Background

The manner in which the Bureau has approached this natural resource planning problem has been to rely on an open, yet complex planning strategy. The planning process has been open to the extent that the public as well as specifically known interest groups have been contacted and solicited for their advice and concerns. The level of public interaction was begun in the late '80s and will continue to expand as the process moves toward a final decision. In 1988 a publication was released, referred to as the State Guidance, which explained the Bureau's procedures and positions on a number of land use issues central to the planning effort.

The purpose of the State Guidance was to explain the options available to planners in creating different land use allocations. The format implemented by the Bureau is a fairly common procedure for evaluating a wide range of complex and integrated issues. The available forest inventory, relative to intensive timber management, ranges between two extremes. The initial alternative management plan (A) assumed that nearly all of the forest inventory could be intensively managed for timber production, and that the silvicultural treatments could be as intensive as they are financially prudent. This alternative has been nicknamed the Maximum Timber Run since it identifies the upper extreme of both timber land availability as well as timber productivity.

The Bureau's alternative at the other end of the land use spectrum (E), emphasizes old-growth protection, non-market forest uses and a less intensive style of timber management. This alternative represents timber production as a residual product, in that the timber produced would be as a result of activities more geared at producing specific types and combinations of ecosystems/habitats, than the activities are aimed at generating the most wood volume in the shortest amount of time. The other three alternative form a progression between these two extremes.

Alternative B attempts to increase wildlife protection and recreation use only on Public Domain (PD) lands or on Oregon & California (O&C) lands where their protection or use is most critical. Alternative C increases the focus on maintaining plant and animal biodiversity, both in the form of specific site protection as well as through modified silvicultural treatments of specific forest stands. Recreational forest use also increases its importance in this alternative. Alternative D is built around the central concept of implementing the ISC, or Thomas Report, which at this time appears to be the preferred recovery plan for the Northern Spotted Owl.

The sites selected for protection or for reduced timber emphasis will reduce the availability of land for intensive timber management. Additionally, the intensity of timber management on the remaining inventory is also influenced. The State Guidance provides planners with a mosaic of issues and with spatially-oriented implications for timber inventory availability. The current planning effort is really only possible with the WODDB, both for defining the spatial relationships inherent in the issues at hand and for relating the environmental impact resulting from harvesting the many sale units required to meet the allowable sale quantity during the next decade. The following sections will present the procedures being adapted to the Bureau's planning effort.

The key concept in the manner in which the Bureau is developing its 1990's RMP is that the land use options are declared before the timber harvest scheduling or environmental impact analysis are calculated. The latter impacts are prefaced on the decisions made prior in the process. Therefore, the five alternatives are designed to represent a range of land use options and the numerical analyses determine the outcomes of these decisions. The methodology does not seek to determine the 'optimal' mix of products and consequences, rather, it only evaluates their net interactions on the estimated allowable cut and the resulting environmental impacts.

The following presents a brief list taken from the State Guidance of the goals and primary objectives for three of the five alternatives to be evaluated. The three are presented to provide the reader with the degree of change present in the alternatives.

Alternative A

Goal: Emphasize high production of timber and other economically important values on all lands to contribute to community stability.

Objectives:
- Produce the highest sustained yield of timber on all suitable forest lands legally available for harvest.
- Contribute to ecological functions important to timber productivity and to habitat diversity to the extent possible, consistent with the allocation for timber production.
- Manage threatened and endangered species habitat as legally required.
- Manage appropriate Congressionaly designated areas to maintain and enhance their scenic values.
- Meet legal requirements for protection of wetlands and water quality, to protect anadromous fish habitat and other relevant values.
- Emphasize substantial developed and dispersed motorized recreation uses.
- Find no additional rivers suitable for designation under the Wild and Scenic Rivers Act.
- make land tenure adjustments which enhance BLM long-term sustained yield timber harvest opportunities.
- Provide no special management in rural (residential) interface areas.
**Alternative C**

Goal: Provide timber production to contribute to community consistent with the maintenance of biological diversity and the variety of other uses such as fish and wildlife habitat, recreation, and scenic resources on all lands.

Objectives:
- Produce a moderate sustained yield of timber.
- Provide biological diversity using a system that maintains some old growth and mature forest, focusing on protection of areas where special status plant and animal species cluster.
- Protect habitat of all threatened and endangered species and species with high potential for listing. Protect habitat of other species of substantial concern through the emphasis on biological diversity and to the extent consistent with moderate timber production.
- Retain existing RNA and ACEs. Provide new ones from eligible areas except where lands managed by others are considered to provide more appropriate opportunities.
- Manage scenic resources in selected areas of high use areas, particularly emphasizing protection in corridors of existing and proposed wild and scenic rivers and major trails.
- Provide substantial protection for anadromous fish habitat, other significant streams, and other water environment.
- Provide for a wide range of recreation opportunities emphasizing dispersed use, while reducing conflicts among recreation user groups.
- Find eligible river segments suitable for designation as scenic or recreational, if they are important and manageable, and designation would not cause adverse economic impact.
- Make land tenure adjustments to benefit a variety of uses and values.
- Adopt appropriate special forest management practices in rural interface areas zoned for moderate or high density residential occupancy.

- Protect all old growth and older mature forests.
- Protect habitat of all threatened and endangered species, species with high potential for listing and species of recognized concern.
- Retain existing RNA and ACEs and designate all eligible areas.
- Manage all identified scenic resources and provide some visual resources protection for all lands.
- Manage all riparian areas and wetlands to maintain and improve water quality and fisheries habitat, and contribute to wildlife habitat diversity.
- Emphasize dispersed non-motorized recreation opportunities.
- Find all eligible river segments suitable for designation as wild, scenic, and recreational rivers.
- Make land tenure adjustments which would emphasize enhancement of non-timber uses and values.
- Adopt special timber harvest and forest management practices extensively buffering rural interface areas zoned for moderate or high density residential occupancy and other rural interface areas as appropriate.

While the objectives and goals provide the overall flavor of each of the alternatives, it is the carefully stated instructions in the State Guidance for a set of eleven ‘issues’ which actually guide the definition of the spatial resolution of the timber inventory. The following section will present these issues as well as the manner in which they direct the development of the timber inventory for Alternative C.

**Defining the Inventory**

Defining the intensive inventory base for Alternative C requires both automated GIS analysis as well as human interaction and decision-making on the part of District personnel. The Districts have a responsibility for participating in the determination of which sites will be protected ‘up-front’ for non-timber uses in the alternative. A three-stage approach was devised and instituted for the purpose of defining the intensive forest inventory available to the harvest scheduling model.

**Step 1:** Before any WODDB processing can be initiated, the District Planning and GIS Coordinators are responsible for working with other District and/or Resource Area personnel for the purpose of determining which specific features in the Recreation (REC), Special River Designation (SRD), Visual Resource Management (VRM), State & Federal Highways (SFH) and the set of plant and animal themes (including TEP, TEF, TEC, TES, TEB, RHN, and PNN) are to be removed from the timber base. Once the
District makes and approves the choices necessary for the
issues defining the alternatives, a special OUT theme is sent
to the Oregon State Office.

Step 2: Once the selections are made, the determination
of the intensive timber inventory can be completed in
WODDB through the use of Command Programming
Language (CPL) software in PRIMOS and MOSS/MAPS.
Automating the processes is necessary since much of the
data has been recorded for individual townships
(approximately 36 square miles) and there are over 400
townships in WODDB. The township level themes were
recorded at a 1:4800 scale.

Step 3: After the Districts have identified locations
designated for special protection and the other spatial
restrictions have been calculated in MOSS/MAPS, WODDB
is also used to generate interim files and plots depicting the
inventory remaining in the timber base. District personnel
use the District-wide plots to aid them in their selection of
stands to be protected under Issue Numbers 2 and 3, Old-
Growth Forests and Habitat Diversity. The completion of this
final land-use issue will directly determine the available
inventory in the Mini-MicroStorms database for the TRIM+
model formulation. A special Old-Growth Block Theme will
be created from the District’s selection process and added to
the WODDB to facilitate future analyses and report

generation.

The following sections outline the procedures which will
be used to define the Active Forest Inventory for each of
the Alternatives, separately. The steps which are predicated
on having Districts involvement in the decision process will
be highlighted.

Automated Analyses

Roads, power lines, railroad beds, as well as all roads
built for interim timber sales between 1988 to 1990 are to be
buffered to a 45-foot width. Non-forest locations are also
identified and removed. Issue Number 1 indicates that all
forest lands be allocated to timber production consistent with
the management direction for other resources, except for the
following timber productivity classes including NonSuitable
Woodland, Suitable Woodland - low site, and Suitable
Woodland - NonSuitable Commercial Forest land.

Issues Numbers 7 and 8 establish Riparian Management
Areas (RMAs) on perennial streams, generally 3rd order or
larger, lakes, ponds, and other waters, to meet Oregon
Forest Practices Act requirements and Oregon water quality
standards. Within RMAs no lands would be considered
‘available’ (to offer timber for sale as part of the allowable
sale quantity). Buffered RMAs for the Upper Willamette SYU
are calculated in WODDB following the following directions:

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<td>150 F</td>
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<td>Lakes - 150 F</td>
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The difference between single and double line streams is
simply that the latter were recorded by identifying the banks
of the river or stream rather than simply the centerline of the
feature. These calculations are all conducted automatically
in the WODDB, but the remaining procedures require
human-based decision-making.

District Input

As explained above, the OUT theme is to be created
before the MOSS/MAPS macros are used to create the
vector and raster files necessary for completing the MOSS/
FMP Issues 2 and 3 phase. District personnel are to identify
the following features for each township with a selected
polygon, for any that may exist:

Issue Number 4 - Protect habitats of Federal Candidate,
State Listed and Bureau Sensitive Species to the full
extent on public domain land, and protect habitats of
Federal Candidate species known only to occur on
BLM-administered lands to the extent considered
necessary to prevent their federal listing.

Issue Number 5 - Retain all existing ACECs and RNAs.
Designate potential ACECs and RNAs that meet
criteria only if the relevant values are not protected by
other authorities.

Issue Number 9 - Continue management of all existing
high-use recreation sites and trails and consider re-
opening sites closed in recent years. Retain options for
new high value potential recreation sites and trails.

Issue Number 9A - River segments eligible for scenic
river status found suitable for designation consistent
with their highest potential classification, and river
segments eligible for wild classification found suitable
for designation as scenic, if all of the following
circumstances exist. If only the economic impact test is
not met, find suitable for designation as recreation.

- no net adverse economic impacts on the local
economy,
- river segment possesses at least one outstandingly
remarkable value for which it is considered by BLM to
be among the top two rivers in the SCORP region,
- BLM can effectively manage the outstanding values of
the river segment.

Once the final District calls are made and approved, the
WODDB can generate acreage estimates for every
Operational Inventory Unit and the land use types which can
be assigned within the unit’s boundaries. The following list
represents the hierarchy used to identify the types of
features which will impact the availability of sites relative to
this alternative for the harvest model formulation. Items at
the top of the list are removed first and are counted first
versus those items identified lower in the hierarchy.
Road
Nonforest
Nonsuitable Woodland
Suitable Woodland - Low Site
Suitable Woodland - NonCommercial Forest Land
OUT - REC, SRD, & VRM1
Threatened & Endangered Species Habitat
Riparian Management Areas
Buffered sites of REC, SRD, SSW, & SFH; Intersected with VRM, as well as viewshed with better than 50 percent BLM lands.
1989 and 1990 Interim Timber Sales

**Automated Analysis**

The final MOSS/MAPS analysis cannot be generated until all OUT Theme selections are identified, since Issue Number 6 requires an intersection between the VRM theme all land designated for VRM II Management which exist in a viewshed where BLM administers at least 50% of the area, and all sites within 1/4 mile of developed recreation sites, state and federal highways, state scenic waterways, and rivers designated under the Federal Wild and Scenic Rivers Act and which are inventoried for VRM Class II Management.

The remaining timber land is considered available inventory for the harvest scheduling model. However, CUT (FY '90 sales) and PLANTED (FY '89 Sales) sites will be noted and their inventory volume reduced appropriately. In the Eugene District, sales which were thinned in FY '89 or '90 are to be identified separately. Finally, in the Medford District, all FY '89 or '90 sales harvested as Shelterwood, Thinning, Mortality Salvage, or Seed Tree Removal are to be identified separately.

**District Input**

After the OUT Theme is created and the WODDB macros are used to determine the inventory subdivisions, the District personnel will create the theme of ‘Picked Blocks’ of old-growth stands in order to complete Issue Numbers 2 and 3. The Guidance states that this alternative should provide for intensive management of wildlife habitat and maintenance of biological diversity. It should strive to attain a balance of forest serial stages and associated plant and animal communities. Varying sized blocks of mature and old-growth forests would be spatially distributed over BLM-administered land, focusing on serial protection of identified areas where special plants and animals cluster.

Each District is to be provided with Resource Area Plots indicating the following items:

- Nonforest
- Nonsuitable Woodland
- Suitable Woodland - Low Site
- Suitable Woodland - NonSuitable Commercial Forest land
- Riparian Management Areas

T&E species recovery areas where timber harvest is prohibited, plot file AE6
- Special Areas/Wilderness Areas
- Public Domain Lands
- Sites under VRM Class I Management - out of base
- Sites under VRM Class II Management - extended rotation

The twin concepts of Biodiversity and Gap Analysis will be used to aid district personnel in the determination of which blocks of old-growth should be marked for protective management. Once all three steps are completed, the remaining inventory is ready to be loaded into the harvest scheduling model.

**Harvest Model Linkage**

Once the land base available for timber management has been defined, the acreage data is downloaded to the PC Database Micro*STORMS, a Revelation-based stand inventory database. The same attributes tied to the Operations Inventory (OI) and Timber Production Capabilities Classification (TPCC) themes in WODDB are also identified in this relational database. The ORACLE database software on the Bureau's Prime computer is used as a bridge between the MOSS/MAPS software and the Micro*STORMS database. The linkage between these two software is accomplished via ASCII file data transfers.

