GEOGRAPHIC INFORMATION SYSTEMS THEMATIC MAPS:

The first step in the design process is analyzing the landscape to understand its complex layers of geology, landform, vegetation, history and culture. In order to perform the analysis, GIS data was collected and then processed into different layers according to themes. The themes each become an individual map. Like laying a transparency over another, these thematic maps are layered over each other to reveal relationships within the complexity of the landscape.

Thirteen data layers were chosen to be combined into the thematic maps: bedrock geology, surficial geology, infrastructure, elevation, hydrology, original vegetation, native plant communities, biodiversity sites, national wetlands inventory, land use, land cover, population change, and land ownership. The thematic maps then produced, at the scale of the GIS study area, are: Bedrock Geology, Surficial Geology, Elevation, Hydrology, Original Vegetation, National Wetlands Inventory, Native Plant Communities, Biodiversity sites, Land Use, Population Change, Land Ownership.

Analyzing the landscape in this layered manner serves as the basis for developing a regional identity through design. Mapping the attributes of a region allows the design to celebrate the uniqueness of the area through use of regional materials, native vegetation, and landform.
BEDROCK GEOLOGY

LEGEND
- River Communities
- Roads
- Lakes
- Streams
- Sandstone & Shale
- Mt. Simon/Jordan
- Sioux Quartzite
- Late Archean Intrusions
- Mafic Meta Volcanics
- Late Archean Granite
- Gneiss & Granite
- County Boundaries
BIODIVERSITY SITES

LEGEND

- River Communities
- Roads
- Lakes
- Streams
- Outstanding Diversity
- High Diversity
- Moderate Diversity
- Below Average Diversity
- County Boundaries

Montevideo
Granite Falls
Redwood Falls
Morton
New Ulm
POPULATION CHANGE 1990-2000

LEGEND
- River Communities
- Roads
- Lakes
- Streams
- -45%/-30%
- -29.99%/-15%
- -14.99%/0%
- .01/15%
- 15.01%/30%
- 30.01%/45%
- County Boundaries

Montevideo
Granite Falls
Redwood Falls
Morton
New Ulm

Yellow Medicine
Lac qui Parle
Swift
Chippewa
Kandiyohi
Meeker
McLeod
Steele
Redwood
Brown
Renville
LAND OWNERSHIP

LEGEND
- River Communities
- Roads
- Lakes
- Streams
- Reservation
- State Land
- Major Property Owners
- Federal Land
- Wildlife Management Areas
- State Park
- Park Land
- Fisheries Land
- Ecological Services
- Reinvest in Minnesota
- Scientific & Natural
- County Boundaries

Map of the region showing various land ownership details.
LAND TRANSFORMATION MODELING OVERVIEW:

THE LAND TRANSFORMATION MODEL (LTM)

Before analysts could make the 2020 and 2050 urban transformation projections, they first simulated a projection for a year for which they had actual urban transformation data. Using data from the years 1991 and 2000, they projected urban transformation of the Minnesota River Trail area for this 9-year period. To do so, they first obtained raw data including satellite images, road maps, land cover maps, and various geographic data layers of the area from the 1991 and 2000 dates.

DATA FOR LTM MODELLING

Data for input to the LTM model was obtained from a variety of sources noted below.

LANDSAT THEMATIC MAPPER IMAGES: Landsat satellites capture moderate resolution images of the earth from space. For the Minnesota River Trail project, analysts classified Landsat images from 1991 and 2000 to generate land cover/land use maps of the study area. The land cover/land use was classified as: Water and rivers, lowland forest, upland forest, agriculture/grass, urban and lowland non-forest.

GAP ANALYSIS PROGRAM (GAP) VEGETATION MAP: The Minnesota GAP vegetation map is a detailed, hierarchically organized vegetation cover map produced by computer classification of combined two-season pairs of early 1990s Landsat imagery. The GAP vegetation map was used to create a lowland mask to separate lowland forest areas from lowland non-forest areas in the Landsat images noted above. It also served as an aid to the generation of land cover/land use classifications.

