TECHNICAL MEMORANDUM - DRAFT

NewFields

Summary of Nitrate Hazard Index (NHI) Analysis for NKWSD

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PROJECT:	North Kern Water Storage District (NKWSD) Irrigated Lands Regulatory Program Support

INTRODUCTION

The Central Valley Regional Water Quality Control Board (CVRWQCB) has issued Order R5-2013-XXXX titled, Waste Discharge Requirements General Order for members of a third-party group within the Tulare Lake Basin, excluding the area of the Westlands Stormwater Coalition in an effort to reclaim and mitigate nitrate losses to groundwater and lessen groundwater quality degradation. As part of these efforts, the areas that have been deemed 'high vulnerability' (Figure 1) in terms of potential nitrate leaching were determined by considering hydrogeology (depth to groundwater and soil texture), monitoring well sampling results and California Department of Pesticide Regulation Groundwater Protection Areas. This area completely encompasses the North Kern Water Storage District boundaries (Figure 1). Current land use and management practices at the land surface were not taken into consideration. This is a significant omission because the majority of the groundwater quality issues present today are relics of different cropping systems and land management strategies that were in place decades ago.

SUMMARY

To most effectively use mitigation efforts, monitor strategically and reduce unnecessary costs to all parties involved, it is important to identify higher risk nitrate leaching areas from locations of lower risk. Accomplishing this requires an understanding of the crop, soil and management practices found on the surface. Current and accurate data resources need to be brought together to achieve this end result.

The North Kern Water Storage District is found in the Southern San Joaquin Valley, in Kern County, California. Because of the crops found in this area and the associated management practices, the land within the NKWSD is thought to be among some of the lowest vulnerability in terms of potential nitrate leaching to groundwater. The purpose of this work was to prove this hypothesis and take advantage of the plentiful NKWSD spatial data of crop type, irrigation method and other variables.

The majority of the crops found in this area are permanent crops with deep roots under efficient (predominantly drip and micro) irrigation systems. It is because of NKWSD and areas like it, that a

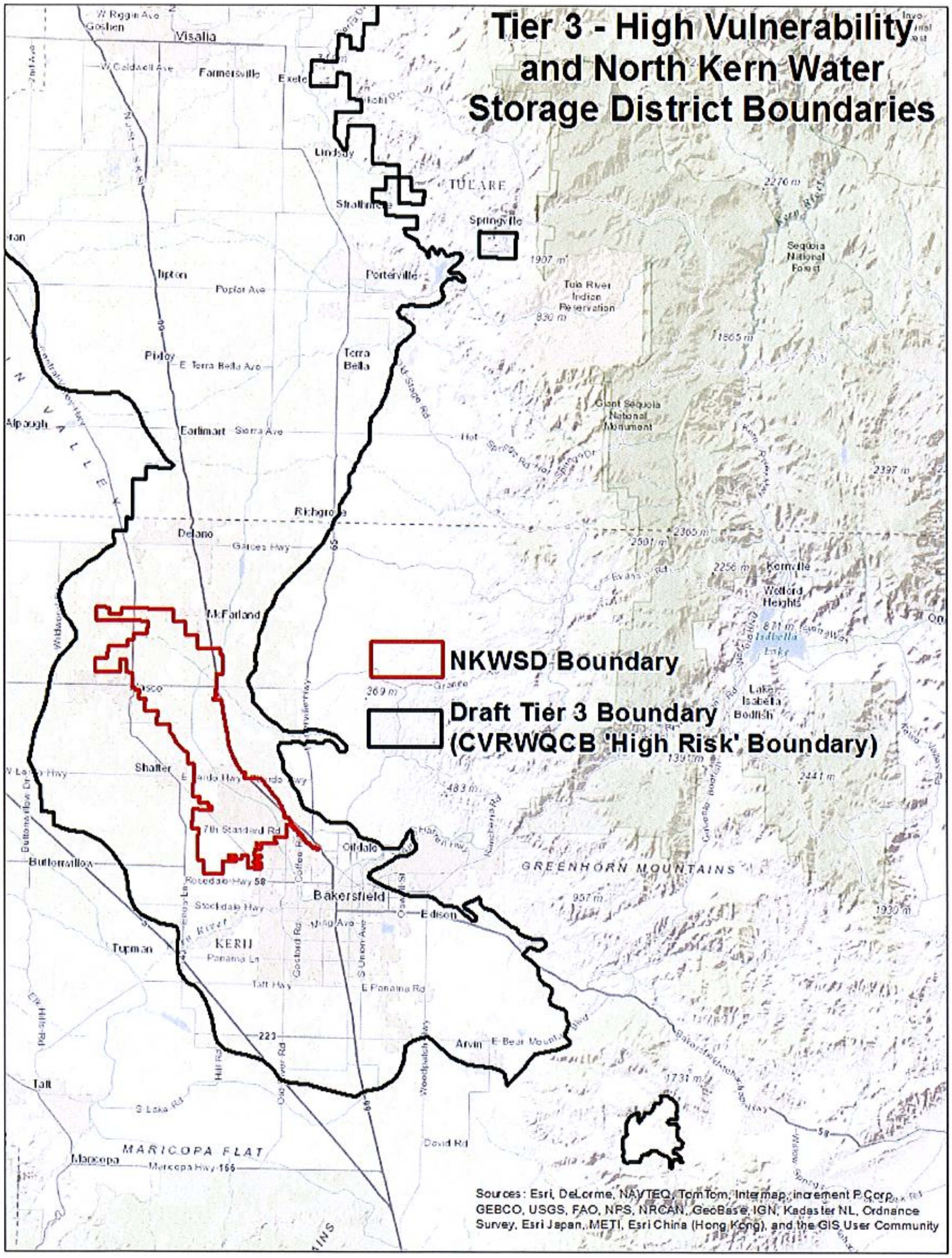

Figure 1. Central Valley Regional Water Quality Control Board tier 3 high vulnerability and North Kern Water Storage District boundaries.