Table 1 presents a listing from the OI units in Township 17S-03E, Section 7, Upper Willamette SYU, for Alternative A. The table demonstrates that the total acreage within an OI unit polygon can be represented by a number of different land use categories. Keying on each stand's attributes and net available acreage, the inventory files can be prepared for the Timber Resource Inventory Model Plus Harvest Scheduling (TRIM Plus) by Resources Economics International.

TRIM Plus allows users to allocate individual OI units and their available inventory to Basic Resource Unit (BRUs) files which are the smallest unit of timberland that has been identified as being a particular type of existing forest stand based on inventory sampling and database information. The Bureau has assigned OI units to individual BRUs based on the stand's major species type, past management (or lack thereof), and expected productivity responsiveness to silvicultural activities. Stands with different ages but with the same past history are combined into a BRU. The inventory specialist on the Eugene District separated the inventory into only five BRU types, (1) well to overstocked Douglas fir stands, (2) minimally to understocked Douglas fir stands, (3) natural stands commercially thinned at age 50, (4) natural stands commercially thinned at age 60, and (5) hardwood stands which could be converted to Douglas fir.

For each BRU file, a companion file called the Grouped Resource Unit (GRU) is also created. THE GRU file represents a collection of current and future management instructions and data sources used by the modeler for influencing the manner in which the stands within the BRU
are, to be managed throughout the simulation. The
information included in a SYU set of BRUs and GRUs will
determine the Allowable Sale Quantity for the next decade.
The beginning inventory in the BRUs, the definition of the
BRUs, and the instructions included in the correlated GRUs
can vary by SYU and District to better model growing
conditions and expected management.

10 Year Scenario: Tying the Harvest to
Reality

Once the allowable sale quantity is determined for an
SYU, the environmental impact of implementing that level of
harvest over the next decade must be determined. The
output from the TRIM Plus model identifies the number of
acres to be harvested during the next decade by age-class
within each BRU. Since the Micro*STORMS database
relates which OI units belong to which BRU/age-classes, it
would initially appear fairly simple to relate the harvest level
calculated in the model to actual harvest sites in the forest.
However, the geographic size and shapes of the OI units
where designed to capture distinct stands by forest type.
They do not naturally correspond to the engineering design
layout for most of the sale units offered to the public via the
bid system used by Federal Agencies in the Pacific
Northwest. A completely new theme was created during the
winter of 1988-89 for the express purpose of creating sale
unit polygons for all merchantable timber lands on the
Bureau’s lands in Western Oregon.

The Representative Timber Sale Unit (RTU) theme was
not only consolidated into WODDB, but the subject names
for all such entities are fully integrated within the Micro*-
STORMS database files for each OI unit. Table 2
demonstrates that for any representative timber sale unit or
representative timber sale unit road that may exist in an OI
unit, the acreage is identified, net of all factors which remove
land from the base. This theme supplies the remaining link
for relating the expected harvest level to timber sale sites
which will have an impact on important environmental
issues. TRIM Plus cannot request for harvest any more
acres than were made available to a particular BRU/age-
class, and the linkage in Micro*STORMS of OI units and
RTU allow the districts to select a subset of sale units which
will satisfy the harvest requirement in the model.

It is important to note that in the past, harvest scheduling-
based planning analyses normally estimated the level of
allowable cut that could be sustained and the field offices
simply used these figures as ‘hunting licenses’. Typically,
once the district knew the harvest level assigned to their
administrative unit, foresters searched for the stands which
would provide the most volume for the easiest/closest/most
cost-effective sale possible. Since the forests in the Pacific
Northwest were initially unmanaged, this approach worked
fairly well. However, the world of public forest management
has changed significantly in the past decade. The
conversion of the natural forest ecosystems to a managed
forest system is nearly complete. It has even changed
direction here in the Pacific Northwest; not only are spatial
issues now much more important, but the timing of
silvicultural treatments and final harvest have become even
more critical in the determination of the highest sustainable
harvest level.

The harvest scheduling model formulation used applies
different levels of productivity to each different BRU and
corresponding age-class via the instructions included in the
GRU files. The harvest scheduling model determines the
upper limit on the next decade’s allowable sale quantity,
based on harvesting specific types of forest stands. The
foresters must attempt to find and harvest such sites during
the implementation of the approved RMP. The creation of
the RTU and RTR Theme, as well as the planning and
methodology developed by the 10 Year Scenario Team have

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Table 1: Township 17S-03E Section 7 - Acreage Hierarchy
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Table 2: Operations Inventory File

been with the express purpose of providing a successful link between the predictions made by the harvest scheduling model and the activities which would occur in the districts during the next decade. The work provides a mechanism for evaluating the impact of each alternative in each SYU on the specific spatial characteristics within the forest ecosystem. In the following paragraphs we will outline the procedures developed to provide a mechanism for assigning individual sale units to the those required to meet the harvest level calculated for each set of alternatives and SYUs.

Once the SYU's harvest level for the next decade has been determined by the TRIM Plus model formulation, the task of selecting which sale units are to be harvested begins. The Micro*STORMS database is used to identify all of the eligible sale units. Eligibility is determined by whether the sale unit is dominated by a BRU/age-class which the model indicated should be harvested. Table 3 lists all of the potential sale units which reside wholly or in part in Section 7 of Township 17S - 03E.

The RTU S17E03_0704 actually overlaps into parts of five Operational Inventory Units. Since the largest acreage in this unit belongs to two CI units which are assigned to the same BRU and age-class, BRU 231115/age class 70, then this unit is identified as a complex sale unit for BRU(23115) and age class (70). The unit is labeled complex since if the unit is selected more than one BRU/age-class will have acreage harvested. This potential sale unit is eligible for selection if the model determined that acreage of this type should be harvested and regenerated during the first decade.
<table>
<thead>
<tr>
<th>RTU Unit</th>
<th>OI Unit</th>
<th>BRU</th>
<th>Age</th>
<th>RTU</th>
<th>AC</th>
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<td></td>
<td></td>
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<td></td>
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<td>44.3</td>
</tr>
</tbody>
</table>

| S17E03_0710 | 812424  | 231140 | 0   | 0.3 |    | 231115      | 70           |
|             | 811441  | 231115 | 70  | 34.2|    |             |              |
|             | 813917  | 231115 | 110 | 4.7 |    |             |              |
|             |         |         |     |     |    |             | 39.2         |

| S17E03_0704 | 811445  | 231115 | 60  | 0.1 |    | 231115      | 70           |
|             | 811444  | 231115 | 70  | 13.7|    |             |              |
|             | 811437  | 231115 | 110 | 11.9|    |             |              |
|             | 811435  | 231130  |    | 0.3 |    |             |              |
|             | 811441  | 231115 | 70  | 18.9|    |             |              |
|             |         |         |     |     |    |             | 44.9         |

| S17E03_0707 | 811439  | 231115 | 70  | 16.9|    | 231115      | 70           |
|             | 813917  | 231115 | 110 | 14.9|    |             |              |
|             |         |         |     |     |    |             | 31.8         |

| S17E03_0713 | 811462  | 231115 | 110 | 1.0 |    | 231115      | 110          |
|             | 813917  | 231115 | 110 | 19.0|    |             |              |
|             |         |         |     |     |    |             | 20.0         |

Table 3: Representative Timber Sale Unit File

The RTU S17E03_0713 represents an example of a discrete sale unit. The unit is referred to as discrete since the two OI units which partially fall within the sale unit, both belong to the same BRU (23125) and age class (110). As far as the model is concerned, selection of this sale unit will only contribute to meeting the harvest requirements of this BRU/age-class. Conversely, the selection of any complex sale unit results in additional acres harvested over than the BRU/age class desired.

If the harvest scheduling model indicates that 30% of the acreage in any given BRU/age-class should be harvested during the next decade, this would imply that there are more potential sale units available to select from than are actually required to mimic the calculations in the model. Since the harvest scheduling model does not know or care where any particular potential timber sale resides, it is up to the actual selection process used to determine which units from where should be selected.

The selection process utilizes an algorithm based on the macro-command language of the Revelatlon database software. The algorithm begins with the oldest age-class in a BRU and attempts to meet the harvest level requested. For each BRU/age-class, the algorithm randomly selects both complex and discrete potential sale units until the number of acres selected matches that of the harvest model. The selection process is random in terms of unit size, location, or whether it is a discrete or complex RTU. Discussions with foresters involved with District timber sales indicated that the selection procedure results in a set of sale units which fairly represent reality.

As the algorithm works through the age-classes within a BRU, the solution set for an age-class will include complex sale units which incorporate acreage of other BRU/age-classes. The algorithm accounts for this 'complex acreage' already accumulated as the procedure works through all BRU/age-classes which the model indicated should have acreage harvested. Harvest acreage totals are maintained and updated as new units are selected. This, after all, represents the primary strength of a database software program.

Once all of the eligible BRU/age-classes have had sale units assigned, one of several conditions may exist. First, if the BRU/age-class was to be completely harvested, the total set of eligible sale units may not equal the acreage indicated in the harvest model's original inventory. This result could be expected since some small pieces of each BRU/age-class will be included in potential sale units which are not desirable for the current harvest. An example of this would be the case where a potential sale unit may be designed where the unit is 35 acres of 50-year-old timber with a 5 acre strip of 150-year old timber along one side of the unit. The combination of timber stand ages may make good sense from the standpoint of the engineering layout of the unit. However, it does not make sense to pick 35 acres of a forest type not desired only to obtain an additional five acres of the 150-year old material needed to completely meet the computations of the harvest scheduling model. Representative timber sale units could be subdivided into small fragments by the spatially-oriented land use highlighted in the State Guidance alternatives. Such small pieces of timber sales, less than five
acres, are also ignored by the selection algorithm and could cause the algorithm to fail in finding all the sale unit acreage indicated in the harvest scheduling model. When this case occurs, no additional acreage can be selected but the quantity of timber harvest missing can be determined.

In the second case, a BRU/age-class that should be partially harvested may actually end up with more than the average requested. If the difference is smaller than the size of the smallest selected discrete sale unit, the set of selected unit remains and the overproduction of timber volume is calculated. Otherwise the excess acreage is reduced by the removal of one or several discrete sale units of the approximate acreage required to bring it into balance.

With the third case, an BRU/age-class may have acreage selected for harvest when the model indicated that the entire acreage should be left to grow and be harvested in a latter decade. This has been a minor problem and has been handled in one of two fashions. If the quantity taken is substantial, then attempts are made to replace the complex sale units involved with other units in the BRU/age-class. The macro-command language can be modified to consider this problem. If the quantity selected is minor, than the resulting timber volume is applied toward the overall decade's total harvest. This volume provides a counter-balance to the under-achievement of harvest volume in the first case mentioned above.

Once the sale units are selected, the required road network necessary to gain access to the units must be identified. The same forest engineers who created the polygons of the potential sale units also mapped out the additional roads which would be required. However, the MOSS/MAPS GIS software does not have the capability of recognizing the adjacency of features in the geographical space. Therefore, we developed a mechanical process to determine which roads need to be added to complete the identification of the next decade's timber program. District analyst can complete the road network identification process in a day for an entire SYU. Since BLM-administered lands are already substantially roaded after 40 years of timber sales, the existing checker-board distribution is intermingled with private timber lands.

Several examples of potential road segments are listed with the potential sale units in Table 2. As the district analysts determine which road segments are needed, they can be identified in the Micro*Storms database and the acreage added to the running totals. Once all these steps are completed, any minor discrepancies can be rectified by modifying the solution slightly via additional analysis with the database.

With the completion of the selection of all the sale units and road segments for an Alternative/SYU, a theme in the WODDB can be created for further analysis of environmental effects. This new theme can be incorporated in an analysis of the impact of clearcuts on the water quality for all watersheds in the SYU. Additionally, the impact of the clearcuts can also be included into a model predicting the survivability of the Northern Spotted Owl.

**Summary**

The methodology outlined for defining the alternatives only provides a limited review of all the possible sets of land-use classifications. It is meant to demonstrate a wide range of potentialities and opportunities. Each District will have an opportunity to craft a 'preferred' alternative based on the lessons learned. Additional comments from the public, as part of the review process, also provide a possibility for further enhancements. The Bureau has chosen a methodology which will not find the 'optimal' solution for determining the 'best' manner for managing the public's natural resources. However, it has the capability of working toward a compromise where the interested parties can consider the trade-offs involved.

The methodology developed and outlined in this paper is not elegant, but it does work. More importantly, it is simple enough that it is being used by District inventory specialists, foresters, GIS specialists, and planners, rather than being completed by support staff in the State Office. With six Districts and at least five alternatives, this is a task which needs to be distributed. It allows the State support staff to do just what it is supposed to do; support the efforts of the Districts while they develop their RMPs. Additionally, several points need to be remembered.

First, the solution set of sale units and road segments only represents an estimate of which units will actually be harvested during the next decade. As we move forward in time, things change; forest fires, diseases, and insects affect forest growth and yield. Future changes in land use classifications will also impact where timber will actually be harvested in the future. This analysis provides an important 'what if' for incorporation into the formal planning process and comparison of alternatives.

Second, the spatial distribution of the selected sale units and road segments may cause undue negative environmental impacts in certain locations. Time does not allow the Districts to modify their solutions. When we finally develop the 'preferred' alternative for each District, there may then be time to adjust the model. This may require reducing the availability of the timber inventory in some locations for a decade or two, thereby lowering the overall sustainable harvest for the SYU.

Third, the linkage of actual sale units to the harvest scheduling model does not complete the analysis. Once the spatial distribution of timber sales are known, other models can be utilized to evaluate their impact on a range of environmental issues. Currently the topics of greatest concern include analyzing the impacts of the alternative on watershed water quality and Northern Spotted Owl survival.

Finally, this methodology does not represent the manner in which harvest scheduling models should be linked to a land information system. Eventually, the harvest model must
cease to be two-dimensional, i.e., volume productivity versus timing. We must develop a three-dimensional model where spatial location can be incorporated into the analysis. Such a system will allow analysts to focus on timber productivity while enhancing or reducing the impact on other forest systems.

