



Technical Components of the Waffle Project

Presented to the Association of Professional Engineers and Geoscientists

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Red River Basin



1924



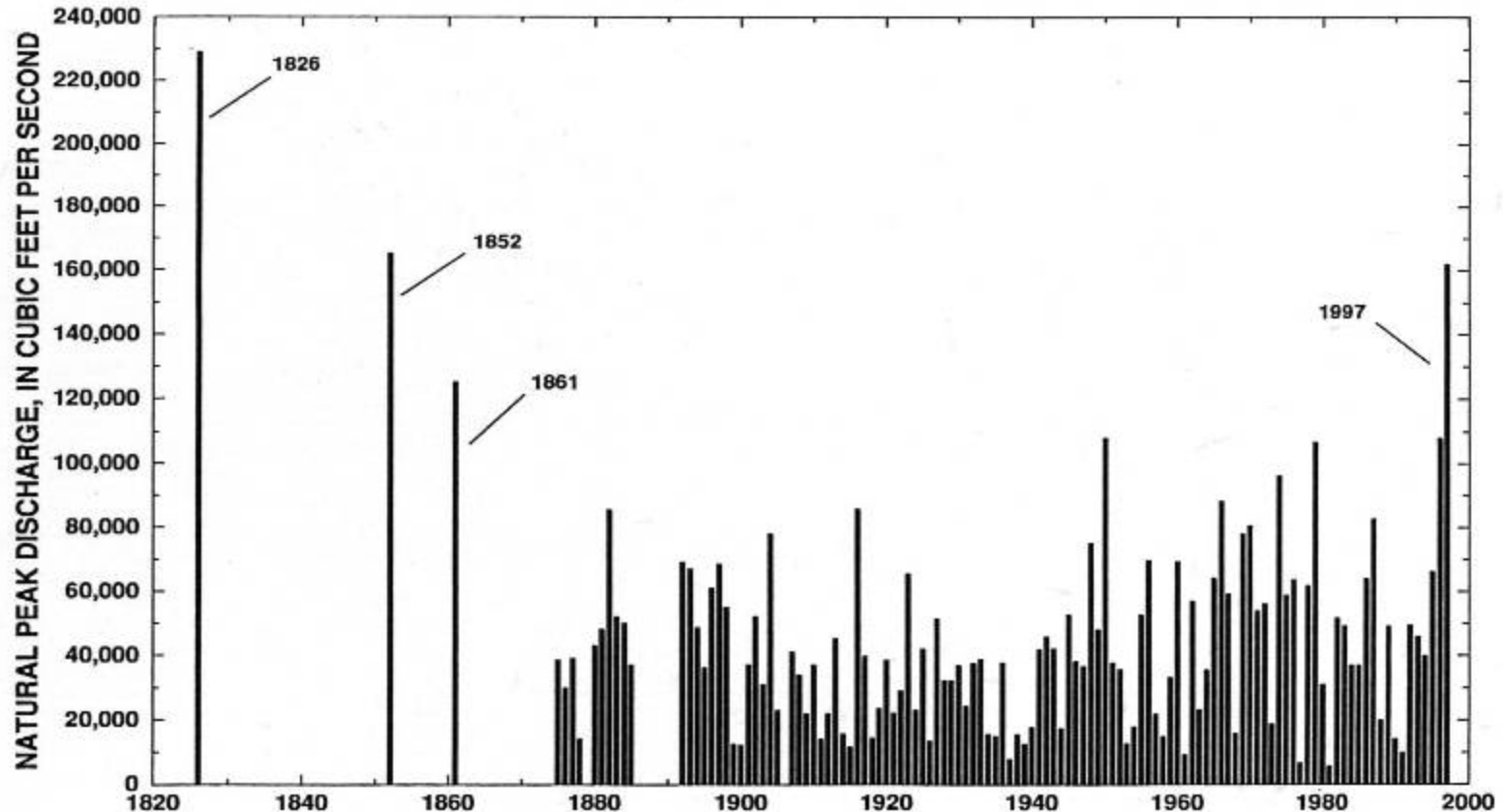
Approximate 1997 Flood Damage Costs



Grand Forks ~ \$2 billion
Red River Basin ~ \$5 billion

Historic Peak Discharges, Winnipeg

RED RIVER AT JAMES AVENUE, WINNIPEG

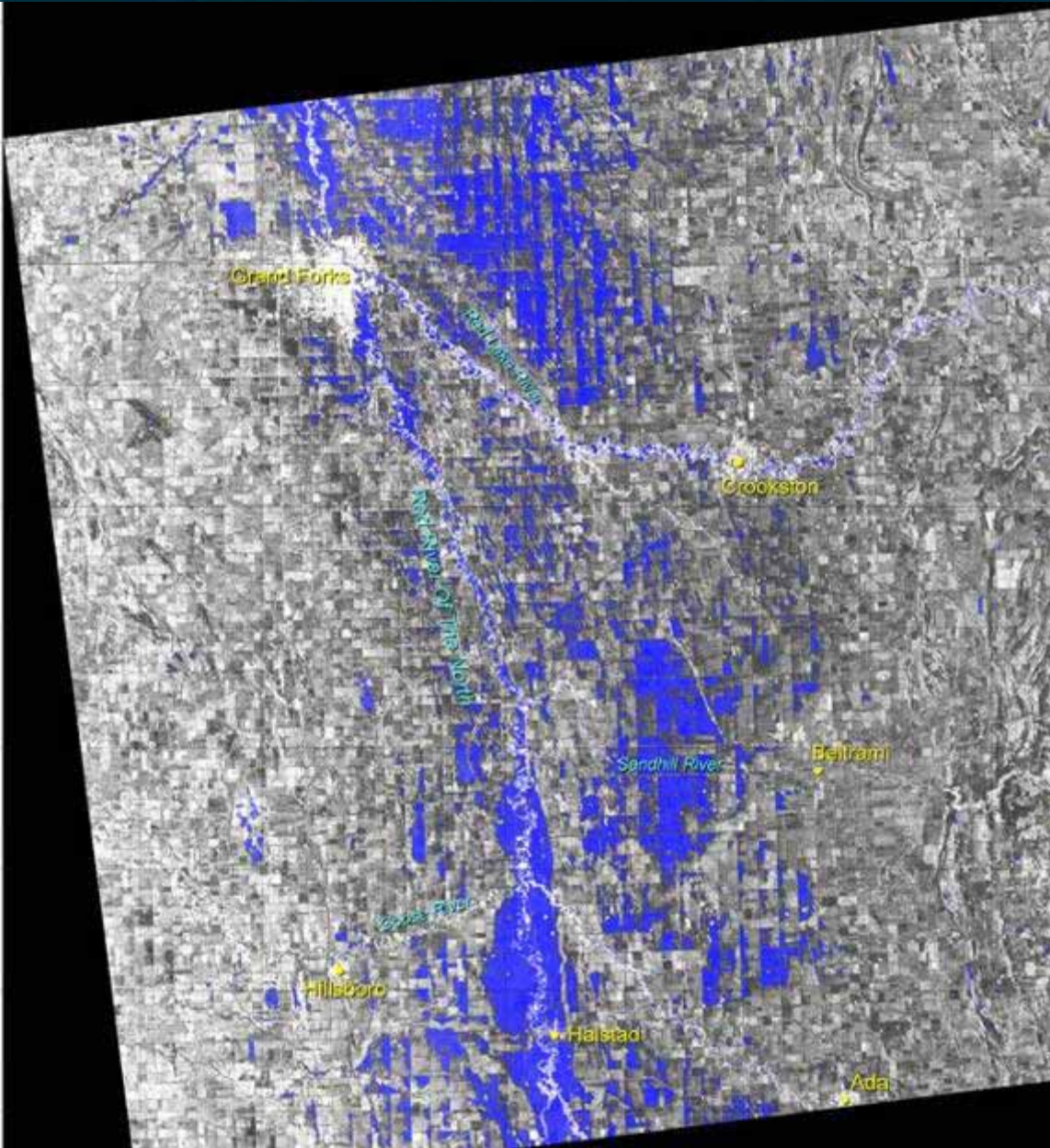


Natural peak discharge for the Red River at James Avenue, Winnipeg, Manitoba. Peaks in 1826, 1852, and 1861 are estimated from historical evidence and peaks after 1875 are based on recorded discharge measurements. [Personal communication, A.A. Warkentin, Manitoba Department of Natural Resources, Water Resources Branch.]

