Identification of Shallow Groundwater Flood Risk Areas, Spring Green Area, Wisconsin

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ABSTRACT

The Spring Green, Wisconsin area has been susceptible to groundwater inundation flooding in the recent past in areas located outside the Federal Emergency Management Agency (FEMA) *Digital Flood Insurance Rate Mapped* (DFIRM) Special Flood Hazard Areas (SFHA) for the Wisconsin River. Historic flooding during June 2008 inundated nearly 7 square miles of the Spring Green area with standing water for 5 months and caused contamination to water supply wells, agricultural crop loss, and damage to houses, building, and infrastructure. The project objectives were to identify areas in portions of southern Richland and Sauk counties, Wisconsin, that are at risk of groundwater flooding, calculate the frequency of return, and identify mitigation measures that may be feasible. This paper focuses on identifying areas that may be at future risk of groundwater flooding. The approach involved the analysis of existing regional and local data sets and the field mapping of shallow groundwater indicators. Field mapping was conducted June 21 through 25, 2010, following heavy spring rains. Multiple lines of evidence were compiled from historical aerial photographs, terrain model analysis, regional geologic and hydrogeologic setting information, the June 2008 flood extent (mapped by Fred Iausly, Sauk County GIS Analyst), and field-mapped indicators such as standing water, soil types, and wetland vegetation to identify areas at potential risk of groundwater inundation flooding. The areas identified as having potential inundation flooding risk were ranked into four qualitative risk classes based on frequency potential. The qualitative risk classes are higher frequency, moderately higher frequency, moderately lower frequency, and lower frequency. The risk map that was generated was used to calibrate a GSFLOW model built to calculate the frequency of return and it was used to assist with an evaluation of potential mitigation measures.

BACKGROUND AND OBJECTIVES

The study area (i.e., Spring Green area) is located in southwestern Sauk County and southeastern Richland County Wisconsin, near the towns of Spring Green and Lone Rock and is situated on the north side of the Wisconsin River valley (Figure 1). In the Spring Green area, the Wisconsin River valley comprises Pleistocene outwash sands and gravels hundreds of feet thick overlying Cambrian sandstones and, to a lesser extent, shales of the Elk Mound Group (Clayton and Attig, 1990). Two terraces occur above the modern Wisconsin River floodplain and are overlain by windblown sand deposits, which create subtle topography on the relatively flat terrace surfaces. The valley is bordered to the north by bluffs of the Driftless Area uplands. Two tributary streams, Bear Creek and Honey Creek, flow out of the uplands and into the Wisconsin River on the west and east sides of the Spring Green area, respectively. A third stream, Big Hollow, drains the uplands and intersects the Wisconsin River valley in the center of the Spring Green area and becomes a losing stream upon entering the valley.

In June 2008, the Spring Green area (Figure 1) experienced extreme flooding due to heavy rains that fell on snow-melt saturated soils and higher than normal water-table conditions. Heavy rains on June 7 and 8, 2008 caused groundwater and overland flow to inundate low-lying areas at the ground surface. Approximately 4,378 acres outside the modern Wisconsin River floodplain were flooded in the Spring Green area (Gotkowitz, 2008) for 5 months causing contamination to water supply wells, agricultural crop loss, and damage to homes, buildings, and infrastructure (FEMA, 2008). Figure 2 shows the extent of flooding mapped by the State of Wisconsin International Charter and Eagle Vision (2008) and Iausly (2008). Most of the flooding occurred on the highest terrace of the Wisconsin River, over a mile away from the modern floodplain, and the Wisconsin River did not overflow its banks at anytime during the flood event. Similar flooding has also occurred to a lesser extent in the Spring Green area in1938 and 1993.