U.S. GEOLOGICAL SURVEY DIGITAL ELEVATION MODELS: Digital Elevation Models, commonly referred to as DEMs, are data files that illustrate an area’s elevation. Before computers, DEMs were simply a collection of elevation points for an area organized into lists or tables. But today, computer software takes this data and generates three-dimensional views of an area based on these elevation points and allowing for a more thorough analysis. DEMs are available through the U.S. Geological Survey (USGS), from the USGS 1:24,000 mapping series. Those roadways that are interstate, trunk highway,

DIGITAL LINE GRAPHS HYDROLOGICAL WATER AND WETLAND DATA: Digital Line Graphs (DLGs) are datasets that represent cartographic information from USGS maps. For the Minnesota River Trail project, analysts used the hydrological water and wetland data layers.

NATIONAL FOREST: The dataset that represents the location of national forest boundaries within the state is Natforest which was created by the U.S. Forest Service. This data was used in the development of an exclusionary layer for the LTM.

INDIAN RESERVES: The dataset that represents the location of Indian reservation boundaries within the state is Reservtn. This data was used in the development of an exclusionary layer for the LTM.


Next, these data were processed using ArcGIS, a computer software package. This allowed analysts to identify ten factors, or predictor variables, affecting urban transformation between 1991 and 2000.
Ten Predictor Variables:

- Elevation
- Slope
- Aspect
- Distance to interstate highway
- Distance to County aid highway
- Distance to lakes
- Distance to streams
- Distance to lowland
- Distance to urban
- Population density

Next, these predictor variables, along with the land cover maps from 1991 and 2000 and an exclusionary layer, were loaded into the LTM. The exclusionary layer, which is a data layer representing land where development is prohibited, included interstate highway, county aid highway in 1991, water and rivers, state and national parks, Indian reservations, and the initial 1991 urban area. To generate the 1991-2000 urban transformation projection, analysts relied on the LTM’s Artificial Neural Network (ANN) to sort the predictor variables, land cover/land use maps, and the exclusionary layer. Artificial neural networks serve the LTM the same way that neurons serve the human brain. Both are an information processing hub.

After the LTM ran its course, a map of “change likelihood values” for the Minnesota River Trail was generated illustrating which areas were highly likely to change from non-urban to urban by 2000.

**URBAN TRANSFORMATION SIMULATION: 2000**

With the “change likelihood values” and the land cover maps from 1991 and 2000, analysts determined that the Minnesota River Trail area experienced a major increase in transformation of non-urban to urban land between 1991 and 2000. In fact, the area classified as urban land increased by 34 percent from 1991 to 2000. To aid the understanding of these changes, we note the area classified as urban land in 1991 was 63,007 acres.

By overlaying this projection on the actual urban transformation between 1991 and 2000, analysts were able to examine the accuracy of the projections. The projection was typically 30-50 percent accurate depending on the part or subregion of the study area considered — a typical pixel level of accuracy for the LTM. Accuracies exceeding 45-50% are considered very unusual and perhaps due to overfitting of the model. However, accuracy can be judged several ways: Agreement in the actual pixels that changed and/or agreement in the total number of pixels changing to urban.
THE LAND TRANSFORMATION MODEL:

The LTM model is a digital tool developed by Michigan State University to assist planners and resource managers to develop improved decisions that affect the environment and local to regional economies. The LTM uses recent land use change, population growth, transportation, proximity or density of important landscape features such as rivers, lakes, recreational sites, and high-quality vantage points as inputs to model future land use change.

The LTM models employs Artificial Neural Networks, similar to the intricate pathways established in the human brain. The Artificial Neural Net is a process that utilizes a machine learning approach to numerically solve relationships between inputs and outputs (Michigan State University 1996). The LTM relies on Geographic Information Systems (GIS), artificial neural network routines, land use data from at least two dates, and customized geospatial analysis tools. Raw GIS data (e.g., thematic layers) is first acquired, then processed, and converted to an ARC/INFO GRID format with cell sizes of 30m x 30m.

INPUTS TO THE LTM MODELLING PROCESS

LandSat Thematic Mapper Images:

LandSat satellites capture moderate resolution images of the earth from space. For this project, analysts classified LandSat TM5 image data from around 1991 and 2000 to generate land cover/land use maps of the study area. Specifically, three Landsat scenes were needed to cover the extent of the Minnesota River Valley; specifically these were path-29 row-29, path-28 row-29, and path-27 row-29. The subsequent land cover classification of the 1991 base layer used one TM image from each scene. The image dates used, in order of path and row given above, were August 19th, 1992; August 26th, 1991; and September 6th, 1992. Images were selected based on their quality (i.e., lack of clouds and haze) and nearness to the base date of 1991. The 2000 land cover classification used images from the ETM+ sensor corresponding to the dates August 4th, 2001, July 23rd, 1999, and September 18th, 1999. Again all images were chosen based on clarity and nearness to the base date 2000. All the images were rectified to the MDOT road layer, with a final rectification error of less than 15 meters.