Source: Red River Water Management Board Report, "1997 Red River Flood".

Waffle Concept

- Utilize existing “depressions” for temporary storage of springtime runoff.
- Release the stored water in a controlled fashion after the flood crest passes.



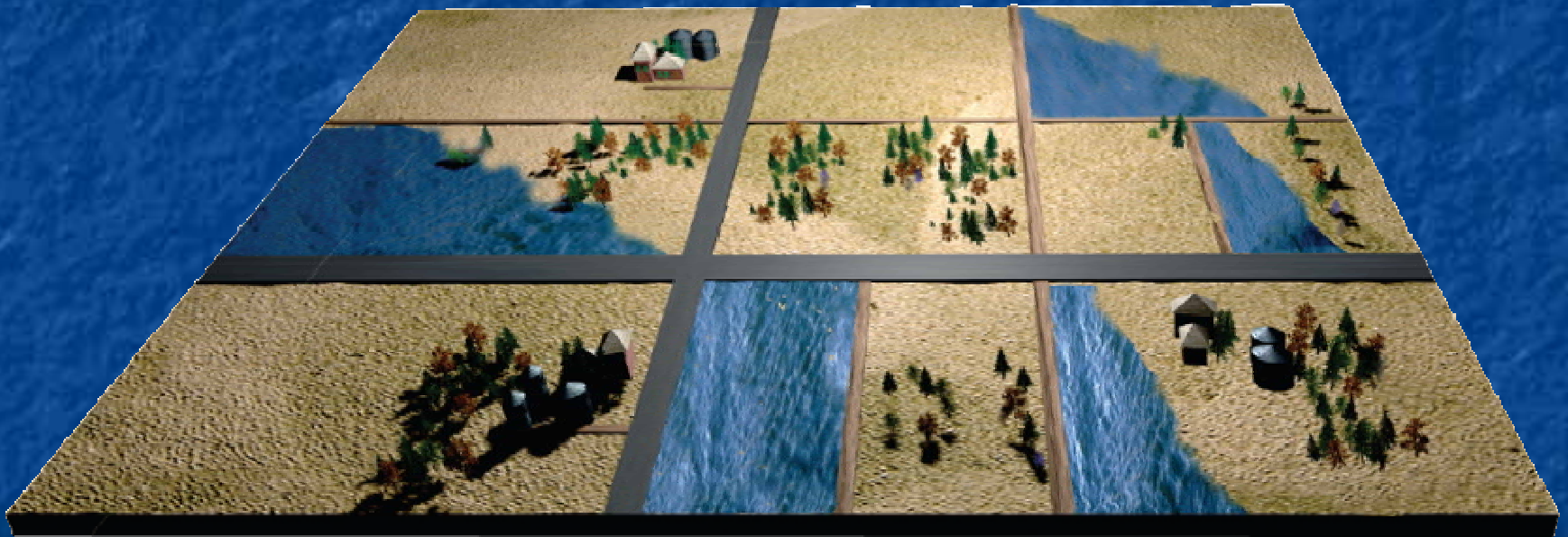
April 19, 1997; RADARSAT Image

Potential Storage Areas



- Low-relief fields bounded by raised roads
- Ditches
- Wetlands/depressions

Basic Concept



Basic Concept



Gated Culvert with Overflow Standpipe

Project Goals

- To investigate the technical and economic feasibility of the Waffle concept for the mitigation of large springtime floods.
- To develop hydrologic and hydraulic models of Red River Basin (RRB) subwatersheds to aid in evaluating the effects of Waffle storage sites.
- To develop a flood mitigation strategy that contains the information necessary to allow for implementation of the Waffle concept.

Project Components

- Technical Components
 - Determination of storage volumes
 - Identification of storage areas
 - Data collection – database construction
 - Model development
 - Waffle field trials
- Social Components
 - Public involvement and outreach
 - Landowner Surveys
- Economic Analysis

Identification of Storage Volumes and Locations

Identification of Storage Areas

- Key identifier of suitable storage areas is topography.
 - Relatively “flat” land bounded by raised roads.
- Approximate storage volumes and locations are required to model the effects of the Waffle throughout the RRB.
- Challenges:
 - In our region, small changes in topography can make a big difference.
 - Existing topographic data is not the best resolution.
 - Road elevation data is lacking.

Readily Available Data Sets

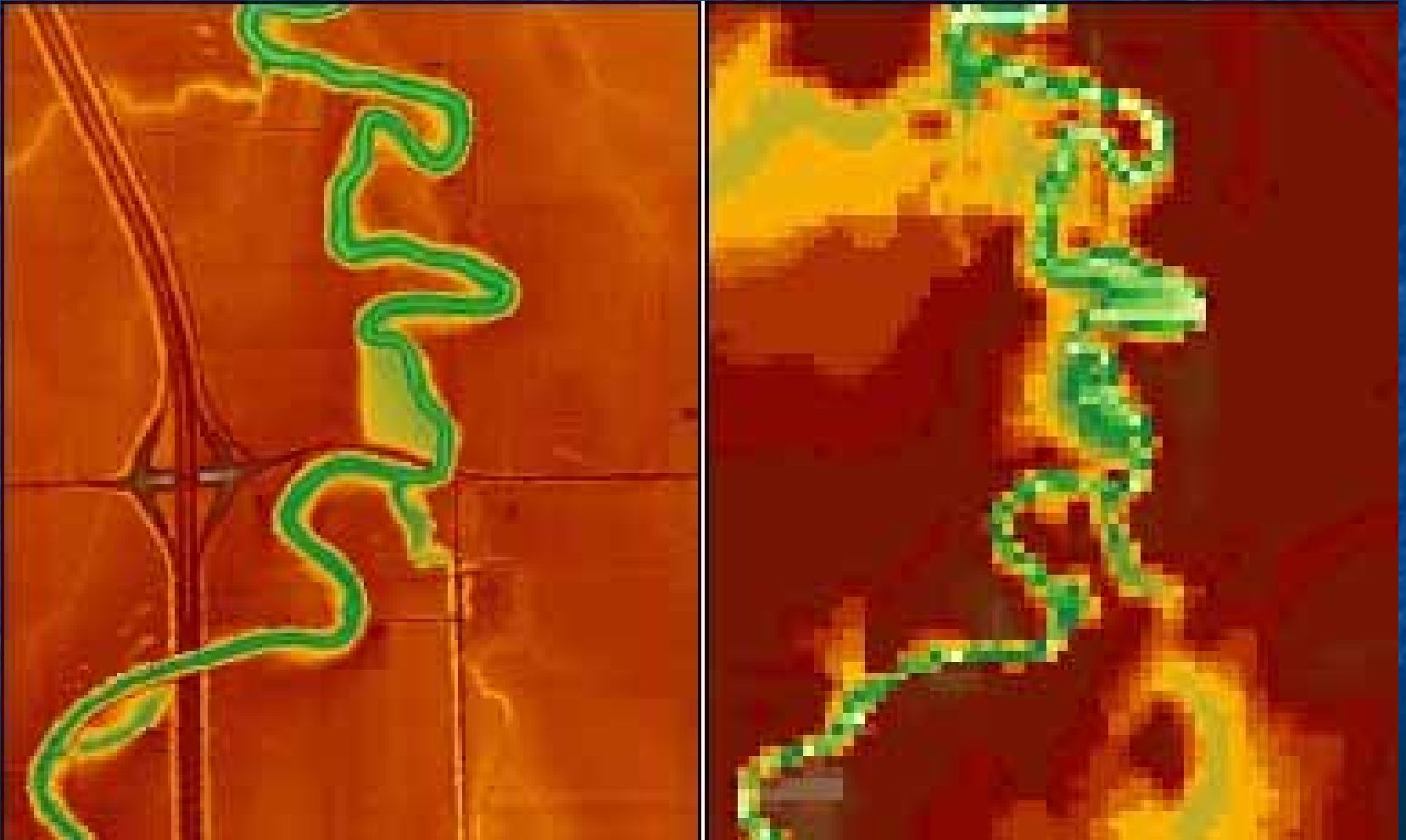
- USGS National Elevation Dataset (NED).
 - 30-meter digital elevation model
- USGS DRG quadrangle maps.
- Digital version of the public land survey system (PLSS), i.e., township, range, section.

