THE NED-2 FOREST ECOSYSTEM MANAGEMENT DSS:

THE INTEGRATION OF A WILDLIFE MODEL FOR THE SOUTHEAST, THE GOAL ANALYSIS AGENT AND THE REPORT GENERATION AGENT

by

SARAH WITZIG

(Under the Direction of Donald Nute)

ABSTRACT

NED-2 is a decision support system for forest ecosystem management developed by the USDA Forest Service and the Artificial Intelligence Center at the University of Georgia. NED-2 provides a tool for resource management by running goal-driven process analyses using future condition rules. The six resource management categories supported are Ecology, Health, Timber, Visual, Water, and Wildlife. This thesis addresses the design and implementation of a Wildlife Model for NED-2 that extends the former wildlife model to the entire eastern part of the United States. The goal analysis and report generation components are documented in terms of functionality and with regard to the integration of the Southeastern Wildlife Model.

INDEX WORDS: Decision Support System, NED-2, ecosystem management, agent, blackboard architecture, goal analysis, wildlife model, wildlife habitat, report generation, hypertext representation, Prolog, Forest Management, knowledge base

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CHAPTER 1

INTRODUCTION

Wildlife habitat management is necessary for several reasons. Controlling wildlife habitat might prevent particular disturbances from endangering species in critical stages of development, like early life stages, rutting or migration (Oil and Gas Commission Website 2004). Loss of habitat for endangered species like the burrowing owl can be illegal and punished with fines and imprisonment (The Santa Cruz Predatory Bird Research Group 2004). The existence of wildlife in a forest might improve the aesthetic, recreational, and economic value. It might attract naturalists and birdwatchers (Hamel 1992:10). Above all, wildlife has a significant impact on the health of our ecosystem and improper management of this resource can have far reaching effects (Wilson 1995:2).

For example, little animals like salamanders can influence the productivity of a whole forest. Salamanders are inconspicuous and become active mostly during the night. Even though salamanders are small creatures that are difficult to spot, the biomass of salamanders is equal to the biomass of mice and shrews. Additionally, the phosphorus levels and protein content in their tissue is higher than those of birds and mammals, and they are an essential food supply for carnivores. A significant drop in salamander occurrence could influence the rate of nutrient cycles and change forest productivity (Wilson 1995:1).

The decision support system NED-2 provides a tool for managing and enhancing wildlife habitat by running goal-driven process analyses using future condition rules to specify the desired habitat. The results of the analyses are output in HTML format.

This is not the only resource management that NED-2 provides. The user can pick between six different goal categories and get decision support for each of them. The categories supported are Ecology, Health, Timber, Visual, Water, and Wildlife. Additional components in the software support different steps in the decision process for optimal forest ecosystem management.

This thesis discusses the background knowledge, research, and implementation of the Southeastern Wildlife Model. This involves the understanding and modification of NED-2's goal analysis functionality and the redesign and implementation of its goal analysis reporting module. The following paragraph gives an outline for this work.

Chapter 2 is a short introduction to the software NED-2, its architecture and components. It also refers to more comprehensive publications on the individual components. Chapter 3 provides background for goal analysis in NED-2. Special focus is given to Timber Goal Analysis and the inference engine. The main objective of this thesis is presented in Chapter 4, which discusses the development of a Wildlife Model for the southeastern United States and its integration with the existing wildlife goals for the northeast. Topics analyzed are knowledge acquisition, knowledge base development, and system integration. Chapter 5 describes how the results are reported in HTML pages. It also explains which processes are involved in the generation of reports and how the report agents interact with the goal analysis. Here, the generation of the southeastern wildlife reports is discussed in detail. Chapter 6 opens a discussion on how users might apply the software to their domain, which questions will arise, and how to draw the most out of the user’s feedback. The actual user evaluation will start by releasing NED-2 beta at the end of October 2004. This document concludes with Chapter 7, suggesting improvements, alternatives, future work, and planned extensions.

Seven Appendices provide the documents used and built during the development. Source code, the current NED-2 version, and related documents are available on a CD available from the Artificial Intelligence Center, University of Georgia, Athens, GA 30602.

CHAPTER 2

A BRIEF REVIEW OF THE NED-2 DECISION SUPPORT SYSTEM

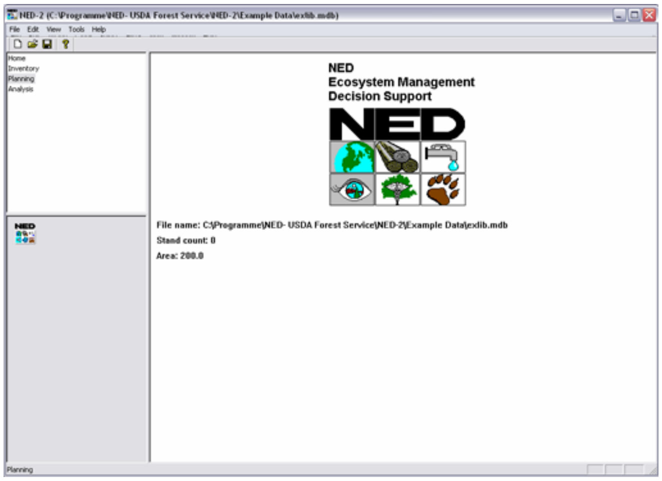
The NED-2 Decision Support System for ecosystem management is being developed by the USDA Forest Service in close collaboration with faculty and students from the Artificial Intelligence Center at the University of Georgia under the supervision of Dr. Donald Nute and Dr. Walter D. Potter.

NED is an acronym for Northeast Decision Model, a decision process for managing forested land in the Northeast of the United States. While the name remains, the software's application area has been extended to the entire eastern part of the United States.

The purpose of the software is to combine several tools for ecosystem management into a single application. The integration of many existing systems under a single interface provides land managers with a convenient and successful decision process program that helps to manage data and goals, analyses, and predicts.

Currently, the interface is divided into three main functions:

1. Management and Analysis of **Inventory** data
2. **Planning,** through goal formulation, treatment definition, treatment plan development, and simulation.
3. Reporting of results of **Analysis** using hypertext documents, a geographic information system (GIS), and tabular representations.



File name: C:\Programme\NED- USDA Forest Service\NED-2\Example Data\exlib.mdb

Stand count: 0

Area: 200.0

Figure 2-1: The NED-2 Home Screen

NED-2's internal data model consists of Microsoft Access databases and Prolog clauses. A NED-2 dataset contains information about a management unit (MU). A management unit is a defined part of forested land that is divided into stands. A stand is a coherent and homogeneous area in the management unit that represents a single forest type. The conditions throughout a stand are similar. Therefore, the management objectives, strategies, and treatments can be applied to the whole area to satisfy a goal.

For each stand the user provides inventory data, e.g. size, location and physical character (Nute et al. 2003b:3). A snapshot is assigned to every stand at a certain point in time for a particular management unit alternative (inventory, baseline[1], simulated plan). This dynamic notion is used to refer to any data in NED-2.

Whenever a new data set is opened or created by a NED-2 user, a new NED-2 WORKING FILE is created. The NED-2 WORKING FILE is a copy of the open database that becomes part of a blackboard, the main component of the NED-2 architecture. Now data can be communicated

[1] The baseline year is a point in time in which data for all stands is available.

through the blackboard. Other databases, incorporated into the system hold additional information about goals, reports, variables and species.

NED-2 is a modular, multi-agent system. Each agent is defined by a domain control module (DCM) that performs one task in the decision process. The blackboard and the agents are implemented in Prolog. The interface agent executes C++ functions to display the program's screens[2]. The agents are semi-autonomous and communicate by placing facts and requests on the blackboard.

Data dictionary files store metaknowledge about the databases and their relations. This metaknowledge helps to integrate the data from the databases into the blackboard. To get data from the blackboard an agent calls the predicate `known/1` that handles the access of facts from the database, facts that have been derived from existing facts and previously asserted Prolog facts. Maier (2002) describes the processes involved in the agent-blackboard communication.

In case of a third-party component the agent would be a wrapper for existing software. The design of the NED-2 architecture allows adding new models and components very easily without extensive knowledge about other already-existing agents. The agents do not know anything about the other agents in the system. The one-place predicate `request/1` represents the current plan of action and takes a list of requests as argument. If an agent identifies a request on the blackboard for a task it was designed to fulfill, it performs the task, places potentially new information on the blackboard and erases the request from the blackboard . From a programmer perspective this means the agents reacts to the first element in the list of requests, erases the old plan from the blackboard and puts the rest of the plan (without the first request) back on the blackboard.

[2] Additional DLLs (Dynamic Link Libraries) are called by agents for calculations on inventory and for reports.

More details about the architecture, ontology, individual models, and agents are given in Nute et al. (2003a). A user perspective and case studies can be found in Twery et al. (2003). Insight into the functionality and implementation of the simulator is given in “The NED Forest Management DSS: The Integration of Growth and Yield Models” by Astrid Glende (Glende 2004). Routh (2004) discusses the NED-2 fire risk model and the integration of GIS into the system.

CHAPTER 3

GOAL ANALYSIS IN NED-2

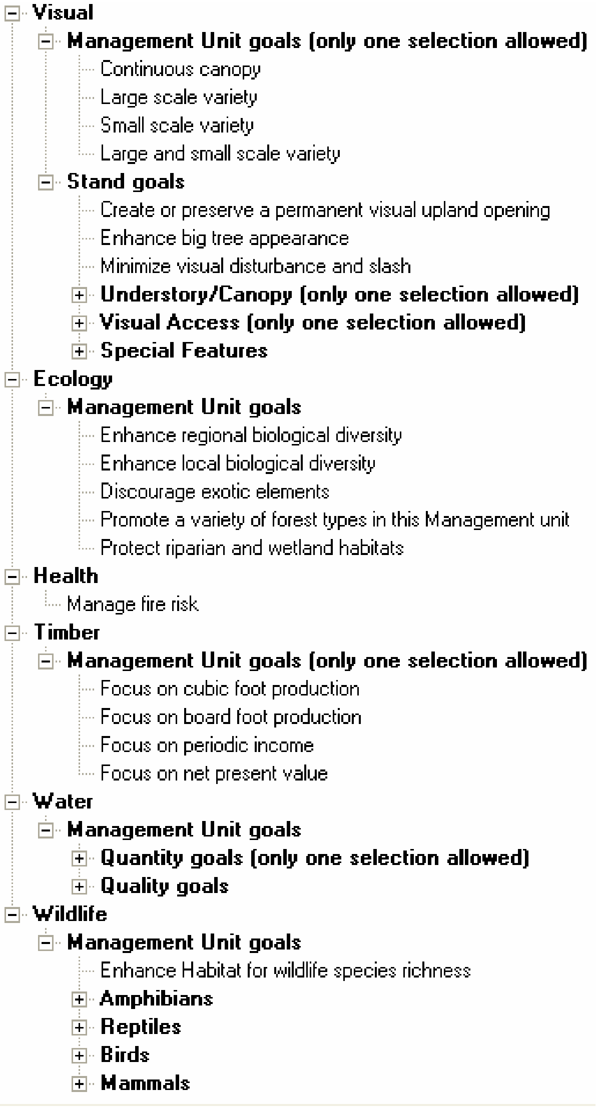
The NED-2 decision process is initiated through two steps: data entry and goal selection. The other components of the software are organized with respect to the goal selection. To achieve and maintain selected goals, the user evaluates the current data, develops and simulates alternative courses of actions, and analyzes these. These tasks are accomplished by the simulation agent, the report agent, and integrated visualization tools.

Currently, NED-2 offers six different goal categories: Visual, Ecology, Health, Timber, Water, and Wildlife. The land manager picks predefined goals from the goal selection screen in the interface (Figure 3-1) and organizes them into goal sets. Then the user can request analysis and reports on the picked goals for developed plans to determine the right course of management action.

Goal analysis is based on six different models, one for each category. A model is a knowledge base of Prolog rules that has been developed by the NED-2 team. The goal analysis agent calls a “fuzzy” backward chaining inference engine that evaluates the rules for output.

Goal analysis takes place on two levels: the stand level and the management unit level. Currently, only the goal category Visual contains stand level goals; all other goals are management unit level goals.

The following paragraphs describe the general format of the goal analysis rules, the Timber Model, and the Wildlife Model for the Northeast and the inference engine. The “fuzzy” backward chaining inference engine was developed by D. Nute, M. Rauscher, Y. Chang, G. Zhu and G. Kim in 2001. Additionally S. Sun, M. Dass, Ningyu and P. Knopp have been involved in the development and implementation of the models for Visual, Ecology, Timber, Water and Wildlife. The Health Model has been developed by M. Rauscher and C. Routh.



- **Visual**
  - **Management Unit goals (only one selection allowed)**
    - Continuous canopy
    - Large scale variety
    - Small scale variety
    - Large and small scale variety
  - **Stand goals**
    - Create or preserve a permanent visual upland opening
    - Enhance big tree appearance
    - Minimize visual disturbance and slash
    - **Understory/Canopy (only one selection allowed)**
    - **Visual Access (only one selection allowed)**
    - **Special Features**
- **Ecology**
  - **Management Unit goals**
    - Enhance regional biological diversity
    - Enhance local biological diversity
    - Discourage exotic elements
    - Promote a variety of forest types in this Management unit
    - Protect riparian and wetland habitats
- **Health**
  - Manage fire risk
- **Timber**
  - **Management Unit goals (only one selection allowed)**
    - Focus on cubic foot production
    - Focus on board foot production
    - Focus on periodic income
    - Focus on net present value
- **Water**
  - **Management Unit goals**
    - **Quantity goals (only one selection allowed)**
    - **Quality goals**
- **Wildlife**
  - **Management Unit goals**
    - Enhance Habitat for wildlife species richness
    - **Amphibians**
    - **Reptiles**
    - **Birds**
    - **Mammals**

Figure 3-1: The Goal Selection Screen

3.1 DESIRED FUTURE CONDITION RULES

All goal analysis rules in NED-2 are stand level rules that are evaluated and analyzed with respect to the whole management unit (except the stand level Visual goals). Each rule consists of desired future conditions (DFCs) that are linked by the logical operators AND and OR. The following Prolog code is the rule for the Ecology goal “Protect riparian and wetland habitats”:

```
riparian_and_wetland([`SNAPSHOT` = A],passed) :-
     (    max([`SNAPSHOT` = A], stand_open, 10),
          min([`SNAPSHOT` = A], stand_rel_dens, 70),
          more([`SNAPSHOT` = A], stand_woody_debris, 0),
          min([`SNAPSHOT` = A], stand_canopy_closure, 25),
          (    (    equal([`SNAPSHOT` = A],stand_is_wetland,1)
                    ;
                    equal([`SNAPSHOT` = A],stand_has_wetland,1)
               ),
               (    equal([`SNAPSHOT` = A],stand_is_riparian,1)
                    ;
                    equal([`SNAPSHOT` = A],stand_has_riparian,1)
     )    )    ).
```

There are six DFCs to protect riparian and wetland habitats: (1) The percent of open area in the stand must be less than or equal to 10%, AND (2) the relative density in the stand must be more than or equal to 70%, AND (3) the coarse woody debris in the stand must be more than 0, AND (4) the canopy closure in the stand must be less than or equal to 25%, AND (5) the stand is a wetland OR the stand contains a wetland area, AND (6) the stand is a riparian area OR the stand contains a riparian area. Each DFC describes the desired relation between a NED-2 variable and an actual value. It consists of an operator (MAX, MIN, MORE, LESS, EQUAL, IN_RANGE, MEMBER_OF, HAVE), an object (that is instantiated to a snapshot), a NED-2 variable, and a target value[3].

3.2 THE "FUZZY" BACKWARD CHAINING INFERENCE ENGINE

In this section I describe the "fuzzy" inference engine in NED-2. This information serves as a background for the following chapters. The code for the inference engine can be found in the file *nedcf.dut* located in the Utilities folder in NED-2.

The DFC rules are evaluated by a "fuzzy" backward chaining inference engine.[4] Each rule is evaluated on a stand level for a single snapshot. If the selected goal is a management unit goal, the rule is evaluated for each stand and the management unit results are summarized in the goal analysis report. The Timber goal analysis applies a more complicated process to the evaluated stand level rules to conclude a management unit goal (see 3.3). If the goal is a stand level goal, the user is asked to pick a subset of stands which will be evaluated and reported on.

