barren	24,275
Deciduous Forest	2,052
Evergreen Forest	9,134
Mixed Forest	3,463
Shrubland	460,946
Grassland/Pasture	930,565
Woody Wetlands	35,809

Table A1: Non-irrigated Crop Designations in CS20 Dataset in Sacramento Valley	
CropScape2020 Non-Irrigated Land use	Acres in Sacramento Valley
Herbaceous Wetlands	80,765
Triticale	20,340.9
Note: Summary of land use in the Sacramento Valley includes areas within the Redding and Sacramento Valley Groundwater Basins and does not include the Cosumnes Subbasin of the San Joaquin Valley Groundwater Basin.	

Note that Winter Wheat and Fallow/Idle are also crops listed in CS20. Although these are not typically irrigated, they are often in rotation with an irrigated crop, and thus the field is considered irrigated.

Visual inspection of aerial imagery confirms that the CS20 designations Shrubland, Developed/High, Developed/Low, Developed/Medium, the three Forest classes, and the two Wetland classes are often non-irrigated lands, as would be expected. However, enough of these lands are irrigated crop fields incorrectly identified as developed or wildlands to cause concern. Similarly, the fields designated Miscellaneous Grain and Hay (G6) in LIQ18 data, and with majority non-irrigated classes in CS20 data, were generally non-irrigated crops, but some of these fields, located in the valley floor areas, clearly are irrigated some years. Thus, even with the addition of the CS20 information, substantial errors still exist in the classification of irrigated vs non-irrigated fields.

A 1.1. Supplementing Land Use Data with Slope Analysis and Riparian Proximity

Irrigated lands are typically less variable in elevation, and the lower slopes of the Sierra foothills and Coast Range, along the valley periphery, are more likely to be non-irrigated than the valley floor. To better model non-irrigated lands, an index of surface topological roughness was developed. The index is equal to the 100 times range in elevation of the feature (in feet) divided by the square root of the area (in square feet) of the feature.

$$R = 100(\text{MaxElev} - \text{MinElev})/\text{SQRT}(\text{Area})$$

This index varies from 0 to 30.6% in the fields defined by the LIQ18 dataset for the Sacramento Valley. The index is effectively a minimum average slope for the feature expressed as a percent. Of the 2,384,731 acres of LIQ18 Sacramento Valley land, 2,018,780 acres fall within features with less than or equal to 1% minimum average slope (R). Looking at the data in a map, the lands with greater than 1% R (totaling 365,951 acres) include a great deal of lands in the Valley floor. A cutoff value of 2% reduces this substantially to 169,418 acres.

Intersecting this slope criteria with the CS20 irrigated crops designation on certain LIQ18 crops yields a good approximation of the truly non-irrigated lands in the LIQ18 data.

For each LIQ18 P3 (Mixed Pasture), P6 (Miscellaneous Grasses), G (Grain), G6 (Miscellaneous Grain and Hay), or X (Unidentified) crop field, if 50% or less of the crop field intersected irrigated crop types in the CS20 data, and the R for that field was greater than 2%, that field was considered a non-irrigated field. The 50% level was chosen based on visual inspection of aerial imagery during summer months, when irrigation practices are obvious. The resulting selection produced crop fields in these several categories of the LIQ18 data that are considered non-irrigated, generally on the margins of the Valley, and left out fields in those categories that are considered irrigated, generally surrounded by other irrigated agriculture and closer to the middle of the valley. Visual inspection of aerial imagery also confirmed that the categorization of these land use types as irrigated or non-irrigated was consistent with the actual land uses, with a small number of fields near larger rivers failing to be correctly identified as irrigated.

Examination of the elevation profiles of these near-river crop fields revealed that in these cases, the levees along larger rivers were causing the field's R variable to increase enough to categorize the field as non-irrigated based on the 1% or even 2% criteria. This error only occurred in fields that were close to rivers', therefore, an additional criterion was introduced. For crop fields with LIQ18 designations P3, P6, G, G6 or X; CS20 data indicating 50% or less irrigated crop types; and R within the range identified as non-irrigated, if the crop field was within a 1/2-mile buffer any 8th (Shreve) order stream, it was still considered irrigated for the purpose of the current analysis (**Figure A1**).

