these decisions, to lower risk to an acceptable level, and to achieve cost-effective road deactivation.

Acknowledgements
Our study was made possible through the efforts and advice of Roy Sidle, Doug Golding, Pat Slaney, Wayne Keddy, Dan Hogan, Bruce Thomson, and Dennis Lozinsky.

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A Practical Approach to Risk Management of Roads Using GIS (ArcView™)

Glynnis M. Horel

A geographic information system, or GIS, has many uses for analyzing and managing land-based infrastructure. This article describes how the GIS program ArcView™ can help to optimize risk-based road deactivation or maintenance programs.

GIS programs link spatial (i.e., visual map) data with database (dbf) files that carry attributes for the theme (polygon, line, or point) that is displayed visually. ArcView™ displays lakes, forest cover, terrain mapping as polygons, streams and roads as lines, and bridges, culverts, and sign locations as points. Attributes are carried in the ArcView™ dbf table for the theme; additional attributes can also be compiled in separate dbf files and then joined to the ArcView™ dbf table. This allows for a virtually unlimited range of attributes and great deal of flexibility in viewing and analyzing data using ArcView™.

The following is a minimum GIS data set that will allow the ArcView™ user to optimize road deactivation, inspection and maintenance programs:

Themes:
- Unit boundaries (watershed, tenure, or operating area) - polygons
- Water bodies (lakes, ocean) - polygons
- Roads - lines
- Streams - lines
- Bridges - points

Attributes:
- Roads: permits, status (maintained mainline, level of deactivation, abandoned, etc.), hazard level
- Streams: fish habitat and non-fish habitat
- Bridges: type, span length

Analysts are determining road hazard levels as part of watershed restoration programs, watershed assessments for forest development plans (CWAPs), and other forest management functions. To capture this information in the GIS is immensely useful for a forest operation that is managing the forest land base for the long term. Where roads have not been previously assessed for hazard, a hazard rating by road segment

Feature

can be constructed using the following, in increasing level of accuracy:

- Slope mapping
- Terrain mapping
- Field assessments for maintenance or deactivation

For a long-term management system on a large land base, the accuracy of the hazard rating tends to improve over time, as information is collected from periodic inspections. Once each road segment has an assigned hazard level, it can be displayed spatially along with fish habitat information and bridge locations, as illustrated in the example on page 7 (colour in the original allows clearer presentation of complex information).

In this example, road hazard levels are combined with relative risk to fish habitat to determine road deactivation priorities. (N.B.: it is necessary to ensure that lower-risk road segments behind high priority sections will not be orphaned.) From viewing the spatial data, the priority level for each road section is assigned to a field in the attribute table. The priority level could be for either deactivation or maintenance, depending on the purpose of the analysis. It is then possible to use the attribute table for further analysis.

Other relevant attributes, such as deactivation or maintenance unit costs ($/km); or equipment productivity data (metres per shift), can also be assigned to each road segment. With this information in a GIS base, you are now positioned to rapidly analyze many different variables and scenarios for your maintenance or deactivation programs.

SUMMARY – ROAD DEACTIVATION PRIORITIES

Priority P1 = highest	Length, km (from GIS)	Hazard Level	Deactivation Cost Cost/km	Total Cost	No. of Bridges	Bridge Removal	Total Cost
P1	4.5	H	$40,000	$179,505			
	5.0	M	$30,000	$149,962			
	0.0	L	$7,000	$0			
Total P1	9.5			$329,467	5	$30,000	$359,467
P2	1.3	H	$40,000	$52,285			
	3.0	M	$30,000	$89,542			
	0.0	L	$7,000	$0			
Total P2	4.3			$141,826	0		$141,826
P3	1.1	H	$40,000	$44,543			
	4.2	M	$30,000	$124,972			
	0.0	L	$7,000	$0			
Total P3	5.3			$169,515	0		$169,515
Other	0.2	H	$40,000	$7,539			
	7.4	M	$30,000	$223,376			
	7.4	L	$7,000	$52,095			
Total Other	15.1			$283,011	0		$283,011
Existing Permanent Deactivation	4.6						
Total Watershed Roads	38.7						

Figure 1. Excel™ spreadsheet showing the combined data for roads and bridges.

The same can be done for other themes related to the work, such as bridges. Attribute tables for bridges can be set up to include factors limiting scheduling to fish windows, specific equipment requirements such as cranes, need for on-site supervision by a fish habitat specialist, or other factors.

You can then visually display road deactivation priorities together with fish window constraints at bridges. The analytical capability of GIS will allow you to determine both work schedules needed in order to meet fish windows, and the cost of carrying out the work. You can then use this information to adjust work schedules to optimize equipment usage. The cost information will also allow you to evaluate the benefits expected from the work relative to the cost of the work.