As seen in the previous section, each DFC describes a target value that an actual value should meet. In a lot of cases, experts differ about these values. It is simply not possible to determine the exact maximum or minimum value of any particular variable that a stand must meet to provide habitat for a given species. This is handled in NED-2 by treating minimum and maximum target values for DFCs as *fuzzy*. Therefore, the goals are evaluated with a "fuzzy" inference engine in the following manner: If the actual (or simulated) value of a DFC is bigger than 110% of a minimum target value, the DFC fully satisfies. If the actual value is between 100% and 110% of the minimum target value, the DFC minimally satisfies. If the actual value is

[3] The exceptions are the HAM type in the Northeastern Wildlife Model and the prescription type in the Timber rules. DFCs for the these variables are evaluated by an additional set of DFC rules.

[4] We use scare-quotes around „fuzzy" here because the NED-2 inference engine does not implement the familiar version of fuzzy reasoning developed by Zadeh and others, but instead uses another method for representing the fuzziness of the target values represented in NED-2 rules.

between 90% and 100% of the minimum target value, the DFC nearly satisfies. If the target is less than 90% of the minimum target value, the DFC fails. These conditions are reversed where the target value for a DFC represents a maximum value required to provide habitat for a species. Accordingly, each condition is assigned a “fuzzy” confidence factor (CF):

- fully satisfied → CF = 1.0
- minimally satisfied → CF = 0.6
- nearly satisfied → CF = 0.4
- failed → CF = 0.0

Once the individual DFC confidence factor has been determined, the whole rule can be inferred: For two AND related DFCs the minimum of the two is the output confidence factor. For two OR related DFCs the maximum of the two is the output confidence factor. Accordingly, the goal status for a snapshot is represented by the returned confidence factor: CF 1.0 means the goal fully passes, CF 0.6 means the goal minimally passes, CF 0.4 means the goal nearly passes and CF 0.0 means the goal completely fails.

Looking at the process from the programmer’s view, each “fuzzy” rule is a Prolog predicate of the following structure:

```
rule(nedcf,Environment,RuleName,Treshold,Rule,String).
```

The first argument `nedcf` indicates that the rule is to be used with the NED-2 “fuzzy” inference engine. The `Environment` variable determines a rule environment which decides which rules are considered for evaluation. Usually, the `Environment` variable is instantiated to the atom `stand_analysis`. The only exception is the Timber analysis for which the rule is picked based on an environment, represented by a prescription forest type.

Each rule has a `RuleName` and a `Threshold`. The `Threshold` determines the maximum confidence factor that a rule can return after evaluation. Usually, this `Threshold` is equal to 1.0, because the goal can maximally fully pass the rule. The Wildlife Model for the Southeast is the exception. There can be up to three rules for one species habitat goal. One rule could describe optimal habitat for a species. A second rule could describe suitable habitat for a species. A third rule could describe marginal habitat for a species. Depending on the level of habitat the threshold is set for each rule: The rule for optimal habitat has a threshold of 1.0 (fully satisfied), the rule for suitable habitat has a threshold of 0.6 (minimally satisfied) and the rule for marginal habitat has a threshold of 0.4 (nearly satisfied).

The fifth argument of rule/5, here called `Rule`, is the rule body. An example has been shown in section 3.1. The last argument is a rule description `String`.

The "fuzzy" inference engine is a backward chainer, picking the rule according to the goal before evaluating it. It is called through the following predicate:

```
call_NEDCF_backward_chainer(Goals,Environment,Threshold,List).
```

Here, Goals is a list of goals that are to be analyzed. `Environment` designates the environment in which the goal will be evaluated. The `Environment` instantiates to the environment variable in the `nedcf` rule. The `Threshold` in the call to the backward chainer must be met before the output of the goal analysis is recorded on the blackboard. `List` specifies if only one rule per goal should be evaluated or if all matching rules should be considered. Also, one can choose if the output information should be stored in a trace document (additionally to on the blackboard). Tracing is only used for development and will be turned off in the release version of NED-2.

The backward chainer fuzzifies each DFC and infers a goal status for the given snapshot. Details on how the individual DFCs are fuzzified are given in Appendix A. Finally, the information is stored on the blackboard with the fact/4 predicate:

```
fact(Pred(Object,Goal),RuleName,CF,TimeStamp)
```

3.3 TIMBER GOAL ANALYSIS

In the usual case, goal analysis happens on a stand level and a summary of the stand-level results are reported for the whole management unit. There is no detailed management unit level analysis. If 100% of the management unit area has *fully passed* the goal, the management unit passes the goal. If 100% of the management unit area *fails* the goal, the management unit fails the goal. In all other cases, the management unit goal status is called *not fully* and the user needs to look at the stand level information to draw any conclusions.

Timber goal analysis is the exception to this pattern of goal analysis. It applies a more complicated system that takes the management unit goal evaluation into consideration. There are two conditions that must be satisfied to pass a Timber goal:

1. The management unit must have balanced size classes.
2. 65% of the management unit area must pass the stand level Timber goal.

Size classes in NED-2 is a variable classifying each stand into one of five size classes according to the medial dbh within a stand. There are five size classes: regeneration, sapling, pole, small sawtimber, and large sawtimber. The NED-2 documentation of the variable with details on its calculation can be found in APPENDIX B. To test for the first condition, the size class for every stand needs to be looked up in the database. Then, the size classes are tallied to the whole management unit according to the area of each stand. A management unit is defined to have balanced size classes if it has 5-15% of the management unit area in the size class regeneration, 35-50% of the management unit area in the size class sapling or pole, 25-40% in the size class small sawtimber, and 10-20% in the size class large sawtimber.

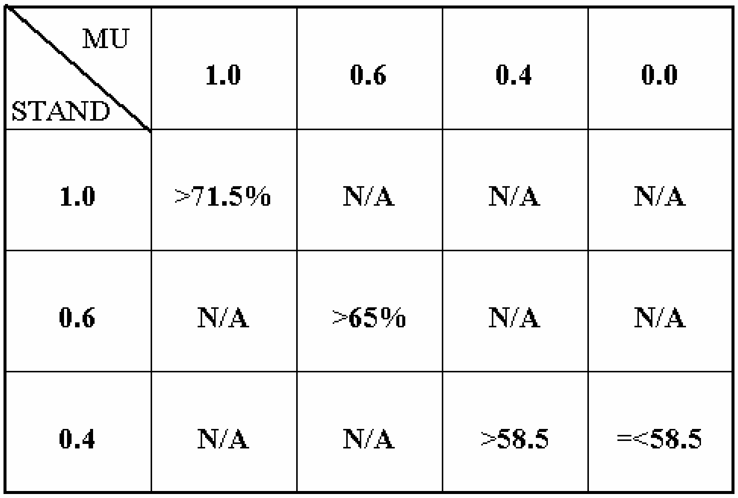
For the second condition the Timber stand goal analysis for the selected goal needs to be performed. There are several Timber rules for one goal, each corresponding to a different prescription type. A prescription type is an assignment of NED-2 forest types to a vegetation type that the Timber Model refers to. There are ten prescription types defined in NED-2:

- `spruce-hardwoods`
- `spruce-fir`
- `white pine`
- `hemlock-hardwoods`
- `Appalachian hardwoods`
- `aspen-birch`
- `Allegheny hardwoods`
- `northern hardwoods`
- `oak-northern hardwoods`
- `oak-hickory`

The prescription types are defined by `nedcf` rules in the Timber knowledge base. For the stand goal analysis we want to pick the Timber rule with the prescription type of the stand. Hence, the Timber goal analysis agent calls the inference engine on the nedcf prescription type rules. Then, it consults the blackboard to see which prescription type succeeded for the stand and passes the prescription type to the inference engine as the `Environment` variable for the actual

Timber goal. Following, the inference engine will know which rule to pick and the "fuzzy" goal analysis is executed. After performing the stand analysis, the stand goal status is tallied to the management unit according to its area. The management unit passes the second condition if 65% of the management unit area passes the goal status. Again, this process is fuzzified. The output is chosen according to the following table:

Table 3-1: "Fuzzification" of Timber Management Unit Goals



MU STAND	1.0	0.6	0.4	0.0
1.0	>71.5%	N/A	N/A	N/A
0.6	N/A	>65%	N/A	N/A
0.4	N/A	N/A	>58.5	=<58.5

If more than 110% of the target value (equivalent to more than 71.5%) of the management unit area satisfies the stand level goals with CF 1.0, then the management unit level goal fully passes. Else, if more than 65% (which is 100% of the target value) of the management unit area satisfies the stand level goals with at least CF 0.6, then the management unit level goal minimally passes. Else, if more than 58.5% (90% of the target value) of the management unit area satisfies the stand level goals with at least CF 0.4, then the management unit level goal nearly passes. In all other cases, the management unit goal fails with CF 0.0.

The management unit goal analysis is performed by the Timber goal report agent that displays the information in an HTML report or places the results of the analysis on the blackboard where the GIS agent can access it, depending on the kind of display the user has requested. APPENDIX C shows an example for a Timber goal analysis report.

3.4 THE WILDLIFE MODEL FOR THE NORTHEAST

This section gives a short overview of the Northeastern Wildlife Model in NED-2 that has been implemented by Shulei Sun and Donald Nute (Sun 2001) and is based upon the wildlife habitat assessment matrix HAMMOD by Cleveland et al. (1998). The Northeastern Wildlife Model served as an example for the development of the Southeastern Wildlife Model.

All goal analysis is based on a set of nedcf rules that are stored in individual knowledge bases. The wildlife rules for the Northeast have the same structure as described in section 3.1. For each of the 223 species there exists exactly one habitat rule. The species are grouped into four categories: amphibians, reptiles, birds, and mammals. All rules are stored in one knowledge base called *wild_dfc.kb*.

Part of the rule is a DFC called `stand_ham_type`. The predicate name refers to the HAMMOD table which is the source habitat matrix for building the Wildlife Model for the Northeast (Sun 2001:18). The `stand_ham_type` DFCs are evaluated by a set of nedcf rules. Similar to the prescription types for the Timber goal analysis, each HAM type is assigned a subset of forest types. An example is the HAM type white pine:

```
rule(nedcf,forest_type,hamft_white_pine,1,
(stand_ham_type(  [`SNAPSHOT` = A], 'white pine' ) :-
   member_of( [`SNAPSHOT` = A], stand_forest_type,
     [pine, 'other softwoods', 'PINUS', 'PIBA2', 'PIRE', 'PIRI',
       'PIST', 'PITA'])),
[`HAM Forest Type is a variable used by the rules in`,
      `the wild_DFC.kb. This rule identifies stand that`,
      `provide Wildlife habitat of the White Pine forest
      type.`]).
```

CHAPTER 4

THE WILDLIFE MODEL FOR THE SOUTHEAST

4.1 KNOWLEDGE ACQUISITION

The most challenging task of developing the Wildlife Model for the Southeast has been the knowledge acquisition. Three main source categories have been identified that provide the core knowledge for the model:

1. literature references
2. habitat matrices and species lists in electronic format
3. expert knowledge

Gathering the sources, understanding the terminology, and studying the literature references were the first steps in the knowledge acquisition. *The Land Manager's Guide to the Birds of the South* by Paul Hamel (1992) and the *Land Manager's Guide to the Amphibians and Reptiles of the South* by Dr. Lawrence A. Wilson (1995) come with habitat matrices, showing which habitat condition is necessary for each species and providing information for each species about abundance status, description, distribution, primary habitat, special requirements, breeding habitat, wintering habitat, reproduction, food habitat, management suggestions, and additional references. Initially, unstructured interviews with Dr. Nute and the rest of the NED-2 team supported the overall understanding and outline of the research aim.

Since experts have the most in depth knowledge of the domain, the next step in acquiring the knowledge consisted of structured interviews with wildlife experts. Consultation with experts was mainly aimed at identifying the essential habitat requirements for the species and discussing measurements in the habitat variables.[5] During a meeting with wildlife expert Linda Thomasma, we discussed the habitat matrices for the birds, reptiles, and amphibians. Margaret Griep is a wildlife expert working on overseeing the wildlife habitat books published by the Nature Conservancy (Hamel 1992 and Wilson 1995). She is also working on a version of the mammals book that has not yet been published. She provided the data from the books in electronic format. This was essential for building an automated rule writer. During a phone interview, Margaret Griep assisted with questions on variables. The forestry experts of the NED-2 team helped with translating habitat conditions into NED-2 variables, identifying variables that were not yet in the system, and general decision-making.

The following essential expert knowledge that influenced the design of the knowledge bases was gained through the research:

A. The Habitat Matrices

a. Domain Knowledge

The matrices provide habitat information for the species on the assumption that

- the correct vegetation type and successional stage is present.
- the rule is applied within the range where the species occurs (Wilson 1995:3).

A vegetation type is defined by the plant species that are dominant for some management unit. In NED-2 we use the term **forest type** where each forest type is defined by the presence of specific tree species within a forest. The birds books define 23 different

[5] For example, canopy closure is a habitat condition for several birds, amphibians, and reptiles. Canopy closure is a NED-2 variable that represents the relation of relative density and stems per unit area. Canopy closure within a stand is measured in percentage. Deciding on a measurement for the variable canopy closure means defining how much percent canopy closure is required in a stand to provide optimal habitat for a species.

vegetation types, and the reptiles and amphibians books define 27 types. Some of the types in the two books overlap.

The successional stages represent different stages and maturity of the tree species in a forest over time. NED-2 represents successional stages by assigning to each stand a size class that is calculated by the medial dbh in the stand. The following size classes are possible: regeneration, sapling, pole, small sawtimber and large sawtimber.

The range of a species are the states or areas the species occurs in.

b. Design Decisions

The vegetation types need to be translated into the NED-2 forest types. Most of the forest types in the Southeastern United States are not yet represented in the NED-2 system. Therefore, new forest types need to be developed and each vegetation type in the matrices needs to be assigned to a forest type (see 4.2). Vegetation types that do not represent forests, like spartina and cave dwelling, and species that only have habitat in these vegetation types need to be filtered out. The vegetation type can be represented by a desired future condition in the rule using the `member_of` predicate (see APPENDIX A):

```
member_of(Object,forest_type,ForestTypeList)
```

Accordingly, the main assumption that the forest type habitat needs to be established is satisfied. The rule can only pass, if the `member_of` DFC succeeds.

The successional stages need to be mapped to the size class values of NED-2. The successional stages habitat conditions are weighted with O, S and M. O stands for optimal habitat, S stands for suitable habitat, and M for marginal habitat. The habitat levels represent the frequency and the numbers in which the species occur. To represent these relations, up to three rules might be generated per species: one rule might represent optimal habitat, one rule might represent suitable habitat and one rule might represent marginal habitat. By setting the `Threshold` in the rules to 1.0, 0.6 and 0.4 the different habitat levels are represented. Accordingly, only the rule with optimal habitat can maximally be fully satisfied. The rule with suitable habitat can maximally be minimally satisfied and the rule with marginal habitat can maximally be nearly satisfied. The size class value itself is represented by a `member_of` DFC:

```
member_of(Object,stand_size_class,SizeClassList)
```

Again, the rule can only pass if the `member_of` DFC is satisfied. However, if so, it can only pass with the maximum habitat level set in the rule.

To ensure that a rule is applied within the species' range, only the species that occur in the current management unit state are displayed on the goal selection screen.

B. The Bird Matrices

a. Domain Knowledge

The bird habitat information is divided up into **wintering** and **breeding** habitat. The following habitat categories are listed:

i. **vegetation type**
ii. **successional stages**
iii. **substrate utilization**
iv. **vegetation layer**
v. **specific requirements**
vi. **standing, flowing water and water quality**

vii. minimal tract size

b. Design Decisions

Breeding and **wintering** habitat for birds are divided into two rule sets: One rule set for breeding and one rule set for wintering. The difference in the breeding and wintering habitat for one single species might be very significant, especially for migrating birds. There is no other possibility to capture a decent habitat analysis without one or the other.

The first two habitat categories for the birds **vegetation type** and **successional stages** have been discussed in the previous paragraph in detail.

The **substrate utilization** and **vegetation layers** have been filtered out of the rules for the following reasons. The substrate utilization habitat conditions are *bare soil* and *leaf litter*. The vegetation layers listed are *herbs*, *shrubs*, *midstory* and *overstory*. According to the wildlife experts, in most cases these variables are not habitat conditions in the sense that their non-existence would endanger the habitat for the species. Secondly, the use of these variables is strongly dependent on the vegetation type that the habitat is tested on. This relation is not represented in the matrix. Therefore, the information given by these two categories is not reliable and cannot be used as DFCs in the rules. Nevertheless, it is additional information that the user might need for his management actions. For this reason, the information is stored in an additional predicate

```
species_uses(+Goal,+WinterorBreeding,+BARESOIL,+LEAFLITTER,
+HERB,+SHRUB,+MIDST,+OVERSTR,+TRACTSIZE).
```

This way, the information can be easily read by the report agent and output as additional information for the user.