Greater emphasis should be placed on the differentiation of risk areas, especially for regulatory and monitoring purposes.

In an effort to spatially support the assertion that the cropped land within the NKWSD is of lower nitrate leaching risk and not a higher risk as currently classified by the CVRWQCB, a tool called the Nitrogen Groundwater Pollution Hazard Index (NHI) was used to preliminarily evaluate the potential level of nitrate leaching risk of each field. NKWSD was used as a test case because similar to Kern County, it possesses annual cropping data by field. NKWSD also has the luxury of recording irrigation method by field as well. Development of a NKWSD-specific NHI through integration of these data resources provides a spectrum of nitrate leaching risk from the combination of soil, crop type and irrigation methods specific to NKWSD. Soils found within NKWSD were taken into consideration as were the 2012 cropping data and current irrigation methods. Soils, crops and irrigation systems that are potentially higher risk were assigned higher numerical values in relation to those that are of lower risk. These assigned values were then assessed for each field to determine the relative nitrate leaching risk, or NHI value.

It should be noted that this work is preliminary in nature and more refinement of actual values assigned to each variable impacting leaching may be conducted in the future. Those efforts were outside the scope this initial evaluation. Saying that, the values used adequately represent the magnitude of nitrate leaching risk for each parameter and result in a reasonable spectrum of risk. If the NHI is adopted as a method by the CVRWQCB, it is expected that a more detailed evaluation of input parameters specific to the Kern Sub-Basin will be conducted.

METHODOLOGY RATIONALE

The NHI method employed for the NKWSD is a modification of the NHI work developed by Wu et al. (2005) and expanded upon by Harter et al. (2012) at the University of California at Davis. The work performed by Harter et al. sought to definitively classify larger regions as 'high vulnerability' or 'low vulnerability' in terms of potential nitrate leaching risk. The approach taken by NewFields differed in the sense that the final outcome of the analysis was not intended to classify parcels in a binary fashion, but rather, show areas that were more vulnerable than others within a spectrum of risk for the region of interest. The end result was intended to be more granular than previous NHI work so it could be used as an example of a tool to better relate management and regulatory efforts and nitrate leaching risk.

The specific index values for each variable of the Wu et al. (2005) and Harter et al. (2012) analyses were not used for the NewFields analysis; rather a preliminary area-specific approach was taken where the dominant variables impacting potential nitrate leaching risk were taken into consideration. The specific index values assigned to each variable are relative compared to how much risk they present compared to their companion variables (e.g. coarse textured soils have higher index values compared to fine textured soils). Other factors such as depth to groundwater, effective precipitation and nitrogen use efficiency could be used to refine and potentially improve the analysis, but the NewFields analysis presented here focused solely on the crops, irrigation methods and soils of the NKWSD. The specific variables used in an NHI analysis can and should be modified based on the region of interest when each analysis is performed.

Data Resources

The data resources used for the NKWSD NHI analysis included the following:

- California Department of Water Resources (DWR) crop mapping from 1990 – These data are presented spatially for comparison purposes to present-day cropping systems (Figure 2).

- NKWSD crop mapping from 2012 – These data are presented for comparison to DWR 1990 crop coverages as well as used for crop type identification for NHI determination (Figure 3).

- NKWSD irrigation method mapping from 2012 – These data were used to spatially identify irrigation method for NHI determination (Figure 4).

- Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) for the NKWSD area – These data were used to spatially identify soil type for NHI determination for both drainage and textural classifications (Figures 5 and 6).