Identification of Storage Locations and Volumes

- Strategy was to use GIS and digital elevation data to determine approximate storage locations and volumes.
- A statistical methodology was employed to help circumvent the issues with using the National Elevation Dataset (NED) for this task.
- Ultimately, Light Detection and Ranging (LIDAR) data was collected for an entire subwatershed for comparison with the NED data.

LIDAR vs NED

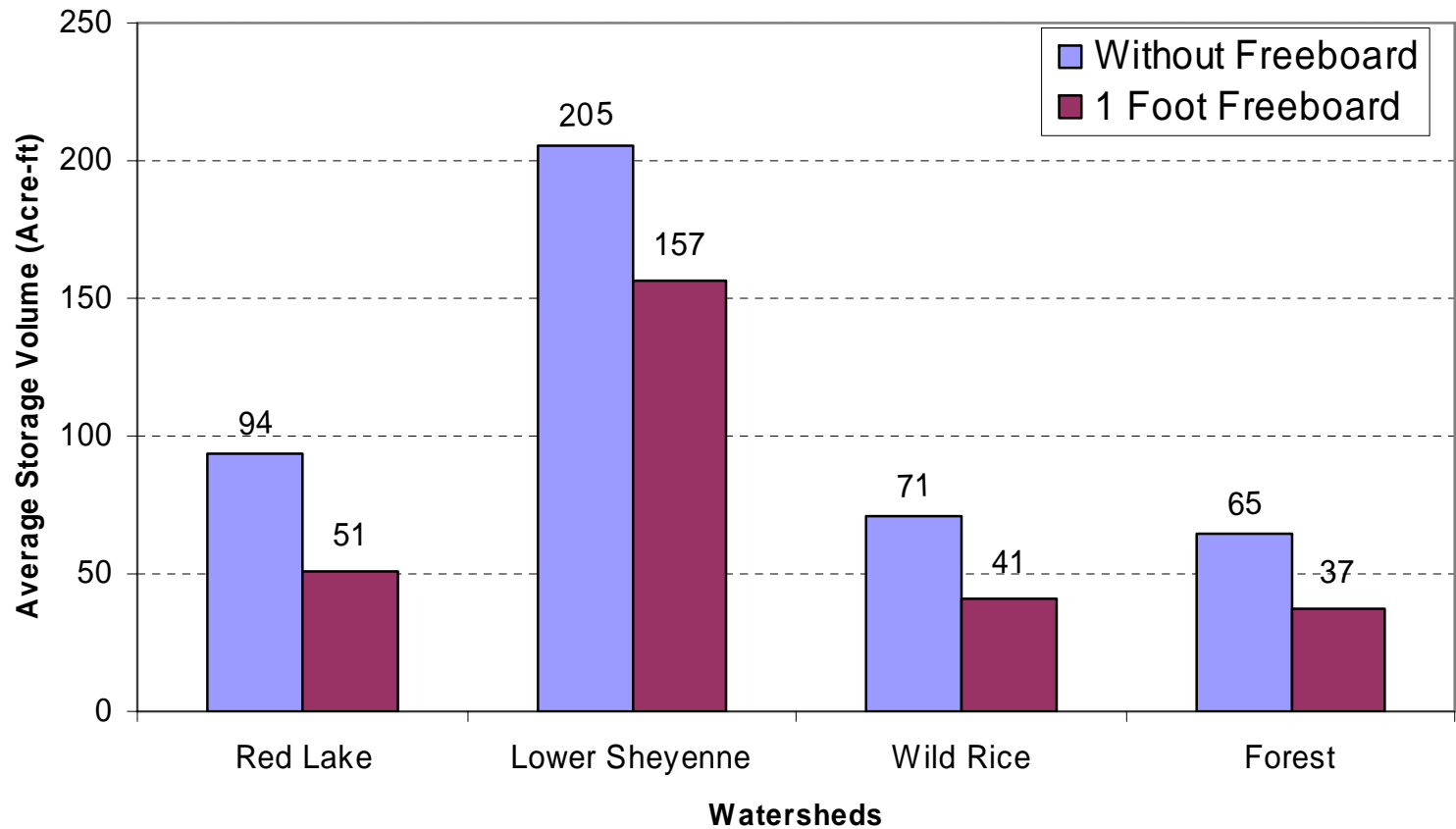
Fargo, ND



Identification of Storage Volumes

- Storage volumes were determined for each subwatershed by detailed analysis of a subset of sections in each area.
- Potential storage areas were categorized based on degree of relief per square mile.
 - Categories were designated as high, medium, low, and zero probability of storage.
- Approximate storage volumes for each category were determined for the subwatersheds of the RRB.
- Volumes were adjusted to account for freeboard and natural storage.