AECOM assisted FEMA in identifying flood hazard and risk areas located outside the Wisconsin River floodplain under the Hazard Mitigation Technical Assistance Program (Contract No. HSFEHQ-09-D-1127, Task Order HSFEHQ-10-J-0003). The task order objectives were to:

1) Identify areas at risk of groundwater flooding
2) Calculate frequency of return
3) Identify mitigation measures that may be feasible

This paper focuses on the first objective: identifying flood risk areas through cost effective mapping techniques including using existing geospatial coverages and mapping field observations.

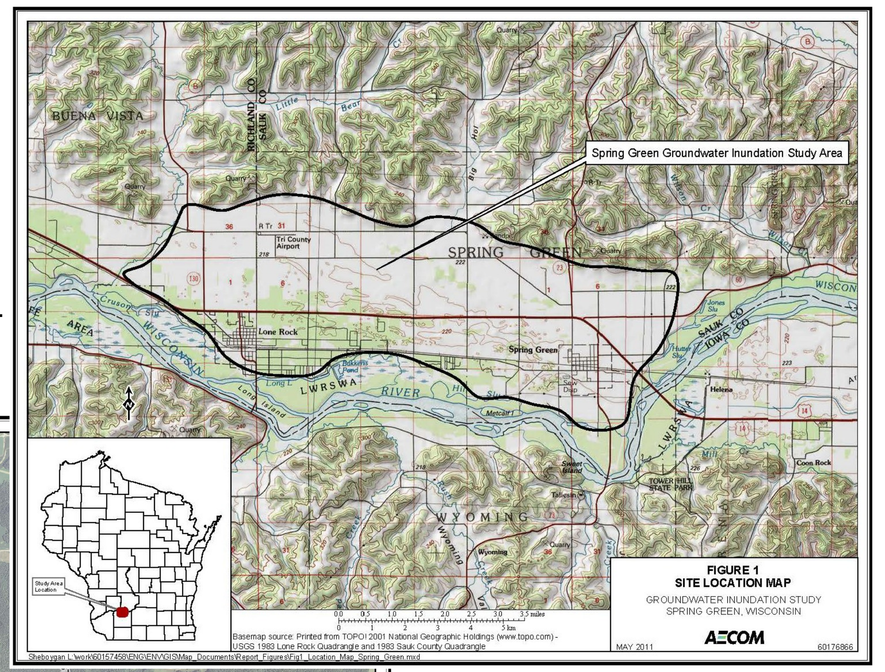

Figure 1- Study Area Location. The study area includes potions of southwestern Sauk County and Southeastern Richland County, Wisconsin, near the towns of Spring Green and Lone Rock and is situated on the north side of the Wisconsin River Valley.

