MEMORANDUM

Date: August 7, 2012

To: File: Russian River; TMDL Development and Planning

From: Forest Fortescue

Subject: GIS Model Development for Assessing Risks from Septic Systems

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Sections of the Russian River are listed for indicator bacteria on the federal 303(d) list of impaired waters of the United States[1]. North Coast Regional Water Quality Control Board (Regional Board) staff are currently developing a Total Maximum Daily Load (TMDL) to address the impairments to water quality in the Russian River Watershed. Failing or sub-standard onsite wastewater treatment systems ("septic systems") are believed to be at least in part responsible for the impairments in the watershed.

The Russian River Watershed (Figure 1) is located within portions of Mendocino and Sonoma Counties. The watershed is divided into nine sub-watersheds. The majority of the population of the watershed resides in the Mark West Creek (the Cities of Santa Rosa, Rohnert Park, Sebastopol and Windsor) and Upper Russian River (City of Ukiah) sub-watersheds.

Figure 1

A Geographical Information System (GIS)-based approach is used to model risks to water quality from across the Russian River Watershed. The basic goal is to assess risk from a leaking or otherwise failing septic systems and to model compliance with the Regional Board's Basin Plan.

NOTE: The use of parcel data in this model was intended only for use as a statistical metric. This model is intended as a planning tool by Regional Board staff and associated stakeholders, not as an assessment of risk to particular properties. No actionable information should be inferred by the use of parcel boundaries.

[1] http://www.swrcb.ca.gov/northcoast/water_issues/programs/tmdls/303d/#current

The Conceptual Model

Regional Board staff developed a GIS-based septic system risk model in order to assist with early TMDL implementation efforts in the Russian River Watershed. The basic structure of the model (Figure 2) draws from four model inputs selected from the Regional Board's *Policy on the Control of Water Quality with Respect to On-Site Waste Treatment and Disposal Practices* (Implementation Plan)[2]:

1. Hill Slope
2. Soil Classification
3. Soil Depth
4. Setbacks from surface water bodies

Each input was assigned a ranking based on relative risk to water quality as quantified by the Implementation Plan. A total risk score was calculated from the four model inputs and the results of the analysis were area-weighted to county assessors' parcel boundaries. A description of the methods used in this analysis can be found in the Methodology section of this document.

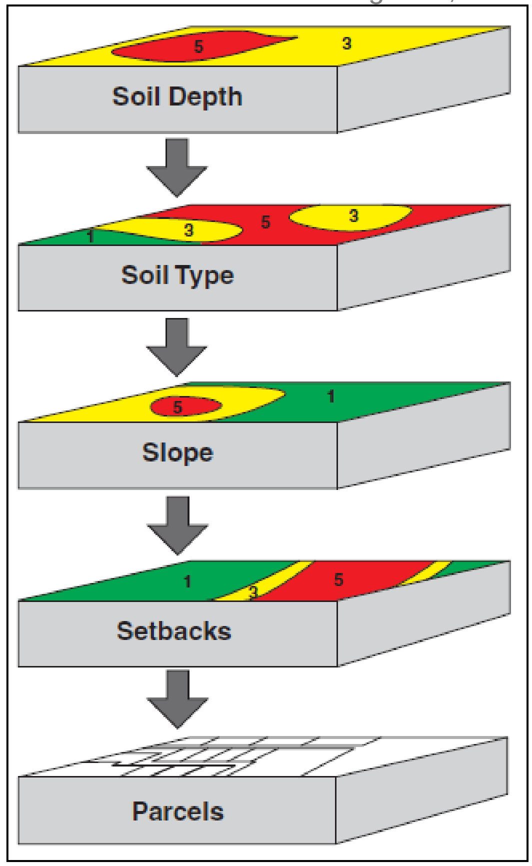


Figure 2

[2] http://www.swrcb.ca.gov/northcoast/water_issues/programs/basin_plan/083105-bp/05_implemention_plans.pdf

GIS Model Development

GIS software was used to spatially analyze the risk to water quality from substandard or failing septic systems in the Russian River Watershed. The four analysis layers were intersected (Figure 2) and the sum of the four risk scores calculated. The resulting total rank score was area-weighted to the parcel in areas of Sonoma and Mendocino Counties that lie within the watershed.