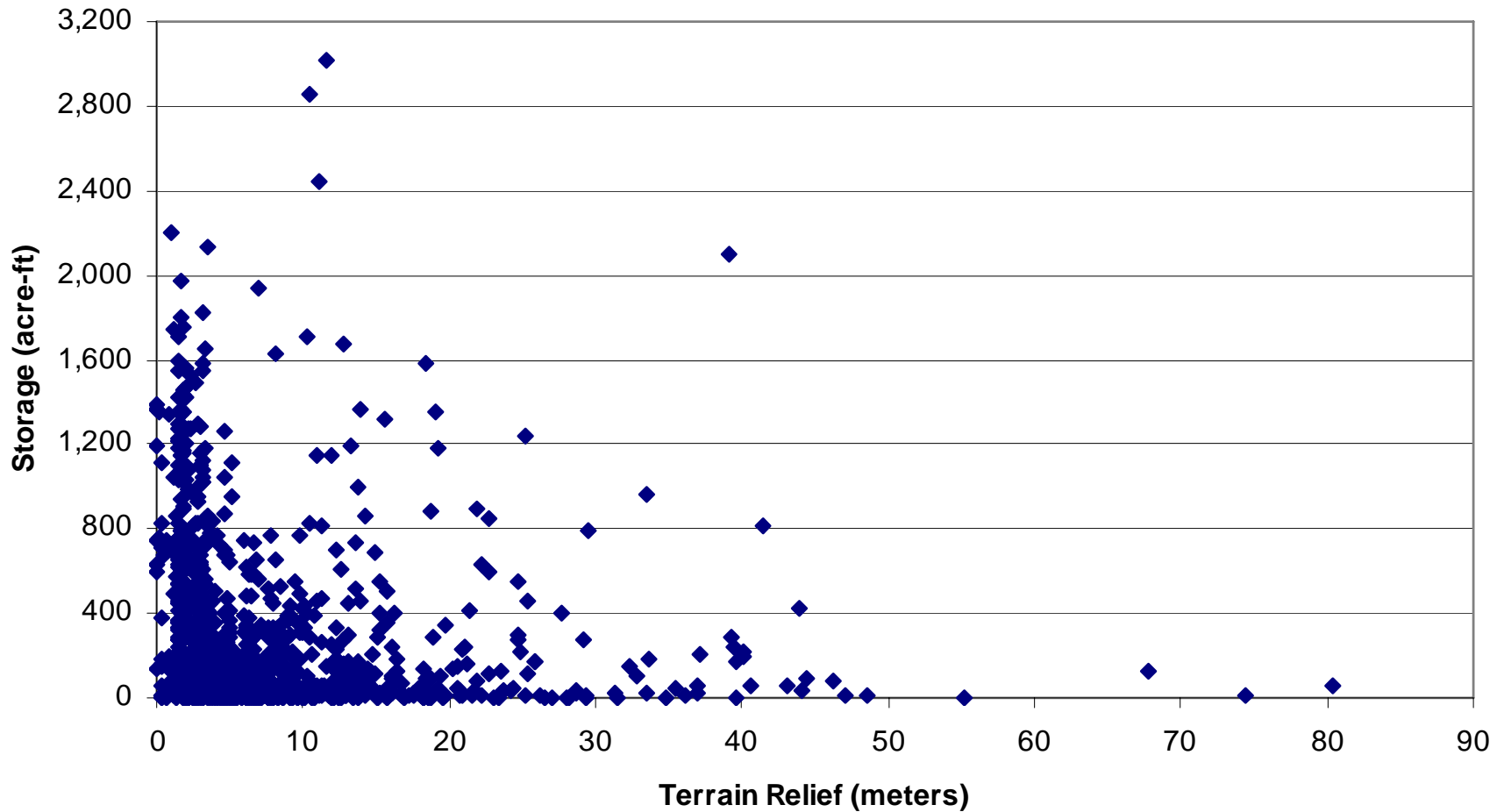
Freeboard Impact



Identification of Storage Locations

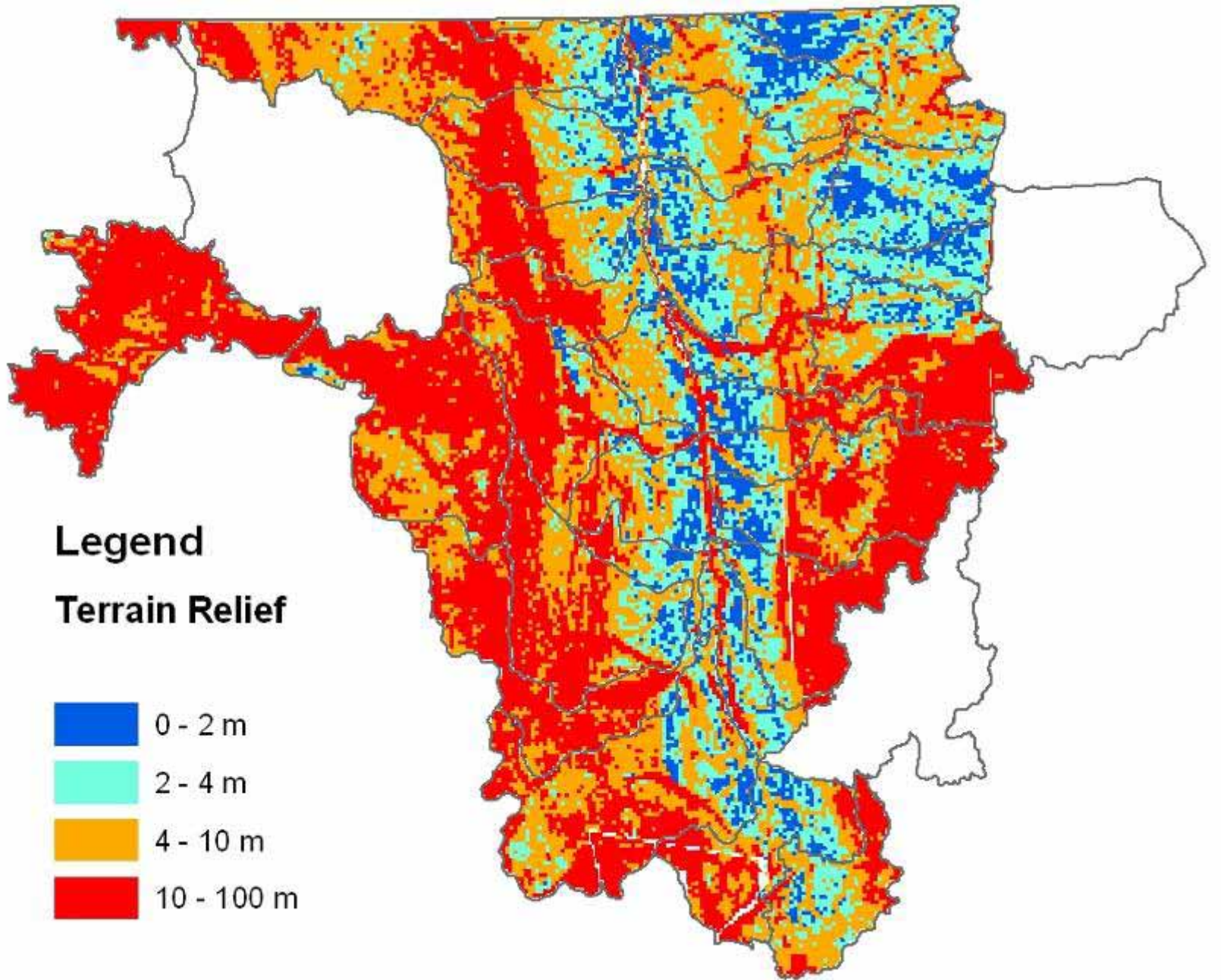
- Initial work determined the potential cumulative storage volume for each watershed.
- For modeling purposes, the calculated volume of water needed to be distributed logically across the landscape.
- We utilized the storage vs. relief relationship.

