



A White Paper on

Developing a

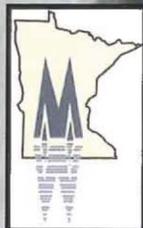
High-Resolution

Digital Elevation Model (DEM)

and

Floodplain Mapping Program

020485



MN DNR Waters and Partners

GB
1399.4
.M6
W45
2002

Roseau, MN
June, 2002

A White Paper on Developing a High-Resolution Digital Elevation Model (DEM) and Floodplain Mapping Program

by
DNR Waters and Partners

RECEIVED

JAN 29 2003

MINNESOTA REFERENCE LIBRARY
STATE OF MINNESOTA
ST. PAUL, MN 55155

Partners:

Association of Minnesota Counties (AMC)
League of Minnesota Cities (LMC)
Minnesota Association of Townships (MAOT)
Minnesota Association of County Surveyors (MACS)
Minnesota Association of County Engineers (MACE)
Minnesota Society of Professional Surveyors (MSPS)
Minnesota Association of County Planning and Zoning Administrators
Minnesota Society of Professional Engineers (MSPE)
Minnesota Chapter of the American Public Works Association (APWA)
Minnesota Chapter of Geographic and Information Technology Association
Minnesota Association of Bankers
Minnesota Chapter of American Planning Association
Minnesota Department of Natural Resources (DNR)
Minnesota Department of Transportation (MnDOT)
Minnesota State Planning Agency
Minnesota Board of Water and Soil Resources (BWSR)
Minnesota Association of Watershed Districts (MAWD)
Minnesota Association of Soil and Water Conservation Districts
University of Minnesota
Federal Emergency Management Agency (FEMA)
US Army Corps of Engineers (USCOE)
US Geological Survey (USGS)
U.S.D.A. Natural Resources Conservation Service (NRCS)
Builders Association of Minnesota

Co-Chairs: Ogbazghi "Obi" Sium (DNR) and Dave Gorg (MnDOT-retired)

A White Paper on Developing a High-Resolution Digital Elevation Model (DEM) and Floodplain Mapping Program

SUMMARY STATEMENT

This white paper outlines the need to develop a statewide high-resolution digital elevation model (DEM) and floodplain mapping program. It briefly describes the background, statement of need, benefits of developing a DEM, and action plan for developing a DEM and floodplain mapping program. A description of the current cost estimate is attached as an addendum.

I.	Background.....	1
II.	Statement of Need.....	3
III.	Benefits of Developing DEM.....	4
IV.	Action Plan for Developing DEM and Floodplain Mapping.....	5
V.	Cost Estimate.....	6
VI.	Appendix.....	8-10
VII.	Draft Resolution.....	11

BACKGROUND

Society is moving into a new era of using technology to manage infrastructure using accurate land information displayed in three dimensions: x and y horizontal coordinates and z, elevation. The public can understand data much easier if presented to them in three dimensions, using today's technology.

Improvements in gathering and displaying elevation data make it economically feasible to gather large amounts of data in a short period of time and have it readily available for distribution to multiple users. A critical use is to create current and accurate floodplain maps.

The National Flood Insurance Program (NFIP) was created by an act of Congress in 1968. It is administered by the Federal Emergency

Management Agency (FEMA), and floodplain maps were developed as part of the program. In 1969, the Governor designated the Department of Natural Resources (DNR) to be the State NFIP Coordinator. At the same time, the Legislature designated the DNR to administer the Minnesota Floodplain Management Act of 1969.