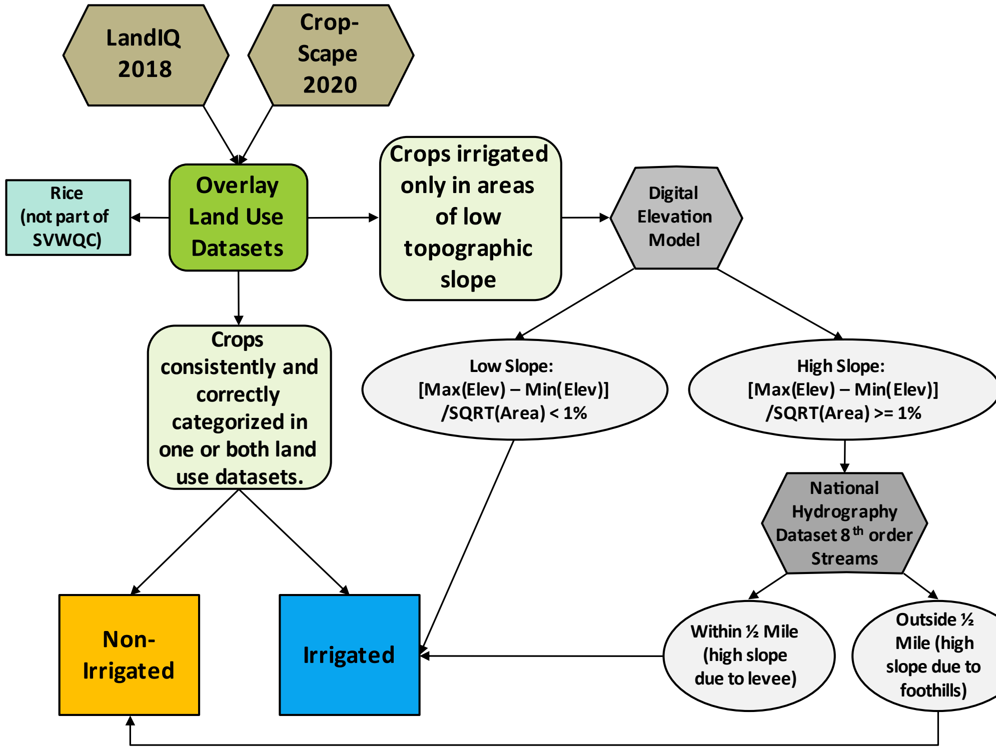

Figure A1: Process Chart for Identifying Most Irrigated Lands with Land IQ 2018, CropScape 2020, Digital Elevation Model, and 8th Order Streams

This process was applied throughout the Coalition to conservatively exclude certain fields from being considered irrigated for the purpose of the land use analysis. However, certain other fields were also removed, based on individual review of aerial imagery.

A 1.2. Specific Land Use Type Problems Identified

Inspection of the intersection between the LIQ18 and CS20 data revealed that the LIQ18 designation G6, in addition to being a general category that needs to be parsed into irrigated and non-irrigated crops, has a number of errors. The CS20 overlap produced many fields with mismatches between the LIQ18 designation and the CS20 designation. Closer examination indicated that the G6 designation was correctly parsed by CS20 in many cases, frequently identifying rice fields that the LIQ18 data had incorrectly characterized. Where LIQ18 data indicate the G6 crop type, and CS20 data indicate a rice field, the field was removed from consideration for the HVA intersection. All LIQ18 Rice-designated fields were also removed.

The Urban (U) LIQ18 class is well correlated with the CS20 Urban classes, however, a small number of LIQ18 fields intersected primarily by CS20 Urban class-designated land uses (Developed/Low, /Medium, or /High-Density designations) were clearly irrigated fields, whereas none of the LIQ18 Urban classes appear to be irrigated lands. Therefore, all LIQ18

Urban lands are considered non-irrigated for the purpose of this analysis, and the CS20 urban classes were ignored.