Disclaimer

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Modeling the Visual Impact of Forest Harvesting: an Integrated Approach

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Abstract
Foresters are under increasing pressure to minimize the visual impact of forest harvesting operations by selecting optimal size, orientation, positioning, and sequence of roads and cutting areas, as well as by adopting selective logging techniques. The manual techniques of sketch mapping and photograph retouching used to illustrate visual impact are now being augmented, or even replaced, by using a geographic information system to combine and display forest cover and topographic data. The primary advantages of this new methodology are its speed, low cost, and lack of human bias in its operation; the disadvantages are the relatively simplistic images produced to date. New technology, first used for special effects in cinematic production, permits controlling not only the texture of the landscape but also atmospheric phenomena and lighting. This paper presents a case study involving these issues.
Concurrent Session 8

**Environmental Issues - Multiple Use**

Sampling the Countryside of Great Britain - GIS for the Detection and Prediction of Rural Change

Oil and Gas Well Drill Site Location Analysis in the Targhee National Forest, Idaho, Using a GIS

GIS and Sustainable Development in Forest Management

The Application of a GIS for Optimizing Multiple Land Uses
Sampling the Countryside of Great Britain: GIS for the Detection and Prediction of Rural Change.

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Colin J Barr

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Merlewood Research Station
Grange-over-Sands
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Abstract

In 1990, the Institute of Terrestrial Ecology completed a survey of the land use and vegetation of Great Britain (GB), repeating and extending the earlier surveys of 1978 and 1984. The surveys, which were structured using the ITE Land Classification, were funded by Government departments and the information collected is being used to assist in central decision making. GIS is being used at several different levels: checking information recorded in the field; incorporating remotely sensed imagery; comparing individual survey sites; linking other census; and surveyed information and presenting the results. The survey uses the Ordnance Survey of GB (OS) 1 km square grid, and collects information on all types of land use. The three dominant forms of land use, agriculture, forestry and urban, are recorded in formats which are as compatible as possible with those used by other specialist organizations (e.g., Forestry Commission, Ministry of Agriculture, Food and Fisheries (MAFF) and Department of the Environment), which allows information collected by different groups to be integrated and data to be exported in accepted styles. The scale selected has proven successful for use at both regional and national levels. The Land Use Research Group at Merlewood has a working knowledge of the requirements of policy advisers and can present ecological information in a variety of relevant ways. Maps and summary statistics are easily produced but estimates of accuracy can raise doubts and lead to results being unfairly undervalued. It is important that GIS is not seen as a system which can only give absolute answers; it must be able to qualify its boundaries and statistics in a comprehensible way. There are a number of statistical methods which can be applied to land cover data, but the presentation of the cartographic results is always the most problematic aspect. The limits of the production and interpretation of error terms are described, detailing elements which are assessed and those which are omitted.

The surveys are a good example of a practical way of collecting and passing information between a variety of sources and disciplines. Results and methods of presentation are discussed.
Introduction

Objective information describing the environment is extremely valuable for assessing the consequences of changes in government policy affecting the countryside. However, the level of detail required in order to make an ecological assessment of the consequences of change, along with the lack of a rigorous set of ecological theories, make it difficult to provide a flexible system capable of supplying both comprehensive and comprehensible information. Decisions and policies at a national level are made by intelligent people who look for assistance and information from specialist groups and organizations. Some of these groups are large and capable of producing detailed census information covering extensive areas. Examples of these in Great Britain (GB) include government offices such as the Ministry of Agriculture, Fisheries and Food and the Forestry Commission.

However, ecological information is different from other measures of land use; rarity of species and habitats is commonly seen as a virtue, and community composition is complex and extremely variable. Ecological information has often been presented to decision makers as expert opinion, which may be difficult to evaluate. An objective, relatively low cost technique is needed to monitor the ecological status of the rural environment. To be of use to policy advisers at national and regional levels the system must be capable of spatial analysis and being linked to other more extensive datasets.

The Institute of Terrestrial Ecology has devised such a monitoring system (Bunce and Heal, 1984 and Howard and Bunce, 1989) and is surveying both the ecology and land use of GB on a regular 6-year cycle starting in 1978.

Applications of GIS

Different functions of GIS are being applied within the survey for different reasons. The survey sites, 512-1 km squares drawn at random from a stratified grid (Figure 1), were mapped in the field for all land cover features. The surveyors used the OS 1:10 000 scale maps as a base map for recording, but these were updated by interpretation of recent aerial photography. Every parcel of land within the sample squares was visited on the ground and the land cover was recorded along with the details of the boundaries. The plant species were recorded wherever they exceeded 25%; in trials, attempts to record in more detail were found to be too time-consuming. The positions of isolated individual trees were also recorded from the aerial photographs and their species were determined during the field survey. The land cover parcels were recorded as distinct features if they were larger than 20m² otherwise, they are recorded as mosaics, automatically producing a limit to the recording of certain features. Linear features including hedgerows and field headlands, were also recorded.

The information was recorded in the field onto five distinct maps:

1. physiography;
2. agriculture and natural vegetation;
3. forestry;
4. boundaries; and,
5. structures and communications.

The information is being digitised and stored in ARC/Info, so that it can be combined with information from the 1978 and 1984 surveys; this makes comparisons between years for the same sites relatively straightforward. Considerable care is being taken to ensure that the ARC coverages only show changes that were recorded in the field. For lowland sites, the process is straightforward, in that field boundaries are usually mapped on the OS base map, so making a copy which is updated by re-labelling is safer than digitizing twice (Figure 2). However, sites in the uplands, where boundaries are less distinct, can cause more of a problem. Frequently, surveyors have had to define the boundaries of parcels in
the field. The 1990 survey has been the first to make use of aerial photographs to help define boundaries, making the mapping more accurate. Judgment has to be used when digitizing to distinguish between real changes and recorder differences. Where the parcels differ, the 1990 result is considered to be more accurate, and is used when the boundaries almost coincide (Figure 3).

Another problem with the boundaries, especially in the more open uplands, are the changes which occur at a boundary. In an arable environment, the fence line may be a sharp boundary between two different crops, but on a moor, identifiable vegetation groups may merge continuously, leaving the surveyor an awkward decision as to where to draw a boundary. To represent the boundary in a GIS as a distinct line is both misleading and incorrect. A number of methods can be used to circumvent the problem, including contouring the densities of habitat types. ITE is investigating the application of fuzzy logic (Chang and Burrough, 1987) to present such boundaries. Although ARC/Info is designed to present crisp boundaries, it is possible to include probabilistic information to present parcels as part of a continuum (Wang et al., 1990).

To increase the precision of recording of botanical features, a number of quadrats were recorded in each sample square. Three different styles were used:

1. nested quadrats of 200m² (Bunce and Shaw, 1973), which were randomly placed throughout the 1 km square and the plant presence and cover recorded;

2. linear quadrats of 1 m x 10 m, which were positioned along hedgerows, streamsides, roadside verges and boundaries; and

3. 4 m² quadrats, which were positioned in additional semi-natural habitats not sampled by the random nested quadrats.

The smaller quadrats and the centre of the nested quadrats can related to the National Vegetation Classification (Rodwell, in press) as used by the Nature Conservancy Council, allowing predictions of national coverage of the types to be made. The sites of all of the quadrats have been mapped and permanently marked with metal plates so that they can be relocated during future surveys. The information recorded in the quadrats can be spatially related to the mapped information, allowing the interpretation of the relative changes in both land use and vegetation. The quadrat information will also be related to soil information, which was collected by field surveyors in 1978 and updated through a contemporary survey of the same sites carried out by the Soil Survey and Land Resource Centre for England and Wales and the Macaulay Land Use Research Institute in Scotland. One of the benefits of collaborative research with leading organizations is that information is collected and presented using methods and terminology which are commonly used, consistent and widely understood.
Definitions

Terminology and definitions can cause problems when working in a multi-discipline project with a number of different organizations. The difficulties only rarely occur at levels of fine detail, but are usually associated with broad definitions. It is essential that accurate descriptions of the terms used to identify parcels are presented with any results but most individuals and groups consider that they understand broad terms. For example, even a common English dictionary includes three different definitions of 'forestry'; land set apart for hunting; a tract of wooded, uncultivated land; and a stretch of land once wooded (Irvine, 1972). The Forestry Commission usually records commercial woodland, ignoring scrub woodland, small copses and scattered trees. However, within their commercial woodland are included rides and clearings. Although other groups also refer to forestry with different definitions (e.g., Monitoring Landscape Change (MLC) and MAFF), their results are usually compared directly without performing the necessary checks for compatibility (Bunce, 1990). The danger is that estimates of
area and extent are rarely questioned if the numeric values are approximately the same. Similar problems are found with other broad definitions such as road areas, agricultural land and physical features. In a different context, the problem has even led to proposals that terms used in everyday speech should be avoided. Birch, (1957), proposed that the biological term 'competition' should be abolished since there was no single definition.

**Estimates of Error**

Although information is recorded about individual sites, the method of presentation is in the form of predictions for land cover and vegetation, either nationally or for large regions. For each feature, the figure is produced by multiplying the mean area per 1 km square for each sample strata, by the known number of squares in that strata, and then summing the strata totals. The sample size is small, 512 in 247 000 or 0.2% of GB, and it would be desirable to increase the size, but, as the sample is based on a grid, the coverage is more evenly dispersed than a simple random sample (SRS), or even a simple stratified sample. Compared to other uses of stratified sampling of populations, eg opinion polls (c. 1000 in 56 000 000 or 0.001%), the sample seems moderately large and has the benefit of the field survey being completed in a short time span (c. 4 months).

It is essential to know the precision attached to any estimates of land use coverage and this can be achieved by calculating error terms. For any given survey design, the methods of calculation are well known (Cochran, 1977). The interpretation of error terms, in whatever form they are expressed, is complicated, especially where the distribution of the variables diverges from normality. Biological factors, especially when rare or managed, frequently show non-normal distributions. Heath is almost bimodal in its distribution both within and between sample strata; it occurs frequently in some land classes but is totally absent from others. Even in the 1 km squares of those land classes where it is found, heather either tends to occur as large blocks or is absent. In such cases, the mean and its standard error do not necessarily represent accurate confidence limits for the land use, although the problem diminishes as the sample size increases. Despite the limitations of the equations, some measure of the standard error of the estimates should be given.

Once calculated, there may be difficulties in presenting error terms; for tabular and graphical data there are a number of standard formats but cartographic results are usually handled with crisp logic. Even statistical cartography does not concentrate on confidence values (Dickinson, 1973). The lack of a standard method of expression causes problems in interpretation as the information is either complex or easily misunderstood. It is tempting to ignore error terms, even when they have been calculated, rather than to educate the audience. To interpret the error terms, it is necessary to understand the methods used to collect the information and to appreciate the assumptions on which they are based. The standard errors for the ITE land cover features surveyed in 1978 have been calculated and compared with the predicted random distribution, derived from the formula presented by Cochran (1977). The application of the stratification showed an improvement over SRS in only 30% of the cases, because of departures from the optimal sampling of the strata (e.g., sampling more in proportion to the area and variation of the strata). It has been calculated that if the sampling had been optimal, then 90% of the features would have had smaller error terms, indicating that the stratification itself was successful for most land cover features. Recent surveys have sampled the strata in proportion to their area, which increases the efficiency for estimation of population totals.

For the estimation of the errors attached to change, there are two general strategic approaches: to measure the same areas on successive occasions, and to carry out separate random samples and detect change from differences between the population means. In the former procedure, as adopted in the current project, any changes detected are certain to have taken place, and the error terms attached to them will relate to the consistency in the size of the change concerned. In the second procedure, the variability within the sample populations on each occasion may be so high that valid change cannot be detected. In the ITE surveys, the 8-1 km squares per strata surveyed in 1978 were resurveyed in 1984, with 3 exceptions, along with 4 extra squares in each strata. Change was estimated in two ways:

1. Comparison of the population estimates (256 squares in 1978 with 384 squares in 1984 and 512 squares in 1990). The standard error of these estimates involve the correlation between the land cover values in the three surveys. A positive correlation means that squares are more likely to have similar values in the surveys.

2. Comparison of changes in individual sites. If the correlation between the values on the two occasions is sufficiently high, greater than 0.85, in enough strata, then it may be more precise to estimate change simply from the squares surveyed twice, ignoring the extra squares surveyed only on the second survey.

An example of these results is the change in wheat between 1978 and 1984 (Barr et al, 1986). The two estimates of change differ, depending upon the number of samples used from the 1984 survey. If only the squares visited on both occasions (8 per land class) are used, the change is an increase of 732 332 ha, with a standard error of 27.47%. If all the information from the 1984 survey is used, the increase is estimated as 885 910 ha, with two estimates for the standard error. If the samples are handled as two distinct populations, the standard error is 27.84%, compared with 21.81% if the covariance for repeated samples is included. The relationship between the size of the estimated standard errors depends on the size of the change. In conclusion, standard errors are a useful measure of the precision of estimates. Although the mean values will not change significantly, the stratification would produce
reductions in the standard error if the sample size was increased, or if the sample was proportional to the areas of the strata.

Summary

Practical difficulties and expense prevent ecologists collecting large census datasets, and historically, the sampling techniques and methods of analysis have evolved to produce efficient systems. The data has a strong spatial element, and is capable of analysis and presentation using GIS techniques, but the style of data requires developments and extensions of the existing methodologies. Particular care should be given to comparisons of statistics from different surveys, especially in relation to the definitions of individual surveyed features. Presentations of error statistics should be accompanied by full and thorough descriptions of methods used.

References


Oil and Gas Well Drill Site Location Analysis in the Targhee National Forest, Idaho, Using a Geographic Information System.

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Abstract
The inherent spatial character and distribution of non-renewable resources make their associated locational data amenable to incorporation into a GIS. The use of a computerized, interactive GIS to manage large and diverse data sets can enhance the probability of resource discovery and, most importantly, improve the decision making process. A vector-based GIS for a portion of Bonneville County, Idaho, is being used to develop and demonstrate the use of GIS techniques in the selection of oil and gas well drilling sites. The present environmental and social factors are considered. These translate into state and federal drilling restrictions, which are spatial in nature and are incorporated into the GIS database. Map overlay functions effectively assess the co-occurrence of oil and gas activity with such factors as land use and wildlife habitat. If conflicts exist, such as the presence of game or special closures or restrictions, the petroleum company can either move its well location or delay drilling, depending on the restriction. These same procedures may also be applied to assist in the decision making process when locating sites for power plants, landfills, and sub-divisions.