The **specific requirements** are important habitat conditions and are AND relations in the rules. The translation of the conditions into NED-2 variables and the measurements for the variables were coordinated with the experts.

Standing, flowing water, and water quality represent essential information that cannot be ignored. Standing water is represented by the NED-2 variables that record permanent ponds, vernal ponds, temporary ponds, and wetland areas. Flowing water is represented by NED-2 variables that record streams and riparian areas. There are no variables in NED-2 that account for water quality. Therefore, three new boolean variables are in planning: fresh water present in a stand; brackish water present in a stand and salt water present in a stand. Together with other variables that need to be added to the system within the scope of the Wildlife Model, these variables are still under development and have not been added to the system yet. The DFCs for the three variables are implemented in the rules already, but commented out for the time being. As a temporary solution these variables are not considered in the rules, but written out in the report in a similar manner as the variables of the predicate `species_uses/9`.

The **minimal tract size** is essential information for bird habitat. For example, the red-shouldered hawk has a home range for breeding of only one square kilometer. However, the tract size, measuring the area it uses - among others for food supply - is about 500 acres (Stravers et al. 1994). Area sensitive birds can be easily chased away by a clear-cut on adjacent stands or similar management actions. As the NED-2 goal analysis happens on a stand level, there is no way to take the minimal tract size into account when developing the rules. Hence, the minimal tract size is added as an argument to the predicate `species_uses/9` and the user will be informed about the importance of the variable.

All DFCs are necessary habitat conditions and will be AND related, except for the case that multiple NED-2 variables represent the same condition.

C. The Amphibians and Reptiles Matrices

a. Domain Knowledge

The following habitat categories are listed for amphibians and reptiles:

i. **forest types**

ii. **successional stages**

iii. **physiographic features**

iv. **specific requirements**

v. **aquatic vegetation**

b. Design Decisions

The first two habitat categories for the amphibians and reptiles are **forest types** and **successional stages**. These were discussed above.

The **physiographic features** describe forest environments, like swamps, lakes and marshes, used by the species for different activities, e.g. breeding. Usually, not every physiographic requirement is needed to provide habitat for a species. In addition, the NED-2 variables might not be as specific as the habitat conditions in the habitat matrices. One NED-2 variable might describe two or three conditions in the matrices. Therefore, the physiographic features are OR relations in the rules.

The **specific requirements** have a much stronger impact on the habitat. Each entry in this category needs the land manager’s attention. Hence, the specific requirements must be AND related in the rules.

Finally, **aquatic vegetation** is a very important variable for amphibians and reptiles. Since NED-2 does not represent aquatic vegetation to the extend needed for the amphibians and reptiles, a new variable, called `stand_aquatic_vegetation` is in planning. Similar to the other variables, it has not yet been added to the system, and is currently displayed in the reports in an additional paragraph.

D. Mammal Matrices

a. Domain Knowledge

The following habitat categories are listed for mammals:

i. **terrestrial habitat and subterranean habitat**

ii. **special habitat factors**

iii. **aquatic habitat**

b. Design Decisions

The **terrestrial habitat and subterranean habitat** is represented by the land cover type variable in NED-2. APPENDIX B documents the NED-2 variable `stand_cover_type` (NED-2 ID for land cover type). As all the terrestrial habitat and subterranean habitat conditions are represented by the same variable that can take only one value for each stand, the conditions must be OR related.

The importance of **special habitat** in the mammals' matrices is equivalent to the importance of specific requirements in the birds, amphibians, and reptiles matrices. Therefore, the DFCs are AND relations.

Aquatic habitat is represented by several NED-2 variables. Again, more than one entry is represented by the same variable as NED-2 is less specific than the habitat matrices and again the conditions must be OR related.

The mammals' habitat matrices do not distinguish between optimal, suitable, and marginal habitat. Therefore, all mammal rules are weighted with a `Threshold` of 1.0.

This summarizes the significant expert knowledge behind the development of the knowledge bases. The individual translations of habitat conditions into NED-2 variables can be reviewed in the documentation of the rule writer program (see companion CD).

Once the expert knowledge was gathered, the knowledge bases needed to be generated (see section 4.3) and used by the system (see section 4.4).

Figure 4-1 is a process map of how knowledge for the Southeastern Wildlife Model was acquired, analyzed, and modeled. It demonstrates the relation between the different steps that have been covered in this subchapter.

4.2 THE FOREST TYPES IN THE SOUTHEAST

The extension of the wildlife resource management in NED-2 to the Southeast involved the development of a new set of forest types. Up to this point NED-2 defined 27 forest types for the Northeast.

David A. Marquis, Mark Twery, and Peter Kollasch developed an algorithm that generates the forest types for NED-2 with the following objectives: (1) The forest type should be calculated by the computer from the stand inventory data only. (2) A set of forest types need to be determined, so that almost every stand in the Northeast could be classified (Marquis et al. 1997).

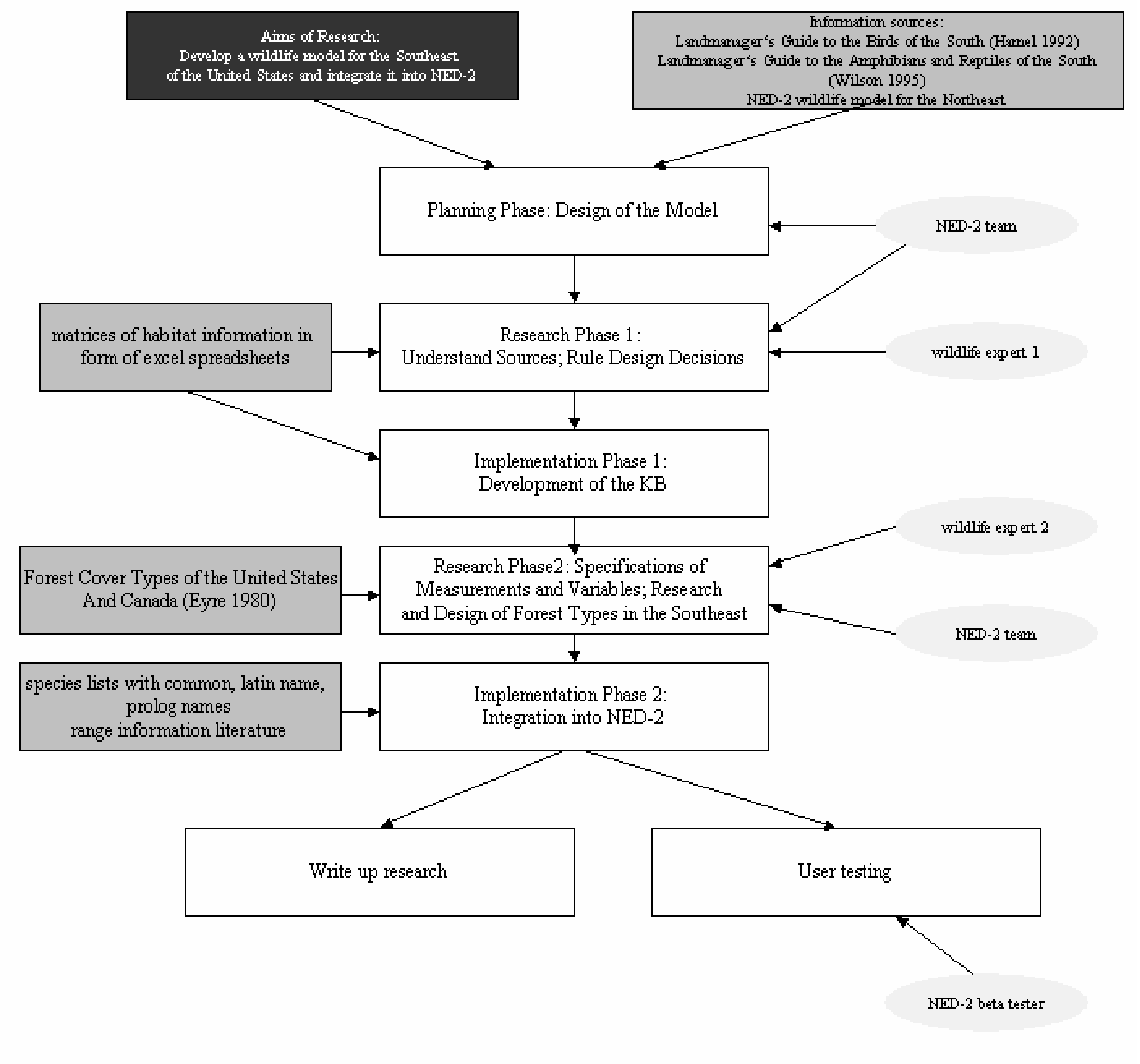

Aims of Research:
Develop a wildlife model for the Southeast
of the United States and integrate it into NED-2
Information sources:
Landmanager's Guide to the Birds of the South (Hamel 1992)
Landmanager's Guide to the Amphibians and Reptiles of the South
(Wilson 1995)
NED-2 wildlife model for the Northeast
Planning Phase: Design of the Model
NED-2 team
matrices of habitat information in
form of excel spreadsheets
Research Phase 1 :
Understand Sources; Rule Design Decisions
wildlife expert 1
Implementation Phase 1:
Development of the KB
wildlife expert 2
Forest Cover Types of the United States
And Canada (Eyre 1980)
Research Phase2: Specifications of
Measurements and Variables; Research
and Design of Forest Types in the Southeast
NED-2 team
species lists with common, latin name,
prolog names
range information literature
Implementation Phase 2:
Integration into NED-2
Write up research
User testing
NED-2 beta tester

Figure 4-1: Process Map: Development of the NED-2 Wildlife Model for the Southeast

Three possible forest types have been defined:

1. Pure Types: At least 80% of the stand basal area is represented by one single species. The forest type name is the species name itself.
2. Base Types or Single-Genus types: Defined by a set of species belonging to the same genus that are called characteristics and a set of species called associates. The

characteristic species represent at least 50% of the stand basal area. The characteristic and the associated species together represent at least 65% of the stand basal area. The forest type name usually indicates the characteristic species genus.

3. Mixed Types: Types that represent mixed-species forest types. Defined by characteristics and associates.
    a. Characteristic species represent at least 50% of the stand basal area. Associate species and characteristic species together represent at least 65% of the stand basal area.
    b. Characteristics consists of two forest types. Then, each forest type must represent at least 25% of the stand basal area. Characteristics and associates represent at least 65% of the stand basal area.

Species that occur as a characteristic species of one type cannot be in the characteristic list of a second type. However, any defined forest type can be a characteristic for any other forest type.

Stands can only have a forest type assigned if they satisfy the size class sapling or higher.

According to this algorithm Mark Twery, who is one of the original designers of the forest type algorithm, assisted in developing 13 base types and seven mixed types for the Southeast. Also, seven of the Northeastern forest types were modified during this process. Figure 4-2 visualizes the development steps in a process map.

The starting point was to build a list of vegetation types that provide habitat for the wildlife species (Hamel 1992 and Wilson 1995). Non-forested vegetation types, like spartina and cave dwelling, have been filtered out as the NED-2 focus is on forest ecosystem management. The vegetation types come with a translation into SAF types (forest cover type descriptions by the

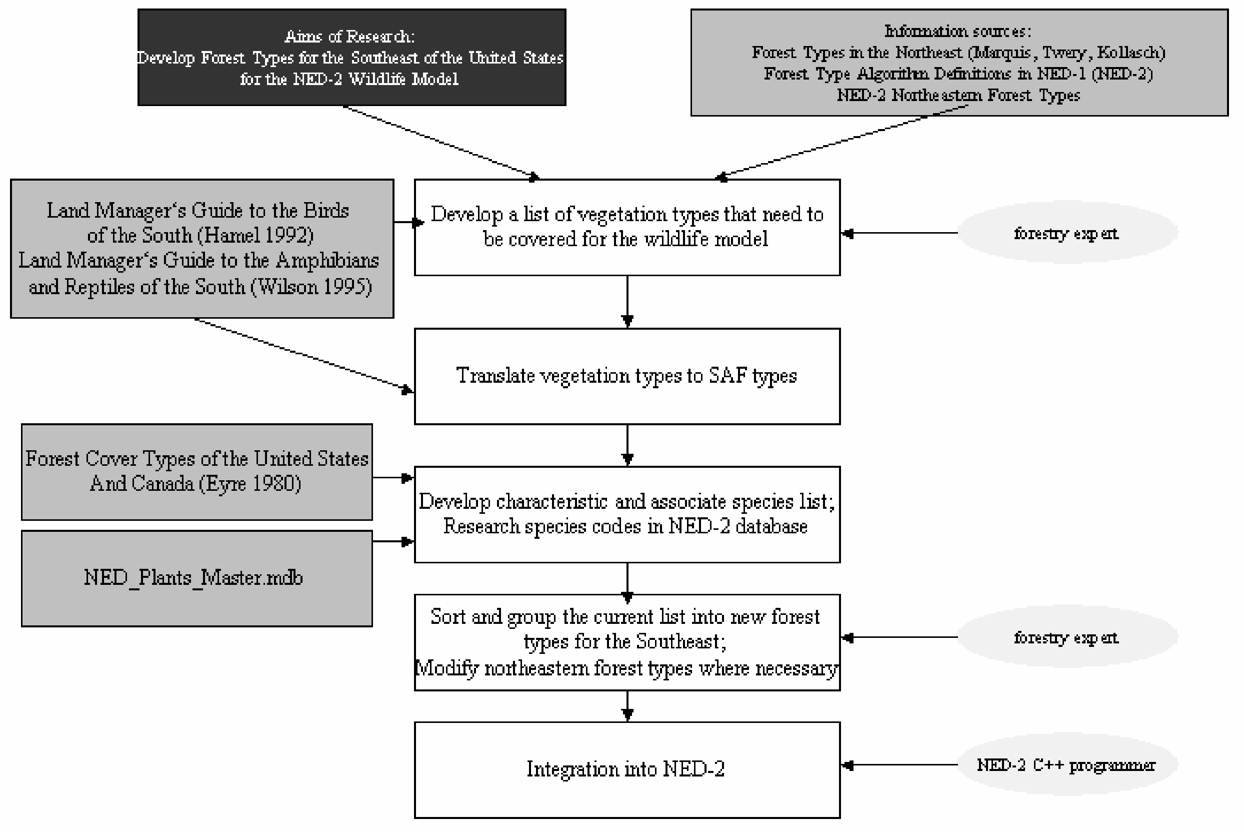

Aims of Research:
Develop Forest Types for the Southeast of the United States
for the NED-2 Wildlife Model
Information sources:
Forest Types in the Northeast (Marquis, Twery, Kollasch)
Forest Type Algorithm Definitions in NED-1 (NED-2)
NED-2 Northeastern Forest Types
Land Manager's Guide to the Birds
of the South (Hamel 1992)
Land Manager's Guide to the Amphibians
and Reptiles of the South (Wilson 1995)
Develop a list of vegetation types that need to
be covered for the wildlife model
forestry expert
Translate vegetation types to SAF types
Forest Cover Types of the United States
And Canada (Eyre 1980)
NED_Plants_Master.mdb
Develop characteristic and associate species list;
Research species codes in NED-2 database
Sort and group the current list into new forest
types for the Southeast;
Modify northeastern forest types where necessary
forestry expert
Integration into NED-2
NED-2 C++ programmer

Figure 4-2: Process map: Development of NED-2 Forest Types in the Southeast

Society of American Foresters.) The SAF types are defined by characteristic and associated species, similar to the forest types in NED-2 (Eyre 1980). Research on the SAF types helped to prepare a list of the required vegetation types, their characteristic and their associated species.

In a final meeting with the forestry expert Mark Twery, the types were regrouped and pooled. The resulting list consists of 20 new southeastern forest types. The final step was the integration into the system by Scott Thomasma, the C++ interface programmer and NED-2 database administrator.

Once the development of the new forest types had been wrapped up, the results could be used in the development of the wildlife knowledge base.

As the forest types had been developed directly from the vegetation cover types, a list translating the wildlife vegetation types into NED-2 forest types was prepared. The Wildlife Model for the Northeast uses the HAM rules to map the NED-2 forest types to the required types in the model. By using the translation list for implementing the rule writer, the additional step of designing rules similar to the HAM rules was not required.

APPENDIX D gives a list of all the current NED-2 forest types, including the newly developed forest types in the Southeast. Research papers used and documents prepared during the research of the forest types have been added to the companion CD. The list of NED-2 forest types is still being revised by the NED-2 forestry experts and will be updated soon.

4.3 THE RULE WRITER PROGRAM

The extension of NED-2 with the Southeastern Wildlife Model added 405 new wildlife species to the system. This does not include the species that already existed in the NED-2 Wildlife Model for the Northeast and that got extended with a second habitat rule for the Southeast. The bird rules come in two rule sets: one for breeding and one for wintering. The extensive number of rules makes it impractical to develop the rules by hand. Hence, a rule writer was created. Once the generation of the rules was automated, it was simple to make modifications to the rules due to design decisions or implementation issues.