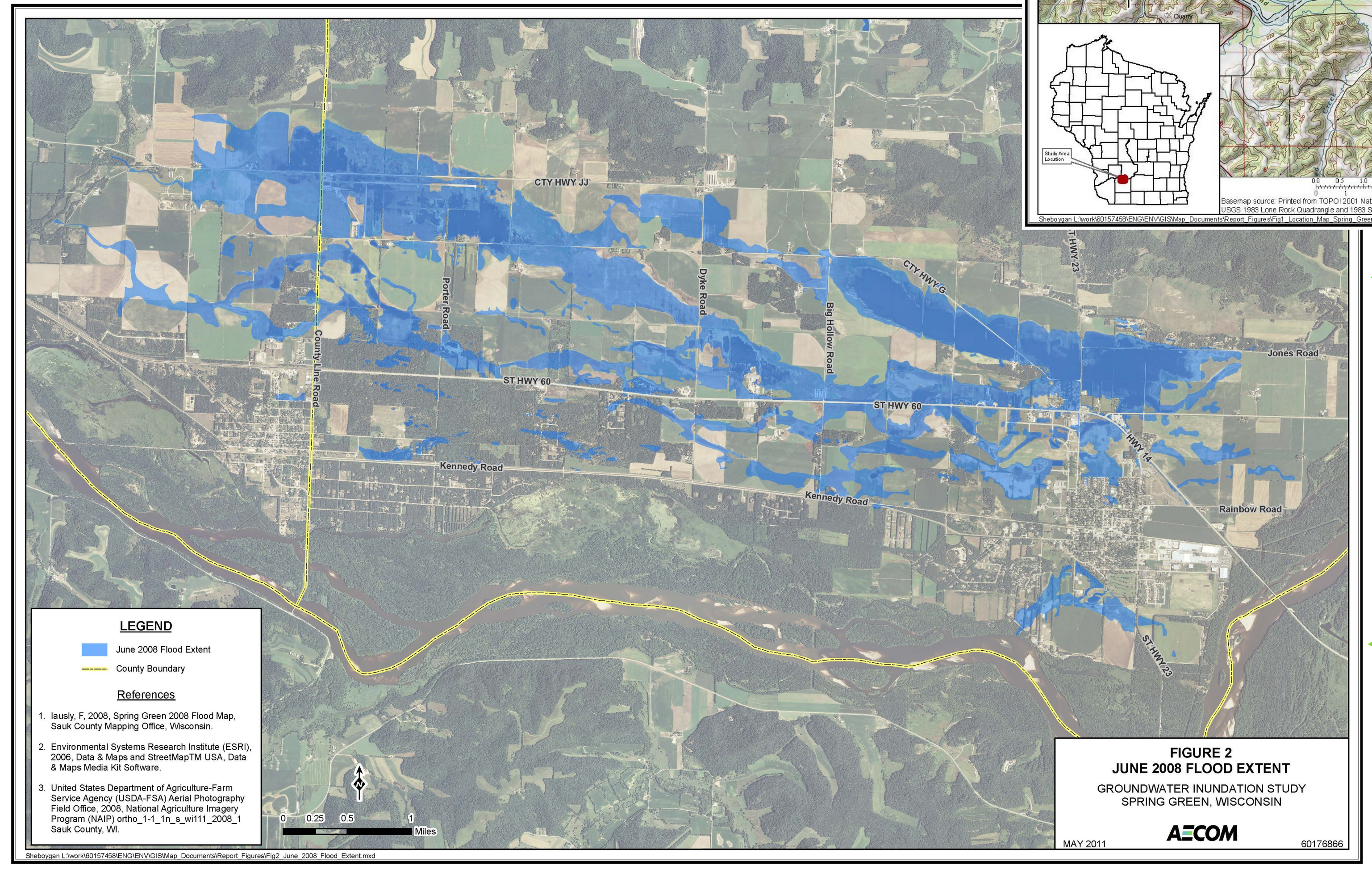

Figure 2 - June 2008 Flood Extent. Flood extent generated by Iausly (2008) from satellite imagery of the Spring Green area for June 17, 2008 and then edited to follow topographic contour.

APPROACH

AECOM's approach involved evaluating existing regional and local datasets and field mapping shallow groundwater indicators. Multiple lines of evidences were used to identify areas at risk to frequent flooding, and the identified areas were qualitatively ranked and mapped using GIS software. The steps followed are summarized below:

- Gathered historical aerial photographs, existing geospatial data layers, and regional/local geology and hydrogeologic information as summarized in Table 1.
- Historical aerial photographs and existing geospatial data layers were examined to preliminarily identify potential flood risk areas.
- Field indicators of shallow groundwater were mapped from June 21 through 25, 2010, following heavy spring rains.
- Outcomes of the field mapping effort were combined with outcomes of the geospatial data and aerial photograph evaluation to generate qualitative risk areas.