Introduction
To assist in the search for oil and gas, petroleum companies have always applied state of the art technology. Today this has come to mean the use of geographic information systems (Lang, 1988). Along with increased exploration, inventory, and the use of remotely sensed data, is the need to efficiently organize the rapidly growing body of information. The inherent spatial character and distribution of non-renewable resources make their associated locational data amenable to incorporation into a GIS. The use of a computerized interactive GIS to manage large and diverse data sets can enhance the probability of resource discovery and, most importantly, improve the decision making process (McLeod et al., 1983).

The analysis capabilities of the GIS model created here allows the user to ask a complex environmental question such as 'locate all areas that are within 500 feet of the normal high waterline of any and all streams, lakes, ponds, and reservoirs.' Such a GIS could be central to the development of environmental policies concerning oil and gas drilling (Gros and Williams, 1988).

Federal and state drilling restrictions vary according to the proposed drilling unit. A listing of restrictions is never complete until an environmental assessment is accomplished. Restrictions may also change without notice. The present system of cataloging particular restrictions in the selected study area is burdensome and does not lend itself to spatial queries.
The purpose of this paper is to present an example of the integration and application of GIS technology for the surface analysis necessary for oil and gas drilling site placement; it explores how computer analysis can assist both the petroleum industry and the forest service in streamlining the decision-making process. By making an 'initial cut' or elimination of unfavourable sites, the GIS user can delineate quickly where drilling might be permitted in the national forest.

**Study Area**

The township selected for the pilot project is located in the Snake River Range, Bonneville County, Idaho. The town of Swan Valley, which lies just outside the southwest corner of the study area may be used as a reference. This township is within the Targhee National Forest, hence, the federal drilling restrictions are issued from the Palisade Ranger District office in Idaho Falls.

This study area was selected for a number of reasons. First, it possesses a number of environmental factors on which GIS buffer functions may be applied. As an area rich in wildlife, timber resources, and natural beauty, state and federal agencies are determined that environmental impacts, due to oil and gas activity, are kept to a minimum. Second, the drilling restrictions are prone to be spatial in nature; these restrictions were converted into GIS analysis functions. Finally, Bonneville County lies in the heart of the Overthrust Belt, which is described by geologists as a complex faulted and thrust zone which runs from Texas to Canada. Certain areas of the Overthrust Belt have produced large qualities of oil and gas. Idaho has yet to produce a commercial oil and/or gas well; nevertheless, petroleum companies still search within its boundaries for hydrocarbon deposits.

**Methods**

This study addresses the following questions:

1. how to streamline the process of selecting an oil and gas well drill site?
2. how to identify and rate alternative drill sites?
3. how to identify environmental and social factors?
4. how to create methods to quickly update drilling restrictions?
5. how to establish a user-friendly environment?

The study design is composed of five major stages:

1. identifying environmental and social factors (drilling restrictions) as stated in the environmental assessment,
2. using Environmental Systems Research Institute's ARC/INFO to develop a database that includes the drilling restrictions which are spatial in nature,
3. performing GIS spatial analysis,
4. creating maps that quickly reveal conflicts between restrictions and drilling and INFO tables that support the map data, and
5. designing a procedure for the efficient updating of state and federal drilling restrictions.

The drilling restrictions used in this study are found in the Environmental Assessments that were conducted for the drilling sites proposed by the Anschutz Corporation. Only restrictions that are spatial in nature are included in this study. Fortunately, this provides enough data from which an 'initial cut' can be made by the petroleum company's GIS staff. Restrictions that are 'non-spatial in nature' may then be used in conjunction with the GIS data to select the final drilling site.

Of extreme importance, and forming the basis for the selection of this study area, are the buffer zones of 500 feet that have been established from the centerline of any and all roads and/or highways within the lease area; and the normal high water line of any and all streams, lakes, ponds, and reservoirs. Buffer zones of 400 feet have been established from the following: any and all springs, and any
Stream Buffers
Bonneville County, Idaho
T2N R44E

improvements either owned, permitted, leased or otherwise authorized by the Forest Service. Buffer zones of 200 feet have been established from any and all trails. Restrictions further stipulate that no well is to be drilled on slopes greater than 40 percent.

In stage two, individual theme layers were created from USGS 7.5 minute topographical maps. 80 foot contour lines and selected very important points (VIP) were first digitized to create the digital elevation model (DEM). The ARC/INFO command ARCTIN was used to create 3-D topology. Surface analysis was then performed to assess slopes over 40 percent. 3-D perspectives may also be generated from the TIN model for display purposes.

Individual theme layers were next created by digitizing all streams, roads, trails, and springs. These features were then buffered with their appropriate distances. To reveal the spatial relationship involved in all the buffered theme layers, the UNION command was used. The DISSOLVE command erased the interior arcs within the overlaid polygons.

Results

The purpose of this pilot study was to determine where oil and gas activity may be conducted within a portion of the Targhee National Forest. Results generated from the GIS model are only an initial cut. Non-spatial restrictions, such as game closures, still need to be factored into the site analysis.
The availability of potential drill sites was quickly reduced as BUFFER, SLOPE, and size restriction commands were applied to the theme layers. The criteria used for the above commands translated directly from the Environmental Assessments. These restrictions, if loosened in whole or in part, could increase the acreage where drilling is allowed. When mitigation of a particular regulation was found to be necessary, the GIS model could quickly be modified and the analysis re-run.

**Summary**

This pilot study has examined environmental restrictions pertaining to oil and gas activity in the Targhee National Forest. A GIS was used to show the spatial relationships between certain drilling restrictions in the study area. Results suggest that a variety of factors greatly reduce the availability of possible drilling sites. Hydrological features and wildlife habitats are important determining factors when addressing the selection of the drilling site.

GISs are rapidly assuming roles as nerve centers in decision support facilities for the management of environmental resources; they are particularly convenient for overlaying multiple information elements and mapping the occurrence of critical combinations of features (Myers, 1983). A GIS stores, manipulate, and displays geographically referenced information. However, a GIS is more than just a repository for massive volumes of data; it is a system for organizing and presenting information needed by researchers, managers, and policy makers (McLeod, 1983).

**Acknowledgement**

I wish to thank the Idaho Mining and Minerals Resource Research Institute (IMMRRR) whose support has assisted me during my research on oil and gas development in Idaho.

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GIS and Sustainable Development in Forest Management

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Abstract
While soaring to popular importance with the public, the media and politicians, the concept of sustainable development seems very familiar to foresters. The foresters' perspective began with sustained yield objectives and has been significantly enhanced with the adoption of integrated resource planning and management. But sustainable development adds new challenges to 'good forest management', including greater consideration to alternate values and to uncertainty and increased public demand for participation in decision making. GIS has emerged as a credible resource management tool and provides many opportunities for improved performance in applying sustainable development principles to forest management. This paper explores the requirements of sustainable development and examines how GIS can be applied to achieve sustainable development in resource management.

Introduction
What is sustainable development?

"Naturally enough, a concept not clearly and consistently defined, with strong emotional appeal, whose economic rationale is more difficult to grasp than might appear at first sight, has been utilized for furthering objectives that are not necessarily in harmony with it."

Surprisingly, in the above quote from S.V. Ciriacy Wantrup's classic natural resource economic text, Resource Conservation, he is referring to conservation, not sustainable development. The statement is applicable to both concepts. Both have considerable emotional and ethical appeal, both have been identified as "Wise Use", whatever that means to each of us.

One thing we can be sure of: sustainable development will be buzzwords for the 1990's and beyond.

There seems to be a tradition that when we talk about sustainable development, we begin by offering our own definition of the concept. This tradition helps to explain why support for sustainable development is something on which both impassioned environmentalists and hard-nosed business leaders can agree, and also why a lot of people are not sure what the term means. The Canadian Institute of Forestry (CIF, 1990) supports the philosophy of sustainable development as defined in the 1987 World Commission on Environment and Development report, Our Common Future often called the Brundtland Report: development that meets the needs of the present
without compromising the ability of future generations to meet their own needs. Further, this is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs. This is the definition we support in this paper.

Sustainable development does not mean no development, it means improving methods for resource development in an environment of increasing demand for resources. Our Common Future suggests that the global GNP must be increased to achieve an adequate and equitable standard of living for all.

Economic trends have always had an impact on environmental trends although the impact was sometimes seen only in retrospect and was frequently discounted. We are now seeing environmental trends beginning to show very real impacts on economic trends.

**How does sustainable development differ from sustained yield management?**

To foresters, sustainable development sounds very familiar; we proudly claim to be among the originals through the practice of sustained yield. If so, why is there such a strong negative perception of the forest industry? Recent public opinion surveys have highlighted a growing dissatisfaction with the way we are perceived to be doing business. A disturbing percentage of the public believe that the forest industry is causing irreversible harm to Canada's forests, and that there is too little government regulation over the forest industry.

Forestry should be a good candidate to lead the way with sustainable development. Well-managed forest operations could be the equivalent of the Brazilian rubber tree tappers, whose defence of the rain forest against slash-and-burn cattle ranchers has made them international heroes. Sustainable economic activity forestalls non-sustainable, destructive practices by making the forest more valuable intact than destroyed. Because forests are a renewable natural resource, they have the potential to be used perpetually for the full spectrum of economic, environmental and social objectives.

While sustained yield management sounds a lot like sustainable development, there are basic ways of thought that must be changed for forestry achieve sustainable development. The attitude that wilderness areas, parks, buffers, wildlife habitat, etc., are direct withdrawals from productive timber land must be replaced. Forest product extraction is one legitimate use of a forest, not the only one, and not the default one. The overwhelmingly negative public perception of forestry practices underscores a gap between expectations of sustainable forests and the reality of sustained yield management.

Forests are a mainstay of balanced ecosystems and provide watershed protection and regulation, wildlife habitat, protection of air and water quality, and provide a wide pool of genetic resources as well as a range of recreational opportunities.

Forests are a notably valuable resource to the world (Forestry Canada, 1990). Forests cover one third of the world's land area; our forests in Canada account for 10 per cent of the world's forested land. In 1987, Canada accounted for 15 per cent of the world's total coniferous roundwood harvest and 16 per cent of softwood lumber, 15 per cent of the world's wood pulp, and was the leader in the manufacture of newsprint, producing 32%. In 1988, the forest sector contributed 3.6 per cent to Canada's gross domestic project and directly employed more than 285 000 people. Forest products represent 18 percent of Canada's total exports and are the largest single earner of foreign exchange.

Sustained yield forest management concentrates on the economic values of forest products. Sustainable development encompasses the many and varied values embodied within the forest ecosystem.

There are a multiplicity of features that can be sustained, and an infinite number of possible levels at which each of those features can be sustained (Baskerville, 1989). Sustaining any one feature, at any given level, does not mean all or any of the other features are also being sustained. Therein lies the basis of the public versus professional deviation with respect to sustainability in the forests of Canada: what do we need; sustainability of volume, sustainability of quality, sustainability of environmental quality, or sustainability of habitat? Sustainability will remain a dominant issue in forestry over the next decade.

**How do we move from sustained yield to sustainable development?**

Our Common Future recommends that, to achieve sustainable development, we must integrate economic and ecological considerations in decision making. This integration requires:

- a political system that secures effective citizen participation in decision making;
- an economic system that is able to generate surpluses and technical knowledge on a self-reliant and sustainable basis;
- a social system that provides for solutions for the tensions arising from disharmonious development;
- a production system that respects the obligation to preserve the ecological base for development;
• a technological system that can continuously search for new solutions;
• an international system that is flexible and has the capacity for self-correction; and
• an administrative system that is flexible and has the capacity for self-correction.

Foresters are not directly responsible for the achievement of all these requirements, but there are many opportunities available to move beyond the sustained yield process to sustainable development. The challenge is to conduct, profitably, more intensive forest management, most probably on a decreased land base. We need the ability to anticipate problems in order to take action in time.

Maini (1989) suggests three considerations are necessary to achieve sustainable development of the forest resource:

• understanding the capacity of the forest to sustain a range of uses while maintaining diversity;
• managing activities within the forest's environmental capacity; and
• using or manipulating the forest environment without prejudicing its ecological integrity and use by future generations.

Integrated Resource Management

The general wide level of acceptance of an integrated resource management approach was the first major step. Most, if not all, government agencies and companies now recognize an integrated approach as a routine process as opposed to an exotic technique.

Refinements are still required. The theory of integrated resource management goes beyond bringing together a forester, a wildlife biologist and a wilderness recreationalist to agree on a plan of action: each should see the same range of opportunities and risks when they look at the same forest or forest stand.

The integrated resource management approach must include a public involvement component to insure direct consultation with constituencies formed by common issues. The public cannot participate in decision making without access to the information.

The Adaptive Approach

The adaptive environmental assessment and management approach offers guidelines and methods to assist with resolving environmental conflicts and problems. It is applicable to assessment and management projects.

Adaptive management consists of a methodically designed and scheduled series of workshops and research.

The process is an ongoing and evolving approach to projects, rather than a one-shot design, and it is of particular value in situations which result in unforeseen problems.

Adaptive management is based on the assumption that because ecosystems are adaptive, to a degree, to changes in the environment, environmental management must also be adaptive (IIASA, 1979). It emphasizes the need for the inclusion of environmental factors from the beginning of the policy design process, the involvement of all stakeholders and the ongoing gathering of relevant information, rather than attempts to gather all the necessary data first. Attempts at comprehensive surveys at the beginning of a project frequently accomplish only expensive, lengthy delays and reams of uninterpreted, unnecessary data yielding no insight to the changes about to occur.

The use of computer models is encouraged as part of the adaptive management to simulate ecosystem, social and economic changes resulting from an action, or choices. The Gulf Island Recreational Land Simulation (GIRLS) study may be familiar to some local foresters (Holting, 1980). It was initiated in 1968 to address varied and increasing demands on resources and ecosystems. Work was stopped in 1970, and, while all the problems were not solved, several key achievements were accomplished, and several key stumbling blocks uncovered. Several of the models developed have continued to accurately predict changes.