The ISODATA algorithm was used to classify the images into the following classes: Water and rivers, lowland forest, upland forest, agriculture/grass, urban and lowland non-forest. These classes were established based on the abilities of the sensor, our research requirements, and by referencing Anderson’s Land Use / Land Cover classification system. The resulting classes are described in table 1.

Table 1. Description of land cover/land use classes.

<table>
<thead>
<tr>
<th>Land cover/land use class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water and Rivers</td>
<td>Permanent open water, lakes</td>
</tr>
<tr>
<td>Lowland forest</td>
<td>Lowland forested area. Forest defined as a minimum of 70% canopy closure. It includes coniferous, deciduous, and mixed forest.</td>
</tr>
<tr>
<td>Upland forest</td>
<td>Upland forested area. Forest defined as a minimum of 70% canopy closure. It includes coniferous, deciduous, and mixed forest.</td>
</tr>
<tr>
<td>Agriculture/grass</td>
<td>Includes planted cropland, rangeland, fallow, and natural grassland.</td>
</tr>
<tr>
<td>Urban</td>
<td>Includes commercial, industrial, residential, and transportation.</td>
</tr>
<tr>
<td>Lowland non-forest</td>
<td>Lands that are sometimes covered with water or have waterlogged soils.</td>
</tr>
</tbody>
</table>
GAP ANALYSIS PROGRAM (GAP) VEGETATION MAP:

The Minnesota GAP vegetation map is a detailed, hierarchically organized vegetation cover map produced by computer classification of combined two-season pairs of early 1990s Landsat imagery. The map was developed as part of the Upper Midwest Gap Analysis Program whose goal it is to maintain biodiversity by identifying those species and plant communities that are not adequately represented in existing conservation lands. There are typically 4 levels or classes in Gap Analysis. The GAP vegetation map was used to create a lowland mask to separate lowland forest areas from lowland non-forest areas in the Landsat images noted above. It also served as an aid to the generation of land cover/land use classifications.

U.S. GEOLOGICAL SURVEY (USGS) DIGITAL ELEVATION MODELS (DEM): The DEMs were standardized to 30-meter grid cells, UTM Zone 15, NAD83, vertical units in feet and were joined into one statewide file. All the DEMs are Level 2 quality. Level 2 DEMs have been processed or smoothed for consistency and edited to remove identifiable systematic errors. A vertical RMSE of one-half of the contour interval, determined by the source map, is the maximum permitted. Systematic errors may not exceed one contour interval specified by the source graphic.

DEPARTMENT OF TRANSPORTATION 2001 ROADS: This data set contains roadway centerlines for roads found on the USGS 1:24,000 mapping series. Those roadways that are Interstate, Trunk Highway, or CSAH (county state/aid Highway) are current through the 2001 construction season. Other roads, if not updated, are depicted as shown on the published quadrangle.

HYDROLOGICAL LAKE AND WETLAND DATA: The 1:100,000 scale hydrography data was derived from USGS Digital Line Graphs (DLG)’s of the same scale. This data contains only the polygon portion of the DLG database. Area features are described as lakes, wetlands, inundated areas, tailings ponds, sewage ponds, fish hatcheries, and other minor water body types.

NATIONAL FOREST: Natforest, which represents national forest boundaries within the state, is a layer of the State of Minnesota BaseMap 2001 which consists of a number of individual data layers or themes digitized from 1:24000 USGS 7.5-minute quadrangles. These data layers fall into the following broad categories: transportation system, civil and political boundaries, and surface water. Natforest originated as a polygon coverage with the U.S. Forest Service. It is available through the Minnesota Department of Transportation.

Indian Reserves: Reservtn, which represents Indian reservation boundaries within the state, is a layer of the State of Minnesota BaseMap 2001, which consists of a number of individual data layers, or themes digitized from 1:24000 USGS 7.5-minute quadrangles. It is available through the Minnesota Department of Transportation.

CENSUS BLOCK: U.S. Census block level data with population information for 1990 and 2000 was obtained from the U.S. Census Bureau.
REFERENCES AND LITERATURE CITED