A 2. Results of Land use Analysis for Irrigated Lands Delineation

In this updated LIQ18 dataset, within the Valley:

1. All LIQ18 crop types other than P3 (Mixed Pasture), P4 (Native Pasture), P6 (Miscellaneous. Grasses), G (Grain), G6 (Miscellaneous. Grain and Hay), C7 (Eucalyptus) and X (Unidentified) are considered irrigated. These six classes are expected to be all or in part non-irrigated.
    a. Of the 5,331 fields (covering 117,100 acres) in the Mixed Pasture category, 346 (covering 4,493 acres) are considered non-irrigated based on the 50% CS20 irrigated threshold, 2% slope threshold, 0.5-mile distance threshold and visual inspection of aerial imagery. However, further examination of aerial imagery indicated that reducing the slope threshold to 1% more accurately reflected the non-irrigated land in this crop class. With that threshold, 886 field covering 14,751 acres were identified as non-irrigated, and this was the final selection used.
    b. All 11 Native Pasture fields (covering 392 acres) are considered non-irrigated.
    c. Of the 392 fields (covering 10,481 acres) in the Miscellaneous. Grasses category, 20 (covering 289 acres) are considered non-irrigated based on the 50% CS20 irrigated threshold, 1% slope threshold, 0.5 mile distance threshold, and visual inspection of aerial imagery.
    d. None of the Grain fields met the criteria for slope or CS20 irrigation status to be removed.
    e. Of the 3,220 fields (covering 102,500 acres) in the Miscellaneous. Grain and Hay category,
        i. 737 fields (covering 26,054 acres) are considered non-irrigated based on the 50% CS20 irrigated threshold, 1% slope threshold, 0.5 mile distance threshold and visual inspection of aerial imagery.
        ii. 97 fields(covering 3426 acres) were designated Rice in CS20 data were also removed from consideration.
        iii. 31 fields(covering 173 acres) designated Developed/Open Space in CS20, and verified as non-irrigated with aerial imagery.
        iv. 63 fields(covering 5,012 acres) designated barley in CS20 are verified to be non-irrigated.
2. Of the 4,982 features, covering 126,266 acres, labeled as Unidentified in the LIQ18 data,
    a. 47 fields (covering 242 acres) were primarily Developed/High, medium, or low Intensity in CS20 data. These were removed from the analysis as they are not irrigated crops.

   b. 42 fields (covering 1965 acres) were primarily Barley, Oats, or Triticale in CS20. These were removed from the analysis as they are not irrigated crops, and they are not grown in rotation with irrigated crops.
   c. 976 fields (covering 19,409 acres) were primarily Grassland/Pasture, Herbaceous Wetlands, Mixed Forest, Open Water, Shrubland, or Woody Wetlands. These were removed from the analysis as they are not irrigated crops.
   d. 675 (covering 33,015 acres) were primarily Rice in CS20. These were removed from the analysis.
3. The 150 LIQ18 features designated Urban, covering 370,723 acres, were considered non-irrigated.
4. 9,931 fields covering 497,222 acres, are Rice or Wild Rice in the LIQ18, and these were removed.
5. For the 1,154 features identified as Rice by CS20, but not identified as Rice or Wild Rice in LIQ18, inspection of aerial imagery indicated that several LIQ18 crop types were often correctly identified by CS20 and incorrectly in LIQ18.
   a. In total, 169 fields that were primarily Rice in CS20, but identified as some other class in LIQ18, covering 12,947 acres, were found to be clearly dedicated rice fields. Many other fields in this class were likely Rice fields as well, but only the most obvious rice fields were treated as rice for this analysis.
      i. LIQ18 Alfalfa and Alfalfa Mix: 16 fields – 9 are Rice bedded and removed from analysis. Alfalfa has been shown to require minimal or no nitrogen fertilizer. Studies on the use of nitrogen fertilizer on alfalfa have shown that it is only beneficial during the first seeding year, and only then under certain soil conditions (Hannaway and Shuler 1993, Putnam et al. 2007). Some types of companion crops may benefit from the use of nitrogen fertilizer.
      ii. LIQ18 Corn/Sorghum/Sudan: 47 fields – 30 are Rice bedded and removed from analysis.
      iii. LIQ18 Dry Beans: 17 fields – 12 are Rice bedded and removed from analysis.
      iv. LIQ18 Melon, Squash, Cucumber: 19 fields – 11 are Rice bedded and removed from analysis.
      v. LIQ18 Miscellaneous Grasses: 10 fields – 2 are Rice bedded and removed from analysis.
      vi. LIQ18 Miscellaneous Truck: 5 fields – 1 are Rice bedded and removed from analysis.
      vii. LIQ18 Mixed Pasture: 49 fields – 5 are Rice bedded and removed from analysis.
      viii. LIQ18 Safflower: 14 fields – 10 are Rice bedded and removed from analysis.

ix. LIQ18 Sunflower: 66 fields – 48 are Rice bedded and removed from analysis.
x. LIQ18 Tomato: 47 fields – 25 are Rice bedded and removed from analysis.
xi. LIQ18 Walnut: 3 fields – 2 are Rice bedded and removed from analysis.
xii. LIQ18 Wheat: 26 fields – 14 are Rice bedded and removed from analysis.