The adaptive management approach itself is adaptive, and learns from failures and much as from successes.

The availability of relevant data and consensus across a diverse group of experts enables the adaptive management approach to provide alternatives which are not only astute, but which can be convincing messages to political decision makers.

Economic Analysis

The potential for non-sustainable development of forests has two primary sources: the so-called nonexclusivity or commons issue, and the wide range of commercial and industrial interests whose decisions affect what happens to the environment but who rarely benefit directly from actions that protect it, or suffer from actions that harm it (Crocker, 1988).

Economic analysis, such as a benefit-cost study, taking into consideration all benefits and costs, can provide a more balanced frame of reference for decision makers by providing some indication of the effect of considered changes. Benefit-cost analyses can yield qualitative and quantitative information about economic and environmental tradeoffs and are tools to support decision making. The weakness of mainstream economic theory as a decision support tool lies in an inability to provide guidance for research or policies to encourage innovation, or to offer a satisfactory perspective across the necessary range of issues and disciplines and effects over time of effects (Mowery, 1990).
Regulations and Incentives

Government regulations and pricing structures will be employed to reflect accurate assessments of real benefits and costs, but it is likely these will not have as great an effect as the growing pressures from consumers. Better public understanding of environmental impacts is already being exhibited in changing market demands, and technology is rapidly advancing to satisfy the new demands. The entire forestry industry is well aware of the pressures to behave as responsible corporate citizens.

The Tool to Bring Them All Together: GIS

Information technology provides a mechanism for managing complexity. Given the size of the land areas, the multitude of interests, and the diversity of resources, the quantity of information exceeds the capacity of a manual system to effectively produce relevant information for decision making. This is particularly true within what is increasingly becoming an iterative process of developing, reviewing, and refining alternatives.

Resource utilization research can help to better identify potentials and limitations and to provide the same or greater benefits from the same or a decreased land base. Integrated resource management, including a strong public involvement component, can improve the development of goals and objectives encompassing all the values of a forest. Adaptive management can provide a framework for the trial and error process of determining what the changes will be and how best to react to them. Economic analysis, regulations and incentives will help to guide us in the right direction.

However, none of these tools are viable without accurate, current information to achieve reliable results.

Geographic information systems have only recently progressed to a stage where they can be used effectively in this complex situation. How can GIS be effectively used to facilitate new land management concepts embraced by sustainable development?

Records Management

A large part of society's need for information is related to the land. Day to day policy making, management, planning and government services are hindered by an inability to associate much of the required land-related information with its physical location. Current GIS are alleviating some of these problems. However, records management must be more than maintaining resource inventories and land use status. Decision making also requires information about the events and impacts of management intervention. More needs to be done to capture events and experiences in addition to measurements and observations of natural resources. This implies that forestry practitioners must record more of the day-to-day activities of resource management and that the systems must better facilitate such capture. New technology for monitoring, connected to information systems by telemetry, and more sophisticated earth observation systems will also provide more current data.

Predictive Modelling

Geographic data bases interfaced to predictive models can provide resource professionals and decision makers with the capability to undertake more 'What if' analyses and comparison of alternatives. Long-term wood supply models connected to GIS are being developed in Canada and the US. Many current planning models are deficient in accommodating integrated resource management concerns, and lack the facility to record experience and to be modified accordingly. The process should include feedback mechanisms that can record the effects of management actions based on simulations and other data analysis and lead to refinement of the models. Again, this may mean that more of the day-to-day activities must be recorded to provide the data to calibrate the models and that resource professionals will spend more time analyzing and interpreting data.

Support for Public Involvement

Having accurate data and being able to communicate it effectively will help to eliminate the value-laden arguments about how much should, and can, be done. GIS can be used to resolve conflicts by presenting the facts to stakeholders in an open forum in which alternatives can be tested. This approach is already being effectively used to resolve many urban land use conflicts. Conflicts result in part from data that is inadequate for clear, undisputed decision making which is both environmentally and economically sound. GIS will be used to deal with resource conflicts by managers who have the courage and willingness to state their goals, to make their plans of action public, and to rationalize how these actions will serve to achieve the goals, to monitor the results or their actions, and to seek explanation of the variance between forecasts and actual outcomes. When used effectively, an information system is not merely a static collection of facts, but a dynamic distribution network for ideas (Baskerville and Moore 1987).

Environmentalists are accused of overstating the issues while developers are accused of basing decisions on short-term economic gains. The general public is unable to obtain a clear picture of the relative degrees of importance of the issues, and it is difficult for politicians to support expensive decisions to support long-term sustainable development (Anderson 1989). For example, over 50% of the sampled population in Richmond didn't know the difference between primary, secondary or tertiary sewage treatment and their relative costs, but they were sufficiently concerned to vote on the issue (Maini and Carlisle 1974). GIS technology can facilitate information integration, cost-effective distribution and promote a multiparticle process.
Groupware and GIS

System vendors are developing a new product called groupware that will make it possible for multi-disciplinary teams to work more effectively on resource planning problems. Data and analytical processes can be shared by several users, each working at their own workstation but able to see the effects of another's analysis. It is analogous to an electronic boardroom that does not require the participants to be in the same location. This technology has yet to be added to any commercial GIS, but, given the pace of development, it is likely not far away. Multi-disciplinary planning has been frustrated by communication problems, caused by differences in jargon, and long delays before the information to support a concern could be provided. Groups of professionals working from consistent data bases, with known constant analysis models, can focus on selecting the best alternative to meet policy objectives, rather than arguing whose information or interpretation is correct.

Conclusion

The challenge of incorporating sustainable development concepts into already complex resource management will be significant, but it is a challenge which must be met. As Gordon Baskerville concluded from his audit of Ontario's Crown Land timber management in 1986: "if there is a dominant feature ... it is the prevalence of all-purpose solutions to non-specific problems." Properly developed and applied, GIS technology can do much to facilitate the development of specific solutions to the complex problems of achieving sustainable development.

It is very easy to become absorbed in the engrossing components of hardware, graphic devices, formats, accuracy assessments, and implementation standards. It is also very easy to be protective of mandates, programs and issues. The challenge we face entails the need to look beyond those day to day preoccupations, to envision new models and opportunities, and to work towards sustainable development using accurate, shared information.

Geographic information systems can provide us with the tools to go beyond the current situation and to make sustainable development both practical and effective.

References


The Application of a GIS System for Optimizing Multiple Land Use

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Abstract
At the Universitaet fuer Bodenkultur (University of Agriculture) in Vienna, a GIS application is being developed, using ARC/INFO- software, which uses different layers of environmental information in order to optimize land use according to a user-defined system of preferences. By applying a ranking system of preferences, each part of the evaluated areas can be assigned all those types of land use which are without negative impacts on higher ranked types. Possible conflicts can also be visualized by extracting mutually excluded land uses. This paper describes the results of the test run of the system, evaluating parts of the Viennese Forest, which represent problems typical of areas neighbouring urban regions.

Introduction: The Problems of Forestry in an Urban Region

To the south and the west of the City of Vienna is a large belt of forest land, called the Vienna Woods. These forests have always been of vital interest to the people living in Vienna. Up to the last century they served as a resource for fuel and construction wood, which resulted in the almost complete deforestation of that area. But in the middle of the 19th century, the danger became so evident that logging was finally reduced to a sustainable level.

Today, these forests must fulfill a multitude of functions and are subject to the growing demands of society in an urban region. First, they have to serve as a recreation area for the city, where about 50% of the citizens surveyed (Glueck, 1984) named walking or hiking in the forests as their favorite recreational activity. The forests around the city also have to ensure ecological balance, especially since they represent areas of minor human influence on nature. The welfare function of these forests is also important, since they serve as a filter against air pollution. The expansion of the city has resulted in development activities and many new settlements were established on former forest land, sometimes without the proper permission. The traffic in and around the city also causes negative impacts on the forest, either by the construction of new highways and roads or by air pollution. There is a lot of hunting activity in these forests, which, because of the district-oriented hunting system in Austria, results in high deer stands and the danger of deer damage.

Finally, one must not forget that a large part of these forests are privately owned and that these owners have a legitimate right to manage their forest land according to the principle of sustained yield.
Forest regional planning is a rather young discipline in Austria but, as the problems of concurrent interests in forest land use increase, so does the importance of planning activities in order to avoid possible conflicts. Geographic information systems may provide an important tool for forest regional planning, as the handling and evaluation of spatial data is one of the main tasks in these planning activities. To explore the possibilities of GIS use in this field and to present future foresters with this technology, a GIS system approach to optimize different types of forest land use has been tested during a course in Forest Regional Planning at the Universität für Bodenkultur in Vienna.

The Study Area

The Lainzer Tiergarten (Lainz Deer Park) is an area of about 2500ha in the Vienna Woods, where all of the above problems are present. In the second half of the 18th century, a wall of about 2m height was built around this area by order of Empress Maria Theresia. The main purpose was to keep the deer inside the Imperial hunting grounds, so that deer damage to the farmlands around would be prevented. Since then, this area has been a hunting reserve, and even today about 80% of the area is closed to the public from November to March. The high game stand in this area has resulted in heavy deer damage and any form of forest regeneration is possible only within fenced areas.

On the other hand, this is one of the most important recreation areas in the Vienna Woods, as it is situated within the borders of the city and is easily accessible by public transport.

There are also some areas of special ecological value, some of which already have been declared nature reserve zones, but conservationists would like to have theses zones enlarged and given a higher class of protection.

Some of the sites in this area are capable of producing high quality oak for veneers, and so there is also a large interest in regular forest management in these areas.

Concepts of Land Use Optimization

The four most important forest land use activities in the study area were selected, in alphabetical order:

- Hunting;
- Nature Conservation;
- Recreation; and
- Wood Production.

Each part of the study area has a potential for each of these land use activities, but some activities have a negative influence on others, and it is not always possible to practice all of them in the same area at the same time. It is therefore necessary to apply a ranking system, so that in the case of negative interference only the higher-ranked land use activity will be assigned to a certain area.

Preference System Definition

It is obvious that a ranking between these activities depends on the individual preferences of the evaluating person or authority, as a forester will apply different preferences than a conservationist or a tourist manager. One of the goals of the project was to get the students to visualize the differences between the preferences of regional planning and those of the forest sector.

Therefore, two systems of preferences were established, a regional and a sectoral one.

The Regional Preference System

For the regional planner, the study area represents a large potential for recreation and environmental compensation for the urban region of Vienna. Therefore, recreation and nature conservation are considered most important. In this system, wood production is ranked third, as it is of higher economic importance than hunting.

The regional preference system is:

1. Recreation;
2. Nature Conservation;
3. Wood Production; and
4. Hunting.

The Sectoral Preference System

This system was established to reflect the interests of the forest sector. Wood production is considered most important and is ranked first. Hunting is ranked second, as the selling of hunting licences is also a potential source of income for the owners of forest land. Nature conservation is ranked third, as it is an important value for foresters, even though it does not render any profit to the land owner. Recreation is ranked fourth, as it causes negative impacts on forest management, without giving the land owner the possibility of financial benefit. On this last point, according to Austrian Forest Law, access to private forest land for recreational purposes cannot be restricted by the land owner. This right of access does not apply to activities such as off-road driving or mountain biking.

The sectoral preference system is:

1. Wood Production;
2. Hunting;
3. Nature Conservation; and
4. Recreation.

Evaluation of Land Use Potentials

For each of the selected land use activities, there is a large variety of potential realisations, according to the potential offered by site conditions. For the land use type Wood Production, for example, the variety ranges from even-aged stands of Norway spruce, where large area clear cuttings are applied, to uneven-aged stands of deciduous
and non-deciduous trees with the application of selective cuttings.

The first step was to evaluate the potential for each of the selected land use activities, using different sources of spatial information. The comparison of potential and present situation then allows the planner to establish a list of measures to achieve the potential optimum on each part of the study area. Within this step, the evaluation for each land use type was done without any regard to other land use types. Four groups of students were assigned the evaluation of the four different land use types. Each group was told to define the solutions for its land use type as extremely as possible, so that in a later step the possible conflicts between the different land use types would be more evident.

Sources of Information

Digitized Data

As it was planned to use a GIS for the management of all spatial information, data already digitized were the most desirable source of information for this project. Fortunately, a variety of digitized spatial information could be obtained from the municipal authority of Vienna. For this project, the following sets of digitized data were used:

- Landuse;
- Biotope Distribution; and
- Digitized Map of Vienna.

Digitizing of Additional Data

As this information proved to be insufficient for the project, further data was required. The additional information was gained from Forest Service of Vienna maps of soil types and forest inventory.

Figure 1 shows how the different sources of information were used for the project.

<table>
<thead>
<tr>
<th>Sources</th>
<th>Data Types</th>
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<tbody>
<tr>
<td>Land Use Distribution Map</td>
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<tr>
<td>Digital Map of Vienna</td>
<td>Existing Infrastructure</td>
</tr>
<tr>
<td>Biotope Distribution Map</td>
<td>Stand Type</td>
</tr>
<tr>
<td>Soil Map</td>
<td>Age</td>
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<tr>
<td>Forest Inventory Maps</td>
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<table>
<thead>
<tr>
<th>Preferred Land Use Activities</th>
<th>Stand Type</th>
<th>Age</th>
<th>Existing Infrastructure</th>
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<tr>
<td>Hunting</td>
<td>C</td>
<td>C</td>
<td>P, C</td>
</tr>
<tr>
<td>Nature Conservation</td>
<td>P, C</td>
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<tr>
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<td>C</td>
</tr>
<tr>
<td>Wood Production</td>
<td>P, C</td>
<td>C</td>
<td>--</td>
</tr>
</tbody>
</table>

P: used to evaluate future potential
C: used to evaluate current situation

Evaluation Process

Different potential areas for each land use activity varied. For example, about 12 potentials existed for Wood Production and only 2 for Hunting. In order to compare the potential of one land use activity with another, a standard had to be defined which would allow such comparisons. Therefore, the number of potential classes for each land use type was reduced to three, where class 3 would be the most desirable for a certain land use type and class 1 the least desirable. A full listing and explanation of the potential classes for land use types would be excessive, so the following is only a rough summary of the potentials assigned to each class.