Attribute tables in ArcView™ are usually set up with fields to automatically calculate length (line themes) or area and perimeter (polygon themes). This allows for numerical analysis of the information displayed visually. However, although ArcView™ has powerful querying and analysis capability, I prefer to transfer data to Excel™ to perform numerical analyses. This is easy to do using ArcView™ dbf files. If the data is in a simple ArcView™ dbf file, you can use Explorer™ to copy the dbf file to another folder. If the data is in tables that have been joined in ArcView™, first export the table into another dbf file to preserve the join, then open the new copy of the dbf file in Excel™ and save it as an Excel™ spreadsheet. I have found that this method allows me to manipulate numerical data and format the spreadsheet to my heart's content while leaving the original ArcView™ dbf files unmolested. It also allows me to combine data from several themes (roads and bridges, in the example I have given here) into one table (Figure 1).

I prefer to add some types of information, such as costs, equipment shifts, or other data that I want to manipulate, in the Excel™ spreadsheet rather than in the ArcView™ attribute table, for example when developing schedules.

So why use GIS for risk management decisions? The types of display and analyses I have described above are easily achieved manually for small areas and

Continued on page 7...

Feature

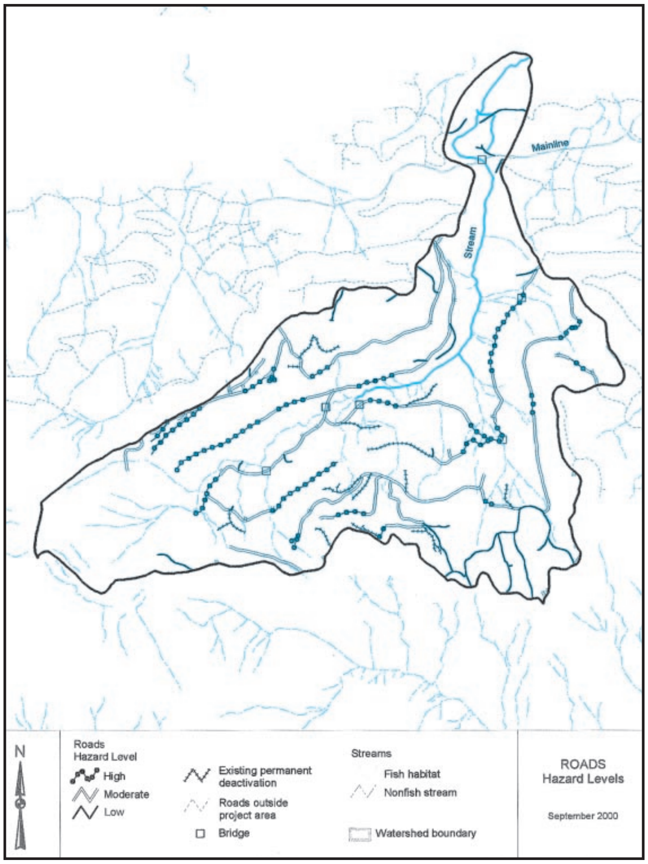

Figure 2. Output for analysis of roads hazard levels.

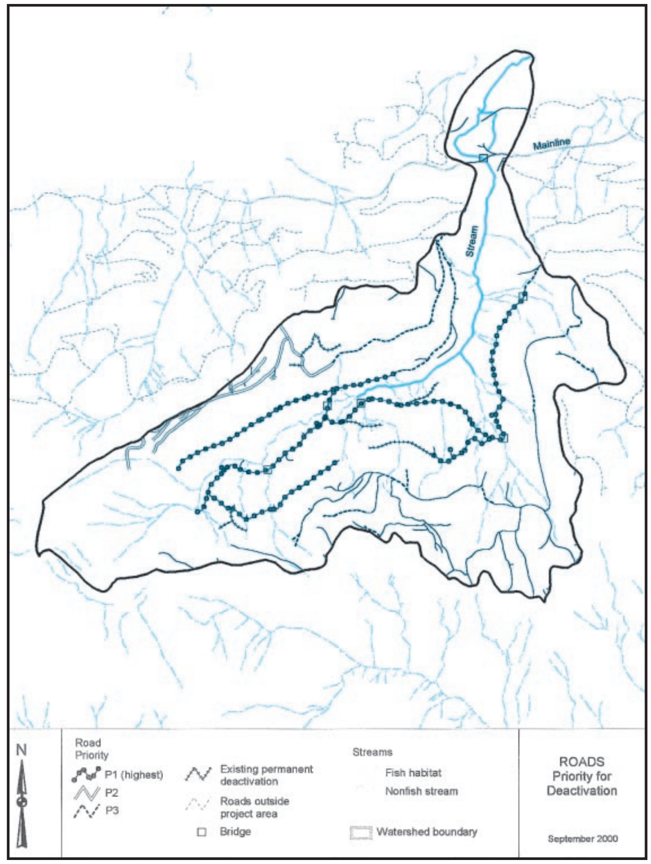

Figure 3. Output for decision analysis regarding priority for roads deactivation.

small road systems, such as in the examples shown in Figures 2 and 3. These advantages are clear. Imagine, however, having to analyze multiple scenarios with changing variables for landbases and complex road systems many times this size, and to track them as they change over time. The real benefit of GIS is in being able to carry out these functions rapidly for large landbases and complex infrastructure systems. If you receive a last minute request to present four or five options for the entire landbase at tomorrow morning's meeting, this system allows you to do so. The ability to display complex information on map sets is especially useful for illustrating your program to decision makers.

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