Table A2: Land IQ 2018 Non-Rice Irrigated Agricultural Land Use Categories in the Sacramento Valley 2022 Definition

Land Use Category	Irrigated Acres
Citrus	27,237
Deciduous Orchard	537,094
Field Crops	156,016
Grain Crops	139,614
Pasture	189,492
Truck	98,179
Vineyard	60,522
Young Perennial	42,212
Unidentified	71,635
Total	**1,322,001**

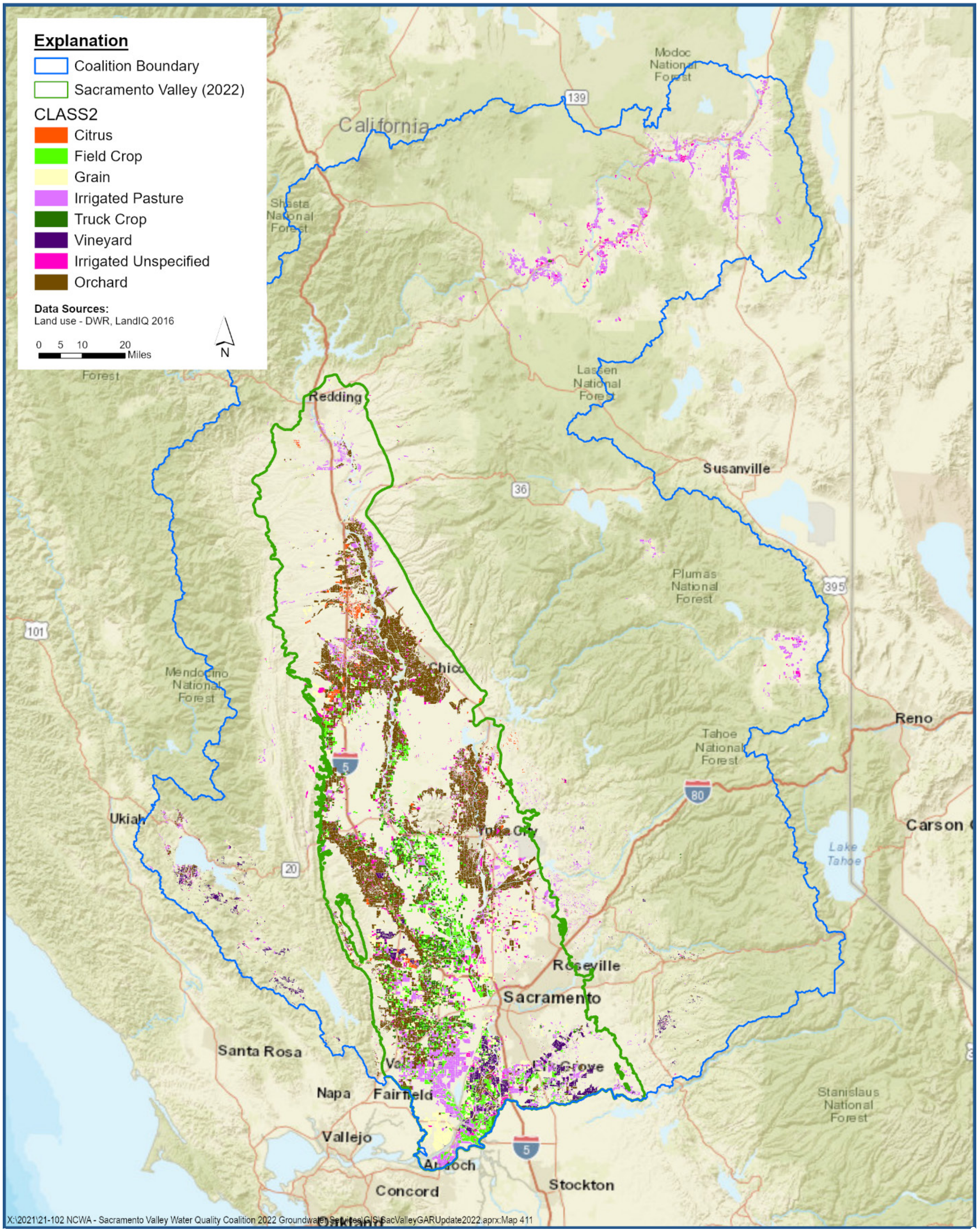

Figure A2: Irrigated Non-Rice Agricultural Lands in Coalition

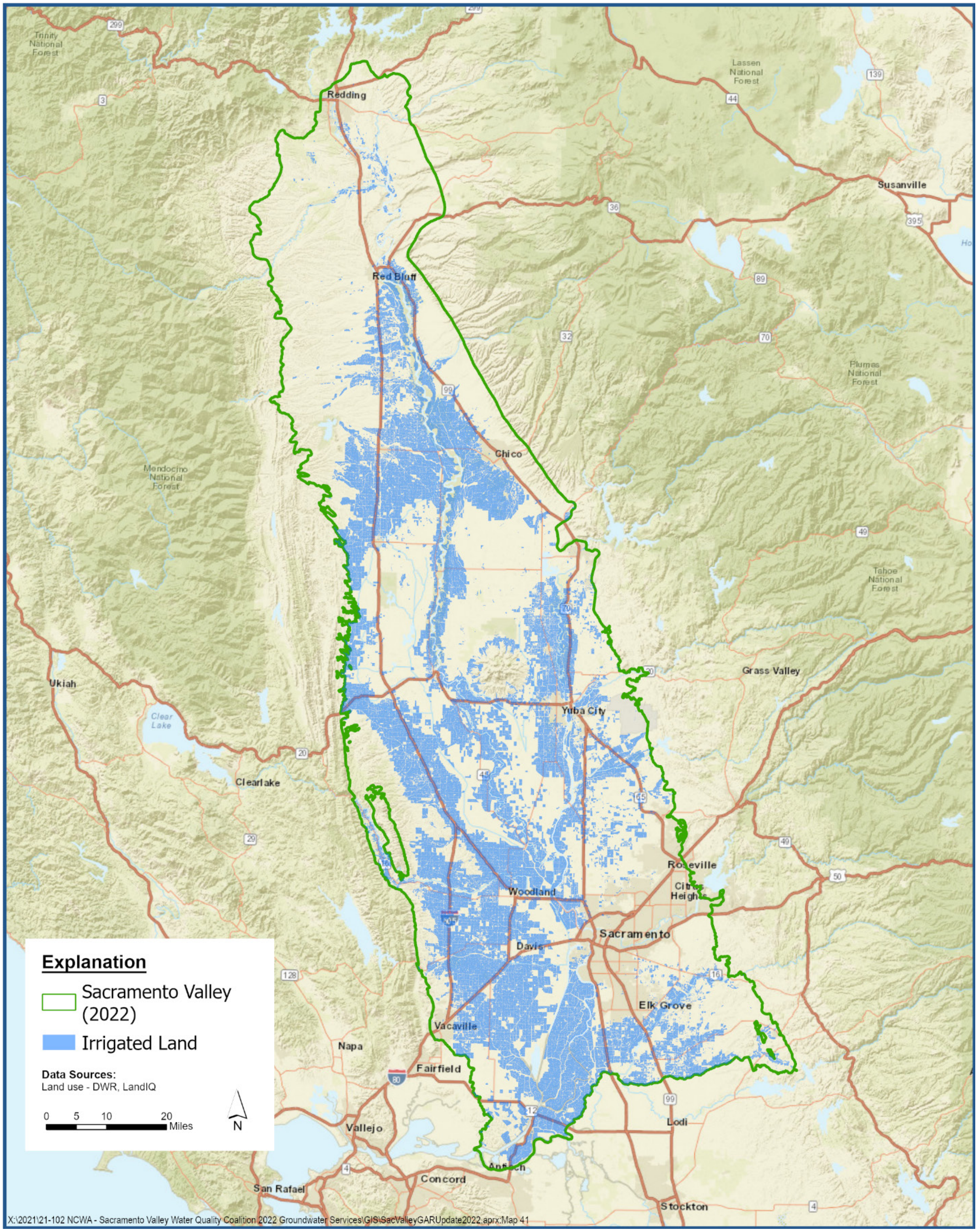

Figure A3: Irrigated Non-Rice Agricultural Lands in Sacramento Valley