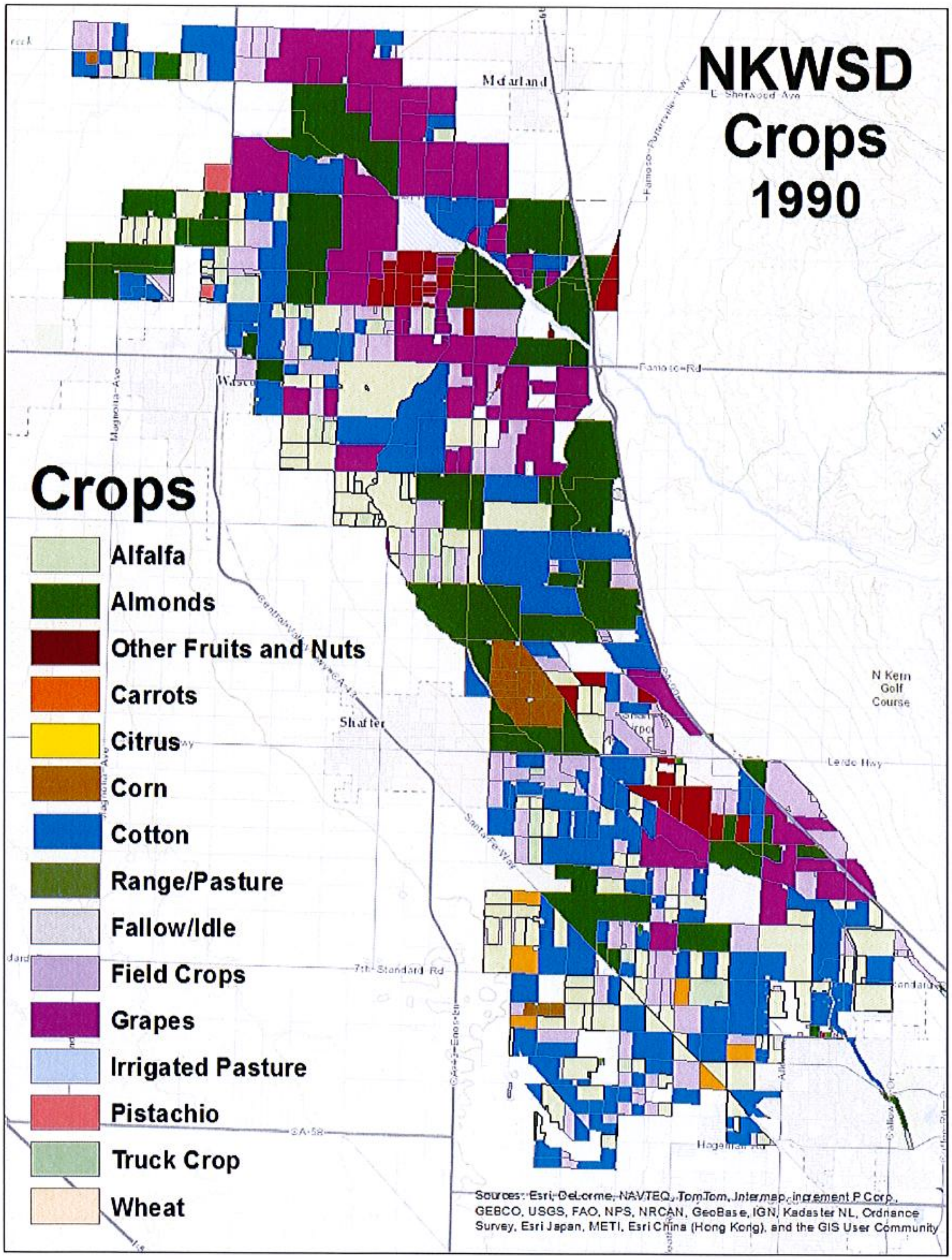

Figure 2. Crop distribution within NKWSD in 1990 (Source: DWR Crop Mapping)

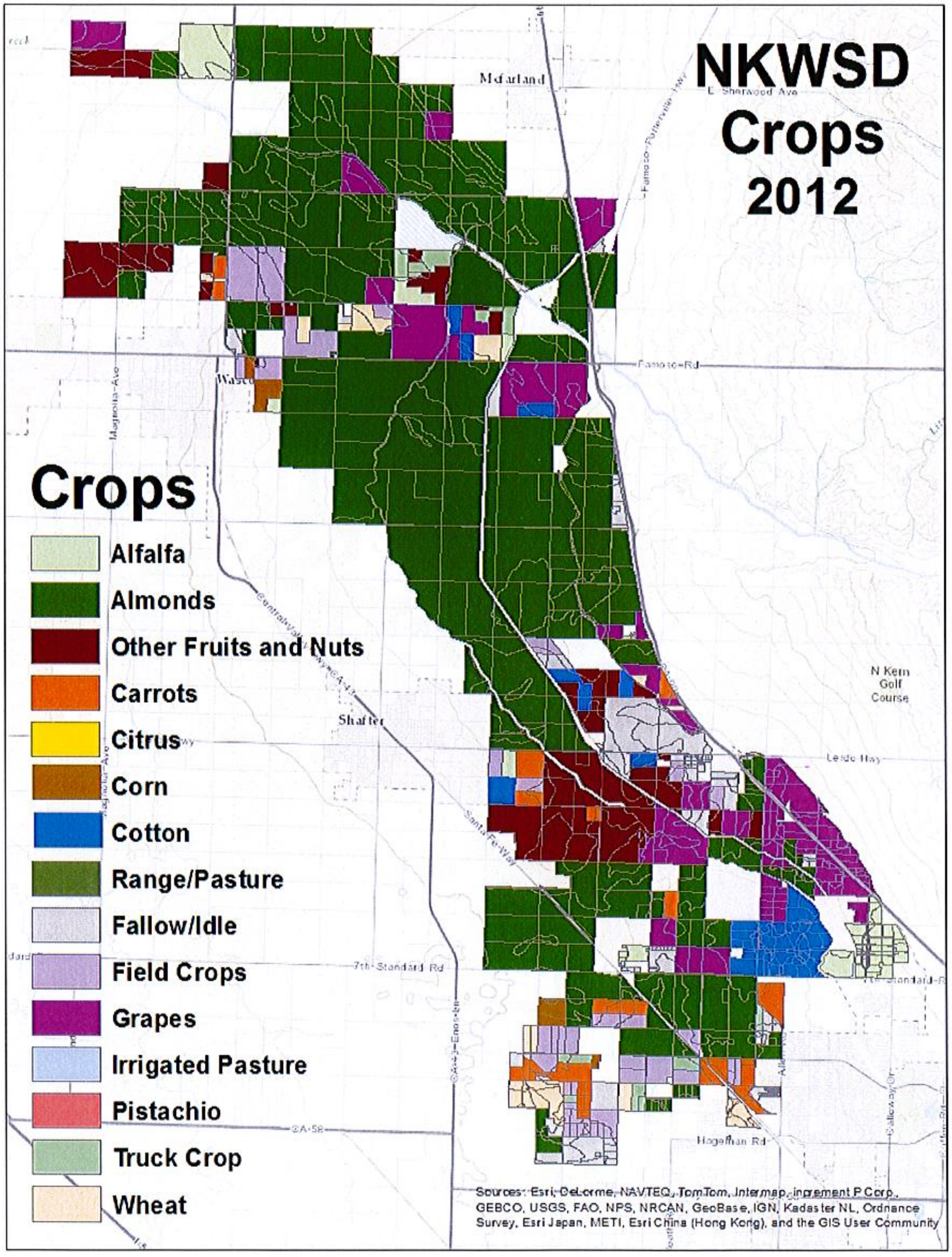

Figure 3. Crop distribution within NKWSD in 2012 (Source: NKWSD Mapping)