Storage vs. Relief

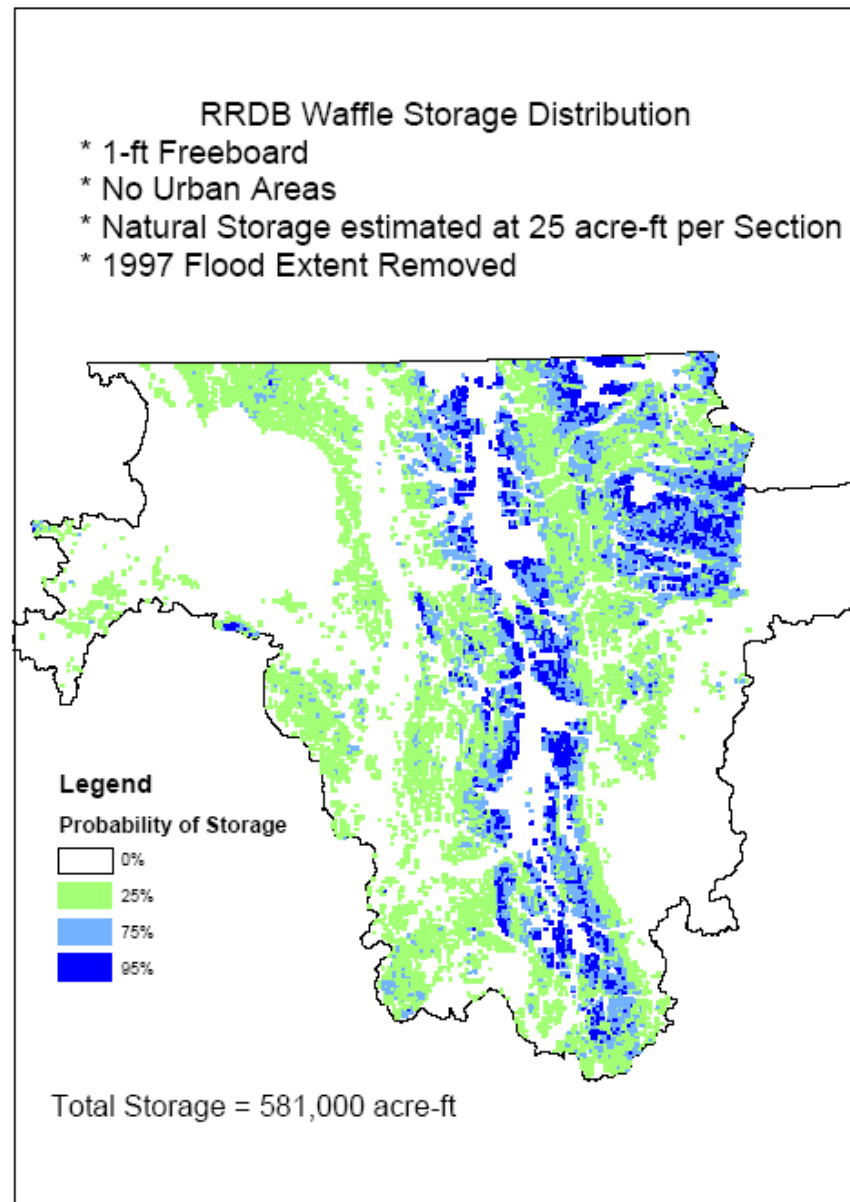


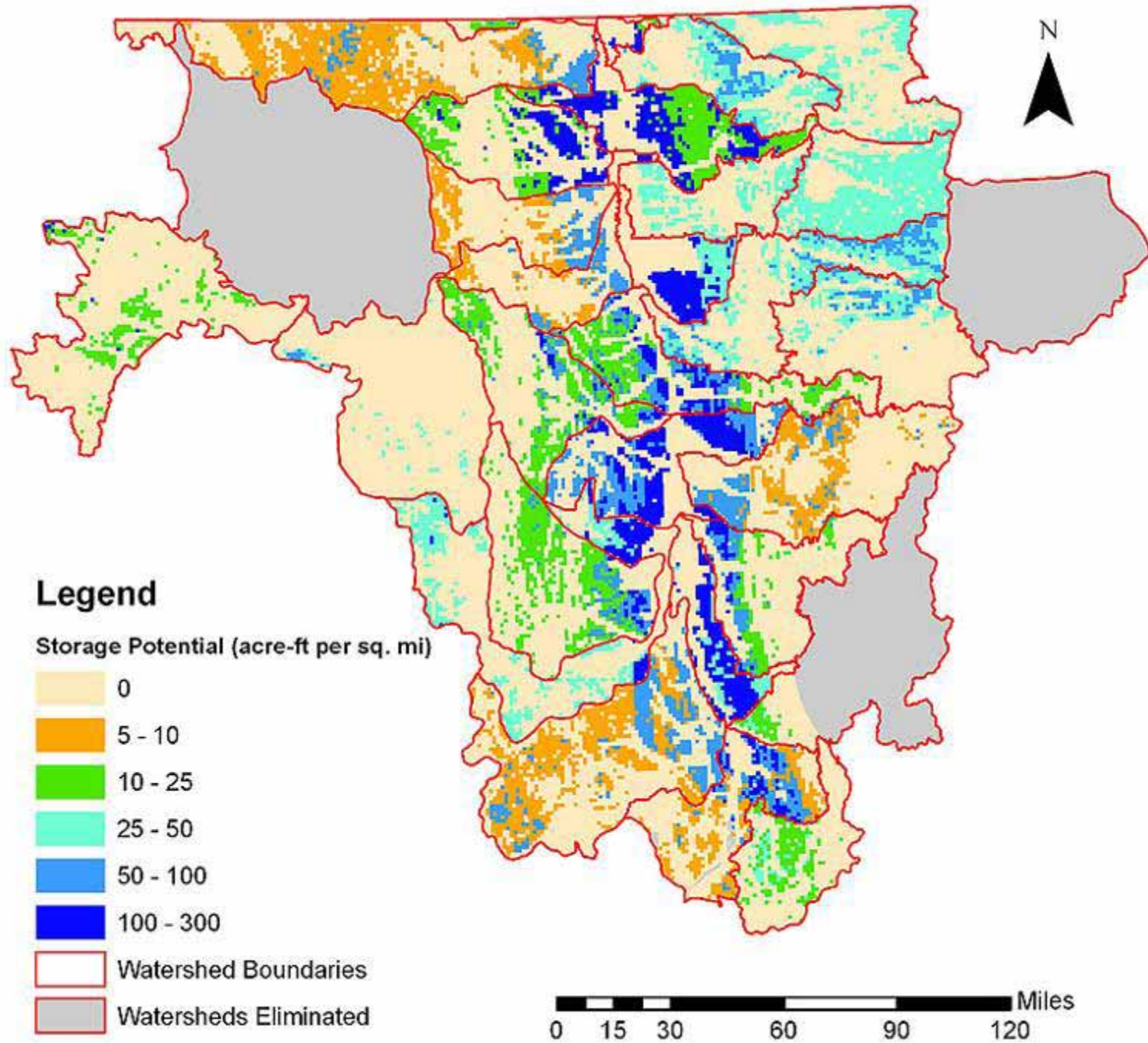
Relief Categories

Meters of Relief	Likelihood of Suitability	Rank
0–2	95%	Very good
2–4	75%	Good
4–10	25%	Poor
10–100	0%	Very poor