Table 1. Geospatial Data and Aerial Photograph Source Summary

Data	County	Source	Reference
LiDAR terrain surface (2-foot topographic contours)	Sauk	Sauk County	3001 Inc (2005)
Geology	Sauk	WGNHS	Clayton and Attig (1990)
Depth-to-Bedrock	Sauk	WGNHS	Gotkowitz and Zeiler (2002)
Water-table Elevation	Sauk	WGNHS	Gotkowitz and Zeiler (2002)
Aerial Photography (2008)	Sauk Richland	USDA NRCS Geospatial Data Gateway (http://datagateway.nrcs.usda.gov)	NAIP
Digital Soil Survey	Sauk Richland	USDA NRCS Geospatial Data Gateway (http://datagateway.nrcs.usda.gov)	USDA NRCS SSURGO
Digital Raster Graphic (DRG)	Sauk Richland	USDA NRCS Geospatial Data Gateway (http://datagateway.nrcs.usda.gov)	USGS
30-meter National Elevation Dataset (NED) - Topographic contours for Richland County were derived from the 30-meter NED for Richland County	Sauk Richland	USDA NRCS Geospatial Data Gateway (http://datagateway.nrcs.usda.gov)	USGS
2008 flood extent and contributing drainages	Sauk Richland	Sauk County Mapping Office	Iausly (2008)
Existing mapped wetlands	Sauk Richland	WDNR	WDNR WWI
National Hydrology Dataset (NHD) - surface hydrology	Sauk Richland	USGS NHD website (http://nhd.usgs.gov/data.html)	USGS USEPA
Historical Aerial Photographs - 1953, 1957, 1958, 1972, 1974, 1981, 1982, 1986, 2005	Sauk Richland	USGS EROS Center website (http://eros.usgs.gov)	Various
FEMA Digital Flood Insurance Rate Map (DFIRM)	Sauk	Sauk County MIS/Mapping Department	FEMA
FEMA advisory floodplain mapping	Richland	Sauk County Zoning Department	FEMA

Notes:
WGNHS - Wisconsin Geological and Natural History Survey
USDA - United States Department of Agriculture
NRCS - Natural Resource Conservation Service
NAIP - National Agricultural Imagery Program
SSURGO - Soil Survey Geographic
WDNR - Wisconsin Department of Natural Resources
WWI - Wisconsin Wetland Inventory
USEPA - United States Environmental Protection Agency
EROS - Earth Resources Observation Systems
FEMA - Federal Emergency Management Agency
USGS - United States Department of Geological Sciences

Photograph 1 - Channelized surface water flow.

Photograph 2 – Standing water observed in a potato field.

Photograph 3 – Cattails growing in a wheat field.

Photograph 4 – Crop stress exhibited in a corn field.

Geospatial Data and Historical Aerial Photograph Analysis

- **Topographic contour and Quaternary geology** - identified geomorphic features that may retain surface water or trap groundwater such as stream terraces, closed depressions within sand dunes, low-lying areas between sand dunes, and features such as small valleys in the Driftless Area that may convey surface water to the flooded area during rainfall events.
- **2008 flood extent mapped by Sauk County (Iausly, 2008)** - reviewed in conjunction with the topographic contours and aerial photographs to assess the influence, if any, of geomorphic features on flooding.
- **Depth of flooding** - calculated by subtracting topographic elevation (2-foot Light Detection And Ranging (LiDAR) terrain model contours) from a flood elevation surface generated from the mapped flood extent (Iausly, 2008).
- **Depth to shallow groundwater** - calculated by subtracting the groundwater elevation surface from the topographic surface. Depth to groundwater contours were created for groundwater depths of 5 feet, 10 feet, and 15 feet below ground surface. Depth to groundwater was overlain on the 2008 flood extent to visualize the correlation between groundwater depths and the 2008 flood extent.
- **Hydric soils and existing Wisconsin Wetland Inventory (WWI) data** - evaluated to identify poorly drained soils and areas where groundwater may be shallow.
- **Depth to bedrock and water table elevations** - compared to assess potential relationships between shallow bedrock and shallow groundwater.
- **Historical aerial photographs** - reviewed for the presence of wet soil conditions. Aerial photos from 1953, 1957, 1958, 1972, 1974, 1981, 1982, 1986, and 2005 were reviewed.