Evaluation for Land Use Wood Production

The soil map was used to get information on the potential for this land use activity within the study area. For information on the current situation, the forest inventory of the municipal forest service was used for the areas within the Lainz Deer Park, as these areas are municipal property. For the outside areas, the biotope distribution map was used.

Priority potential classes for use type Wood Production

<table>
<thead>
<tr>
<th>CLASS</th>
<th>POTENTIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>W3</td>
<td>Oak veneer</td>
</tr>
<tr>
<td></td>
<td>Other deciduous trees</td>
</tr>
<tr>
<td></td>
<td>Norway spruce, Austrian pine</td>
</tr>
<tr>
<td>W2</td>
<td>Reforestation of grass land (energy wood plantations, Christmas tree production)</td>
</tr>
<tr>
<td>W1</td>
<td>Protection forests, wetlands</td>
</tr>
</tbody>
</table>

Evaluation for Land Use Hunting

To define potentials for this activity, existing installations were also included into the evaluation process. The group responsible for this land use activity defined two types of potential, where the wall around the Lainz Deer Park is the main criterion for the spatial distribution of these types. Inside the deer park, a very intensive hunting management would be applied, including a raise-in deer stand, with accompanying measures such as intensive feeding. Outside the wall, an extensive system would be applied, including a reduction of deer stands to a sustainable level such that deer damage would be eliminated.

Priority potential classes for use Hunting

<table>
<thead>
<tr>
<th>CLASS</th>
<th>POTENTIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>H3</td>
<td>Intensive hunting (inside deer park)</td>
</tr>
<tr>
<td>H1</td>
<td>Extensive hunting (outside deer park)</td>
</tr>
</tbody>
</table>

Evaluation for Land Use Nature Conservation

The soil map was also used for this activity, whereas the present situation was taken from the biotope distribution map.
Priority potential classes for use type Nature Conservation

<table>
<thead>
<tr>
<th>CLASS</th>
<th>POTENTIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>Quercus sp./Abies alba</td>
</tr>
<tr>
<td>N2</td>
<td>Quercus sp./Fagus sylvatica</td>
</tr>
<tr>
<td>N3</td>
<td>Dry meadows</td>
</tr>
<tr>
<td></td>
<td>Wetlands</td>
</tr>
<tr>
<td></td>
<td>Riparian buffers</td>
</tr>
<tr>
<td></td>
<td>Quercus cerris</td>
</tr>
<tr>
<td></td>
<td>Quercus pubescens</td>
</tr>
<tr>
<td></td>
<td>Pinus silvestris</td>
</tr>
</tbody>
</table>

Evaluation for Land Use Recreation

The evaluation for this land use activity was based on site conditions and the presence of an existing infrastructure. The main part of the classification was the definition of zones for intensive recreation activities on one hand and those for extensive activities on the other hand.

Priority classes of potentials for Recreation

<table>
<thead>
<tr>
<th>CLASS</th>
<th>POTENTIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Medium-aged mixed stands</td>
</tr>
<tr>
<td>R2</td>
<td>Maintenance of areas around existing infrastructure (e.g., restaurants)</td>
</tr>
<tr>
<td>R3</td>
<td>Free areas for intensive activities up to 20% of the test area (lunch areas, resting places, etc..)</td>
</tr>
</tbody>
</table>

Information overlays

For all parts of the study area, a full geometric and thematic overlay was performed for all of the described information input layers. The resulting layer was then used to assign the potential classes as described above. Each polygon of this new layer contains the information of all basic input layers as well as the information on the assigned land use potentials.

Definition of Interference Matrices

During the next step of the project, the interferences between the different potential classes for all use types were evaluated. Six matrices were defined, each of which contains the comparison between two land use types. These matrices are listed below: a ‘0’ means negative interference between two classes, a ‘1’ means that no interference occurs.

<table>
<thead>
<tr>
<th>RECREATION / NATURE CONSERVATION</th>
<th>RECREATION / HUNTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>R3 N2 R1 H3 0 0 0 W3 0 0 1</td>
<td></td>
</tr>
<tr>
<td>N3 0 0 1 R3 2</td>
<td></td>
</tr>
<tr>
<td>N2 0 1 1 R2 1</td>
<td></td>
</tr>
<tr>
<td>N1 1 1 1 R1 1</td>
<td></td>
</tr>
</tbody>
</table>

Optimization of Land Use According to Preference Systems

The main step was to define land use combinations, according to the defined preference systems, with regard to the interference matrices. First, a ranking between the potential classes of all land use types was established for each of the two preference systems.

Ranking for regional system preferences

<table>
<thead>
<tr>
<th>Rank:</th>
<th>Potential:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R3 R2 N3 N1 W3 W2 H3 W1 H1</td>
</tr>
</tbody>
</table>

Ranking for sectoral (forestry) system of preferences:

<table>
<thead>
<tr>
<th>Rank:</th>
<th>Potential:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>W3 W2 H3 W1 N3 H1 N2 R3 N1 R2 R1</td>
</tr>
</tbody>
</table>

With this ranking performed, it was possible to select the highest ranked land use potential for a certain area as the LEADING LANDUSE TYPE (LLUT). Any other type of land use on this area can then only be undertaken if it does not interfere with the LLUT.

According to the criteria defined, a certain area was assigned the following land use potentials:

- WOOD PRODUCTION: 3 W3
- HUNTING: 3 H3
- NATURE CONSERVATION: 2 N2
- RECREATION: 1 R1

In the Regional preference system, these potentials are ranked R1 > N2 > W3 > H3

So Recreation, with potential class R1 is the LLUT in this area. Ranked next is N2. According to the interference matrix, there is no interference between R1 and N2, so Nature Conservation with potential class N2 is also assigned to this area. In the interference matrix, the next potential W3 interferes with N1, so Wood Production will not be assigned to this area. The same applies to Hunting, as H3 interferes with R1.
In the Sectoral system of preferences the ranking is: W3 > H3 > N2 > R1. In this system Wood Production is the LLUT for this area, and Hunting is not assigned to this area, as there is interference between H3 and W3. There is also interference between N2 and W3, so Nature Conservation will not be assigned to this area. R1 does not interfere with N2 or W3, the interference between H3 and R1 is irrelevant, as H3 is not assigned to this area, thus Recreation with the potential class of R1 is also assigned to this area.

**Automatization of Land Use Assignment**

Basically, the method which was applied for land use optimization in this project is a system of vector and matrix operations, which can easily be formed into a system of logical algorithms. The ARC/INFO AML-Arc Macro Language allows the programming of such operations and so an AML program was written to perform the described land use assignment. Figure 2 shows the flowchart of this application. The use of a programming language like FORTRAN or C for this purpose would permit faster and more efficient computation, but from the author's point of view, minimum run time is not very essential in this project and the features of AML are sufficient for the desired purpose. By using an AML program, it is also very easy to start this program from other AML applications, such as a customized menu system.

**Land Use Assignment Maps**

With the optimized land use assignments performed, the GIS can produce maps showing the distribution of the assigned land uses for the whole study area, as shown in Figures 3 and 4, based on the regional and sectoral preference systems, respectively.

**Conflict Maps**

The exclusion of a certain land use from an area means that conflicts will arise with all those people who have an interest in the now-excluded land use. With the information stored in the GIS, it is possible to produce maps that show which land use types are excluded from what areas. These maps are the inverses of the land use assignment maps. Figures 5 and 6 are conflict maps based on the regional and sectoral preference systems, respectively.

**Necessary Action Maps**

The result of all the information overlays contains not only information on the land use potentials but also information on the current situation. By comparing the potential with the current situation, it is possible to define a list of actions which have to be taken to turn the current situation into the potential optimum. These lists are established for all land use types. For a given area, those actions necessary to reach the potential optimum for the LLUT (leading land use type) will be taken.

After the assignment of necessary actions has been performed by a system of 'IF-THEN' operations, this information can be mapped. Figures 7 and 8 are necessary action maps based on the regional and sectoral preference systems, respectively.

Here is a short description for each of the listed actions.

**Actions for LLUT Wood Production:**

W1: Current situation is the potential optimum; continue current management practices

W2-W7: Current situation is not the potential optimum; change management practices to reach desired optimum

**Actions for LLUT Hunting**

H1: Immediate cutting of stands older than 70 years (shorten falling cycle to 70 years)

H2: Convert non-deciduous monocultures to mixed stands

**Actions for LLUT Nature Conservation**

N1: Current situation is the potential optimum; preserve it

N2: Current situation is not the potential optimum; change vegetation types and density

*Figure 2. Flowchart for USEVAL.AML*
Figure 3. Forest Land Use Assignment, Regional System of Preferences
FOREST LAND USE CONCEPT *Lainz Deer Park*

LEGEND:
- Recreation
- Nature-Conservation
- Wood Production
- Hunting
- Wall Around Deer Park

ORIGINAL DATA:
DIGITAL TRANSFER:
- Biotope Distribution Map
- Digitized Map of Vegetation
- Digitized Land Use Distribution

DIGITIZED DURING PROJECT:
- Soil Distribution Map
- Forest Inventory Map

FOREST LAND USE ASSIGNMENT
SECTORAL SYSTEM OF PREFERENCES

Figure 4. Forest Land Use Assignment, Sectoral System of Preferences
Figure 5. Map of Conflicts, Regional System of Preferences
Figure 6. Map of Conflicts, Sectoral System of Preferences
Figure 7. Map of Necessary Actions, Regional System of Preferences
Figure 8. Map of Necessary Actions, Sectoral System of Preferences
Actions for LLUT Recreation

R1: Preservation and enhancement of existing meadows
R4: Preservation and management of existing infrastructure
R5: Current forest stand is the optimum; preserve it
R6: Current forest stand is not the optimum; change management practices

The total cost of implementing each preference system was calculated by summing the product of component areas and the costs per hectare for the various applicable actions.

Figure 9 shows the comparison of costs for the two systems of preferences. The total costs for the realisation of the regional system of preferences are almost double those for the sectoral system. This is due to the large number of relatively expensive actions required for LLUT Recreation.

Conclusions

The optimization of multiple forest land use will be a major task for foresters in the future. This is extremely evident in a small country like Austria, where it is not possible to assign one type of land use to a large area, such as the national parks in North America. The fact, that in Austria, about 70% of all forest lands are privately owned must be considered in this process. Forest regional planning tries to provide solutions for the conflicts which might arise from the competing interests. As the evaluation and ranking of the different interests depends on the position and views of the evaluator, it is never possible to define a really objective solution.

The concept shown in this paper attempts to consider these facts by demanding a clear definition of preferences at the beginning of the evaluation; these preferences exert a major influence on all succeeding procedures. By presenting the results for two different systems of preferences, the influence of differences can be seen.

Each step of the evaluation is dependent on clearly-defined criteria and so the results can easily be explained and discussed.

The results of this test run have shown that the design method can also be applied to larger areas. Within the next year, a similar evaluation will be performed for the entire Vienna Woods.

Comparison of Additional Costs
(Currency: Austrian Schilling)

![Graph showing comparison of additional costs](image)

Figure 9. Comparison of Additional Costs
The project served also as a platform for introducing GIS technology to students without prior experience in this field. It was not possible, and was not intended either, to turn the forest regional planning course into a full GIS basics course, but it was possible to transmit the basic concepts of the technology. The students learned how to define criteria and rules for the management of spatial information in a GIS-processable form. This should be of value later, when it will be necessary for them to cooperate with GIS experts from regional planning departments. Nonetheless, the project also showed that there is a need to introduce GIS knowledge into the forestry curriculum at an earlier stage, so that basic knowledge does not need to be taught during an applied project. The establishment of a GIS center at the Universität für Bodenkultur in Vienna will help to improve this situation.

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Concurrent Session 9

Techniques - Issues and Concepts
The Provision of General Access to Spatially Integrated Data
Spatio-temporal Analysis Using GIS
GIS and Open Systems Interconnection: Application Layer Protocols
Scanning for GIS Applications
The Provision of General Access to Spatially Integrated Data

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Abstract

Many organizations in government and the private sector collect and maintain spatial databases to effectively manage resources within their jurisdictions. Integrating this data from different sources enhances its value to participating organizations. Integrated data enables more informed decisions based on greater knowledge of more varied parameters.

Many issues need to be addressed to enable the timely integration and distribution of large data sets from data providers to data consumers. This paper examines issues associated with providing the infrastructure necessary to support general access to spatially-related data from multiple sources. The paper also recommends some critical actions required in order to succeed in such an endeavor.

Introduction

Government and the private sector have a considerable investment in data. The data covers a multitude of uses and is stored both in manual form and on different hardware platforms with their various operating systems and disparate database management systems.

These islands of data contain overlaps, duplications and discrepancies. Major efficiencies can be achieved by gathering the data once and allowing access to multiple users. Productivity and effectiveness are further enhanced when everyone uses the same consistent data set.

Some of the data is spatial. It relates to a location on the earth’s surface and it may be defined by a series of coordinates, for example latitude and longitude; or by matching to some characteristic that is itself geo-located, as in a parcel identification number or street address.

Traditionally, both government and industry have been concerned primarily with data from within their own organizations, with limited external linkages. However, both are realizing that the value of their systems is defined not by the hardware or the applications that run on it, nor by the substantially higher costs of acquiring the data itself. The value of the data is the use to which it can be put, and the value increases if it is integrated. The value of the whole is worth more than the sum of the parts.

As greater data integration is achieved within an organization, the need to go outside to obtain and supply information becomes more
apparent. There is a desire to establish inter-enterprise information networks (Figure 1). This is occurring for both spatial and conventional data, as evidenced by the increasing use of electronic data interchange.

This paper examines issues associated with integrating data and presenting it to a variety of users across a geographically dispersed environment. It outlines the actions required to realize the benefits from such an undertaking.

**Business Needs**

Both government and the private sector are continually faced with the need to provide better customer service and to improve the efficiency of their operations. The private sector must also establish, and maintain, a competitive advantage while differentiating themselves from the competition. Both sectors seek to establish a growth path for their information technology investments. This will ensure they do not find themselves with an outmoded system whose investment value far exceeds its current business value.