100 % of Potential
Storage Areas



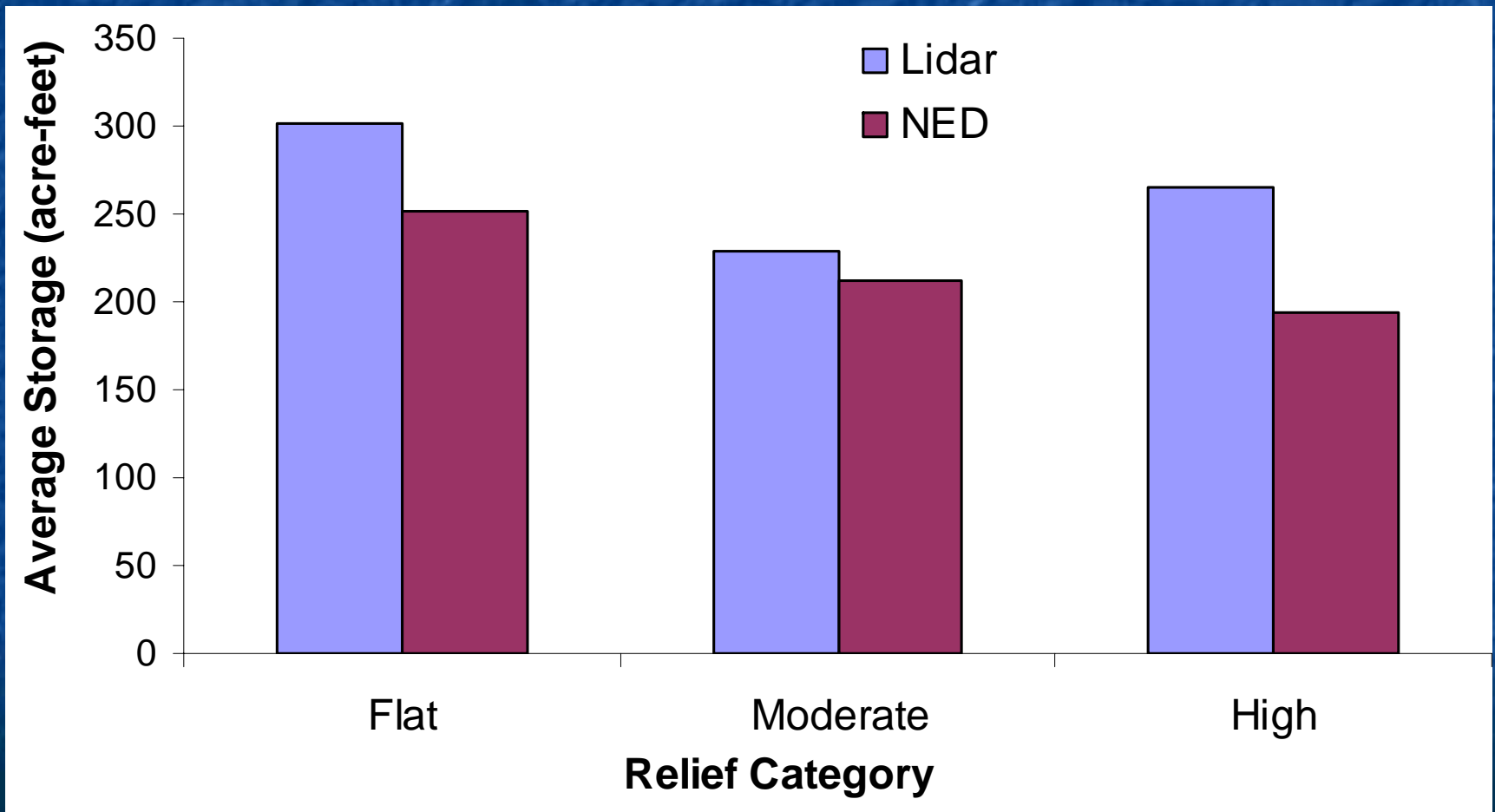


Validation of Concept

- High-resolution LIDAR data was collected for the Forest River watershed.
 - 1-meter resolution
 - 15 cm vertical accuracy
- NED storage volume estimates were compared to estimates using LIDAR.
 - Masters Thesis project through UND Geography Department



Average Storage Volume per Sample Section



Modeling Component

Modeling Goals

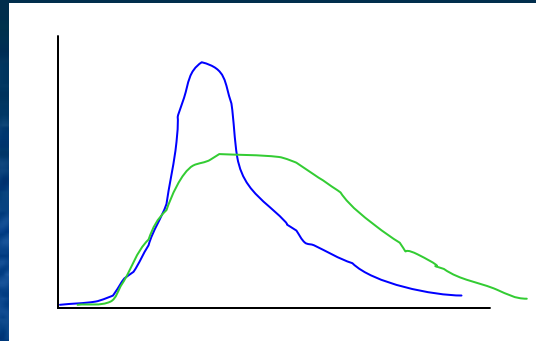
- To determine the impacts of Waffle storage on flood reduction during various historical and hypothetical spring flood events.
- To investigate the duration of storage and the timing of water release as functions of storage location in the RRB.

EERC Modeling Approach

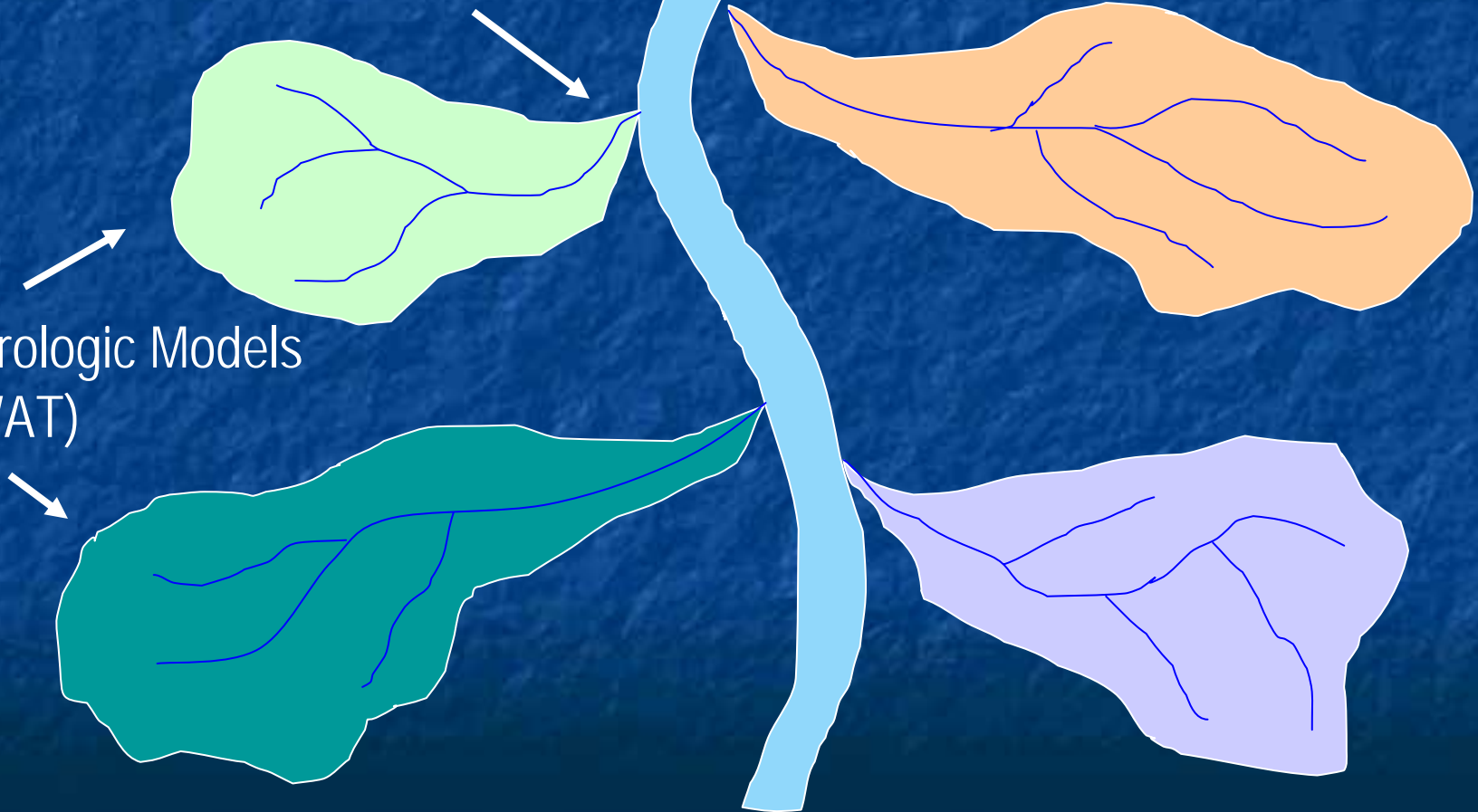
- Development of hydrologic models for each of the subwatersheds in the RRB.
- Development of a main stem Red River hydraulic model.
- Integration of the subwatershed models into the main stem model to relate proposed watershed storage options to river stage reductions.