The four model inputs were selected from criteria outline in the Regional Board Implementation Plan. Rankings for each input layer were assigned from 0 (no ranking) to 5 (high risk). Table 1 details the ranking criteria for each of the input layers.

Table 1: Model Ranking Overview (from Poster)

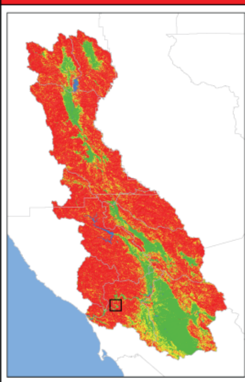
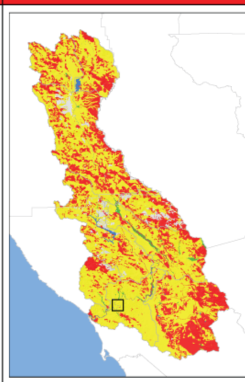
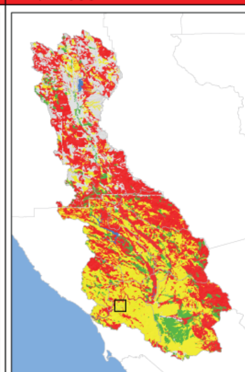
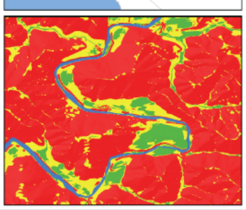
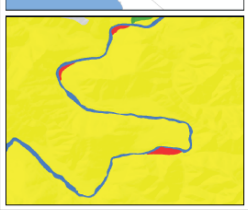
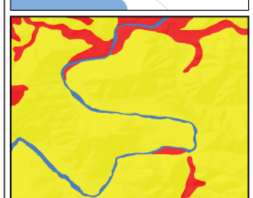
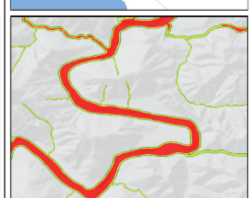
Rank	**Hill Slope**	**Hydrologic Soil Groups**	**Soil Depth**	**Setbacks**
Data Source	National Elevation Dataset 1/3 Arc-Second (10m) Digital Elevation Model	NRCS SSURGO Dataset Portions of Sonoma and Mendocino Counties (CA097,CA687, CA694)	NRCS SSURGO Dataset Portions of Sonoma and Mendocino Counties (CA097,CA687, CA694)	-NHD 24k-Flowlines -WBD (HUC10) -FEMA dFIRMs Portions of Sonoma and Mendocino Counties
Not Ranked	None	Not Assigned in SSURGO Database	Not Assigned in SSURGO Database	Areas Beyond Setbacks
Low Risk (Rank 1)	**0°- 10° Slopes**	**A**	**Greater than 48" Soil Thickness**	**50'-100' (Perennial Streams) 25'-50' (Ephemeral Streams)**
Moderate (Rank 3)	**10°- 30° Slopes**	**B,C**	**Between 36" and 48" Soil Thickness**	**0'-50' (Perennial Streams) 0'-25' (Ephemeral Streams)**
High Risk (Rank 5)	**30° and Greater Slopes**	**D**	**Less than 36" Soil Thickness**	**Within FEMA-Defined Floodway**
Russian River Watershed				
303(d) Listed Reach (Fife Creek to Dutch Bill Creek)				
Regulatory Reference	NCRWQCB Basin Plan On-Site System Implementation Plan	Analog for Percolation Suitability Chart (Figure 4-2 in Implementation Plan) SSURGO Hydrologic Soil Groups Correlated to EPA600/R-00/008	NCRWQCB Basin Plan On-Site System Implementation Plan	NCRWQCB Basin Plan On-Site System Implementation Plan
Regional Board Basin Plan Maximum Values	Hill Slope greater than 30 degrees prohibited for leach field installation	Hydrologic Soil Group D determined to be roughly analogous to the 'Unacceptable' (Zone 4) classification in Basin Plan.	Less than 36" to saturated soil/bedrock below leaching trench prohibited	FEMA-designated Floodway used as an analog to the 10 year floodplain referenced in the Implementation Plan

Table 1: Ranking Criteria for model parameters

Hill Slope

Hill slope was derived from 10-meter Digital Elevation Models (DEMs) using the Spatial Analyst extension in ArcGIS 9.3.1. The slope layer was derived from National Elevation Dataset (NED) 10m Digital Elevation Model (DEM)s accessed from the USGS' Seamless website[3]. The slope raster was reclassified by the values detailed in Table 2 (Figure 3).