Field Mapping

Field mapping was conducted from June 21 through 25, 2010, from roadside right-of ways and was generally limited to areas within the 2008 flood extent.

- **Geomorphic landforms** - confirmed landforms identified during the prefield analysis of topographic contours, Quaternary geology, and aerial photographs.
- **Surface water features** - identified channelized surface water flow (Photograph 1) and small valleys that convey surface water to the Spring Green area terraces from Driftless Area bluffs.
- **Field characteristics indicative of shallow groundwater conditions** -
  - ⇒ ***Standing water and/or saturated soils*** - coarse, sandy soils such as those typical of the Spring Green area allow water to move rapidly through the soil. Therefore, standing water in the Spring Green area is likely to be the result of groundwater that has risen above the ground surface (Photograph 2).
  - ⇒ ***Soil characteristics indicative of saturated soils*** - very dark and greasy-feeling soil surface or grayish colored subsoil or subsoil mottled with orange colored masses (USDA-NRCS, 2010).
  - ⇒ ***Growth of wetland species*** - vegetation tolerant of wet, oxygen depleted soils caused by shallow water table included cattail, reed canary grass, rushes, willows, and smartweeds. Species such as cattail thrive when the water table is persistently very near or at the soils surface (Photograph 3).
  - ⇒ ***Stress on upland species*** - vegetation species intolerant of wet, oxygen depleted soils included crops (corn, soybeans, and potatoes) and pine trees. Indicators of stressed crops were small plant size compared to surrounding plants (Photograph 4), yellowing leaves, and curled leaves on corn plants. Pine stress was indicated by brown or absent needles.