When looking at the opportunities for spatial data integration, the issues examined are not confined to geo-related information, they extend to other forms of conventional data. Management Information Systems departments have worked to integrate the data held on their various corporate systems and, in effect, have tried to make a patchwork quilt from islands of automation.

The business case to employ information technology in government or industry has generally been automation of a manual process. This has often been undertaken as a functional, and/or departmental initiative, rather than as part of a larger strategy of changing the business process through the application of technology. The result is often the fossilization of an outmoded business process in a costly system implementation.

For conventional data, the new business need may be met by re-engineering the system, restructuring the database or even starting fresh. Fortunately, we may now be able avoid this by placing a shell around older systems. Existing multi-platform computer systems can hide behind a new, more manageable and flexible system. Older systems do not have be altered and the new user interfaces and data integration can be achieved faster and at a lower cost.

Geographic Information Systems (GIS) have existed for some time as tools for handling spatial data. It is only recently that GIS has emerged as a significant area of technology to be applied to strategic business systems. The number of conferences related to land information and their increasing attendance is testimony to the emergence of GIS as an important tool. However, GIS remains an immature technology; ask anyone who has faced the lack of standards when trying to achieve data transfer between GISs.

**The Challenge**

More organizations are realizing the importance of using spatial data to effectively manage the resources within their jurisdiction. But they also have to come to terms with the high costs of acquiring and maintaining it. They find that much of the data already exists and ask 'why not buy rather than build?'

The challenge is how to access spatially related data from a variety of sources and successfully integrate it to meet business needs.
The Solution

Information brokerage is a key concept in meeting this challenge. The concept involves taking data from a variety of sources, primarily government, and assembling, repackaging and presenting it to consumers in the form which is of greatest value to them.

![Figure 2. The Information Brokerage Concept](image)

The data is then available as an information service in one of three ways: (1) basic information as a general public offering, such as tourist information; (2) customized for a particular industry, such as Real Estate listings; or (3) customized for a particular client, such as transit information.

If the Information Brokerage concept is locally applied, the amount of data enhancement would vary. It is likely there will be alliances with private sector organizations who are already in the business of repackaging data and who would then serve as information service providers to an information service network.

![Figure 3. Data Dissemination - Information Brokerage Scenario](image)

Government and industry data would be made available across a public network on a transaction and/or royalty basis. Customer specific data may be made available across a private network.

Government also desires the benefits of data sharing as witnessed by the Corporate Land Information Strategic Plan of the Government of B.C. Both government and industry may require the same infrastructure since their data sharing issues are very similar (Figure 4).

![Figure 4. Data Integration Infrastructure Concept](image)

Benefits

Creating an information brokerage as the means to share data has many advantages:

1. It offers universal access as a public service with one stop shopping;

2. The economy of scale allows investment in the necessary infrastructure for ubiquitous access and in the leading edge technologies for the data delivery;

3. Data can be integrated and customized before delivery for customers who are unable, or unwilling, to do it in-house. There is an opportunity for organizations to add value and participate as information service providers to a wide client base across the network;

4. Central management allows for simpler data management, centralized billing and royalty collection; and,

5. The government can be insulated from the business of data dissemination.

Without such an information brokerage, there will likely be a series of retail outlets reselling certain data to limited users. This will not require the significant investment in infrastructure required by the Information Brokerage and will allow more participants. However, it will present some problems:

1. There will be costs to government and overheads associated with maintaining distribution to multiple outlets and the related billing and royalty collection;

2. There will be customer confusion as to which outlet has what data with limited access and only limited data integration before delivery. This will be disadvantageous to smaller clients; and,

3. There will be a complex data management problem with multiple copies of data sets being held by retailers.
Issues

GIS is one of many tools that will be used to meet the challenge of integrating spatial data. There are a number of technology-related issues to consider in establishing any form of Information Brokerage. These include:

1. GIS - The key to relating the data by keying to its geo-location. GIS must be used for the management, analysis and graphical presentation of the spatial data.

2. Object Oriented Languages - How can this emerging tool be used for application development and the management of data as objects on distributed databases? The establishment of data repository and data management tools is required to allow access to constantly changing independent data sources.

3. Surround Technology - How to employ this for system integration by encasing existing systems housing conventional attribute data?

4. Presentation - How to integrate multimedia and apply the graphical environment in superior user interfaces?

5. Architecture - Performance and cost will determine the location of the data and its processing. This will change as both hardware and communication costs fall.

6. Communications - It will be essential to have a high bandwidth infrastructure available, at reasonable cost, suitable for large spatial data sets and associated graphics. Sophisticated real-time network management will be required to support the distributed environment.

There are also the normal data issues including:

1. Accuracy - Not simply the accuracy of one data set in all its forms, but the accuracy of a combined data set and how that is represented.

2. Maintenance - Who maintains the data and how is that reconciled with user needs when the data concerned is an integrated set?

3. Timeliness - Speedy delivery of data is especially important where its temporal nature is significant.

4. Ownership - Who owns the data when it has been integrated into a new product? What are the copyright and royalty implications and requirements?

Unfortunately, some of the most difficult issues are organizational, such as:

1. Access - Data is held by a variety of federal, provincial and local government organizations as well as private sector companies. There are often inconsistent policies regarding public access to the data and often no policy at all.

2. Risk Management - How to reduce risks to acceptable levels that allow sufficient returns to justify the significant industry investment required to establish the necessary infrastructure.

3. Legal - Who is liable for errors found in products based on multiple source data? What legal protection is available to the user and vendor?

4. Administrative - How to effectively manage billing and royalty collection for use of brokered data and integrated data products.

Conclusion

Fortunately the skills to solve many of the technical issues exist and we are starting to see a desire to tackle some of the organizational ones. These issues can not be resolved by one organization working alone.

There are already a number of successful, regional multi-participant projects. These are based on a common need to establish a landbase on which the various local organizations can base their own data. Organizations must look further than this and establish the mechanisms to share, and use, the vast quantities of existing spatial data.

To accomplish this, organizations need a new type of multi-participant project. It will require partnerships between companies expert in the various technology areas and between private sector distributors of the data and the government, as the principal data supplier.

Actions Required

The government can not be expected to resolve all the issues discussed in this paper. However, there must be a willingness from all levels of government to work with the private sector to solve these problems and realize the benefits together.

Notable critical success factors are:

- Joint leadership and participation in the information brokerage;

- Clear and consistent policies on access to public data, costs, copyrights and royalties that encourage the required private sector investment; and,

- The establishment and promotion of spatial data interchange standards.

Admittedly, there will be a high cost attached to establishing the necessary infrastructure. But, this is an investment with considerable future benefits. Few organizations have the vision and skills to meet the challenge. Those that do will have established the means to achieve greater efficiency in both government and industry. They will also have confirmed a leadership position for Canada with its attendant competitive and export advantages.
Spatio-temporal Analysis Using GIS

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Abstract

The majority of commercially developed GIS assume a time static spatial database. The bulk of all real world GIS applications, however, do contain spatio-temporal variability that may be of importance when preparing routine reports or conducting spatial analysis. This paper will introduce and examine a number of spatio-temporal issues which GIS should ideally be able to handle. A taxonomy of spatio-temporal applications is proposed.
GIS and OSI
Application Layer Protocols

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Abstract

Within the world of data communications, an internationally-accepted standard has been formalized by the International Standards Organization. The Open Systems Interconnection basic reference model (ISO 7498) is the standard specification paradigm for describing network architectures and distributed systems. Currently, ISO is standardizing several data management and transfer services and protocols within OSI's application layer that will directly impact the continued development of Geographic Information Systems. Since the combination of GIS and Data Base Management Systems provide organizations with spatial data management services, how might OSI standardize their union within the context of Spatial Data Base Management Systems (SDBMS)?

There are at least three ways in which OSI can standardize the management and transfer of spatial data.

Firstly, OSI is an open standard upon which open systems can be specified and understood. The standard is well entrenched within the telecommunications industry and is 'spoken' by many computer networking specialists. The OSI model itself, then, is a standard protocol facilitating the design and specification of open systems.

Secondly, related OSI standards are useful in the specification of data transfer protocols between heterogeneous Geographic Information Systems. To date, the Province of Ontario and the Canadian Hydrographic Service have produced two such specifications within the OSI paradigm, MDIF and MACDIF, respectively, using a formal description technique known as the Abstract Syntax Notation - One (ISO 8824).

Thirdly, and most importantly, OSI application layer data management, access and transfer services and protocols will give rise to standard implementations of SDBMS and other distributed database applications accommodating very large data banks such as British Columbia's spatial data base. As it will be shown, the management of B.C.'s spatial data base is both logically distributed across many ministries and physically distributed across many dissimilar computers and many similar data management application systems such as GIS and DBMS.

In order to justify the assertions made above, this paper will present a brief introduction to OSI, will explore the relationship between DBMS and SDBMS, will provide a contrived example of a spatial data base and it's distributed implementation, will describe the integrity-preserving two-phase commit protocol and will finally conclude by relating the discussion to the results produced by the Ministry of Crown Lands during the last year.
OSI: An introduction

The Basic Reference Model of Open Systems Interconnection (IS 7498) is an abstract model of a functional computer network. OSI is the only universally acceptable standard for specifying the behavioural properties of network architectures and distributed systems. The model and its related standards define precisely the manner in which two computer systems communicate with each other without specifying detailed implementation issues like the physical medium of exchange (e.g., coax cable versus shared memory versus magnetic tape) (Judge, 1988). The OSI model decomposes a conversation between two computer systems into seven distinct layers. Of these seven layers, the top four are collectively referred to as the application layer while the bottom three are collectively referred to as the network layer. Figure 1 presents a simplified illustration of the abstract OSI model.

In this simplified illustration, the boxed objects correspond to individual layers. Each layer may be recursively subdivided into sublayers. Regardless, each layer or sublayer offers services to the layer above via its protocol entities. Each protocol entity is confined to a single layer and provides a set of services to its users and its peers. These services define the external behaviours of the protocol entity and constitute its service specification. As far as a user is concerned, each protocol entity can be regarded as a black box whose internal behaviour is hidden from view. The implementor, using the service specification as a contract, provides a conforming implementation of the entity's internal behaviours according to the rules and guidelines set out in a protocol specification. Those readers familiar with object-oriented implementation environments like Smalltalk, Actor and Windows 3.0 will notice many similarities between OSI and an object-oriented paradigm. Perhaps OSI or one of its formal description techniques will eventually facilitate the standardization of an object-oriented paradigm.

Examples of application layer protocols currently being standardized by the Institute of Electrical and Electronics Engineers and the ISO respectively include the Portable Operating System Interface Environment (POSIX) and the Structured Query Language (SQL). Both POSIX and SQL are similar in that each provides its user with a common interface to operating system services and data base management system services.

In addition to SQL, an OSI working group within ISO is standardizing other application layer protocols related to the management and transfer of data within a distributed environment. In the true spirit of OSI, this working group is itself distributed around the world. In Canada, the Canadian Advisory Council (CAC) is the national group that monitors, contributes, and votes on the international standards being developed. Although the Canadian Standards Association is responsible for approving national standards, most of the various committees within the CAC working group are coordinated and thus fulfill both roles.

The Relationship Between DBMS and SDBMS

Generally-speaking, data base management systems facilitate the sharing and storage of data within a secure and predictable environment. In order to provide such an environment, data base management systems employ synchronization mechanisms that serialize data base transactions into logical atomic units of work. Within a seemingly single step, these transactions can be either rolled back or committed permanently to secondary storage. As an example, consider the frequently executed banking transaction that debits funds from one account and then credits these funds to another. Not only do these separate events need to be serialized, they need to be grouped into a single atomic transaction. For the entire transaction to succeed, each individual event must succeed; otherwise, the state and integrity of the data base is unpredictable. For this reason and others, it is useful to classify SDBMS as evolved descendants of more general and traditional DBMS. In other words, a SDBMS is a DBMS and more.

Traditional DBMS are routinely fitted with simple data types like numbers and characters, although some extend this range by including abstract data types like money, date and time. SDBMS, on the other hand, further extend this range of inherited data types to include spatially-oriented abstract data types like points, lines and polygons. Unlike traditional DBMS, standard 'off-the-shelf' implementations of spatial data base management systems are virtually unavailable. As a result, existing spatial data base management systems and their prototypes are non-standard implementations of integrated computer systems resulting from isolated efforts put forth by GIS vendors and those consultants within the computer industry that refer to themselves as system integrators.

The Hypothetical Design of a Spatial Data Base

Given an increased awareness of environmental issues, the intrinsic utility of digital data stored within spatial data bases is well established. It is estimated that within British Columbia alone, the volume of spatial data owned and managed by the provincial government ranges in the hundreds of gigabytes. For reasons other than its extremely large size, the management of British Columbia's spatial data base is spread across several ministries and many heterogeneous computer software and hardware systems.

GIS & OSI

Application Layer Protocols

| Application Layer | software interface | Network Layer | physical medium | Network Layer | software interface | Application Layer |

Figure 1: Simplified OSI Model
Therefore, spatial data bases like British Columbia's stand to benefit significantly from networked applications such as distributed database management systems.

In order to illustrate the relevance of distributed data base management systems to spatial data bases, a hypothetical example of a mineral claims spatial data base is presented. The conceptual mineral claims spatial data base is described in terms of a uniform homogeneous relational data model extended to support complex objects. This object-oriented extension to the relational data model described by Gardarin (1989) is compatible with the universal relation of Ullman (1982). Subsequently, the conceptual mineral claims spatial data base is modelled in Figure 2 as a single relation.

<table>
<thead>
<tr>
<th>ClaimNo.</th>
<th>Owner</th>
<th>RecordDate</th>
<th>SketchMap</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>&quot;Tom&quot;</td>
<td>901231</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>&quot;Bob&quot;</td>
<td>910101</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2*

For simplicity's sake, the universal relation of the mineral claims spatial data base has only five attributes associated with it. The values of these five attributes are characterized by the following abstract data types: ClaimNo, Owner, RecordDate and SketchMap. Although considered esoteric by the uninitiated, the design and specification of abstract data types (ADT) is a popular data abstraction technique employed by computer scientists during design of data base schemas and network architectures. In fact, the following paragraphs pertaining to ADTs nicely complement the discussion thus far as ADTs and OSI exemplify two of the most powerful description techniques known to computer science: abstraction and decomposition (Wulf et al., 1981).