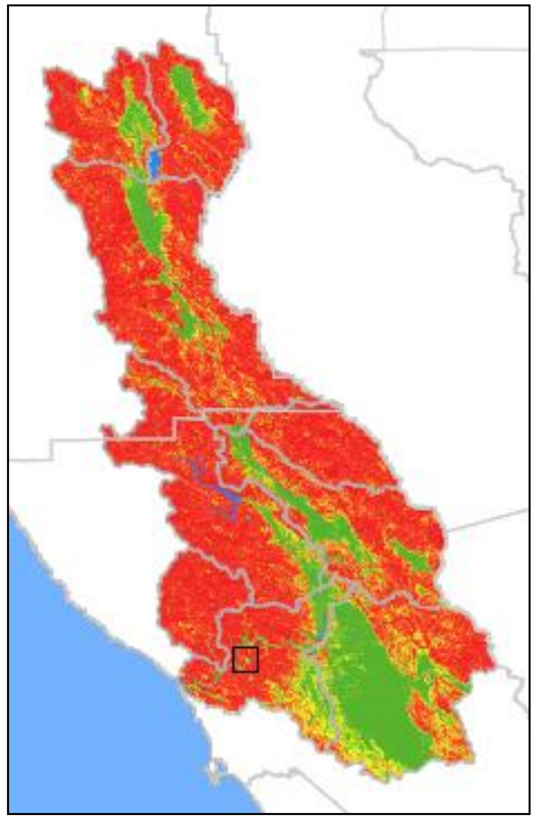


Figure 3

The Regional Board's Implementation Plan states that slopes greater than 30 percent are prohibited for leach field installation. For the initial (2011) iteration of the risk model Staff used degrees rather than slope percentage to assess a risk value for hill slope. The 2012 update to risk model replaced the degree-based slope layer with a percent-based slope layer.

Table 2: Hill Slope Ranking

Rank	***Hill Slope***
1 (Low Risk)	0%-10% Slopes
3 (Moderate Risk)	10%-30% Slopes
5 (High Risk)	30% and Greater Slopes

Soil Depth

Soil depth data were derived from the Soil Survey Geographic (SSURGO) Database. Soil horizon depths are described as a minimum and maximum depth for a particular mapped soil unit. Data were extracted from the appropriate SSURGO database table and the average of the maximum and minimum depths for the deepest soil layer was used to assess the ranking (Figure 4).

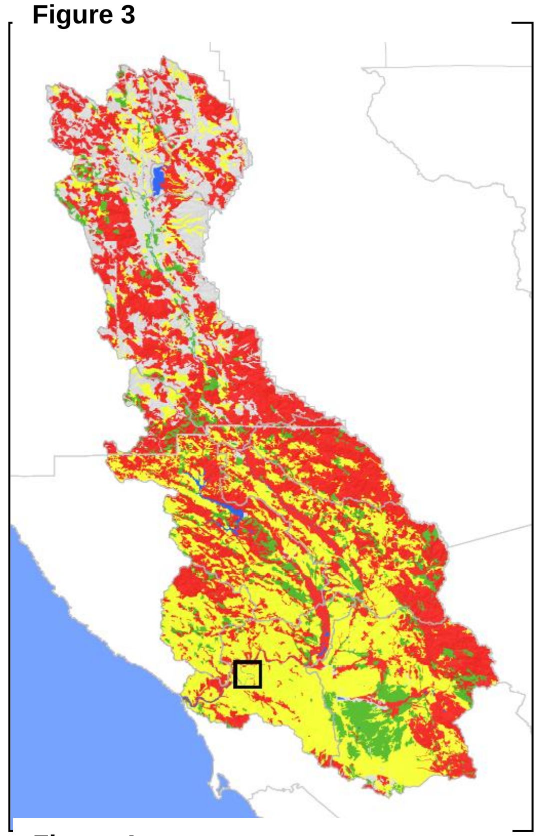


Figure 4

The Implementation Plan requires greater than 36 inches of soil below the leaching trench for installation of a leach field.