Hydrologic Model Output = Hydraulic Model Input

Main Stem Hydraulic Model(s)
(HEC-RAS; MIKE11)

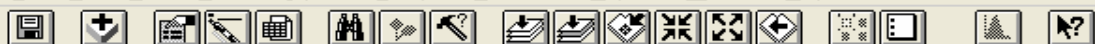


Hydrologic Models
(SWAT)



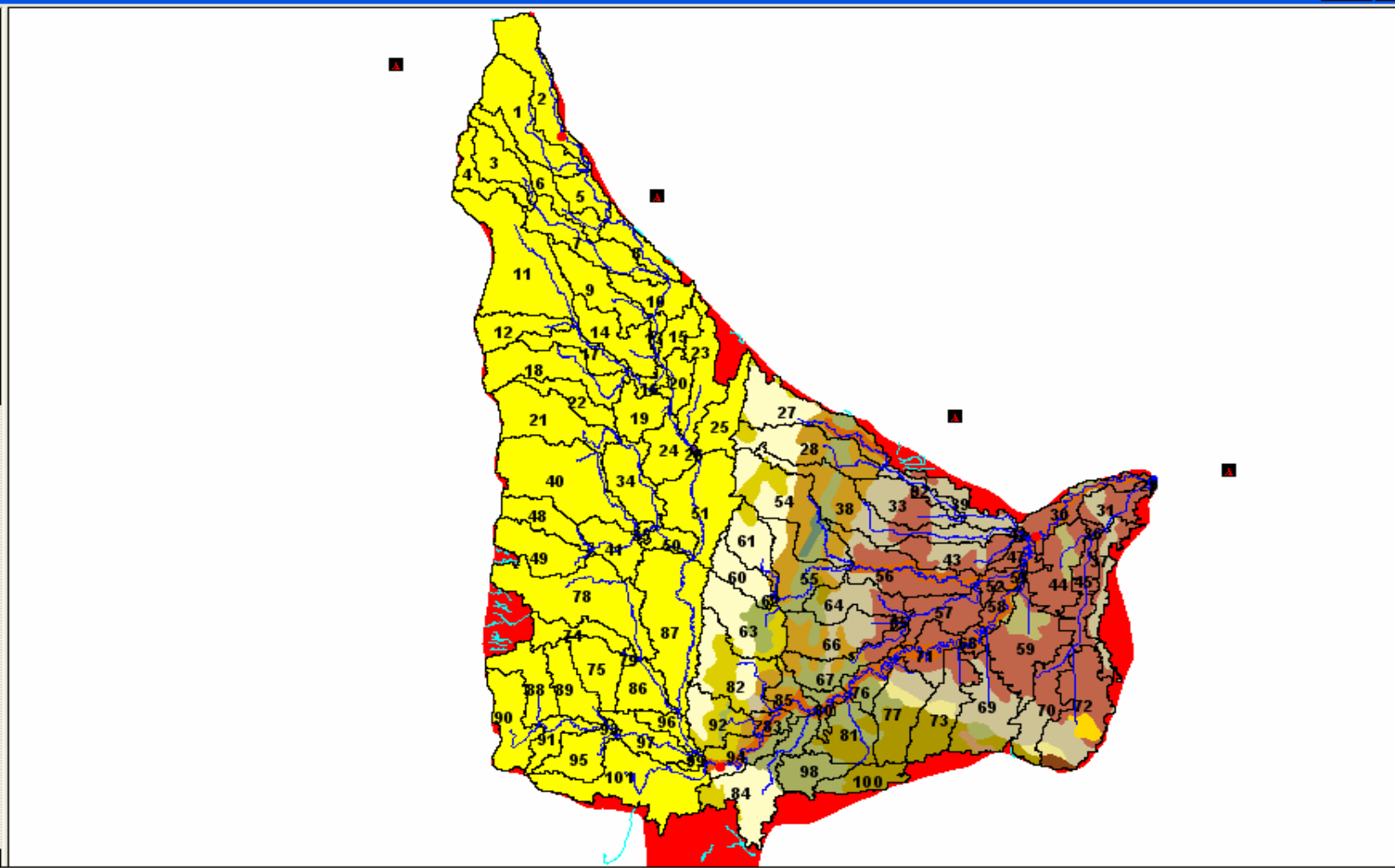
Progress

- Hydrologic models for each of the subwatersheds in the RRB (except the Devil's Lake watershed) have been developed and calibrated using the Soil and Water Assessment Tool (SWAT).
- SWAT is a water quantity and quality model developed by the USDA-ARS and US EPA.



SWAT View

- Gage_location.shp
- Weagages
- Tempgages
- Streams
- Raingages
- Subbasins
- SoilClass
 - ND001
 - ND002
 - ND004
 - ND007
 - ND008
 - ND011
 - ND012
 - ND013
 - ND019
 - ND020
 - ND021
 - ND025
 - ND026
 - ND039
 - ND040
 - ND043
 - ND045
 - ND046
 - ND047
 - ND054
 - ND066
- SwatLandUseClass
 - AGRC
 - AGRL
 - AGRR
 - FRSD



Waffle Evaluation Methodology

- For each subwatershed, simulate the pre- and post-Waffle flow hydrographs at the outlet and at other selected evaluation locations.
- The Waffle effect at an evaluation location is measured as peak discharge reduction.
- The evaluation is being conducted for various historical flood events with 100%, 75%, and 50% of identified Waffle storage.

Reductions Within a Watershed

24 Possible Model Runs to Quantify Waffle Storage Impacts

Flood Event

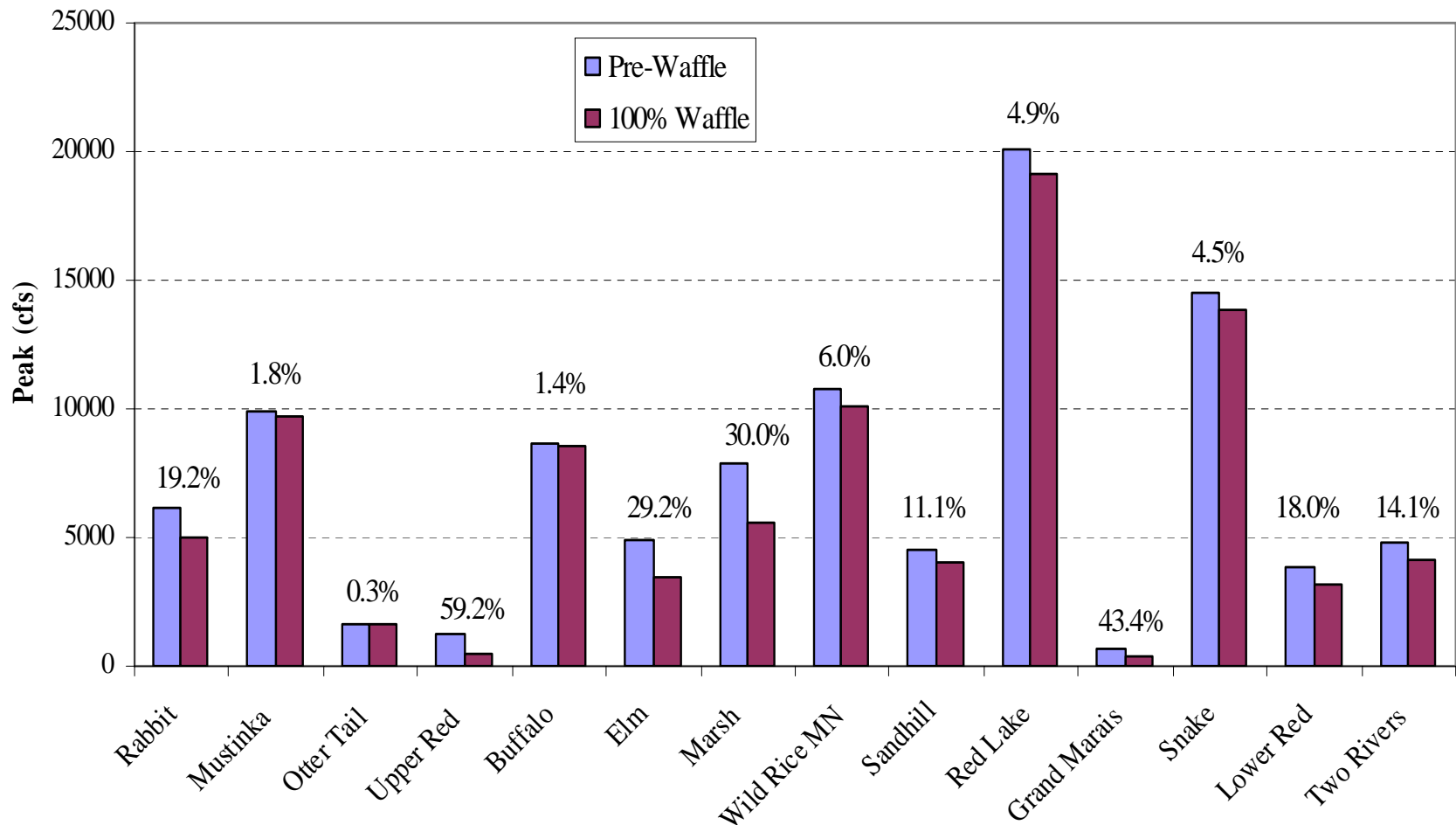
Percentage of Identified Waffle Storage Areas



What we've found so far....