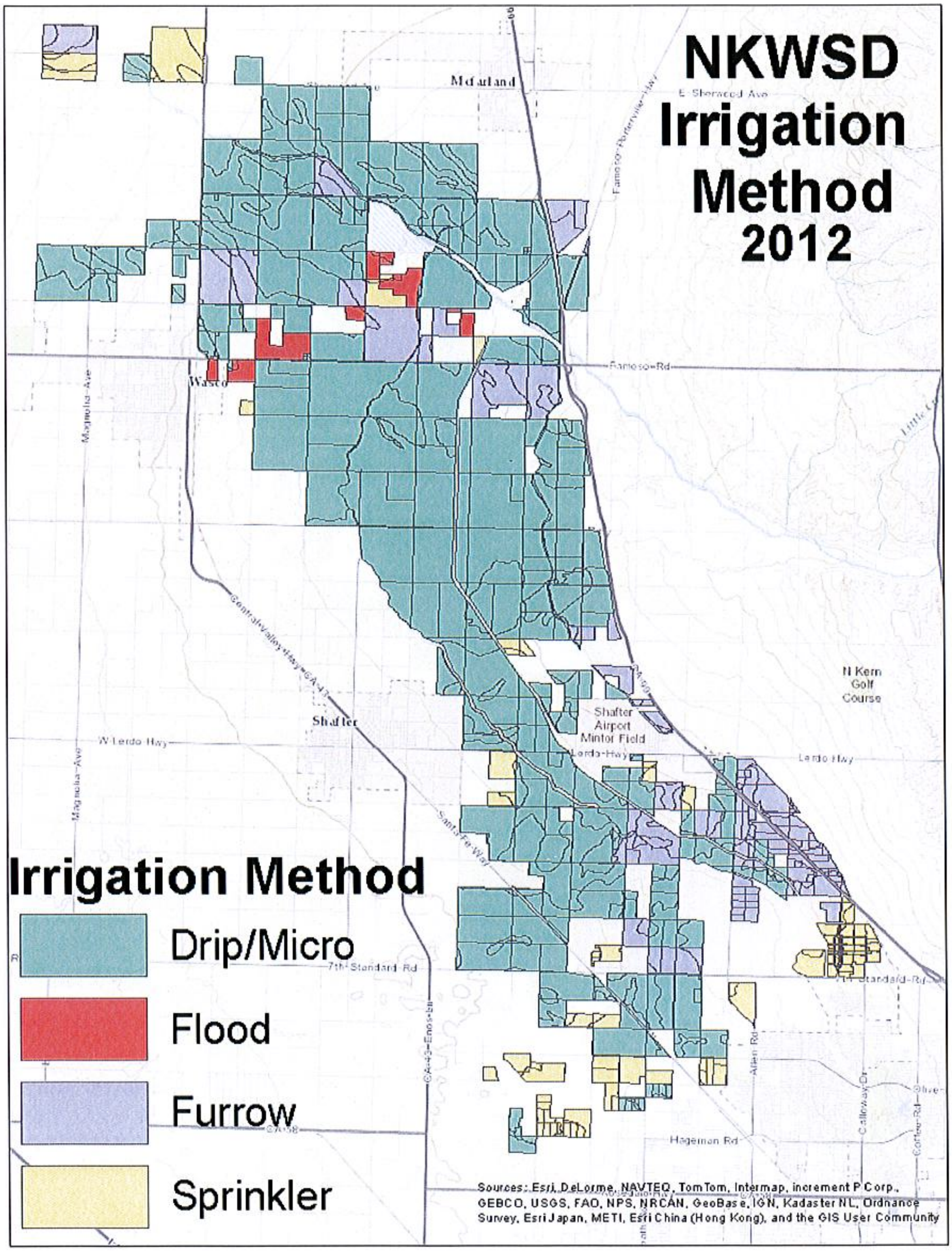

Figure 4. Distribution of irrigation methods within NKWSD (Source: NKWSD Mapping)