All files discussed in this section can be found on the companion CD. Due to the length of the files the data was not added as an appendix, but is available in electronic format.

The input into the rule writer are Excel files that store the habitat matrices. The bird matrices are stored in four Excel files: *SPFTABL1.XLS*, *SPFTABL2.XLS*, *SPFTABL3.XLS*, *SPFTABL4.XLS*. Each matrix stores the species habitat information for a set of vegetation types. Therefore, if a species occurs in several vegetation types, it has entries in the different files.

The reptiles and amphibians matrices are stored in two files: *FORTYPE.XLS* and *HABFEAT.XLS*. The first matrix stores the forest type information for all species, the second matrix stores all other habitat data.

The mammals matrices come with three files: *terr_subterr_habitats.xls*, *special_hab_factors.xls* and *aquatic_habitats.xls*. The files list the different subcategories of habitat conditions for all species.

Each of the three species groups (birds, amphibians and reptiles, mammals) required the implementation of an individual rule writer due to differences in

1. format and count of input files
2. spelling of the used variables
3. interpretations of variables and measurements for different species groups
4. the output of the rules (breeding and wintering for birds; optimal, suitable and marginal habitat for birds and for amphibians and reptiles)

Of course, the main structure of the programs could be reused and modified according to the differences.

The following elements are the same for all three rule writers:

1. A *species_meta_data.pl* program uses the DDE (Dynamic Data Exchange) interface of LPA Prolog to link with the application Excel (Shalfield 2002). It reads in the data of the Excel files and generates a temporary file with the available habitat knowledge in intermediate format.

2. A *species_rules.pl* program reads the metaknowledge bases and writes the rules into an output file that generates the knowledge base. The *birds_rules.pl* program generates two output files: one for breeding rules and one for wintering rules.
3. Each *species_rules.pl* program implements
    a. the writing of the general rule structure.
    b. the conversion of the species name to a Prolog atom.
    c. a check for optimal, suitable, or marginal habitat and the setting of the correct `Threshold.`
    d. the generation of a `RuleName` that is the concatenation of the atom 'wi_' for wildlife, if applicable the atom 'opt_', 'sui_' or 'mar_', indicating the habitat level of a rule, and the species Prolog atom.
    e. the division between rules for the Northeast, the Southeast, breeding and wintering habitat. The rule conclusion predicates are named as follows:
        - `habitat_available` is the existing predicate for the Northeastern Wildlife Model.
        - `south_habitat_available` is the new predicate for the Southeastern Wildlife Model. This applies to the mammals, amphibians and reptiles.
        - `breed_habitat_available` and `winter_habitat_available` are the predicates used for the bird species rules.

    Originally, the `Environment` variable was planned to indicate the model analyzed. This would allow the goal analysis agent to pick the rule according to a model stated in the `Environment` for evaluation. But the report agent would have no way of knowing which results on the blackboard belong to which model as the `Environment` variable is not stored on the blackboard by the inference engine. Therefore, the rule predicate was used to indicate the difference.

f. the AND and OR relation that has been defined during the knowledge acquisition.

g. the mapping of the habitat condition from the matrices to the DFC.

h. the generation of a rule description string.

The *bird_rules.pl* program also outputs the `species_uses/9` predicate discussed in the previous section.

An example for a rule structure written by the rule generator for **Ringed Salamander** is given in the following:

```
% rule structure for optimal habitat for ringed salamander
% threshold variable is set to 1.0 due to optimal habitat

rule(nedcf,stand_analysis,wi_opt_ringed_salamander,1,

% rule applies to Southeastern Model

(south_habitat_available(
[`SNAPSHOT`=A,species(ringed_salamander)],passed ) :-

% the following DFCs must be met

member_of([`SNAPSHOT`= A],stand_forest_type,['appalachian
hardwoods','bottomland hardwoods','loblolly pine-shortleaf
pine','mesic mixed pine-hardwoods']),
member_of([`SNAPSHOT`= A],stand_size_class,['large
sawtimber','small sawtimber']),
(    equal( [`SNAPSHOT`= A],stand_has_wetland,1);
     equal( [`SNAPSHOT`= A],stand_is_wetland,1);
     equal( [`SNAPSHOT`= A],stand_perm_ponds,1);
     equal( [`SNAPSHOT`= A],stand_temp_ponds,1);
     more( [`SNAPSHOT`= A],stand_wetland,0)
),
more( [`SNAPSHOT` = A],stand_canopy_closure, 25),

% moist soil is one of the variables not added to NED-2, yet
% the DFC is commented out, but recorded in the report
% equal( [`SNAPSHOT` = A],stand_moist_soil,1),

more( [`SNAPSHOT` = A],stand_litter, 0),
more( [`SNAPSHOT` = A],stand_woody_debris,0)),

% a rule description string is the last argument

[`This rule determines a degree of confidence that a snapshot
of`,`a stand provides habitat for Ringed Salamander. `]).
```

The following code extract from the *bird_rules.pl* program explains how the habitat conditions are mapped to the individual DFCs:

```
% big_trees/1
% for nesting, perching, foraging and any combination of these,
% one big tree is enough to satisfy the requirement
% else, for all requirements (* and *?) more than or
% equal to 50% of the trees in the stand should be big trees

big_trees(X) :-     member(X,['N','P','F','FP','NP']),
                    write(`,`),put(12),
                    write(`min([`),
                    put(96),
                    write(`SNAPSHOT`),
                    put(96),
                    write(` = A],stand_big_trees, 1)`),
                    !.

big_trees(X) :-     member(X,['*','*?']),
                    write(`,`),
                    put(12),
                    write(`known(`),
                    put(96),
                    write(`Stand_snapshots_measures`),
                    put(96),
                    write(`:`),
                    put(96),
                    write(`stand_trees_per`),
                    put(96),
                    write(`([`),
                    put(96),
                    write(`SNAPSHOT`),
                    put(96),
                    write(`=A],TreesPer),_,`),
                    put(96),
                    write(`NED-2 WORKING FILE`),
                    put(96),
                    write(`),`),
                    put(12),
                    write(`BT is TreesPer/2,`),
                    put(12),
                    write(`more( [`),
                    put(96),
                    write(`SNAPSHOT`),
                    put(96),
                    write(` = A],stand_big_trees, BT)`),
                    !.

big_trees(_) :- !.
```

Big trees are a necessary habitat condition for birds. If big trees are needed for nesting, perching, and foraging, one big tree in a stand satisfies the condition. Otherwise at least 50% of the trees in the stand should be big trees. The first predicate defines the case in which one big tree is needed in a stand. It checks if the entry in the habitat matrices is equal to `'N'` for nesting, `'P'` for perching, `'F'` for foraging, `'FP'` for foraging and perching or `'NP'` for nesting and perching. In this case it writes out a DFC with the following structure:

```
min([`SNAPSHOT`=A],stand_big_trees,1)
```

This indicates that one or more big trees in the stand satisfy the condition. If the first predicate fails, the second predicate checks if big trees are needed for all kinds of requirements (`'*'` or `'*?'` entry). Then it outputs the following DFC structure:

```
known(`Stand_snapshots_measures`:``stand_trees_per`(
          [`SNAPSHOT`=A],TreesPer),_,`NED-2 WORKING FILE`),
BT is TreesPer/2,
min([`SNAPSHOT`=A],stand_big_trees, BT),
```

The first two lines use the `known/3` predicate to access the database and get the number of trees in the stand. This number is divided by two to get the count of 50% of the trees in the stand. Then the `min` relation checks if this or a higher number of trees are big trees.

4.4 INTEGRATION INTO NED-2

Integration into NED-2 was the final step in the development process. Several design decision had to be made. Two problems were raised during the integration of the Southeastern Wildlife Model. First, several possibilities for determining which wildlife species are loaded into the goal selection screen were elaborated. Loading all species of the two models in the goal selection screen allows the user to pick any species. This would include the species that do not occur in the management unit according to the species ranges. Also, species with rules in two models can be picked. The latter results in the second problem: the goal analysis agent would not know which model to apply.

Loading species of one model at a time, determined either by the management unit state (the southeastern states apply the Southeastern Wildlife Model; the northeastern states apply the Northeastern Wildlife Model) or by loading species based on a user selected model would be one alternative. Then the goal analysis agent would have exact information about which model to use to evaluate a habitat goal. For the first approach each state needs to be assigned to a model. As the models overlap for some states, this assignment becomes problematic. Even though our forest experts compromised on an assignment without any overlap, one problem remains: the user can still select species for a management unit state that do not occur in the state according to its range data.

The final solution added a range column to the goals database. For each species the range information was entered into the system. Hence, only the subset of species that actually occur in the management unit state is loaded into the goal selection pane. If no state is entered the user is asked to enter a state. If he does not enter a state no wildlife species will be loaded.

On the request of the forestry experts to get all possible information for a target species into the report, the goal analysis agent was implemented to evaluate all rules found for a species, i.e. rules from both models. Then, the report displays the different results with information about the applied models. It is up to the user to decide which rule evaluation is suitable.

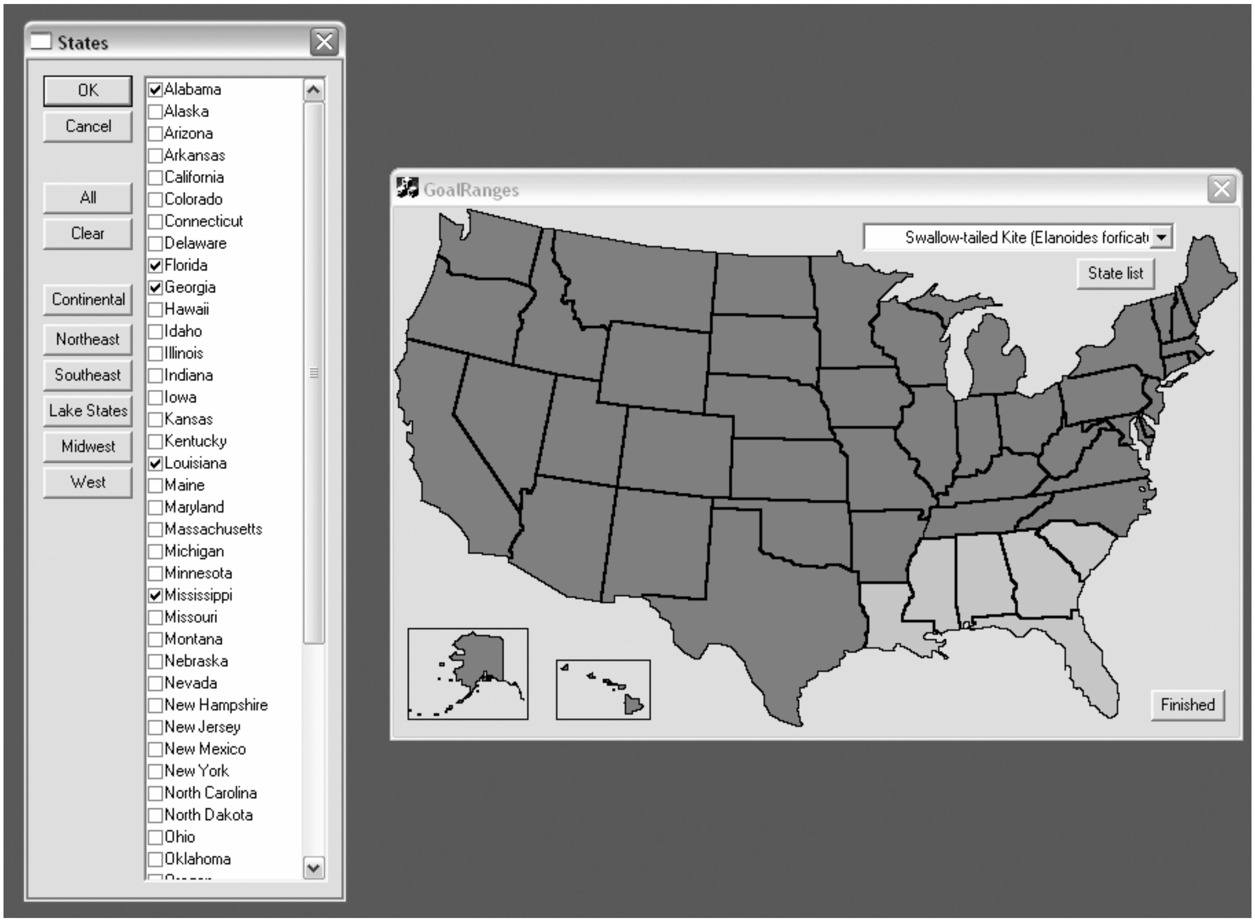
The following list summarizes the steps taken in integrating the Wildlife Model for the Southeast:

1. Preparation of the species lists with common names, Latin names and Prolog names.
2. Identification of species in both models and decision-making on common spelling. This involved modifying some rules in the Northeastern Wildlife Model.
3. Entering the ranges of every species into the database. This was realized by using the program **GoalRanges.exe** by Scott Thomasma which is a part of the NED-2 software. The program is a dialog window where each goal in the NED-2 database can be picked and the ranges can be entered either by clicking on a map of the United States or by clicking on the state name in an extra pop up window (see Figure 4.3.). The application **GoalRanges.exe** can be found in the NED-2 folder on the companion CD.

   The data entered for the species ranges comes from the following sources:

   a. Land manager's Guide to the Amphibians and Reptiles of the South (Wilson 1995)
   b. Land Manager's Guide to the Birds of the South (Hamel 1992)
   c. State-specific Lists of Indigenous Mammals (The American Society of Mammalogists 2004)
   d. New England Wildlife (DeGraff et al. 2001)

   These sources covered the species of the Southeastern Wildlife Model and occurrences of species in New England. It covers only a subset of states for mammals; therefore the ranges might be incomplete. A wildlife expert needs to go through the lists in the future and update them.



☑ Alabama
□ Alaska
□ Arizona
□ Arkansas
□ California
□ Colorado
□ Connecticut
□ Delaware
☑ Florida
☑ Georgia
□ Hawaii
□ Idaho
□ Illinois
□ Indiana
□ Iowa
□ Kansas
□ Kentucky
☑ Louisiana
□ Maine
□ Maryland
□ Massachusetts
□ Michigan
□ Minnesota
☑ Mississippi
□ Missouri
□ Montana
□ Nebraska
□ Nevada
□ New Hampshire
□ New Jersey
□ New Mexico
□ New York
□ North Carolina
□ North Dakota
□ Ohio
□ Oklahoma

Swallow-tailed Kite (Elanoides forficatı

Figure 4-3: The NED-2 Goal Ranges Program

4. Modification of the goal analysis agent: The loading of the knowledge bases was integrated into the goal analysis agent. Four new knowledge bases were added to the system: *swild_birds_breed_dfc.kb*, *swild_birds_winter_dfc.kb*, *swild_mammals_dfc.kb* and *swild_repamph_dfc.kb*. The agent evaluates rules from both models for a species that has been selected and puts the information on the blackboard. Also, in case of multiple rules for one species and one model, the agent checks for the rule with the best results / highest CF for each snapshot. Then it retracts all other results for the current snapshot

from the blackboard. Multiple rules for one species and model are rules that represent different habitat levels (optimal, suitable and marginal). Hence, the report agent does not need to filter out the best result later. The inference engine stores the `RuleName` with the rule result on the blackboard, so that the report agent will have exact information on which rule has been used.

5. Implementation of wildlife reports (see Chapter 5).

CHAPTER 5

REPORT GENERATION

5.1 GENERATING REPORTS

In NED-2, one way to look at the data entered, analyzed, and simulated is by generating a set of reports. There are three groups of reports:

1. Plan Comparison Reports
2. Management Unit Level Reports
3. Stand Level Reports

There are seven plan comparison reports, a total of 23 management unit level reports and 29 stand level reports in NED-2. Report generation is carried out by three different agents: the planning agent, the report analyzer agent, and the report writer agent.

The management unit level reports include the goal analysis reports. Additionally, to the usual report generation, the goal analysis reports require the goal analysis to be executed. This adds two more agents to the process: the goal analysis agent and the goal report agent. How the agents interact with each other will be demonstrated later in this chapter.

To generate a report the user picks one of the reports in the report selection screen (Figure 5-1).