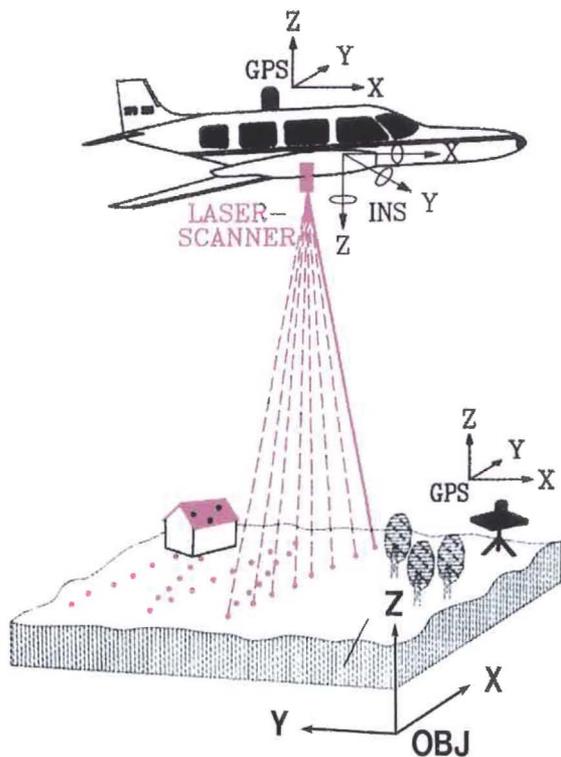
Minnesota's floodplain maps are outdated; 50 percent of the flood maps are more than 20 years old. Furthermore, the maps were delineated using topographic base maps with contour intervals of 10 feet, except in the flat Red River of the North basin, where the contour intervals were five feet. The status of the flood maps and the lack of high-resolution elevation data pose great difficulties on a daily basis for

counties and cities that are charged with implementing floodplain regulations (Minnesota Statutes 103F.101 – 103F.165) and NFIP regulations (44 CFR Parts 59-78). Inaccuracies in floodplain maps also create additional unnecessary costs during financing and refinancing of home purchases.

Recently, LIDAR (Light Detection and Ranging - see side bar) technology has made it feasible to address the chronic lack of high-resolution elevation data and the need to identify and map flood hazard areas. DNR Waters initiated the formation of a group representing state agencies, county and city governments, interest groups and federal agencies who would use high-resolution elevation data. Potential uses include general planning, constructing and managing municipal and private infrastructure, precision agriculture and natural resources management. The group met to share information and to help prepare for a workshop that was held with stakeholders on May 2, 2002 at the Science Museum of Minnesota.

At the workshop, John Dorman, Program Director, North Carolina Floodplain Mapping Program, described how his state is successfully developing high-resolution elevation data and mapping flood hazard areas. Mike Buckley, Director, FEMA Hazards Mapping Division, shared information about FEMA's flood map modernization program and stated that, after many years of waiting, FEMA is finally poised to receive \$300 million per year in each of the next three federal fiscal years for national flood map modernization. A panel representing local governments, interest groups, and state/federal agencies stated their need and support for the development of high-resolution elevation data. The over 100 attendees were very enthused about the whole idea.

LIDAR TECHNOLOGY



LIDAR uses lasers to emit light pulses that strike the ground and reflect back to the airborne sensor. With the precise altitude and position of the aircraft known, the elevation of surface points can be determined based on the time required for the pulse to return to the sensor.

STATEMENT of NEED

The overwhelming majority of the attendees at the May 2nd workshop strongly expressed the need to develop a high resolution DEM and floodplain mapping program. The State of Minnesota, like the State of North Carolina, needs to expeditiously initiate a program of developing a high-resolution DEM and floodplain mapping program in order to correctly identify and map flood hazard areas and enable local governments and state and federal agencies to efficiently and effectively manage land and water resources as well as infrastructure.

In 1993 and 1997, flooding caused \$1.7 billion and \$1.5 billion in damages, respectively, to homes, farmlands, commercial and industrial structures and to transportation and drainage infrastructure. Focusing on 1997, a total of \$830 million, about half of the total estimated damage, was spent thereafter by state, federal and private agencies towards recovery. The City of East Grand Forks has spent \$75 million to acquire and demolish or relocate homes and commercial buildings out of the floodplain and to rehabilitate or build new homes and businesses. An additional \$135 million will be spent in the next 2-3 years to provide the city with a system of permanent flood protection levees.