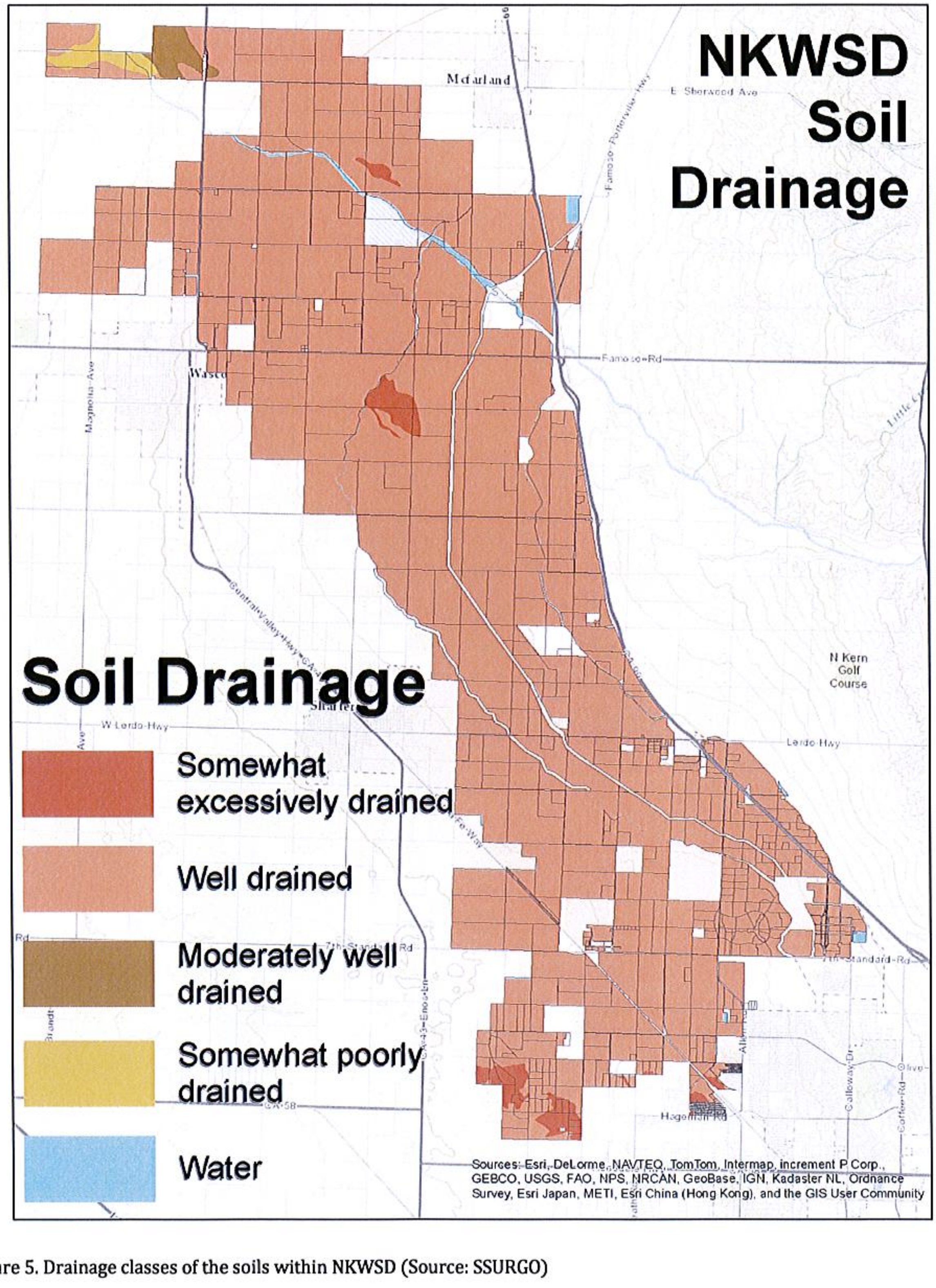

Figure 5. Drainage classes of the soils within NKWSD (Source: SSURGO)

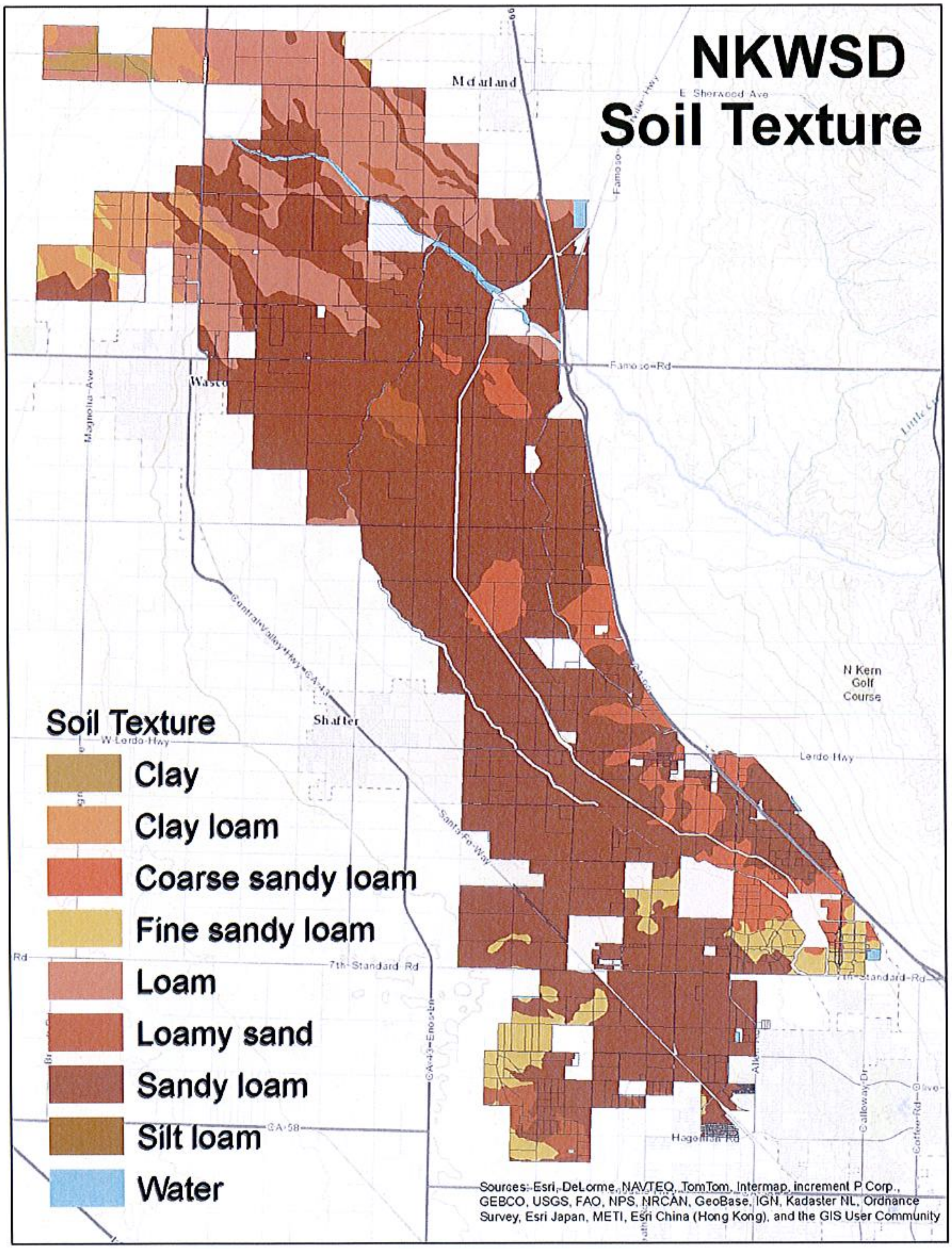

Figure 6. Soil texture of the soils within NKWSD (Source: SSURGO)

NHI Variables Development

Soils

Soil drainage class and soil texture (Figures 5 and 6) greatly influence the movement of water through the profile and potential transport of soluble materials to groundwater. In general, areas with coarser soils and/or soils that drain quickly pose a greater potential risk to nitrate leaching than those that are poorly drained. Therefore, in the NHI system, a higher rank is assigned to soils that possess more rapid drainage.

The seven drainage classes recognized by the USDA were simply numbered from one to seven; one being the lowest risk (very poorly drained) to seven being the highest risk (excessively drained) (Table 1). Using a series of geo-processing tools, the numerical value assigned to each drainage class was applied to the spatial soils layer provided by SSURGO. Each soil polygon within the SSURGO spatial soils layer then had a NHI assigned to it based on the drainage class of that soil polygon.