Given the data in Figure 2, let us compare the two data types SketchMap and Owner. While the SketchMap ADT appears to descend from a geometric data type, the Owner ADT appears to descend from a character string data type. Rather than decompose the SketchMap ADT into its apparently obvious constituents, let us decompose the Owner ADT by focusing upon a possible implementation.

Although many computer programming languages provide built-in support for the creation and manipulation of character strings of varying length, Pascal does not. Pascal programmers then are forced to implement character strings as ordered collections of individual objects whose values are characterized by the primitive, built-in data type Char. The Pascal programmer must provide translation algorithms between the primitive operations associated with the Char data type and the abstract operations associated with the constructed string data type.

**A Hypothetical Distributed Implementation of a Spatial Data Base**

As illustrated, Figure 2 achieves the data management goal of physical data independence by preserving both network and location transparency. Whether or not the data is physically distributed either horizontally or vertically is irrelevant to the user (IBM Technical Report). However, since we are interested in distributed systems, this section of
Def twoPhaseCommit( self, aProposedTransaction, theTimeOutPeriod ) {

  /* firstly, decompose the proposed transaction into its GIS and DBMS subtransactions */
  proposedSubTransactionA := theGISPart( proposedTransaction );
  proposedSubTransactionB := theDBMSPart( proposedTransaction );

  /* secondly, simultaneously ask each system to vote upon their respective transaction */
  insertVote( theBallotBox, sendBallot( GIS, proposedSubTransactionA ) ) |||
  insertVote( theBallotBox, sendBallot( DBMS, proposedSubTransactionB ) );

  /* thirdly, check the ballots and react accordingly */
  if NO_VOTE in theBallotBox then
    sendAbortTransaction( GIS, proposedSubTransactionA ) |||
    sendAbortTransaction( DBMS, proposedSubTransactionB );
  else
    commitResults := sendCommit( GIS, proposedSubTransactionA ) |||
    sendCommit( DBMS, proposedSubTransactionB );
    if any( commitResults ) == FAIL or the TimeOut Period == 0 then
      sendRollBack( GIS, proposedSubTransactionA ) |||
      sendRollBack( DBMS, proposedSubTransactionB );
    else
      sendUpdateTransactionLog( self, proposedTransaction );
  endif;

  /* end two-phase commit protocol */
}

Figure 4: An implementation of the two-phase commit protocol

the paper describes a distributed implementation of the conceptual data base illustrated in Figure 2.

In essence, we have already applied horizontal distribution to our solution. As you will recall, this paper began by investigating the relationship between distributed data bases and the spatial data base of British Columbia. We are now focusing upon a single map theme: mineral claims. As it was stated earlier, British Columbia’s spatial data base is distributed across several ministries. In order to accommodate this requirement and distribute the rows of British Columbia’s spatial data base across several ministries, we can add the data type Ministry to our physical data base and create a corresponding view that hides the horizontal distribution from the conceptual data base and its users. We can horizontally distribute the rows of the mineral claims spatial data base by adding another data type, say, Mining Division, thereby facilitating the distributed management and administration of mineral claims geographically within the province.

More interestingly, we can also vertically distribute the columns of the conceptual spatial data base across heterogeneous data management application systems like GIS and DBMS. As illustrated in Figure 3, the columns of the mineral claim records are vertically distributed. In this example, the data types ClaimNo, Owner and RecordDate are managed by a DBMS while the SketchMap is managed by a GIS. This example of vertical distribution corresponds to a common DBMS integration strategy employed by several GIS vendors in their attempt to meet the higher-level requirements of the conceptual data base and its users.

In order to manage the vertical distribution of the implementation, we have added several additional attributes to the physical data base. The attributes characterized by the data types Robld, Gobld and Cobld, invisible to the conceptual data base, correspond to record object identifier, graphical object identifier and connection object identifier respectively. In the example, each one-to-one relationship between a record object and a graphical object is represented by a connection. In order to preserve the integrity of the distributed spatial data base, we must preserve the integrity of the connections. The management of the connections then must be governed by a standard protocol.

The Two-Phase Commit Protocol

The two-phase commit protocol is so named because of the ‘voting’ phase followed by the ‘decision to react accordingly’ phase. The co-ordinator (e.g., the distributed data base manager) asks each participant, the GIS and the DBMS, whether or not they are willing and able to carry out their respective sub-transactions locally. If either system responds with a no vote, the proposed global transaction is aborted and the user will have to try again later. On the other hand, if both participants vote yes, then each participant is commanded to execute their respective sub-transaction locally. Should either participant fail or not respond within a prearranged time-out period, both systems are commanded to roll back to their prior state.

For reasons unknown, the two-phase commit protocol is not the subject of any known international standard. However, several manufacturers of DBMS have implemented it’s precursor. The following computer program listing, written in an extended version of Actor 3.0, is an object-oriented implementation of the two-phase commit adapted from Ullman (1988). For this example, Actor 3.0 has been extended with a parallel operator, |||, meaning that each operand (e.g., message) should be broadcast simultaneously over the network.
In order to illustrate the effects of the two-phase commit, the following scenario is presented. Suppose a user accessing the spatial data base via a GIS wishes to delete a mineral claim while at the same time another user accessing the same mineral claim via another GIS or a DBMS is attempting to change it. Given that a distributed data base manager serializes these discrete events, then the two-phase commit protocol guarantees that either the change takes place and the delete does not or that the delete takes place and the change does not. In either case, the distributed data base manager preserves data integrity leaving the spatial data base in a consistent state.

**Conclusion**

Towards the implementation of British Columbia's spatial data base, the Ministry of Crown Lands has broken some new ground. An open network architecture is emerging. It is intended that this technical architecture will some day support British Columbia's spatial data base.

The emerging architecture is illustrated in Figure 5. Based upon a layered approach, the architecture acknowledges existing ISO standards, including the OSI model itself. Within the architecture, only the application layer introduces protocols that have yet to become national or international standards. Other potentially relevant standards either established or adopted by OSI include protocols for file transfer, access and management, remote data base access, virtual terminal emulation, networked and distributed operating systems, a message handling system, a reference model for data management, an information resource dictionary system, and a directory system.

For reasons that are more human than they are technological, it is predicted that several years will elapse before the technical architecture described here or its successor is standardized within British Columbia, let alone the rest of Canada. Standards like OSI are paramount to the successful implementation of British Columbia's spatial data base. Without these standards and the open systems they give rise to, organizations like the government of British Columbia will endlessly spend taxpayer's money upon computer systems that are both difficult if not impossible to maintain and enhance in the face of an ever-changing computer technology.

**References**


Scanning for GIS Applications

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Abstract
Due to the recent advances in scanning, the technology has become a credible alternative for both CAD and GIS applications. A major misconception is that scanning produces either a raster or a vector file which is made up of broken line segments with all elements on one layer. If utilized properly, a scanning system can produce a GIS-compatible file that is layered, feature coded or separated, and made up of continuous lines and ASCII text strings which can be utilized as centroids or labels for polygons. This scanned and product, if prepared correctly, can be ready for import into a GIS for cleaning and building of topology. Some scanning service companies are now offering data that is 'GIS ready' in the desired format.

Introduction
With increased interest in GIS for a number of applications, the requirement for a fast, cost-effective and accurate method of data loading has become a real issue in the minds of many users.

It is not the intention of this paper to convince the reader that scanning is the total solution for all GIS data loading. The present status of scanning in general will be examined and the pros and cons of the technology and its effectiveness for GIS will be explored.

It is always interesting to see a company or government office purchase a GIS. Once this new acquisition is in place, the huge task of loading all of the desired data becomes only too real. With the usual methods such as digitizing, this task can often become overwhelming. New advances in scanning allow the technology to be a viable method of data loading for GIS applications.

Background of Scanning
Not too many years ago, scanning was looked upon in many circles as a method of conversion without merit. This was simply because the raster format produced by scanners was not revisable, nor compatible with the majority of vector-based CAD software formats.

Recently, scanning manufacturers have found methods to convert raster information into vector line work. This created a beginning point in providing compatibility with vector-based software and as a viable alternative to labour-intensive manual digitizing.

Present Scanning Technology
Today, there are several manufacturers of scanning hardware and software. As in any industry, there are high-, medium- and low-end products available in the scanning market. These systems are available on various platforms.
Higher-end products offer some impressive capabilities in automatic vectorization. This comes with a price tag that could choke the healthiest of budgets.

Medium-priced scanning products offer vectorization, often with fairly successful results. The trick with any system is to determine the amount of clean-up that is required.

Scanning systems at the lower end of the market tend to offer scanners that take longer to rasterize a document. Most of them simply offer raster tracing in a CAD environment, rather than automatic vectorization. However, some vectorization is available even with this lower end product line.

Products at all levels of the market have their own merit on a cost versus performance basis. It’s true that you get what you pay for. Sometimes it simply depends upon your budget.

**Evaluating Scanning for GIS Applications**

**Suitability of Scanning for GIS**

It would appear that the suitability of scanning for base mapping purposes is largely hinged upon the opinion of the people involved, regarding the importance of accuracy in the particular project. Another major factor is the accuracy of the source maps available.

The reality of scanning capabilities is that the technology can recreate a source map in a digital format with a high degree of accuracy, depending upon the system and resolution used. However, scanning can only recreate the same accuracy as was present in the original source map. The argument which prevails, therefore, is that it makes no sense to perpetuate the same errors which have been created over the years in creating and updating that map. This argument has merit, especially when poor practices in maintaining control have been used on original source maps, particularly in municipal or cadastral applications.

The solution to this problem in many cases is in the use of ‘rubber sheeting’ or ‘linear/non-linear transformation’ capabilities in many GIS packages. If some control points can be established, such as survey monuments, the rubber sheeting capabilities can be utilized to greatly increase the accuracy of the base map. This same technique can be used in both resource and legal mapping applications to enhance the digital end product of scanning.

If the GIS user does not feel that these adjustments adequately enhance the scanned file for base mapping, the technology can still be used for loading information which is not as dependent upon a precise location, such as contours, text for lot dimensions, signage, water and sewer information. This information can then be merged as levels over the existing base map.

**Benefits of Scanning**

Scanning offers GIS users some impressive benefits in data loading.

**Turn-around Time**

Automatic vectorization found in many high-end scanning systems decreases the amount of interactive work required by an operator. This allows scanning to accomplish the same work in a fraction of the time as manual digitizing or direct input. One example is a project done by SCAN Conversion Services Inc., for a local municipality. The GIS coordinator had estimated the project to require approximately one and one half years to complete the conversion of several hundred contour and legal maps using their own resources. The project was completed in three months using scanning technology.

**Price**

Depending upon the source material available, scanning can convert maps at a fraction of the cost of other methods.
Because this is so dependent upon the condition of the original map, it is important to always do a scanning test to determine all aspects of the conversion, including price considerations. Often, maps which are in poor shape can still be processed at less cost than other methods. A considerable savings can be realized by processing only the features in a map that are required. Many think that scanning must process all elements in a map; this is not the case. One can pick and choose amongst the desired features.

**Accuracy**

Scanners at the higher end of the market are able to provide a high level of accuracy. Scanning at a resolution of 500 dpi, some scanners are able to recreate a map accurate to .04% of the original drawing.

To ensure that the highest level of accuracy is achieved, the automatic vectorization of some scanning systems process a line by vectorizing the precise centre of a raster line. This is much more accurate than digitizing, where determining the centre of a line is left up to the steadiness of an operator’s hand.

**Contract Work versus In-House**

Perhaps the very first question which an organization must ask itself is, “Can we do the scanning in-house?”

**In-House**

For organizations with adequate resources to carry out this task in-house, the following are considerations which must be addressed:

1. Is the organization willing to invest in the considerable training and learning curve that is associated with scanning technology? Unfortunately, a scanner is not a black box which spews out a perfect CAD or GIS product. There is a certain finesse that is required to make the system perform at its peak.

2. In addition to the cost of the hardware and software, the maintenance and constant upgrades of the system must also be kept in mind. As scanning progresses, software upgrades are frequent, mandatory (so as not to be left behind) and very expensive.

3. When the scanning task is completed, will the equipment be a white elephant which has lost a large percentage of its original value?

**Contracting Services**

If an organization cannot justify these three basic criteria, the task of selecting a service company begins.

When choosing such a company, the following may be helpful hints in making the right choice:

1. The company’s reputation;

2. What is their ability to second-guess your technical requirements?

3. It is highly advisable to do a test. The company with the best price may not be capable of fulfilling your technical or time frame requirements.

4. Ask the potential service company what type of source material will be necessary to provide the best results in terms of accuracy, cost and turn-around time.

In many cases the answer is obvious, due to resources. The contracting of a service company is therefore the logical choice.

**Creating the Best Scanned Product**

Regardless of whether an organization does its scanning in-house or with a service company, the following points may help in achieving the best results in accuracy, price and turn-around:

1. Determine your requirements in advance to avoid confusion. Feature coding, representation of data, what portions of work are best done by the scanning company and those best done in-house. For instance, key punching of attributes, symbology, building of topology.

2. Do a test to streamline those requirements and establish efficiencies.

3. Select the best source material available. As a rule of thumb, the best results in scanning are produced from material with the following characteristics:

   a. Clean line work - The less background or fuzziness present in a source map, the easier it is for the scanner to interpret the information. Mylars or some other stable media is preferred to produce the most accurate results.

   b. Intersecting lines - The more lines that intersect in a map, the higher the chance that the automatic vectorization may break the line or continue along on the wrong line. If this is widespread, more clean up will be required, which affects the price of the conversion.

   c. Line types - A clean solid line is the preference of most scanners. Generally, any dashed or dotted line will either require tracing or repair. The clean up software used in conjunction with scanning can quickly repair these lines to a continuous solid line very efficiently. The end product will always be excellent (depending upon the operator), but the price will be affected somewhat.

   d. Separation of features - One method which has been found to be effective is to separate certain features onto different source maps.

      1. Forest polygons
      2. Planimetric
      3. Contours