Furthermore, counties, cities, townships, private firms, the DNR, and the Minnesota Department of Transportation (MnDOT) spend millions of dollars every year to collect high-resolution elevation data in order to plan and implement programs mandated by state and federal agencies. Most data collection is done by traditional methods which is extremely expensive and comparatively slow.

The current estimated cost of developing a DEM and floodplain mapping program in Minnesota is about \$80 million. Two thirds (\$53 million) of the cost is for the DEM development and one third (\$27 million) is for floodplain mapping. FEMA will contribute as part of their floodplain map modernization program as discussed below.

Minnesota's floodplain management program will potentially obtain a total of \$15-20 million in cost share in the 2003, 2004, and 2005 federal fiscal years, without a DEM. If the 2003 Minnesota Legislature authorizes a high-resolution DEM and floodplain mapping program, there is a window of opportunity for FEMA's contribution to potentially be \$25-30 million, based on North Carolina's experience of FEMA contributing 34 percent. In addition, the DEM will reduce the costs by 35% for developing hydrologic and hydraulic analysis.

BENEFITS of DEVELOPING a DEM and FLOODPLAIN MAPPING PROGRAM

The availability of a statewide high-resolution DEM will herald a sweeping change in how we do business in Minnesota. The State of North Carolina conducted a study of the benefit/cost ratio for its program of developing a DEM and floodplain mapping program. The result was an astounding ratio of 3.5:1. In other words, for every \$1 that the State of North Carolina spent on this program, the rate of return was \$3.50. If the State of Minnesota implements this program, the savings would be tremendous, benefitting state and local governments and private firms. Some of the activities that would benefit from a high-resolution DEM are as follows. Additional information is provided in the appendix on pages 9-11.

Accurate Floodplain Maps. Accurate mapping of flood hazard areas would improve the planning and siting of flood protection measures and administration of the NFIP and the state Floodplain Management Act. In addition, homeowners would not be required to buy costly flood insurance if they are not in a floodplain. High-resolution DEMs will reduce a homeowner's expense in providing more accurate survey data required in the letter of map revision (LOMR) and letter of map amendment (LOMA) applications. In new flood insurance studies (FISs), the updated flood insurance rate maps (FIRMs) will benefit from more accurate mapping and will reduce costs in administering revisions or amendments to the effective floodplain mapping.

Transportation Infrastructure. Planning, design, construction and maintenance of transportation infrastructure benefits greatly by the availability of accurate and comprehensive high-resolution terrain data. This data would lead to increased efficiency and quality in hydrologic and hydraulic analysis and design work important for dealing with water flowing off or under roadways. DEM data would support transportation project streamlining because preliminary drainage design could begin without waiting for drainage area mapping to be completed. The DEM data will also support better communication about drainage issues, both within Mn/DOT, other government units and the public, because of the ability to create clearly understood graphics.

Land Use Management. Availability and use of a DEM would expedite planning and development of land use for precision agriculture, drainage systems, land subdivision, utilities, commercial and industrial districts, etc., and improve the quality of soils mapping. Washington County, for example, uses DEMs to help make a wide variety of land-use decisions - see page 11.



ACTION PLAN for DEVELOPING a DEM and FLOODPLAIN MAPPING PROGRAM

Surface and Groundwater Models.

Availability of a DEM would make it possible to build and run mathematical models representing rivers, lakes, and groundwater flow systems on a regional basis. Regional models are essential tools in timely response and coordination between government agencies and the communities in the state.

Natural Resources Management. Minnesota's quality of life and sustainability of its water and land resources (forestry, fish and wildlife, minerals, etc.) depend on wise management of these resources. One of the data inputs in planning and implementing sound management ideas is high-resolution elevation data. A DEM would significantly enhance the ability to manage natural resources efficiently and effectively.

Conflict Reduction. Availability and use of a DEM would significantly reduce conflicts that occur between regulators and developers, and between competing interest groups. A DEM would help to provide more credible and defensible decisions.