In addition to the drainage class of the soil, other soil properties of each soil mapping unit (Tables 1 and 2) may be considered as refinement of the soil input parameter in the future if deemed appropriate. For example, the use of the soil textural class could be used in addition to or in place of the drainage class.

Table 1. Variable ranking for soil drainage class

Drainage Class	Variable Ranking
Excessively drained	7
Somewhat excessively drained	6
Well drained	5
Moderately well drained	4
Somewhat poorly drained	3
Poorly drained	2
Very poorly drained	1

Table 2. Example additional variable for soil textural input.

Textural Classification	Textural Grouping	Variable Ranking
Coarse sandy loam	Coarse	3
Loamy coarse sand	Coarse	3
Loamy fine sand	Coarse	3
Loamy sand	Coarse	3
Sand	Coarse	3
Fine sandy loam	Medium	2
Loam	Medium	2
Sandy clay loam	Medium	2
Sandy loam	Medium	2
Silt loam	Medium	2
Silty clay	Fine	1
Silty clay loam	Fine	1
Clay loam	Fine	1

CROPS

Crop data by field for 2012 were provided by NKWSD. The crops were either grouped with other like crops (for example, peaches and plums) because of similar characteristics and/or because of small acreage (i.e. truck crops, such as peppers and other vegetables). Most crops were used as provided (e.g. almonds, citrus, cotton). The variable ranking for each crop type was established based on known rooting depths. Crops with greater rooting depths were assigned smaller variable rankings because of their increased potential to mine nitrate throughout a deeper soil profile. The shallower rooted crops received higher variable rankings according to respective rooting depths (Table 3). The rankings were then assigned to individual crops based on effective rooting depths.

While the only crop-specific factor considered in this analysis was the rooting depth of the particular crop, other factors such as nitrogen use efficiency, timing and duration of nitrogen uptake, total annual nitrogen applied, etc. could be used to further refine the NHI results.

Table 3. Variable Ranking for Rooting Depth

Rooting Depth Index (ft)	Variable Ranking
>4.5	1
3.0-4.5	2
1.6-2.9	3
0-1.5	4

IRRIGATION METHOD

The irrigation method (Figure 4) used in each parcel was included with the crop data supplied by NKWSD. Relative and common irrigation efficiencies for four methods (flood, furrow, sprinkler and drip/micro) were considered when assigning variable rankings for each method. Method of applied water (e.g. gravity or pressurized system) was also considered. Due to the greater risk of passing water through the root zone with gravity as compared to pressurized, more controlled systems, variable rankings were modified accordingly (Table 4). For example, greater weight was placed on flood and furrow irrigation and were given higher values respectively. It should be noted that this was performed to provide an example of how variable rankings can be modified according to known expertise, research results, local knowledge, unique conditions, etc. Ultimately, however the resultant NHI shows the relative differences by field as long as appropriate partitioning and ranking of the variables takes place. Actual ranking values are of lesser importance as compared to appropriate separation of the variable itself (e.g. type of irrigation method, range of rooting depth, etc.)

Table 4. Variable Ranking for Irrigation Method

Irrigation Method	Variable Ranking
Flood	5
Furrow	4
Sprinkler	2
Drip/Micro	1

NHI Determination

Once variable rankings were assigned to each of the partitioned variables (soil drainage class/soil texture group, crop type rooting depth, irrigation method for each crop), the three individual index values were combined and resulted in a single NHI value for each field. For the purposes in demonstrating changes in risk over time, an NHI was developed using soil texture as the soil parameter for both 1990 and 2012 (Figures 7 and 8). Significant differences exist between this 20+ year time frame which shows the improvement and lower risk to groundwater due to inherent changes in agriculture. Another NHI was developed utilizing soil drainage class (Figure 9). Very few differences exist between Figures 8 and 9 indicating that as long as the variables are partitioned reasonably, a clear spectrum of risk can be determined. A more important factor is consideration of the variables (e.g. crop type, soil type, irrigation method, etc.) to be included in the NHI initially. Note that the relative vulnerability of an individual field is similar when both NHI analyses are compared. The range of NHI results using soil drainage class is larger than the range of results using soil texture because the range of index values for drainage class is larger (1-7) than the range for soil texture (1-3). However, relative to the range of results produced by each analysis, the vulnerability of each field is similar.

Interpretation and Conclusions from the NKWSD NHI Analysis

Within the last 20+ years, the cropping patterns within NKWSD have largely shifted from generally shallower-rooted annual crops such as a variety of row and field crops (Figure 2) to more permanent, deeper-rooted crops such as almonds and grapes (Figure 3). Correspondingly, irrigation practices have shifted from less efficient, gravity supplied methods (e.g. flood and furrow) to more efficient and uniform pressurized systems (e.g. sprinkler and drip/micro). This shift in crop types and irrigation methods is not unique to the NKWSD, rather common across much of the Kern Sub-Basin. The benefit of this shift can be clearly shown when viewing the results of an NHI for historic conditions from 1990 (Figure 7) to current conditions as of 2012 (Figures 8 and 9).

There are a few areas within the NKWSD that have a higher nitrate leaching risk than other areas. For the vast majority of this area however, the risk of nitrate leaching within NKWSD is negligible due to the reasons previously mentioned. That being said, NKWSD is currently completely contained with an area classified as "high vulnerability" by the CVRWQCB. These two classifications are currently in complete opposition to one another.

Current land use and management practices at the land surface were not taken into consideration when establishing the generalized and broad-reaching "high vulnerability" classification. This is a significant omission because the majority of the groundwater quality issues present today are relics of different cropping systems and land management strategies that were in place decades ago.