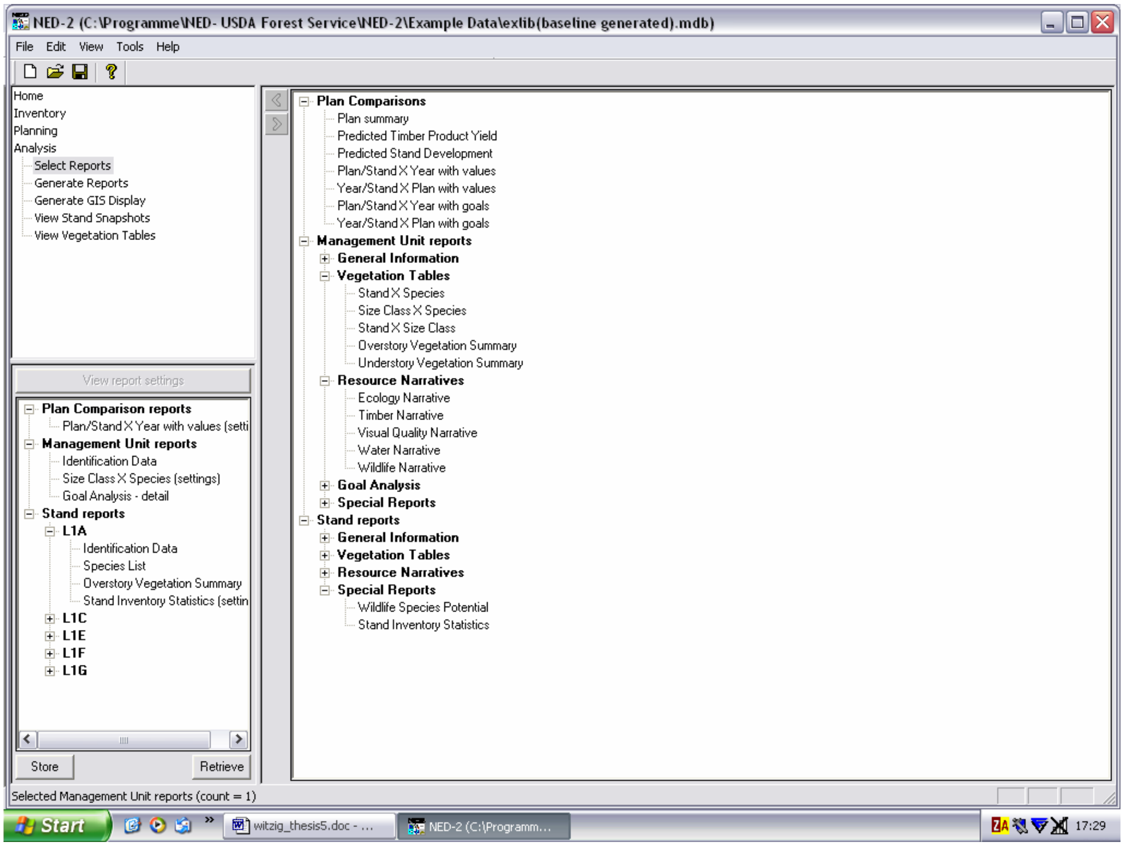
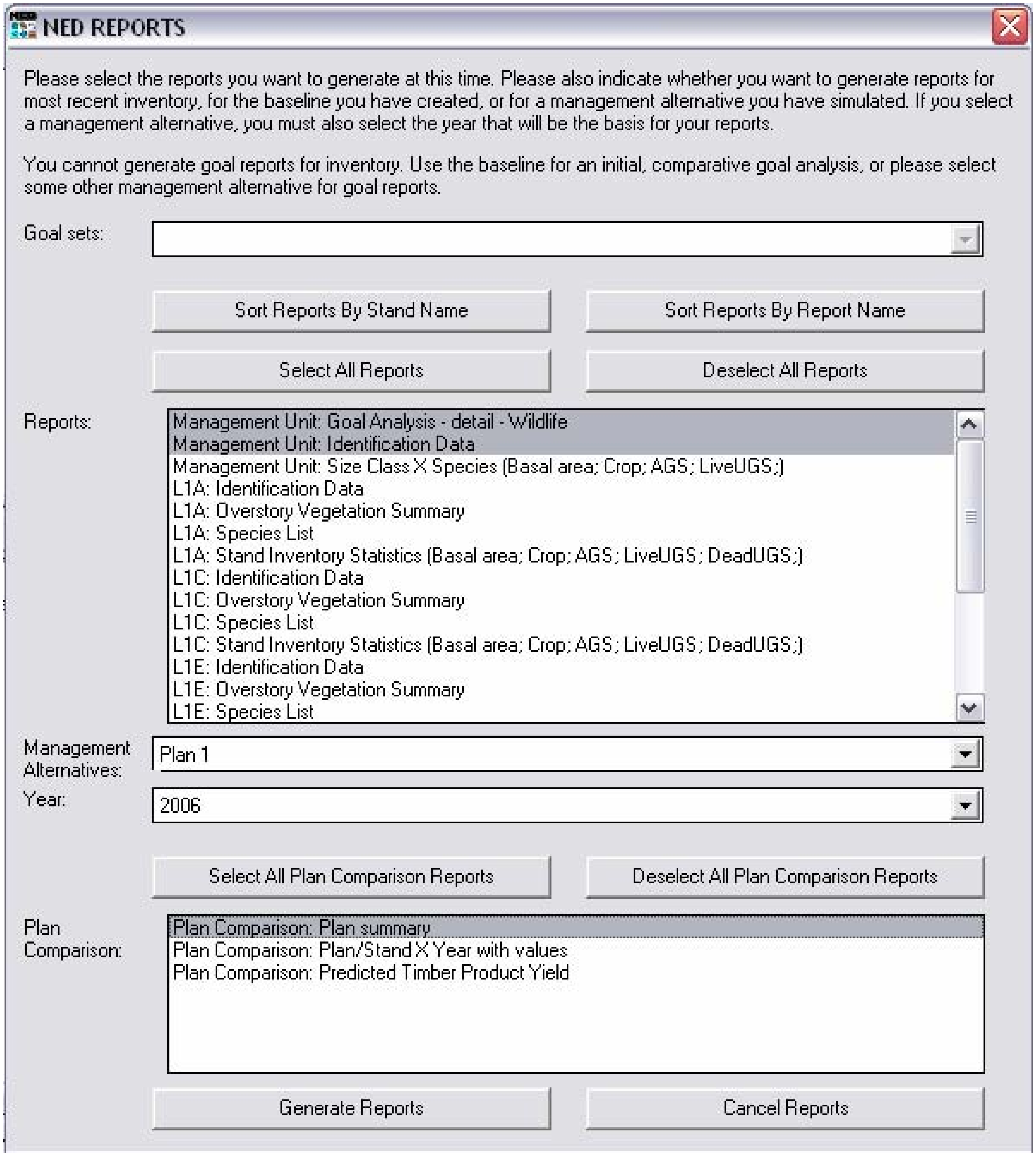


Figure 5-1: The Report Selection Screen

Once the user clicks the option *Generate Report* a dialog pops up where a goal set, a subset of reports, and - in case of management unit and stand level reports - a management unit alternative and year can be chosen (Figure 5-2).



NED REPORTS

Please select the reports you want to generate at this time. Please also indicate whether you want to generate reports for most recent inventory, for the baseline you have created, or for a management alternative you have simulated. If you select a management alternative, you must also select the year that will be the basis for your reports.

You cannot generate goal reports for inventory. Use the baseline for an initial, comparative goal analysis, or please select some other management alternative for goal reports.

Goal sets:

Reports:

- Management Unit: Goal Analysis - detail - Wildlife
- Management Unit: Identification Data
- Management Unit: Size Class X Species (Basal area; Crop; AGS; LiveUGS;)
- L1A: Identification Data
- L1A: Overstory Vegetation Summary
- L1A: Species List
- L1A: Stand Inventory Statistics (Basal area; Crop; AGS; LiveUGS; DeadUGS;)
- L1C: Identification Data
- L1C: Overstory Vegetation Summary
- L1C: Species List
- L1C: Stand Inventory Statistics (Basal area; Crop; AGS; LiveUGS; DeadUGS;)
- L1E: Identification Data
- L1E: Overstory Vegetation Summary
- L1E: Species List

Management Alternatives: Plan 1

Year: 2006

Select All Plan Comparison Reports
Deselect All Plan Comparison Reports

Plan Comparison:

- Plan Comparison: Plan summary
- Plan Comparison: Plan/Stand X Year with values
- Plan Comparison: Predicted Timber Product Yield

Figure 5-2: The Report Selection Dialog

Before the system starts the report generation, the user has the option to chose a destination folder for the reports. The default folder is the *Reports* folder in NED-2 with the following structure:

```
Reports/Management Unit Name/Management Unit Alternative - Year
```

Once the reports have been generated, the report writer agent opens the default browser with the main HTML pages consisting of two frames: a table of contents and the activate report.

5.2 THE REPORT GENERATION AGENTS

Each of the three report generation agents performs a different subtask in the report generation process. Once a user has picked a set of plans, the **planning agent** generates a plan to be put on the blackboard that outlines the steps for the report generation. With the *selected_report* request the planning agent communicates which reports have been selected. The last element of the plan is called *write_html* and takes care of generating the table of contents and opening up the web browser. The **report analysis agent** responds to the *selected_report* request and calls the appropriate predicates to generate the report data. Then, it outputs a request on the blackboard for the report to be written (*report_to_write*). The **Report Writer Agent** has two tasks: (1) It reacts to the request *report_to_write* for writing a selected report and (2) generates the main page with the table of contents (*write_html* request). The following diagram visualizes this process:

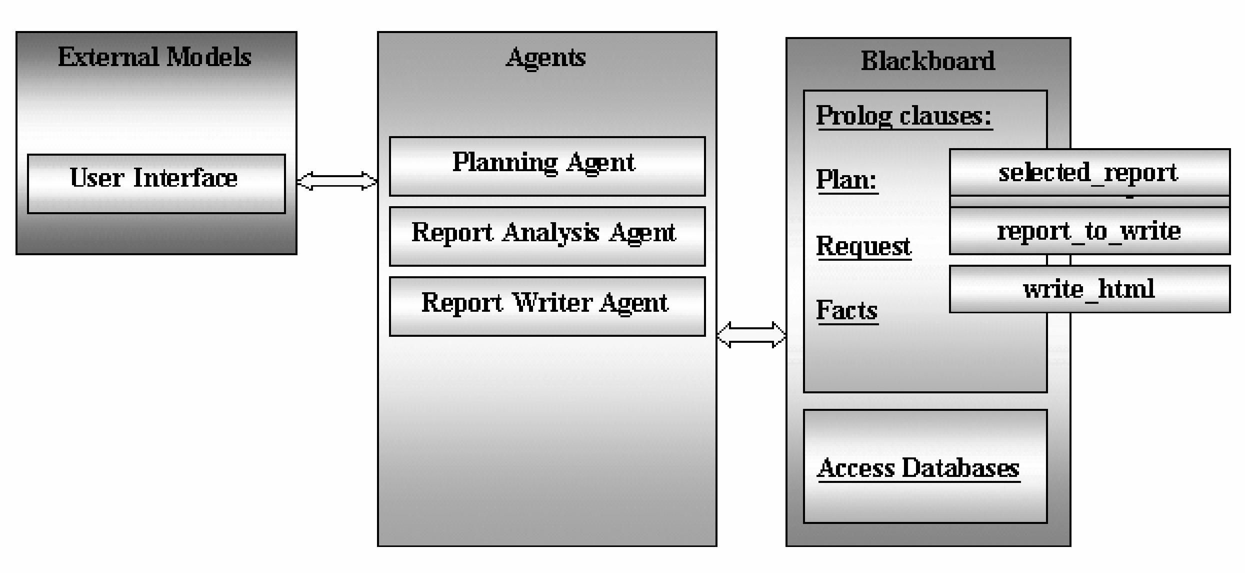


Figure 5-3: Interacting Report Generation Agents

5.2.1 THE PLANNING AGENT

The planning agent generates the report selection dialog (Figure 5-2). It looks up which reports have been pre-selected by the user and adds them to the listbox in the dialog. The planning agent implements intelligent behavior through the following functionality:

- The planning agent knows if the user has not simulated plans and it will not add plan comparison reports to the dialog in this case.
- The planning agent knows from which goal categories the user picked goals (Ecology, Health, Timber, Visual, Water, Wildlife), and once the user selects the goal analysis report, it will display only the goal analysis reports for the picked categories (e.g. *Goal Analysis – detail – Wildlife*). Goal analysis is only allowed on baseline and future plans; so the agent will not allow the user to pick a goal analysis report in combination with the inventory management unit alternative. If the user has grouped the goals in goal sets, the

user can select a goal set from the corresponding combobox. Again, the planning agent knows which of the selected goals and their categories belong to the selected goal set and will display only those reports in the listbox. If a user changes the goal set, the planning agent updates the listbox.

- The planning agent knows if only inventory data is available, if baseline data has been generated, or if plans have been simulated. In the case of plans it knows the year for which the plan has been simulated. According to this information it allows the user to pick a management unit alternative and a year.
- The planning agent has the same intelligence as the report writer agent to parse specification strings that specify a report. Specification strings store details that a user selected when choosing the report and are written in parenthesis behind the report in the listbox.
- The planning agent filters out stand level reports for which no data has been simulated. This is essential if plans are simulated for selected stands only.
- The planning agent knows which folder the reports are written to and offers a default folder. It ensures that the reports are written to the correct folder and warns the user about overwriting reports.

After the user has selected a set of reports and a destination folder, the planning agent generates requests of the following structure:

```
selected_report([+ID,+STAND,+REPORT_ID,+SPECS,+VIEW])
```

The `ID` is a display rank according to which each report is generated and displayed. The `STAND` is the picked stand for a stand level report and –1 for a management unit level or plan comparison report. The `REPORT_ID` is the Prolog name of the report, the `SPECS` are the specifications for a report and the `VIEW` is a list of snapshots representing the management unit alternative and year picked. For plan comparison reports this is a list of all snapshots representing the baseline and simulated plans. In case of a goal analysis report, the planning agent adds a request for goal analysis on the blackboard.

5.2.2 THE REPORT ANALYSIS AGENT

The report analysis agent answers to the request *selected_report* and takes the required action. Usually, this means a call to some Prolog predicate that generates the report data. The report data and a note that the report has been generated are stored on the blackboard. The note that the report has been generated is to inform the report writer agent of the necessary information for creating the table of contents:

```
generated_report([+ID,+STAND,+REPORT_ID,+SPECS,+OutputFile])
```

Then, for every report generated, the agent puts a *report_to_write* request on the blackboard:

```
report_to_write([+ID,+STAND,+REPORT_ID,+SPECS,+OutputFile])
```

The matching last element in the list of the two predicates ensures that the *OutputFile* name will match the link in the table of contents.

In case of a plan comparison report, the report analysis agent filters out the *report_to_write* requests. The plan comparison report is written on the fly into the destination folder. This modification had to be made while testing the plan comparison reports on the dataset JordanCreek.mdb. The dataset consist of 500 stands which generated strings too large to be stored. Accordingly the information was written to the output file immediately.

The goal analysis reports used to be generated by a separate agent, called analysis report agent. Now, goal analysis report generation has been adapted to use the report analyzer agent (see 5.3).

5.2.3 THE REPORT WRITER AGENT

The first task of the report writer agent is to answer to the *report_to_write* request: It consults a template with place holders for the report data. Then, it gets the required data from the blackboard and fills in the template. The resulting file is stored in the report folder. The process is visualized by the following diagram:

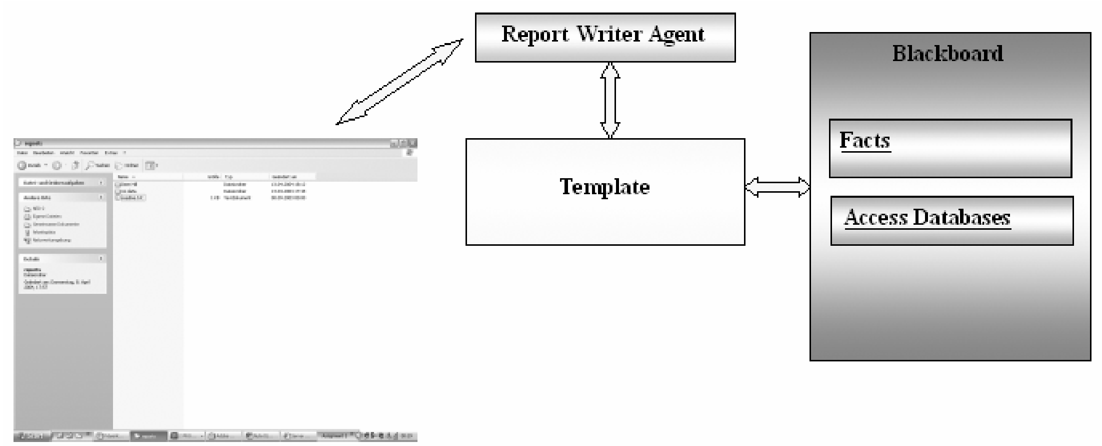


Figure 5-4: The Report Writer Agent

The second task of the report writer agent is to generate and open up the table of contents in the default browser. This happens in reply to the *write_html* request.