To implement and develop a DEM and floodplain mapping initiative, the following actions need to be taken:

1. DNR Waters, as the state NFIP coordinator and administrator of the Floodplain Management Act, would continue to take the lead in the process of initiating and implementing the effort.
2. DNR Waters would coordinate with, and seek input from, the Governor's Council on Geographic Information and its working committees, other state agencies, local governments, interest groups, and federal agencies by creating a forum for information sharing. The forum would act as an advisory group to DNR Waters.
3. DNR Waters would encourage the advisory group to inform policy makers about the urgent need and present window of opportunity to create and implement the program.
4. Funding is needed from the Minnesota Legislature and other sources to create and maintain the program.
5. DNR Waters would work with FEMA through a partnership, called Cooperating Technical Partners (CTP), to leverage FEMA's floodplain mapping modernization funds, lowering costs to no more than a 66%/34%, state/federal share.
6. The DEM database would be maintained by a state agency and would be available at no cost.
7. DNR Waters would provide digital flood maps and the associated hydrologic/hydraulic models and data at no cost.
8. Existing high-resolution digital elevation data would be inventoried and assimilated if the data meets minimum FEMA standards.

COST ESTIMATE

To arrive at a detailed cost estimate, appropriate data for streams/ivers were collected and some broad assumptions were made. It is assumed that the project would be completed over a period of six years.

To determine the DEM cost, a state map with the major watersheds, labeled by priority, was prepared (see page 7). The area of each major drainage basin was tabulated and the DEM cost was calculated. The task would also include building digital terrain models (DTM) from the DEM, which would require 120 ground elevation control points per county. The cost to develop a DEM and DTM would be \$41 million.

Information and technology (IT) needs, along with staffing, are projected to cost \$5 million and \$7 million respectively.

The floodplain mapping cost assumed the cost to complete hydrologic studies (determination of flow frequencies) of sub-watersheds for major tributaries, and the cost for hydraulic analyses. These costs were determined county-by-county from FEMA flood insurance studies and from USGS quadrangle maps. The total cost to conduct hydrologic and hydraulic studies and to produce digital flood insurance rate maps (DFIRMs) is approximately \$27 million.

Funding Scenario (millions of dollars):