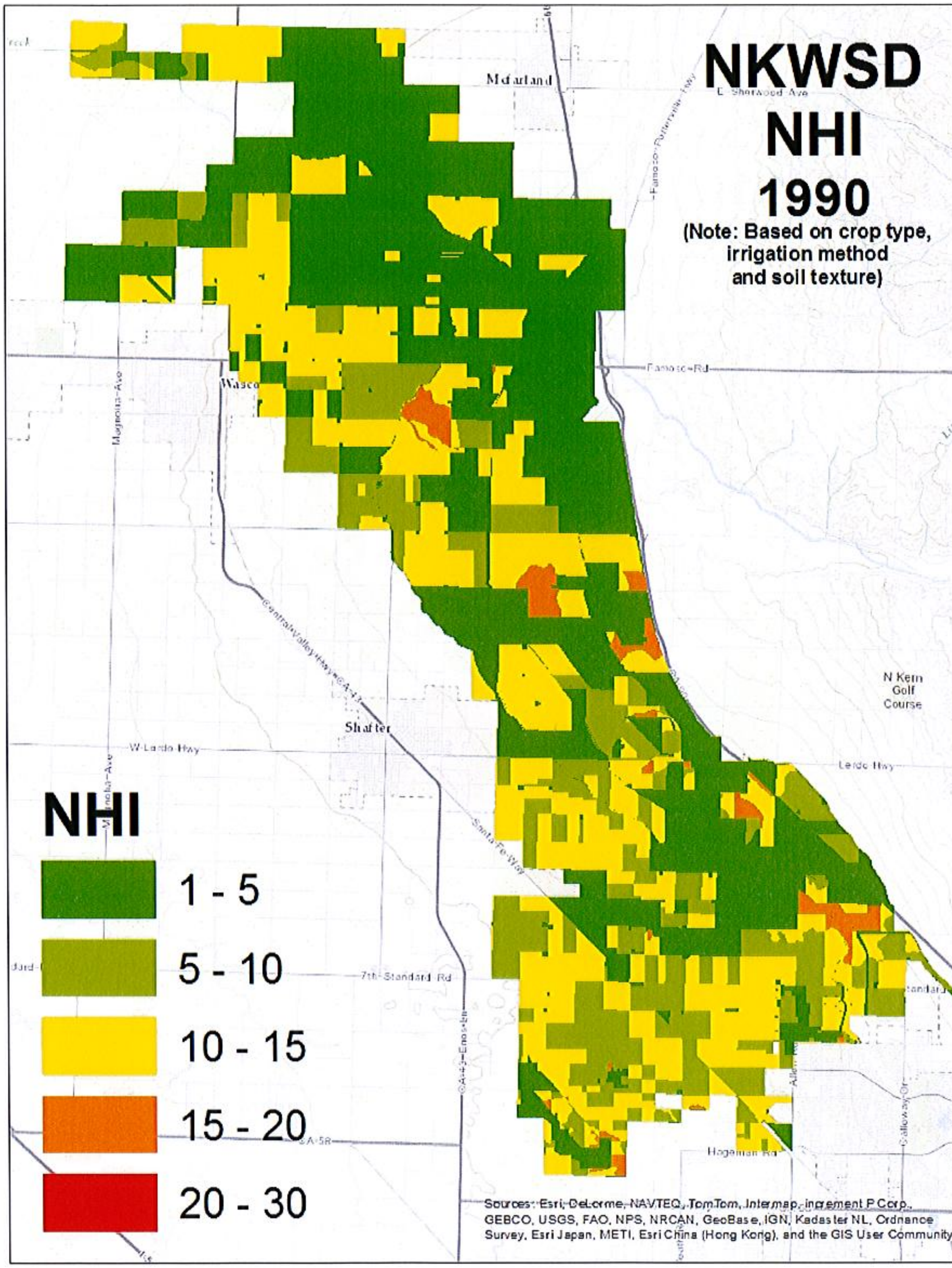

Figure 7. Nitrogen Hazard Index for NKWSD in 1990 using soil texture for the soil component