Table 3: Soil Depth Ranking

Rank	***Soil Depth***
1 (Low Risk)	Greater than 48" Average Soil Thickness
3 (Moderate Risk)	Between 36" and 48" Average Soil Thickness
5 (High Risk)	Less than 36" Average Soil Thickness

[3] http://seamless.usgs.gov/

Soil Composition

Soil composition data were derived from the Soil Survey Geographic (SSURGO) Database. Hydrologic Soil Groups[4] were used as an analog for site-specific soil composition and hydrology. The Regional Board's Implementation Plan contains a soil composition ternary diagram (Figure 4-2) that defines four zones of soils and ranks them as either acceptable or unacceptable for septic system installation.

Of the available ranking characteristics in the SSURGO dataset, Hydrologic Soil Groups (Table 4) were chosen as the "best fit" criteria to describe the requirements of the Implementation Plan (Figure 5). Data from the database were joined to the GIS shapefiles supplied with the three SSURGO surveys.

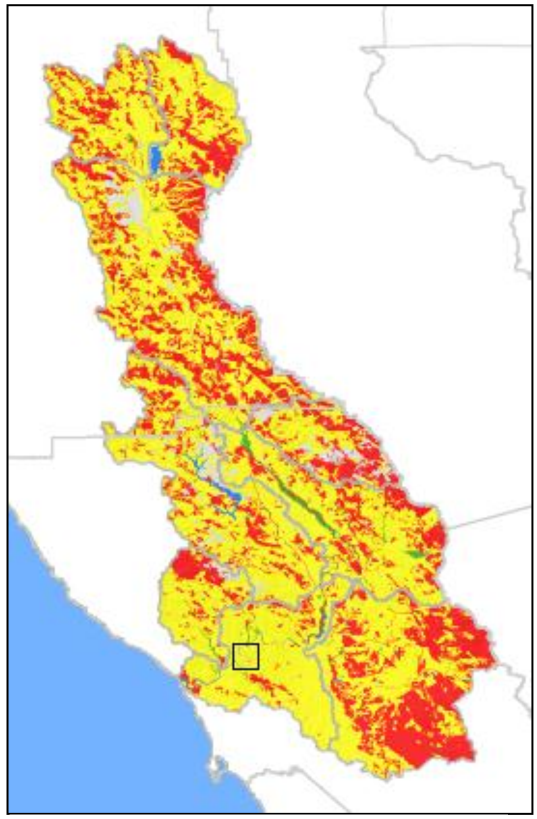


Figure 5

Table 4: Soil Composition Ranking and Description

Rank	***Hydrologic Soil Group(s)***	***Description***
1 (Low Risk)	A	***Group A***—*Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.*
3 (Moderate Risk)	B,C	***Group B***—*Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.* ***Group C***—*Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.*
5 (High Risk)	D	***Group D—****Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table within 60 centimeters [24 inches] of the surface are in this group, although some may have a dual classification, if they can be adequately drained.*

[4] http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba

Stream Setbacks

Stream setbacks were created using the ArcGIS Buffer geo-processing tool on National Hydrologic Dataset (NHD) stream shapefiles and FEMA Digital Flood Insurance Rate Maps (DFIRM)s (Figure 6). Perennial and intermittent/ephemeral stream data were used to define buffer distances from the NHD dataset and the buffers were composited to create the final setback layer.

Rankings were assigned from the setbacks required in the Implementation Plan for the installation of leach fields (Table 5). High Risk (prohibited from development) areas are described as being within the 10-year floodplain in the Implementation Plan. FEMA-defined floodways were used as an analog for the 10-year floodplain as 10 year delineations were unavailable in GIS formats.