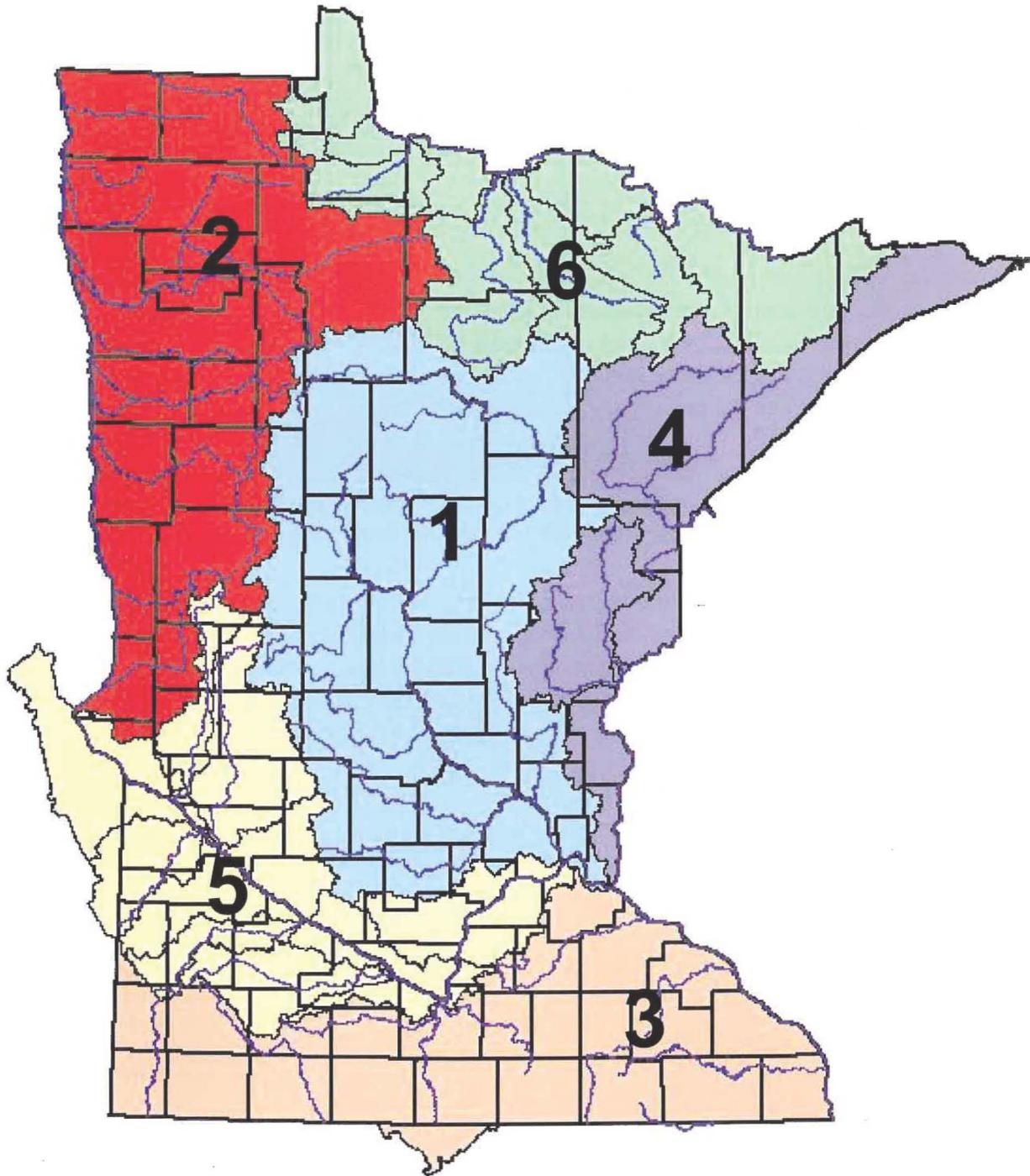
Minnesota Fiscal year	2004	2005	2006	2007	2008
Minnesota Legislature (Appropriation to DNR)	\$13		\$14		\$23
FEMA	\$10	\$7	\$10		
MnDOT (Ground elevation quality control*)	\$0.5	\$0.5	\$0.5	\$0.5	\$1
Total by year	\$23.5	\$7.5	\$24.5	\$0.5	\$24

Total.....\$80 million

* in-kind services

The benefits would be significant for investing in a statewide high-resolution DEM and floodplain mapping program. We have good quantitative data, based on work in North Carolina, indicating a benefit-cost ratio of 3.5:1 on flooding alone. Details of flood experiences in Minnesota illustrate how these benefits could be realized at home.

DEM and Floodplain Mapping Project Phasing Priorities



APPENDIX

BENEFITS of DEM and FLOODPLAIN MAPS

A statewide high-resolution digital elevation model (DEM) would provide critical information to create current and accurate floodplain maps that would benefit Minnesota, but would also benefit other activities of government and the private sector. This appendix is intended to document the extent of those two benefits.¹

The State of North Carolina has suffered from flooding, mostly due to hurricanes, and conducted an intensive benefit/cost study to estimate the value of having good floodplain maps. They concluded that “for every dollar spent on mapping, the payback is \$3.50.”² Part of the reason for this high ratio of benefit to cost is the relatively low cost of new LIDAR technology. Compared to traditional methods of collecting elevation data, LIDAR is 30-50 percent cheaper.

North Carolina experiences annual flood damages of \$56 million. Minnesota averaged a whopping \$90 million annually in expenses reimbursed by state and federal agencies in the 1990's. Flooding in Minnesota during 1997 alone caused an estimated \$1.5 billion in damages. The damages would have been worse were it not for the permanent flood control structures in place, the measures taken in advance of the floods and the emergency measures taken during the floods. Significant flood damages were inflicted on the Cities of East Grand Forks, Ada and Breckenridge, but over 40 communities were spared by preventive actions. Better floodplain maps would have reduced that damage even further by helping communities manage their floodplains before the floods and by directing mitigation efforts during the events.