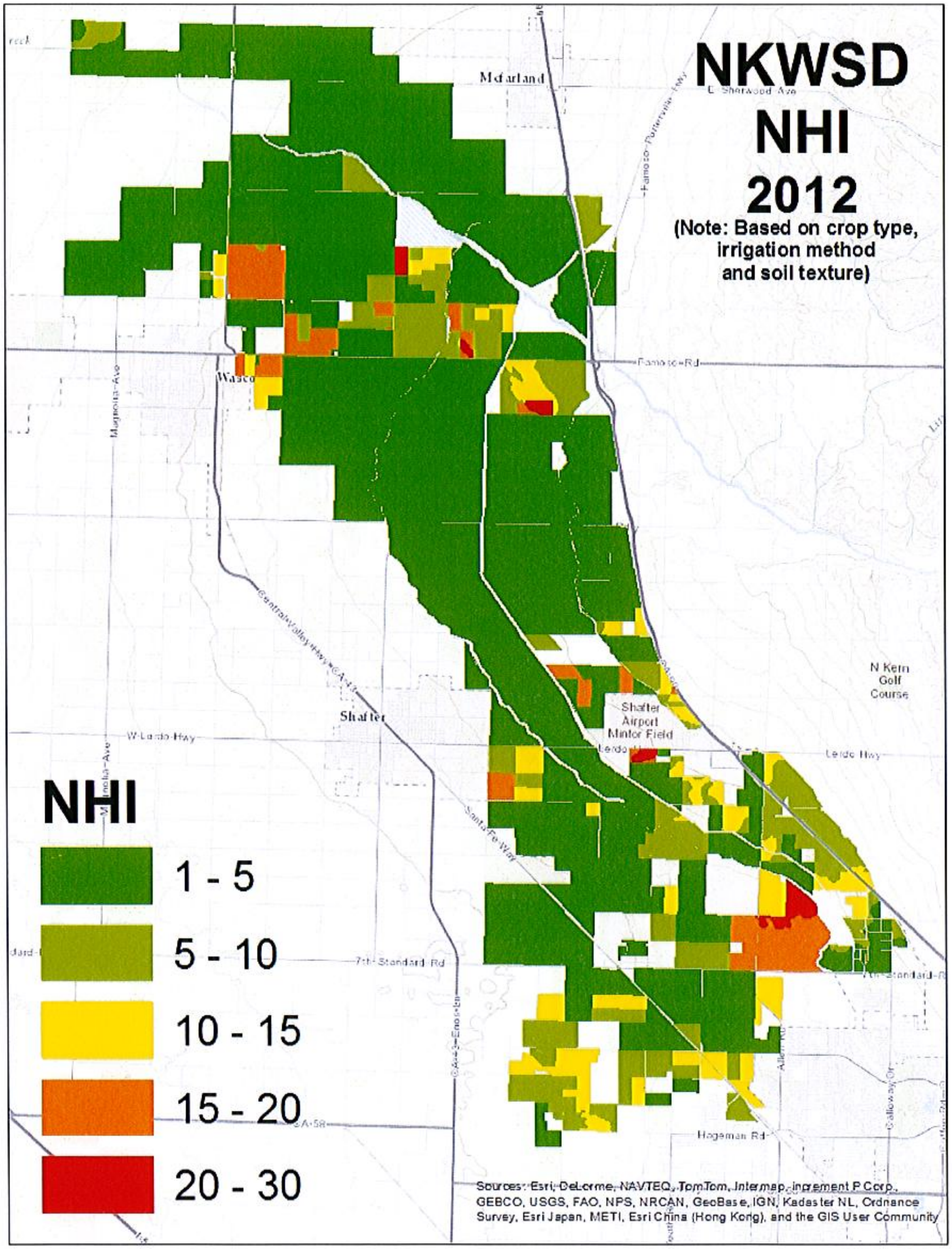

Figure 8. Nitrogen Hazard Index for NKWSD using soil texture for the soil component

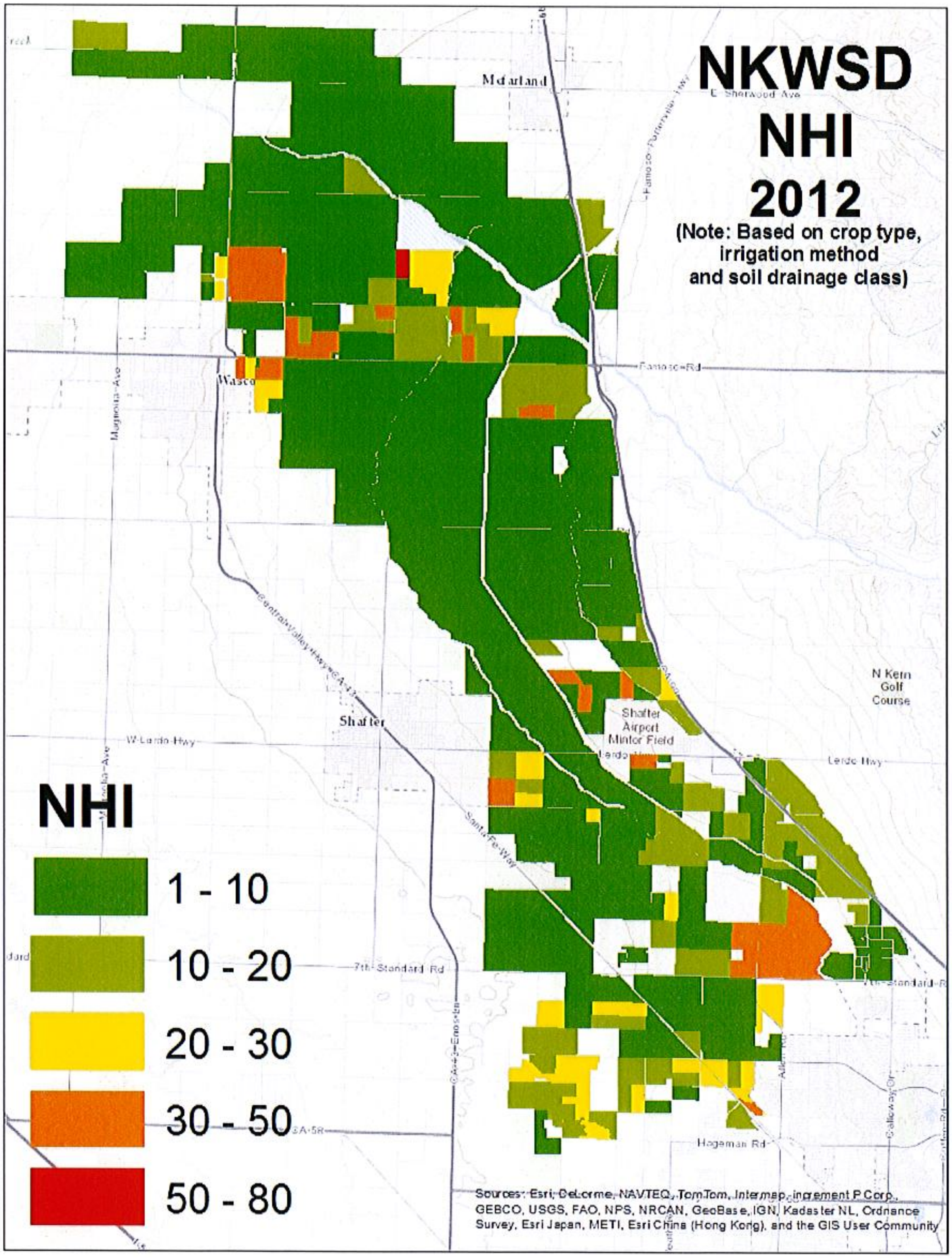

Figure 9. Nitrogen Hazard Index for NKWSD using soil drainage class for the soil component

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Wu, L., Letey, J., French, C., Wood, Y. & Birkle, D. (2005) Nitrate leaching hazard index developed for irrigated agriculture. Journal of soil and water conservation, 60, 90–95.