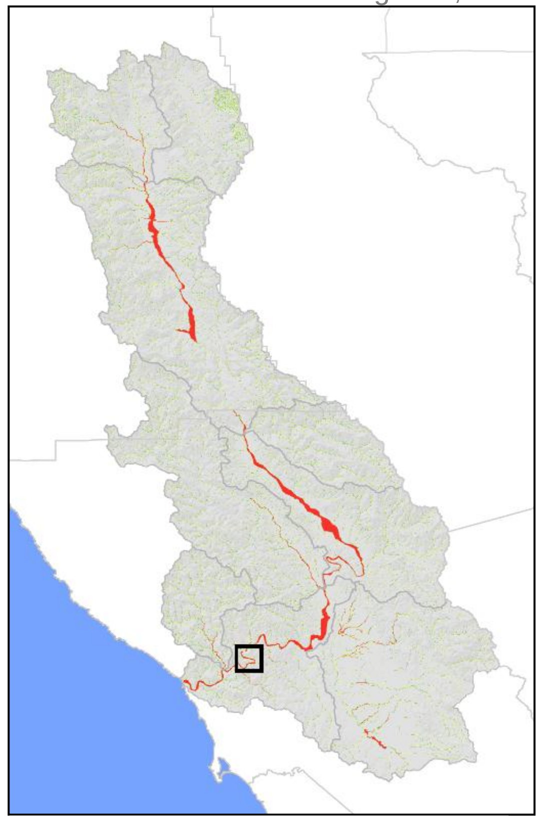


Figure 6

Table 5: Stream Setback Ranking

Rank	***Stream Setbacks***
1 (Low Risk)	50'-100' (Perennial Streams) 25'-50' (Ephemeral Streams)
3 (Moderate Risk)	0'-50' (Perennial Streams) 0'-25' (Ephemeral Streams)
5 (High Risk)	Within the FEMA-Defined Floodway (analog for 10-year floodplain)

Methodology

2011 Model Design

The four input layers were converted to polygon shapefiles as necessary[5] and intersected using ArcGIS 9.3.1's Intersect geo-processing tool to generate an output polygon shapefile. As shown in Figure 7, the intersection process divides the total area of the watershed into many small 'slices'. Each 'slice' contained the four individual rank scores. The individual rank scores of each 'slice' were summed to yield a total ranking score ranging from zero[6] to twenty. The area of each 'slice' was also calculated.

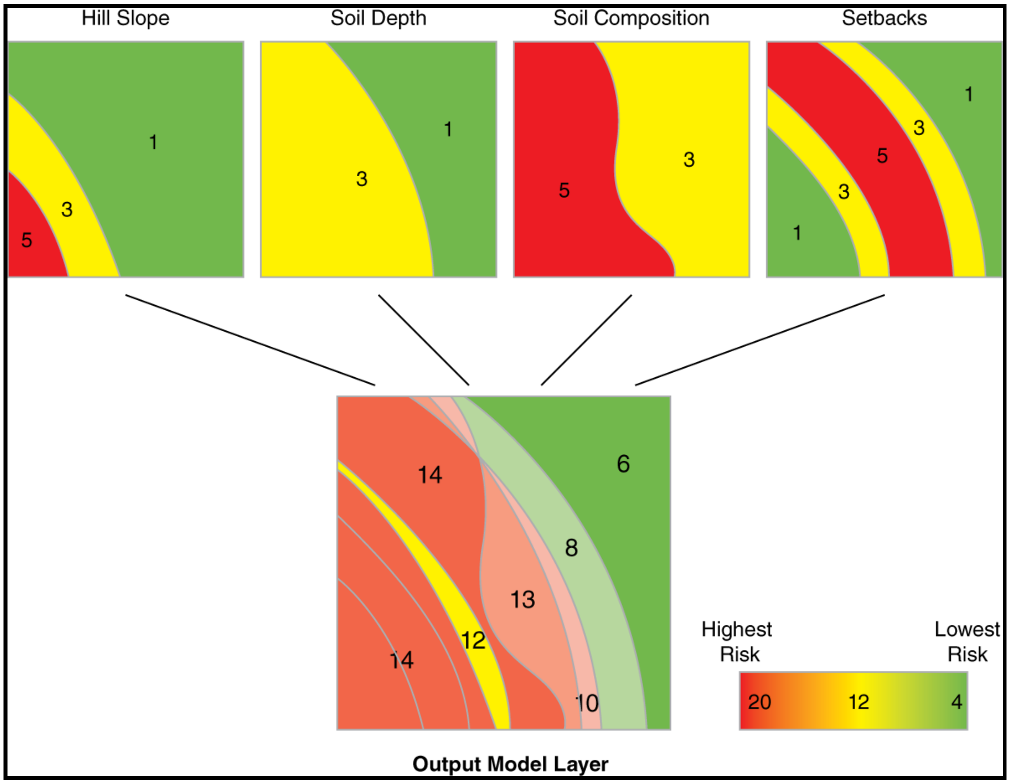


Figure 7

The rankings were scaled to a meaningful spatial metric. All of the potential 'slice' ranks across the total area of a given parcel were weighted to generate a more realistic spatial description of risk. Sonoma and Mendocino County parcel map shapefiles were merged and clipped to the boundaries of the Russian River watershed.