5.3 GOAL ANALYSIS REPORT GENERATION

The goal analysis reports are considered to be the exception in the report generation process. Usually, the reports consist of several interlinked hypertext documents. The goal analysis report generation has recently been revised.

5.3.1 THE OLD DESIGN AND ITS DOWNSIDES

The forest manager used to have two options to generate goal analysis reports: management unit goal analysis reports and stand level goal analysis reports.

If the report planning agent detected a goal analysis report, it would get all selected goals from the blackboard and add an individual goal report for each goal in the report selection listbox. Then the user could choose a subset of the goal analysis reports to be generated. For every selected goal analysis report, the report planning agent put a goal analysis request on the blackboard. To generate the report, the planning agent created a request directed to a separate agent, called the analysis report agent.

The goal analysis agent would respond to the request and perform the analysis. Afterwards, the analysis report agent would create the corresponding report. The agent used to look up which management unit level reports and stand level reports had been selected and build one summarizing goal analysis report interlinked with the selected reports.

The interaction of the agents during this process is visualized in the following diagram:

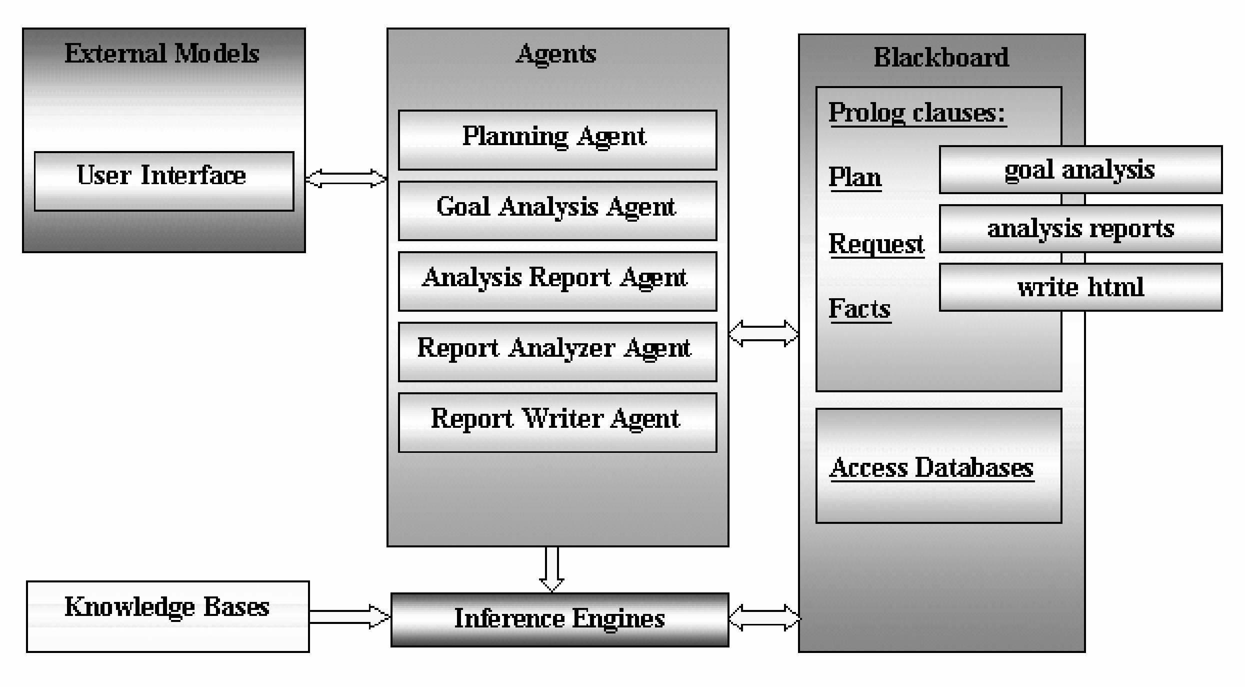


Figure 5-5: The Goal Analysis Report Generation – Old Design

The process of outputting the goal analysis report by the analysis report agent and the report structure is illustrated in Figure 5-6.

Two problems occurred with this design. From the programming point of view, goal analysis report generation represents an exception to the usual report generation process. The planning agent needs to handle this exception when building the plan. Also, the efficient design of using a template to generate the reports has not been considered in the process.

From the report design perspective this implementation is also inefficient. All six goal categories are generalized into one goal analysis report generation routine. The recently implemented Health Model does not fit into this generalization. The Health Model required a report of a completely different format. The Timber report has its own definition for how to evaluate a management unit goal (see 3.3). Hence, it needed to be designed individually as well.

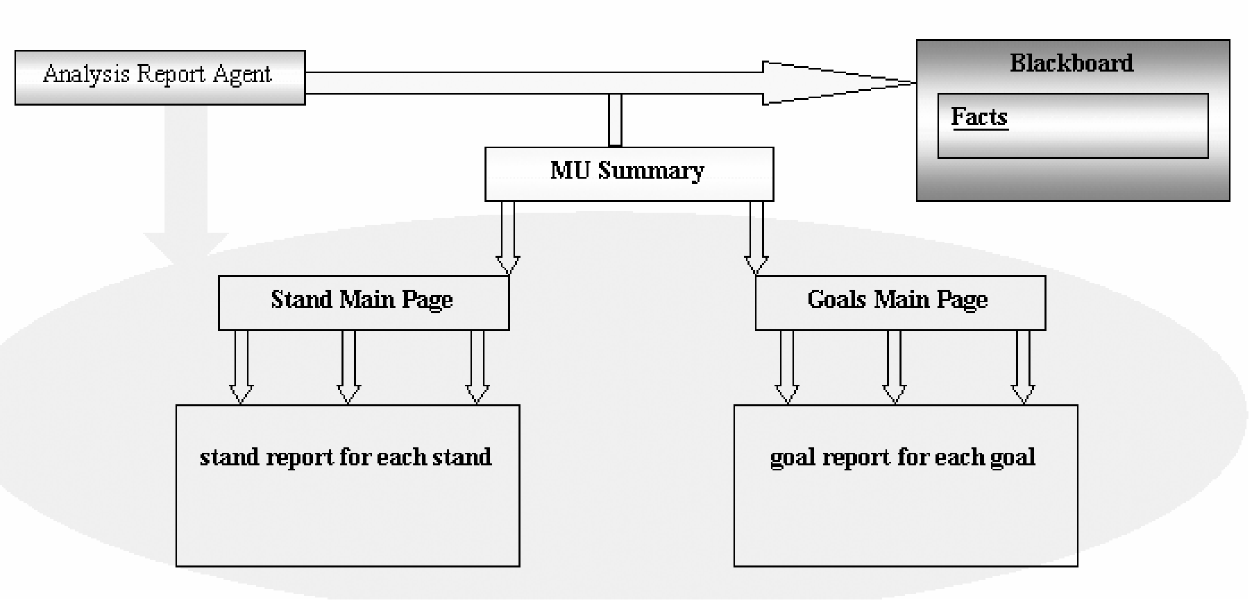


Figure 5-6: The Analysis Report Agent

Finally, the integration of the Southeastern Wildlife Model required a redesign of the Wildlife reports. Rather than handling all these reports as exceptions, a new structure for generating the goal analysis reports was favored.

5.3.2 THE NEW DESIGN

The two main objectives for the redesign of the goal analysis agents were (1) to use the report generation agents and templates to generate the main report pages and (2) to separate the goal analysis reports from each other according to their goal categories.

The following diagram illustrates the new design:

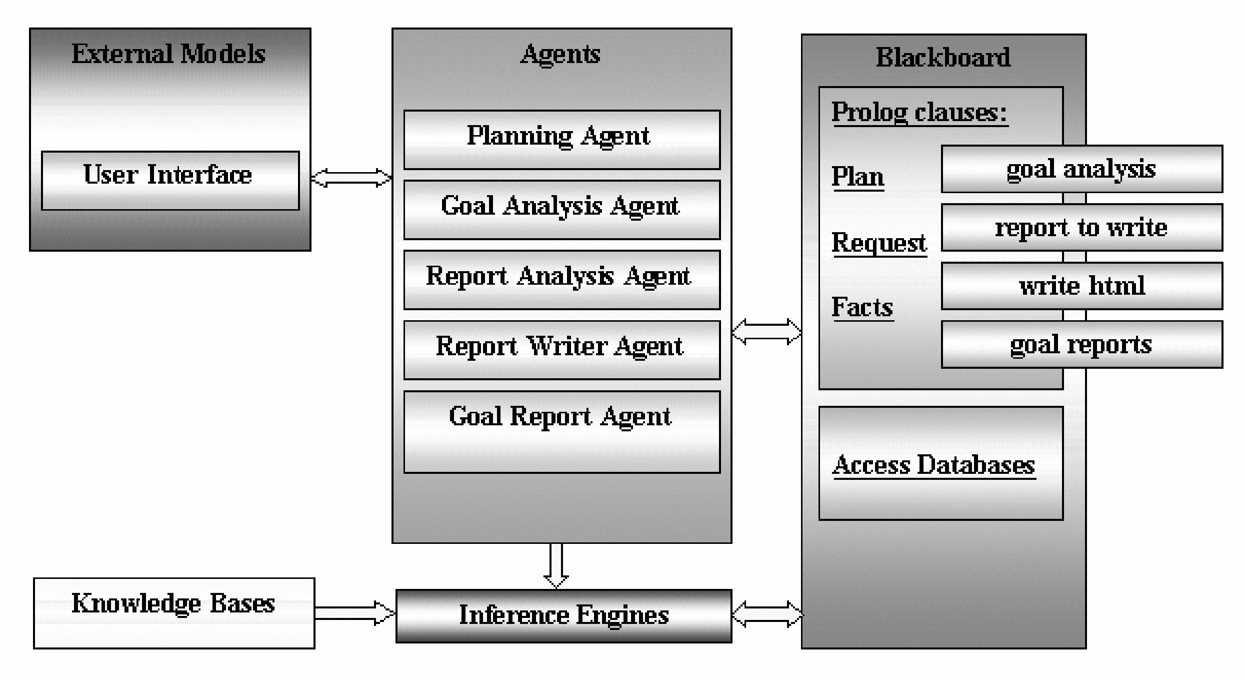


Figure 5-7: The Goal Analysis Report Generation – New Design

The analysis report agent has been removed from the system. The user picks only the goal analysis report on a management unit level. The stand level information has been replaced by an additional table in the management unit level report.

The report planning agent looks up which goal categories have been selected and then adds the corresponding report to the listbox in the report selection dialog:

1. Goal Analysis for Wildlife
2. Goal Analysis for Timber
3. Goal Analysis for Ecology
4. Goal Analysis for Visual
5. Goal Analysis for Health
6. Goal Analysis for Water

Each of the reports is treated individually. First, the report analyzer agent and the report writer agent generate a top level report by applying a template. For the Health and the Timber reports the process is finished here. The Health report is a one page report only. The Timber report applies to one single goal since only one Timber goal can be selected for a management unit.

The top level reports for the other goal categories have links to the individual goal pages. These individual goal pages are generated by a new agent: the goal report agent. Each of the categories implements its own goal report agent. When generating the links on the top level report, the report analyzer agent leaves a request for each goal on the blackboard. Now, the goal report agent can answer to the request and output the individual goal report.

The process is visualized in the following diagram:

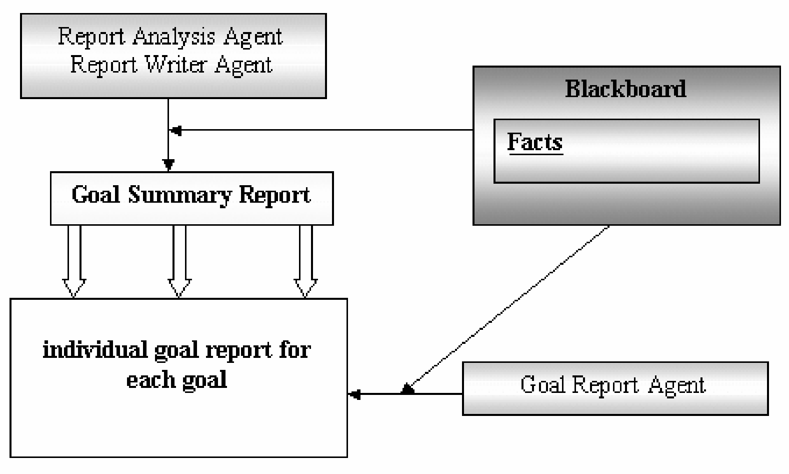


Figure 5-8: The Goal Report Agent

5.4 THE WILDLIFE GOAL ANALYSIS REPORTS

The Wildlife goal analysis reports display the data from the two wildlife models. The top level page displays the following information:

1. List of Wildlife goals chosen
2. Summary Analysis Table: including all selected Wildlife goals, their management unit goal status, the number of stands in the management unit, and how many stands fully satisfied, minimally satisfied, nearly satisfied, and failed the goal.
3. Stand Summary Table: including the goal status for every goal and stand (the goal status is indicated by an icon.)

APPENDIX E shows an example for a top level Wildlife report.

All possible goals are displayed in the tables. In the case of a species that has rules in both models, the table gets two entries: one for the Southeastern Wildlife Model and one for the Northeastern Wildlife Model. Also, if a bird from the Southeastern Model is picked it might get up to two entries: one for breeding habitat and one for wintering habitat. The goals in the tables are linked with the individual goal reports.

The individual goal reports for the Northeast and the Southeast have the same basic structure:

1. An introduction explains the model and the report.
2. Conditions for the rules associated with this goal are displayed.
3. DFC table: listing all DFCs and their actual value. The stand in the table is colored according to its status: fully satisfied is green, minimally satisfied is blue, nearly satisfied is orange, and failed is red[6].

[6] The colors might have to be revised in the future to consider red-green and similar color blindness.

4. Summary Analysis: Information for the goal and the management unit in terms of number of stands and management unit area.

The Southeastern Wildlife Model adds a paragraph at the end of each report. This paragraph describes the habitat conditions the species uses, but which are not essential in the goal evaluation or which have no equivalent NED-2 variable yet.

The Southeastern Wildlife Model also needs to consider the case of multiple rules applied to one goal. If a species has more than one rule, i.e. a rule for optimal habitat, a rule for suitable habitat, and a rule for marginal habitat, it can happen that different snapshots are evaluated by different rules. For every snapshot the goal analysis agent puts the best outcome with the corresponding rule on the blackboard. Then, the goal report agent informs the user about which rule has been applied for which stand.

APPENDIX E shows two example reports from the Southeastern Wildlife Model for the *Gray Myotis* and the *Evening Grosbeak*, generated on the NED-2 test dataset *exlib.mdb* for the baseline year. The original HTML reports can be reviewed on the companion CD.

To get the goal status information, the report generation agents and the goal report agents use the predicate fact/4 that is stored on the blackboard:

```
fact(+RulePred,+CF,+RuleName,+TimeStamp)
```

The `RulePred` is the rule conclusion predicate with the snapshot and species information as arguments, e.g.

```
breed_habitat_available([`SNAPSHOT`=6,species(turkey_vulture)],
                            passed).
```

The CF is the output from the “fuzzy” inference engine after the goal analysis. The RuleName is the name of the rule that helps identifying the correct rule for the rule parser (in the case of multiple rules for one species). The last argument is a time stamp.

The rule parser recognizes the rules and outputs them in a more readable format for the user. Also, it parses the list of DFCs used in the rules to be used in the DFC table.

CHAPTER 6

THE WILDLIFE MODEL IN APPLICATION

Feedback from the user will be essential to improve and extend the system. Concerning the Wildlife Model, the following questions will be particularly interesting.

Observing how the user applies NED-2 and the information gained through the system will help to improve the model. Currently, we assume that a user performs goal analysis on a current year and on a year in the future for which a plan is generated. By comparing the current and the future year, the user can draw conclusions on management actions.

Using the model in terms of finding the correct management action according to goals might not be the only possible application for the system. During the development of the Wildlife Model for the Southeast, the concern was raised that the data represents goals for providing habitat for a species, not goals for the presence of a species. Contrariwise, plantations that did not qualify for wild turkey habitat, have been found to be crammed full of wild turkeys. So the Wildlife Model in application will stimulate the research in determining habitat for the species and will test the assumptions and underlying logic on which wildlife researchers base their habitat knowledge.