- The location of Waffle storage strongly influences how much stream flows are reduced.
- Peak flow reductions vary considerably.

1997 Flow Reductions at the Outlets of Selected Watersheds for 100% Waffle Storage



Next Step: Evaluation of Stage Reductions along the Mainstem

- Simulate the pre- and post-Waffle water surface elevations along the mainstem using the Hydraulic Engineering Center's River Analysis System (HEC-RAS) model with the pre- and post-Waffle hydrographs as inputs.
- The stage reduction will be evaluated at several key locations along the mainstem.
- The focus will be on the 1997 flood with various combinations of Waffle storage.

Main Stem Modeling Progress

- The EERC and the U.S. Army Corps of Engineers (USACE) are cooperatively developing an unsteady-state main stem model using HEC-RAS:
 - USACE: Upstream of Halstad, Minnesota.
 - EERC: Downstream of Halstad, Minnesota.
- The MIKE-11 main stem model is being extended to Lake Traverse by Water Management Consultants (funded by the RRBC) – final model will include the entire Red River (to Lake Winnipeg).

Waffle Field Trials

Waffle Field Trials

Goal:

- To evaluate the Waffle concept and flood mitigation procedure on a reduced scale.
- To verify and further calibrate the models developed through the project.
- To provide field data to aid in the economic analysis of the concept.
- To quantify the effects of temporary, spring-time water storage on the land.

Parameters Evaluated

- Water volume reduction in adjacent ditches.
- Planting dates and crop yields.
- Soil moisture and temperature.
- Soil nutrients and water quality.
- Road stability.
- Meteorological conditions.



2005 Field Trial Locations



Shelly, Minnesota, Site

- Located five miles east of Shelly, Minnesota.
- Full section of agricultural land.
- Stored approximately 150 acre-feet of water.
- Storage duration of 14 days.



Lake Bronson, Minnesota, Site

- Located approximately 3 miles southwest of Lake Bronson, Minnesota.
- Full section of Conservation Reserve Program (CRP) coverage.
- Stored approximately 150 acre-feet of water.
- Storage duration of 7 days.



Agassiz Wildlife Refuge, Minnesota, Site

- Located on southwest corner of Agassiz Wildlife Refuge in Minnesota.
- 400 acres of CRP coverage.
- Entire section contained within constructed berm and adjacent to judicial ditch.
- Approximately 200 acre-feet of storage.
- Storage duration of 28 days.

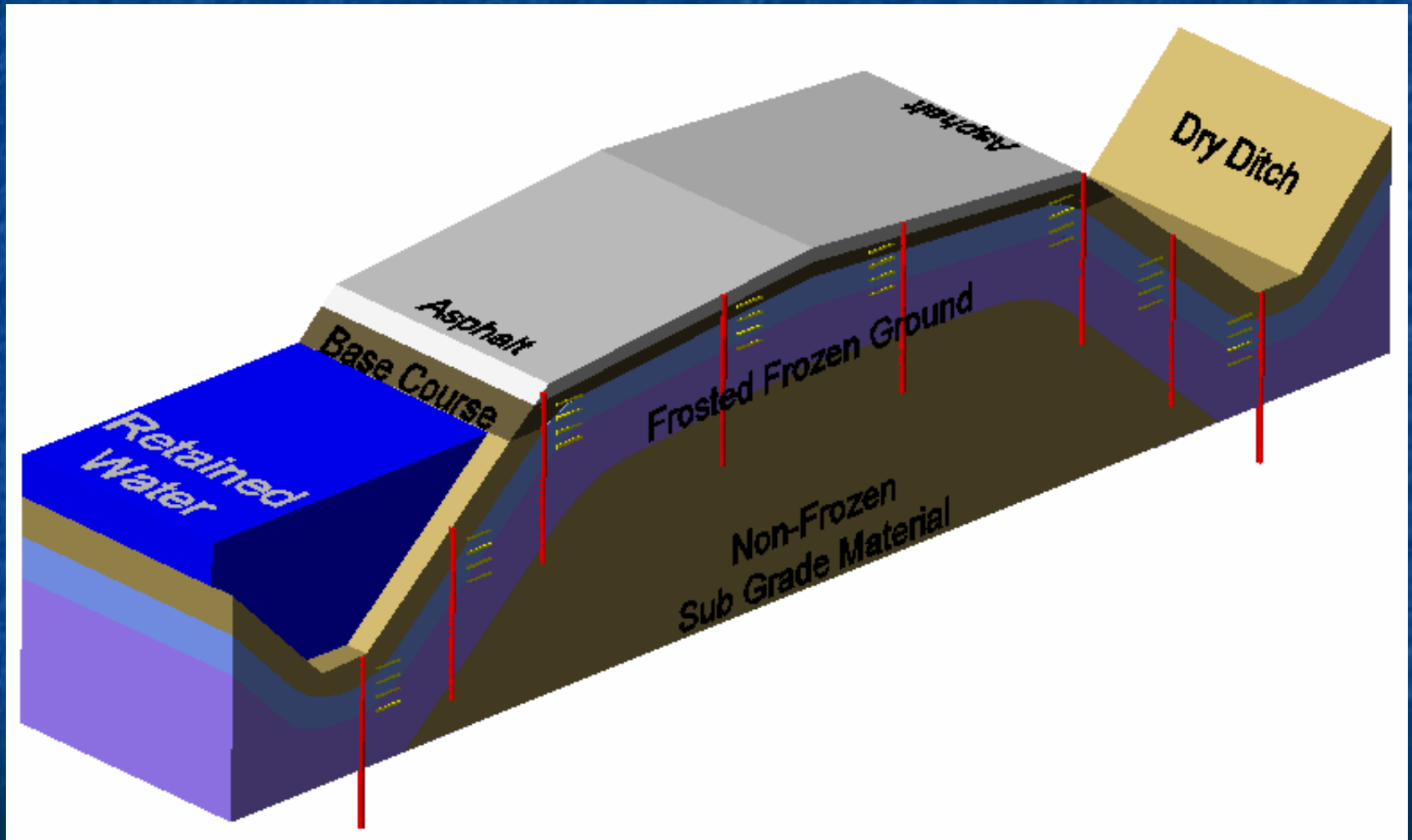


Gilby, North Dakota, Site

- Located approximately 5 miles east of Gilby, North Dakota.
- 440 acres of CRP coverage.
- Water contained by constructed berm on east and north sides of land.
- Approximately 140 acre-feet of storage
- Indefinite storage duration.



Road Stability Evaluation



General Field Trial Conclusions

- Peak flow reductions in adjacent ditches ranged from 12 to 30%.
- No adverse impacts to water or soil chemistry were observed.
- Crop yield differences between flooded and non-flood portions of the Shelly site and adjacent farm land were negligible.
- CRP vegetation health was not adversely impacted due to water storage.

General Field Trial Conclusions

- Field tests indicated that road stability should not be compromised during spring time water storage due to sufficient frost depth.
- The rate of frost removal in the soil is accelerated under areas of water storage.

Implications for Canada

- Potential for significant flood mitigation impacts.
- Initial studies suggest that enough water would be stored on the US side of the RRB to mitigate major flooding in Canada.
- This will be further investigated as the main stem modeling effort progresses.

Questions?

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