Formula for area-weighting the parcels for the final model:

$$\sum \frac{A_S}{A_{Tot}} * R_{Tot}$$

Where:

- A_S = Area of a 'slice'
- A_{Tot} = Total area of a parcel
- R_{Tot} = Total ranking for each 'slice'.

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[5] Required for the original hill slope raster image file

[6] Note: Rankings of zero are possible due to the intersection of areas of 'no data'

2012 Model Design

In August 2012 the Septic System Risk Model was updated. The updates were:

- Replacing the degree-based slope input layer with a percent-based slope layer
- Converting results of analysis to a 10-meter raster, rather than using an area-weighted parcel vector base

Results

The parcels within each of the nine sub-watersheds of the Russian River watershed[7] were selected with a Select by Location operation in ArcMap. The resulting data was plotted in Excel and histograms and central distribution plots displaying the distribution of rank scores by sub-watershed. A box plot (Figure 8) was also produced to compare the rankings across the entire watershed.

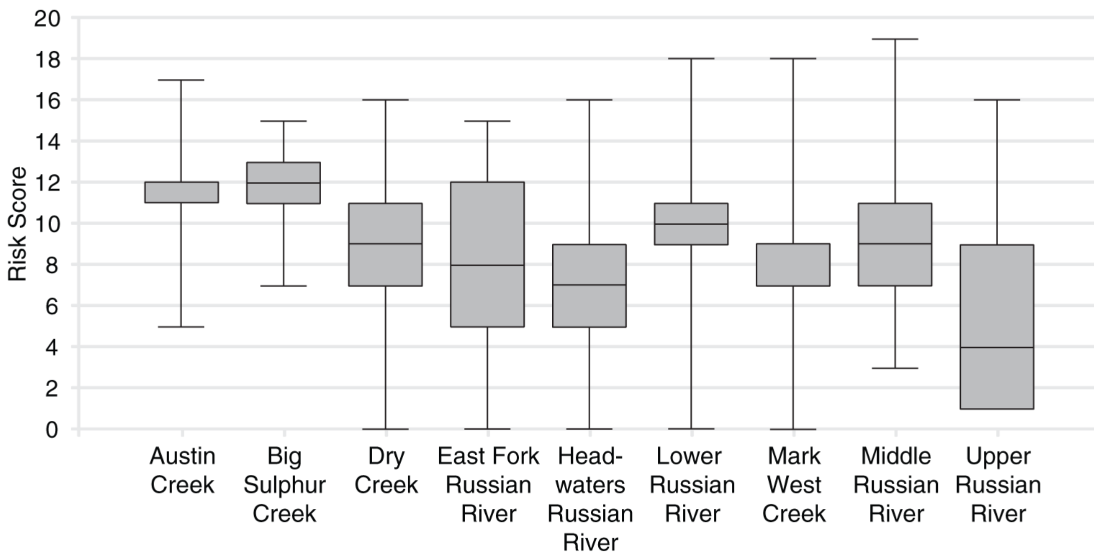

Figure 8

Conclusions and Future Work

The Austin Creek, Big Sulphur Creek, and Lower Russian River sub-watersheds were determined to have the highest risk overall. High relief terrain, coupled with shallow soils and, in the case of the Lower Russian River sub-watershed, a large amount of land occupied adjacent to the floodplain (and related poorly-suited soils) of the Russian River contribute to the relatively high rankings.

Several issues with the data came to light as the model was developed. The Mendocino County SSURGO databases contain areas (notably Potter Valley and the City of Ukiah in the Upper Russian River sub-watershed) where there is no soil data for composition or depth. The resulting distribution of risk scores in the Upper Russian River sub-watershed are skewed low because the greatest number of parcels in that area lie within the Ukiah city boundaries.

Future revisions of the model will incorporate sewered areas to mitigate for the issues mentioned above. Land use information will also be added to the weighting formula of

[7] Sub-Watershed delineation by Watershed Boundary Dataset HUC10 shapefile.

the final model. The final version of this model will utilize a spatial regression technique to replace parcels with a ‘heat map’ showing zones of potential risk across the watershed.

The Implementation Plan is currently (as of September, 2011) undergoing revision. Development of the next version of this model will begin once the revision process has completed and will incorporate any changes made to the requirements of the Policy.