Local governments currently are trying to make decisions about flood events, decisions that could be much easier with current and accurate floodplain maps. These decisions could save lives and money, but officials are flying blind. For example, the City of East Grand Forks gets roughly 300 building permit applications per year and is struggling with old floodplain maps and less than optimal elevation data as it tries to make decisions about whether or not to approve them. Meanwhile, the city gets over 500 calls a year from banks and others about whether buildings are in or out of the floodplain. In the Roseau County, which recently suffered flood damage to some 1500 homes, local officials are trying to reduce future damage by planning projects that include levees, bypass channels, and upstream divisions - projects that can be planned well only with better floodplain and DEM data.

¹ A number of people provided key information reported in this appendix. They include:

Ann Banitt, Hydraulic Engineer, US Army Corps of Engineers; Jay Bell, Professor of Soil, Water and Climate, University of Minnesota; Jeff Grosso, Surveyor, City of Saint Paul; Tom Lutgen, Floodplain Program Hydrologist, Waters Division, Minnesota Department of Natural Resources; Larry Nybeck, Deputy Director/County Surveyor, Survey and Land Management Division, Washington County; and Lisa Sayler, Hydraulics Automation Engineer, Minnesota Department of Transportation.

² Smith, Brandon R. 2002. Floodplain Fliers: North Carolina's Massive LIDAR Project, *GeoSpatial Solutions*, February, 28-33.

Many Minnesota homeowners spend money on expensive federal flood insurance, unnecessarily, because old floodplain maps incorrectly identify them as living within the floodplain. On the other hand, many other homeowners are in danger of losing their homes to floods and do not have the insurance necessary to rebuild, because old maps do not accurately reflect their risk.

The state has other significant uses for high-resolution DEMs. One example comes from hydrologists at MnDOT who talk about it as “Heaven on Earth.” They say the data would lead to increased efficiency and quality in hydrologic and hydraulic analysis and design – work important for dealing with water flowing off roadways or under them. DEM data would support transportation project streamlining because preliminary drainage design work could begin without waiting for drainage area mapping to be completed. The DEM data would also support better communication about drainage issues within MnDOT, other governmental units and the public, because of the ability to create clearly understood 3-dimensional graphics.

Soil maps are critical for farmers, developers and natural resource managers. Many Minnesota counties have older soil maps that can be upgraded by utilizing DEMs to correct spatial displacement of soil boundaries. The University of Minnesota has developed a process that worked successfully in many counties.³ High-resolution DEMs could improve this process and help more counties get the soil maps they need.

Local government would also benefit from a high-resolution DEM. Dakota County has worked with 11 of its cities and an electric utility to create a powerful GIS that includes high-resolution elevation data.⁴ The elevation data proved particularly useful to the City of Burnsville in bidding

³ National Research Council. 2001. *NSDI Partnership Programs: Rethinking the Focus*, National Academy Press: Washington, D.C., page 43.

⁴ Craig, William J. and Donald D. Johnson. 1997. GIS Technology Benefits Add Up in Dakota County/Cities Partnership, *Minnesota Cities*, January/February, pp. 10-12.



out a road construction project. When the winning bidder learned of the availability of the DEM data, he immediately refunded \$60,000 to the city as cost savings for the project. The city has subsequently saved two weeks and \$4,800 on preliminary field work for every road construction project it undertakes.

Washington County recently developed a high-resolution DEM and found a significant interest in purchasing maps and digital data by developers, surveyors, engineers, government agencies, and the general public. Washington County uses the elevation data on a regular basis for the following purposes:

- Reviewing subdivisions plats
- Reviewing mining operations
- Bluff line delineations
- Cell phone tower siting
- Wetland delineations
- Flood management control (spring flooding)
- Modernizing FEMA flood insurance rate maps (FIRM)
- Issuing conditional use permits
- Landlocked basin studies
- Zoning violations
- Public Hearings:
 - Board of Adjustment and Appeals
 - Planning and Advisory Commission
 - Plat Commission
 - County Board Meetings

Already, some Minnesota state and local government organizations are benefiting from isolated investments in such programs. Others are eagerly anticipating full state coverage, with clear plans about how the information could be used.