RESULTS

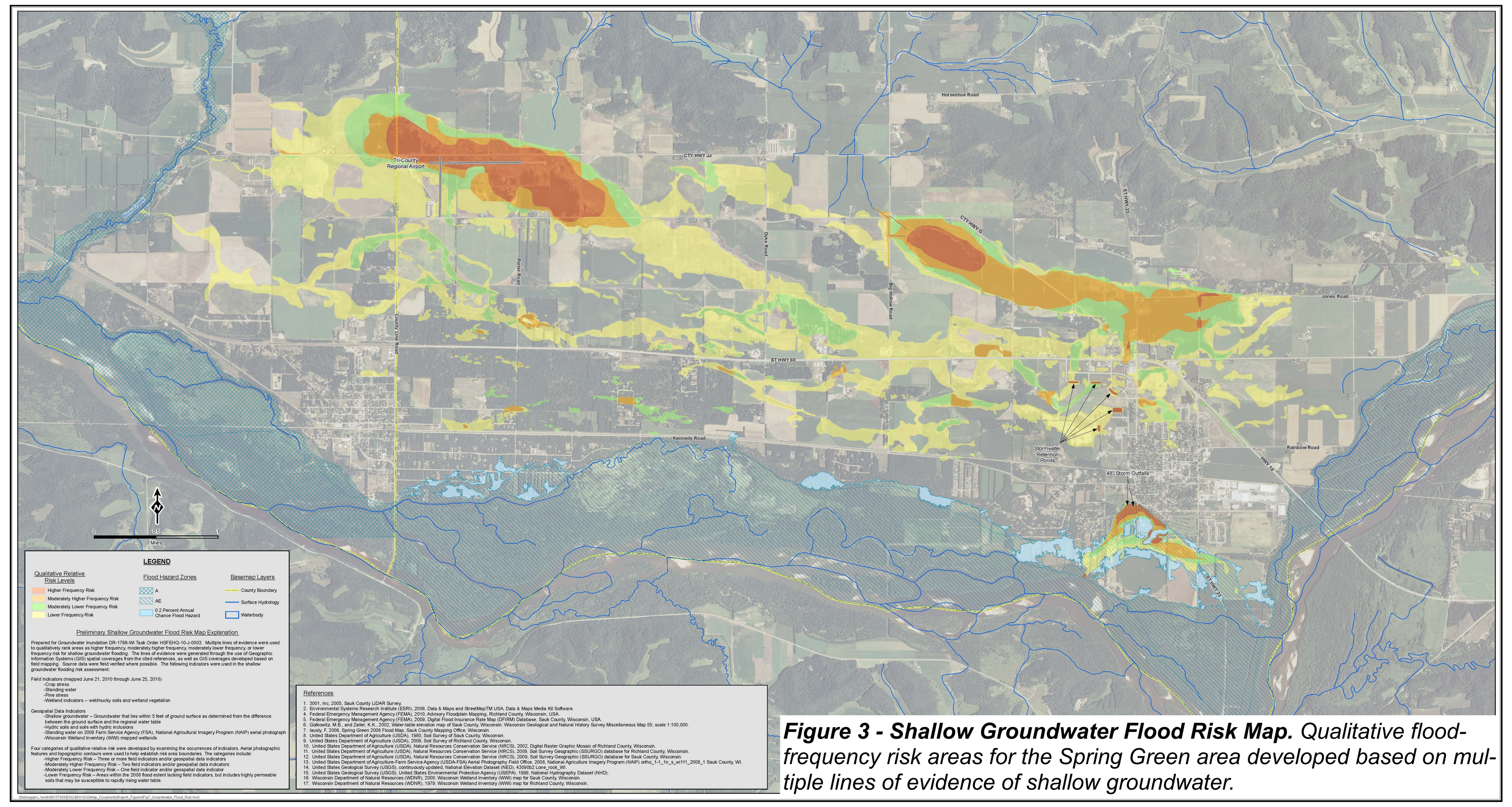

Figure 3 - Shallow Groundwater Flood Risk Map. Qualitative flood-frequency risk areas for the Spring Green area developed based on multiple lines of evidence of shallow groundwater.

Qualitative Risk Ranking

Source data and source data derived GIS coverages and field indicator coverages were used in the evaluation. Qualitative flood-frequency risk areas (Figure 3) were developed based on multiple lines of evidence of shallow groundwater and include:

- ⇒ **Higher Frequency Risk** – Three or more field indicators and/or source data indicators
- ⇒ **Moderately Higher Frequency Risk** – Two field indicators and/or source data indicators
- ⇒ **Moderately Lower Frequency Risk** – One source data indicator
- ⇒ **Lower Frequency Risk** – Areas within the 2008 flood extent lacking field indicators, but includes highly permeable soils that may be susceptible to rapidly rising water table.

Source Data and Derivative Indicators

- Hydric soils and soils with hydric inclusions
- Shallow groundwater (groundwater that lies within 5 feet of ground surface*)
- Wisconsin Wetland Inventory (WWI) for Sauk and Richland County
- Standing water on 2008 NAIP aerial photograph

Field Indicators (mapped June 21, 2010 through June 25, 2010)

- Crop stress
- Wetland indicators (saturated soils, hydric soils, wetland vegetation)
- Pine stress
- Standing water

* Shallow groundwater was defined as 5 feet below ground surface based on the evaluation of water levels at the Mazomanie monitoring well (DN83) during groundwater inundation events (i.e., 1993 and 2008) by Gotkowitz (2009).

Discussion

1) The qualitative risk areas reflect field conditions that existed during the period of June 21 through 25, 2010, and general regional conditions portrayed by source data records.

2) Testing of wetland water quality and soils may be a useful tool to assess the impact of groundwater on hydric soils.

3) Accuracy of the risk areas map could be improved with long-term monitoring of field indicators and groundwater levels.

4) Frequency risk does not consider the degree of impact on developed structures or other financial losses (e.g., crop loss, road service loss). Areas with frequent, small magnitude groundwater inundation tend to be less developed due to persistent wet soil conditions.

5) Significant land use changes associated with development or engineered flood controls could modify risk areas.

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