**DRAFT RESOLUTION SUPPORTING FUNDING to DEVELOP
a STATEWIDE HIGH-RESOLUTION DIGITAL ELEVATION MODEL (DEM)
and a FLOODPLAIN MAPPING PROGRAM**

Whereas, proper administration of state mandated floodplain management ordinances requires complete and accurate floodplain maps and related hydraulic data;

Whereas, counties and cities have the responsibility to administer floodplain management ordinances based on floodplain maps and related hydraulic data;

Whereas, current floodplain maps and related hydraulic data are outdated, inaccurate, and are a source of conflict between counties/cities and home/business owners in floodplains;

Whereas, counties and cities look to MN DNR for assistance to administer floodplain ordinances;

Whereas, MN DNR needs funding to collect statewide high-resolution elevation data to develop a digital elevation model (DEM) as a base map to identify flood hazard areas in the state and to provide the information to the counties and cities;

Whereas, DNR Waters, in cooperation with its partners, has prepared a white paper on developing a high-resolution DEM and floodplain mapping program;

Whereas, LIDAR technology is the most cost effective way to collect high-resolution data;

Whereas, availability of high-resolution data is essential for engineering, surveying, GIS and soil mapping; and for planning, design, and management of transportation infrastructures and flood control structures;

Whereas, the state could leverage up to 34 percent of the total cost of the program from the Federal Emergency Management Agency (FEMA) if a DEM and floodplain mapping program were funded and implemented;

Now, Therefore, Be It Resolved that the District ____ Board of Commissioners requests the Minnesota Legislature to fund the Minnesota Department of Natural Resources' effort to develop a statewide DEM and floodplain mapping program.

Chair, District ____ Board of Commissioners

Secretary, District ____ Board of Commissioners

Date _____

Date _____

This information is available in an alternative format upon request

Equal opportunity to participate in and benefit from programs of the Minnesota Department of Natural Resources is available to all individuals regardless of race, color, national origin, sex, sexual orientation, marital status, status with regard to public assistance, age or disability. Discrimination inquiries should be sent to: MN/DNR, 500 Lafayette Road, St. Paul, MN 55155-4031; or the Equal Opportunity Office, Department of the Interior, Washington, D.C. 20240.

The DNR Information Center phone numbers:

Twin Cities: (651) 296-6157

MN Toll Free: 1-888-646-6367 (or 888-MINNDNR)

Telecommunication Device for the Deaf:

(651) 296-5484

MN Toll Free: 1-800-657-3929

World Wide Web Site Address:

<http://www.dnr.state.mn.us/waters>

©2002 State of Minnesota, Department of Natural Resources

 Printed on recycled paper

PHOTO CREDITS

Cover: Roseau, June 2002. Photo by Dennis Cameron, DNR Division of Forestry.

Page 3 (top): Norman County Road, 2002. Photo by Kevin Ruud,
Norman County Emergency Management.

Page 3 (bottom): East Grand Forks, 1997. Photo by Larry Duke (Retired) DNR I&E.

Page 4: Breckenridge, 1997. Photo by Cliff Barth, Mayor of Breckenridge.

Page 5: Norman County Road, 2002. Photo by Kevin Ruud,
Norman County Emergency Management.

Page 9: Navy Island along Shepard Road, St. Paul, 2001. Photo by Toby McAdams,
DNR Waters.

Page 10: Overflow from the Wild Rice River (near Ada) from County Road 9; June 2002.
Photo by Lisa Bendtsen, DNR Waters.

9: Navy Island along Shepard Road, St. Paul, 2001. Photo by Toby McAdams,
DNR Waters.