CHAPTER 7

FUTURE WORK

This chapter suggests extensions and future work on the resource management components of NED-2.

Currently, the resource management goals are restricted to six categories. This list might be extended by other models. However, to ensure that a user can pick the goal he really wants to select, the user would need the possibility to define his own goals. By providing an interface that allows the user to generate DFC rules and knowledge bases, new goals could be defined and old goals could be redefined based on the user's expert knowledge and area-specific data. Obviously, this would involve major revisions in the NED-2 system.

A more urgent extension would be the development of a management unit level goal analysis that is adjusted to each goal category. Except for a few Visual stand level goals, NED-2 offers the evaluation of management unit goals. For most of the goals a bigger area like a whole management unit is more likely to pass a goal than an individual stand. The Timber goal analysis executes a management level goal analysis (on the results of the stand level goal analysis): A management unit level goal is defined by (1) balanced size classes in the management unit and (2) 65% of the area of the management unit satisfies the stand level goal analysis. The other goal categories do not implement such a management unit analysis. They just report a management unit to *pass (fail)* a goal if 100% of the management unit area *passes (fails)* the stand level goal. In any other case the management unit goal status is called *not fully*. The available sources do not provide a management unit level goal analysis for the Wildlife Model. Experts need to define what such an analysis might look like. The minimal tract size in the bird habitat matrices might be considered in the process.

The next planned extension is a Wildlife Model for the Michigan area. The program MIWild developed by the DNR (Department of Natural Resources) in Michigan will be used to develop the background knowledge.

Also planned for the near future is a model for game species. The model could apply a more detailed rule system to give a better habitat analysis. Such specific rules need to be researched, but a starting point could be the wild turkey habitat rules developed by Craig Harper at the University of Tennessee at Knoxville (see APPENDIX F).

Under development is the addition of ten new variables to NED-2 in the scope of the new Wildlife Model. The new variables have been discussed during the development of the Wildlife Model, but agreement about the specifications has not been reached. The knowledge bases for the Wildlife species do implement these variables. For the time being the variables have been commented out of the code. The user is informed about their importance in the reports. APPENDIX G lists the variables under construction for future reference.

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APPENDIX A

“FUZZIFICATION” OF THE DESIRED FUTURE CONDITIONS

The following list represents the DFC predicates that are handled by the NED-2 “fuzzy” inference engine. `Object` represents the snapshot that the goal analysis is looking at. `Variable` is the NED-2 Prolog predicate that represents the variable for the desired future condition and the `Value` represents the target value.

- `equal(Object,Variable,Value)`

  The `equal` DFC checks if the actual value for the given `Variable` for the given object is equal to the given target `Value`. If the target `Value` is a numerical value, the “fuzzy” calculations are applied and the result is compared to the actual value. If the target `Value` is not a numerical value it is compared to the actual value and gets a CF of 1.0 or 0.0.

- `in_range(Object,Variable,Range)`

  The `in_range` DFC checks if the given `Variable` is in the range of the two target values listed in `Range` for the given view. The inference engine applies the “fuzzy” calculations to both target values and according to where the actual value lies, it returns a CF.

- `sum_in_range(Object,Variables,Range)`

  The `sum_in_range` DFC sums up the variables stored in the list `Variables`. Then, it tests if the sum is in the given `Range`. Again, the “fuzzy” calculations are applied to the target values in the `Range` list.

- `min(Object,Variable,MinValue)`

  The `min` DFC applies the “fuzzy” calculation to the target value `MinValue`. If the actual value of the variable for the `Object` is bigger than or equal to the “fuzzy” value, it gets the corresponding confidence factor.

- `max(Object,Variable,MaxValue)`

  The `max` DFC applies the “fuzzy” calculation to the target value `MaxValue`. If the actual value of the variable for the `Object` is smaller than or equal to the “fuzzy” value, it gets the corresponding confidence factor.

- `less(Object,Variable,Value)`

  The `less` DFC applies the “fuzzy” calculation to the target `Value`. If the actual value of the variable for the `Object` is smaller than the “fuzzy” value, it gets the corresponding confidence factor.

- `more(Object,Variable,Value)`

  The `more` DFC applies the “fuzzy” calculation to the target `Value`. If the actual value of the variable for the `Object` is bigger than the “fuzzy” value, it gets the corresponding confidence factor.

- member_of(Object,Variable,ValueList)

  The member_of DFC tests if the actual value of the Variable for the given Object is a member of ValueList. In case of membership, the CF 1.0 is returned, else the CF 0.0 is returned.

- Attr(Object,Value)
  - The term Attr(Object,Value) can be a fact on the blackboard. Then, the CF is stored with the fact on the blackboard.
  - The term Attr(Object,Value) can be a conclusion. Then, the corresponding rule is consulted and evaluated.

- Pred

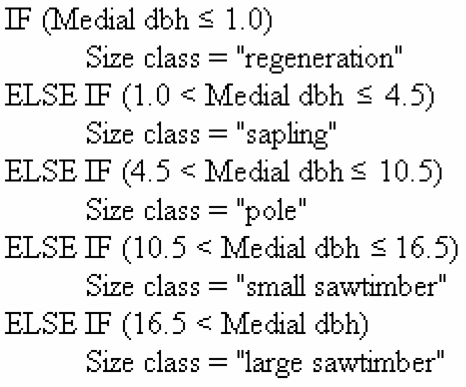
  The term Pred can be a build-in predicate. Some rules for the goals in NED-2 do not require any DFCs or have not been implemented, yet. Then, the DFC consists of the build-in Prolog predicate true.

APPENDIX B

NED-2 VARIABLE DOCUMENTATIONS

1. Size class

Variable name	Size class
Level	Stand
Table	Stand_snapshots_measures
ID (table column)	stand_size_class
Description	Stand size class
Column heading	Size class
Row heading	Size class
Variable type	Category
Validation rule	"regeneration" Or "sapling" Or "pole" Or "small sawtimber" Or "large sawtimber" Or Is Null
Validation text	Size class must be 1="regeneration", 2="sapling", 3="pole", 4="small sawtimber" or 5="large sawtimber"
Valid codes	1 = regeneration 2 = sapling 3 = pole 4 = small sawtimber 5 = large sawtimber
Needed	No
Editable	No
Tallied	No
Defaulted	No
Calculated	Yes

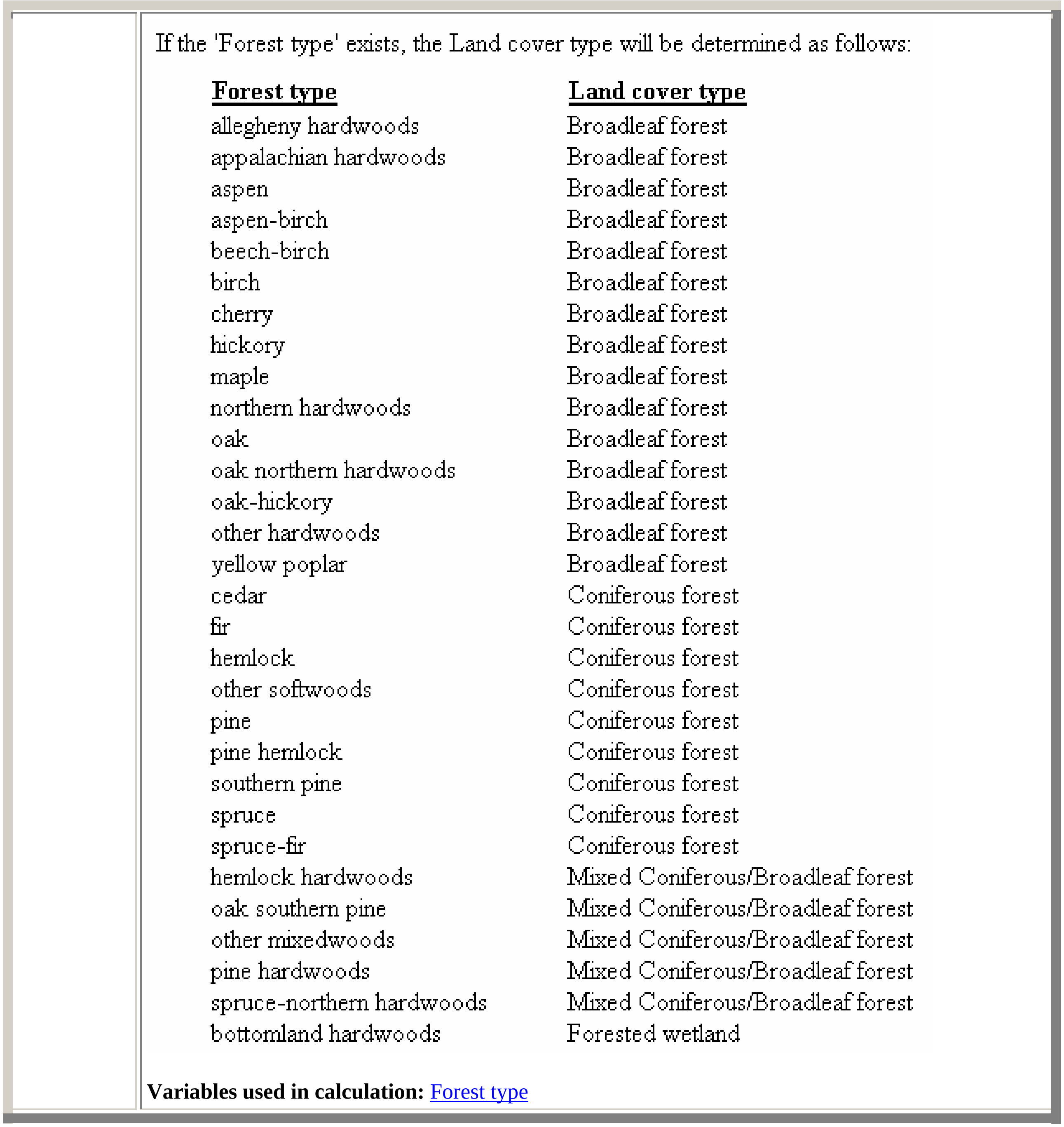
	
	IF (Medial dbh ≤ 1.0)
	    Size class = "regeneration"
	ELSE IF (1.0 < Medial dbh ≤ 4.5)
	    Size class = "sapling"
	ELSE IF (4.5 < Medial dbh ≤ 10.5)
	    Size class = "pole"
	ELSE IF (10.5 < Medial dbh ≤ 16.5)
	    Size class = "small sawtimber"
	ELSE IF (16.5 < Medial dbh)
	    Size class = "large sawtimber"
	
	Variables used in calculation: Medial dbh

2. Land cover type

Variable name	Land cover type
Level	Stand
Table	Stand_snapshots_measures
ID (table column)	stand_cover_type
Description	Land cover type of stand
Column heading	Land cover
Row heading	Land cover type
Variable type	Category
Validation rule	"Urban and built-up land" Or "Agricultural land" Or "Brush or transitional between open and forested" Or "Forest" Or "Water" Or "Wetlands (not including open water; palustrine wetlands only)" Or "Barren land" Or "Tundra" Or "Permanent snow and ice" Or "Residential" Or "Commercial, Services & Institutional" Or "Industrial" Or "Transportation, Communication and Utilities" Or "Industrial/Commercial complexes" Or "Mixed urban or built-up land" Or "Other urban or built-up land" Or "Cropland and pasture" Or "Orchards, bush fruits, vineyards, nurseries & ornamental horticulture" Or "Confined feeding operations" Or "Other agricultural land" Or "primarily herbaceous, non woody vegetation (75% or more cover)" Or "primarily shrub/brush (75% or more cover)" Or "mixed herbaceous and shrub/brush" Or "Broadleaf forest" Or "Coniferous forest" Or "Mixed Coniferous/Broadleaf forest" Or "Rivers, canals and other waterways" Or "Lakes and ponds" Or "Reservoirs (and other artificial water surfaces)" Or "Bays/Estuaries" Or "Aquatic bed" Or "Moss/Lichen (includes bogs and fens)" Or "Emergent wetland" Or "Scrub-Shrub wetland" Or "Forested wetland" Or "Salt flats" Or "Beaches and river banks" Or "Sandy areas (non-beaches)" Or

	"Bare/Exposed rock" Or "Strip mines, Quarries and Gravel pits" Or "Transitional" Or "Mixed barren land" Or "Shrub and brush" Or "Herbaceous" Or "Bare Ground" Or "Wet" Or "Mixed" Or Is Null
Validation text	Land cover type must be 1="Urban and built-up land", 2="Agricultural land", 3="Brush or transitional between open and forested", 4="Forest", 5="Water", 6="Wetlands (not including open water; palustrine wetlands only)", 7="Barren land", 8="Tundra", 9="Permanent snow and ice", 11="Residential", 12="Commercial, Services & Institutional", 13="Industrial", 14="Transportation, Communication and Utilities", 15="Industrial/Commercial complexes", 16="Mixed urban or built-up land", 17="Other urban or built-up land", 21="Cropland and pasture", 22="Orchards, bush fruits, vineyards, nurseries & ornamental horticulture", 23="Confined feeding operations", 24="Other agricultural land", 31="primarily herbaceous, non woody vegetation (75% or more cover)", 32="primarily shrub/brush (75% or more cover)", 33="mixed herbaceous and shrub/brush", 41="Broadleaf forest", 42="Coniferous forest", 43="Mixed Coniferous/Broadleaf forest", 51="Rivers, canals and other waterways", 52="Lakes and ponds", 53="Reservoirs (and other artificial water surfaces)", 54="Bays/Estuaries", 61="Aquatic bed", 62="Moss/Lichen (includes bogs and fens)", 63="Emergent wetland", 64="Scrub-Shrub wetland", 65="Forested wetland", 71="Salt flats", 72="Beaches and river banks", 73="Sandy areas (non-beaches)", 74="Bare/Exposed rock", 75="Strip mines, Quarries and Gravel pits", 76="Transitional", 77="Mixed barren land", 81="Shrub and brush", 82="Herbaceous", 83="Bare Ground", 84="Wet" or 85="Mixed"
Valid codes	1 = Urban and built-up land 2 = Agricultural land 3 = Brush or transitional between open and forested 4 = Forest 5 = Water 6 = Wetlands (not including open water; palustrine wetlands only) 7 = Barren land 8 = Tundra 9 = Permanent snow and ice 11 = Residential 12 = Commercial, Services & Institutional 13 = Industrial 14 = Transportation, Communication and Utilities 15 = Industrial/Commercial complexes 16 = Mixed urban or built-up land 17 = Other urban or built-up land 21 = Cropland and pasture 22 = Orchards, bush fruits, vineyards, nurseries & ornamental horticulture 23 = Confined feeding operations 24 = Other agricultural land 31 = primarily herbaceous, non woody vegetation (75% or more cover) 32 = primarily shrub/brush (75% or more cover) 33 = mixed herbaceous and shrub/brush 41 = Broadleaf forest 42 = Coniferous forest 43 = Mixed Coniferous/Broadleaf forest 51 = Rivers, canals and other waterways 52 = Lakes and ponds 53 = Reservoirs (and other artificial water surfaces) 54 = Bays/Estuaries 61 = Aquatic bed 62 = Moss/Lichen (includes bogs and fens) 63 = Emergent wetland 64 = Scrub-Shrub wetland 65 = Forested wetland

	71 = Salt flats 72 = Beaches and river banks 73 = Sandy areas (non-beaches) 74 = Bare/Exposed rock 75 = Strip mines, Quarries and Gravel pits 76 = Transitional 77 = Mixed barren land 81 = Shrub and brush 82 = Herbaceous 83 = Bare Ground 84 = Wet 85 = Mixed
Needed	No
Editable	Yes
Tallied	yes **Field procedure:** Enter the proper Anderson Level type from the following codes: 1 = urban; 2 = agriculture; 3 = rangeland; 4 = forest; 5 = Water; 6 = wetland; 7 = barren; 8 = tundra; 9 = perennial snow. If the stand is a wetland forest, type it as wetland (5).
Defaulted	No
Calculated	yes



If the 'Forest type' exists, the Land cover type will be determined as follows:

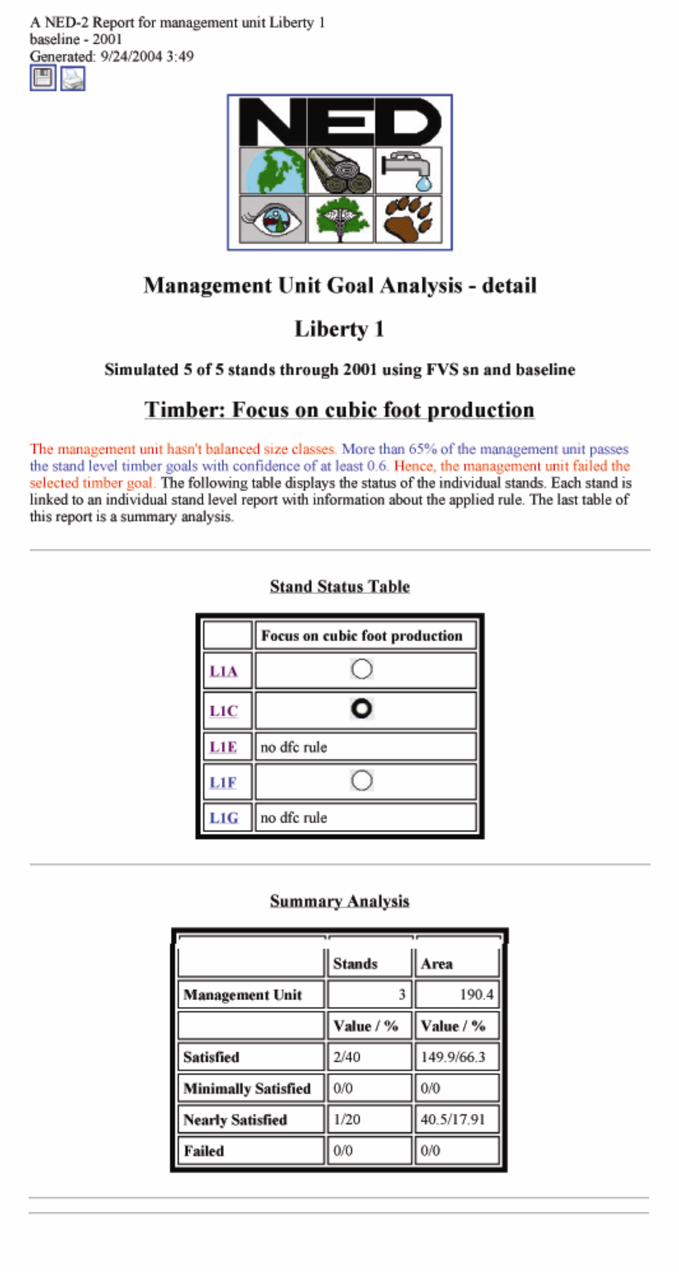
Forest type	**Land cover type**
allegheny hardwoods	Broadleaf forest
appalachian hardwoods	Broadleaf forest
aspen	Broadleaf forest
aspen-birch	Broadleaf forest
beech-birch	Broadleaf forest
birch	Broadleaf forest
cherry	Broadleaf forest
hickory	Broadleaf forest
maple	Broadleaf forest
northern hardwoods	Broadleaf forest
oak	Broadleaf forest
oak northern hardwoods	Broadleaf forest
oak-hickory	Broadleaf forest
other hardwoods	Broadleaf forest
yellow poplar	Broadleaf forest
cedar	Coniferous forest
fir	Coniferous forest
hemlock	Coniferous forest
other softwoods	Coniferous forest
pine	Coniferous forest
pine hemlock	Coniferous forest
southern pine	Coniferous forest
spruce	Coniferous forest
spruce-fir	Coniferous forest
hemlock hardwoods	Mixed Coniferous/Broadleaf forest
oak southern pine	Mixed Coniferous/Broadleaf forest
other mixedwoods	Mixed Coniferous/Broadleaf forest
pine hardwoods	Mixed Coniferous/Broadleaf forest
spruce-northern hardwoods	Mixed Coniferous/Broadleaf forest
bottomland hardwoods	Forested wetland

Variables used in calculation: Forest type

APPENDIX C

TIMBER ANALYSIS REPORT

1. Top Level Report



A NED-2 Report for management unit Liberty 1
baseline - 2001
Generated: 9/24/2004 3:49

Management Unit Goal Analysis - detail

Liberty 1

Simulated 5 of 5 stands through 2001 using FVS sn and baseline

Timber: Focus on cubic foot production

The management unit hasn't balanced size classes. More than 65% of the management unit passes the stand level timber goals with confidence of at least 0.6. Hence, the management unit failed the selected timber goal. The following table displays the status of the individual stands. Each stand is linked to an individual stand level report with information about the applied rule. The last table of this report is a summary analysis.

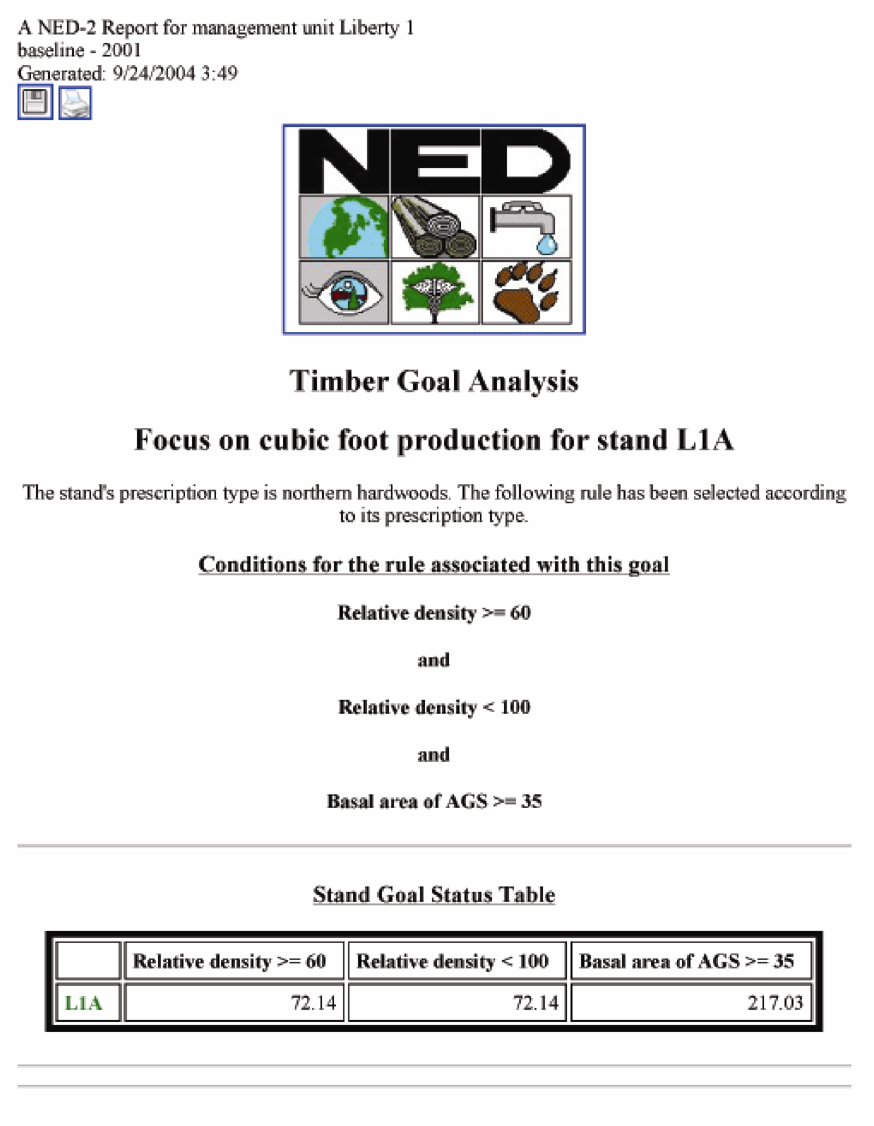
Stand Status Table

	Focus on cubic foot production
L1A	○
L1C	**○**
L1E	no dfc rule
L1F	○
L1G	no dfc rule

Summary Analysis

	Stands	Area
Management Unit	3	190.4
	Value / %	Value / %
Satisfied	2/40	149.9/66.3
Minimally Satisfied	0/0	0/0
Nearly Satisfied	1/20	40.5/17.91
Failed	0/0	0/0

2. <u>Individual Stand Level Report</u>



A NED-2 Report for management unit Liberty 1
baseline - 2001
Generated: 9/24/2004 3:49

Timber Goal Analysis

Focus on cubic foot production for stand L1A

The stand's prescription type is northern hardwoods. The following rule has been selected according to its prescription type.

Conditions for the rule associated with this goal

Relative density >= 60

and

Relative density < 100

and

Basal area of AGS >= 35

Stand Goal Status Table

	Relative density >= 60	Relative density < 100	Basal area of AGS >= 35
L1A	72.14	72.14	217.03

APPENDIX D

NED-2 FOREST TYPES

The following lists all the current NED-2 forest types. The characteristic and associated species that define the forest types can be found on the enclosed CD in the NED_Plants_Master.mdb in the NED-2 folder.

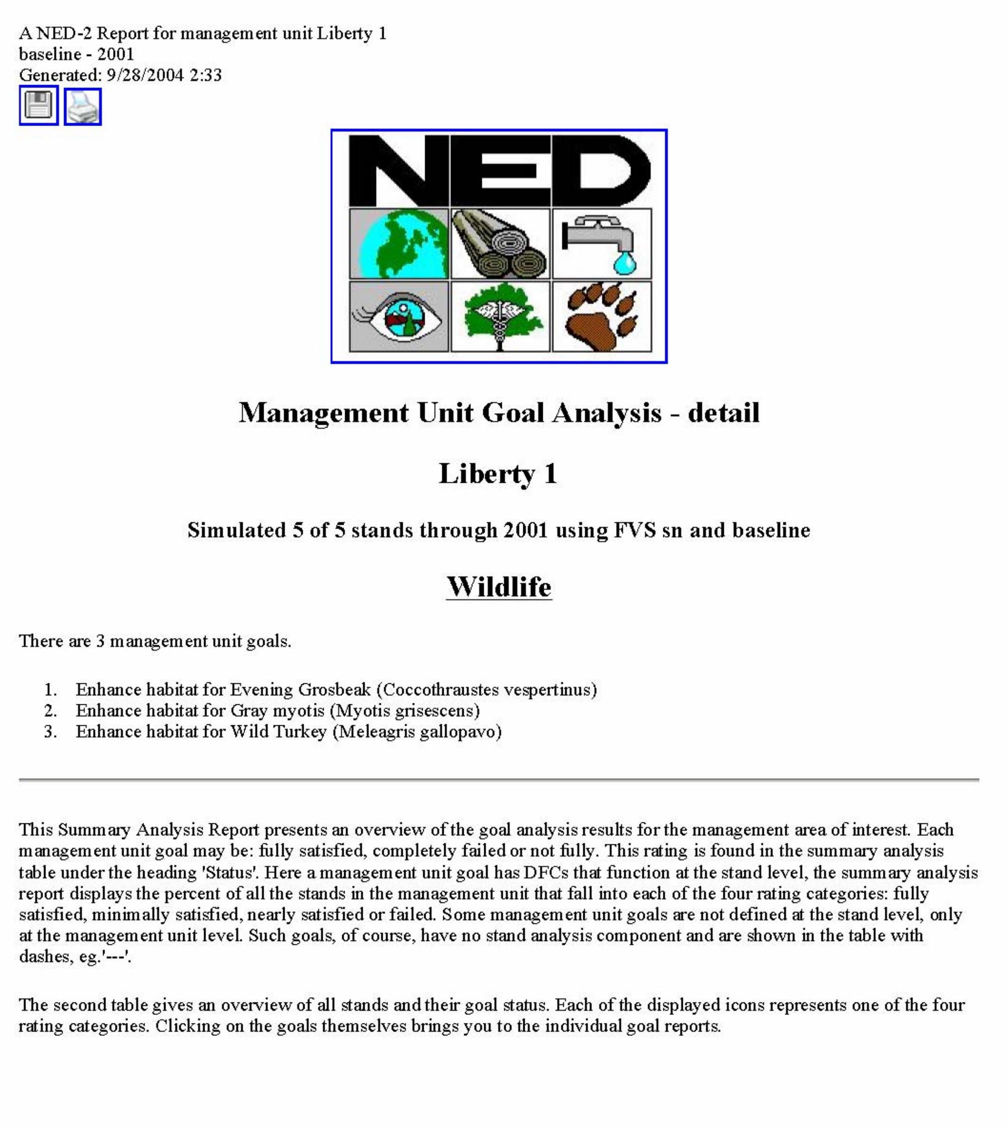
allegheny hardwoods
appalachian hardwoods
Aspen
aspen-birch
bay-swamp pocosin
beech magnolia
beech-birch
Birch
bottomland hardwoods
Cedar
Cherry
Fir
Hemlock
hemlock hardwoods
Hickory
live oak maritime
loblolly pine-shortleaf pine
longleaf pine
longleaf pine-scrub oak
Mangroves
Maple
mesic mixed pine-hardwoods
mesic mixed southern pine
mixed pine-hardwoods
northern hardwoods
Oak
oak northern hardwoods

oak southern pine
oak-hickory
Pine
Pine hardwoods
Pine hemlock
pond pine
pond pine pocosin
sand pine-southern scrub oak
southern bottomland hardwoods
southern mixed mesic hardwoods
southern pine
southern scrub oak
Spruce
spruce-fir
spruce-northern hardwoods
tropical hardwoods
white pine-hemlock
xeric mixed pine-hardwoods
xeric mixed southern pine
yellow poplar

APPENDIX E

GOAL ANALYSIS REPORTS FOR WILDLIFE

1. Top Level Wildlife Report with links to individual goal reports



A NED-2 Report for management unit Liberty 1
baseline - 2001
Generated: 9/28/2004 2:33

Management Unit Goal Analysis - detail

Liberty 1

Simulated 5 of 5 stands through 2001 using FVS sn and baseline

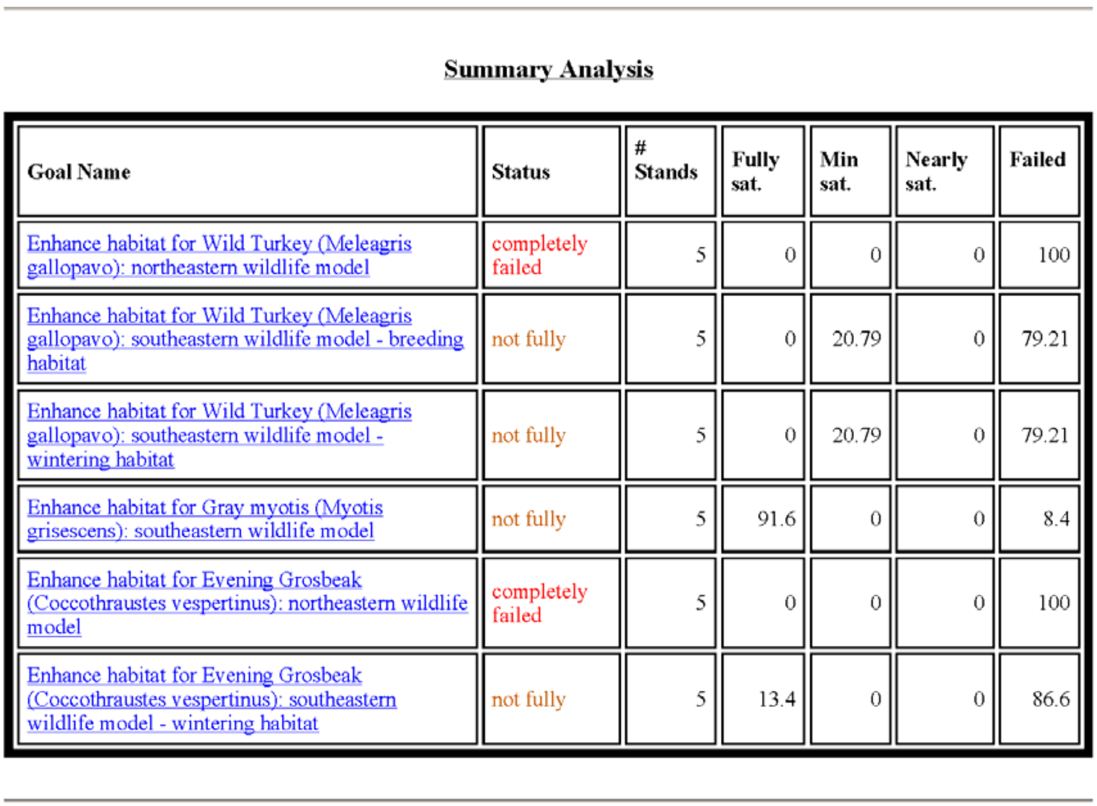
Wildlife

There are 3 management unit goals.

1. Enhance habitat for Evening Grosbeak (Coccothraustes vespertinus)
2. Enhance habitat for Gray myotis (Myotis grisescens)
3. Enhance habitat for Wild Turkey (Meleagris gallopavo)

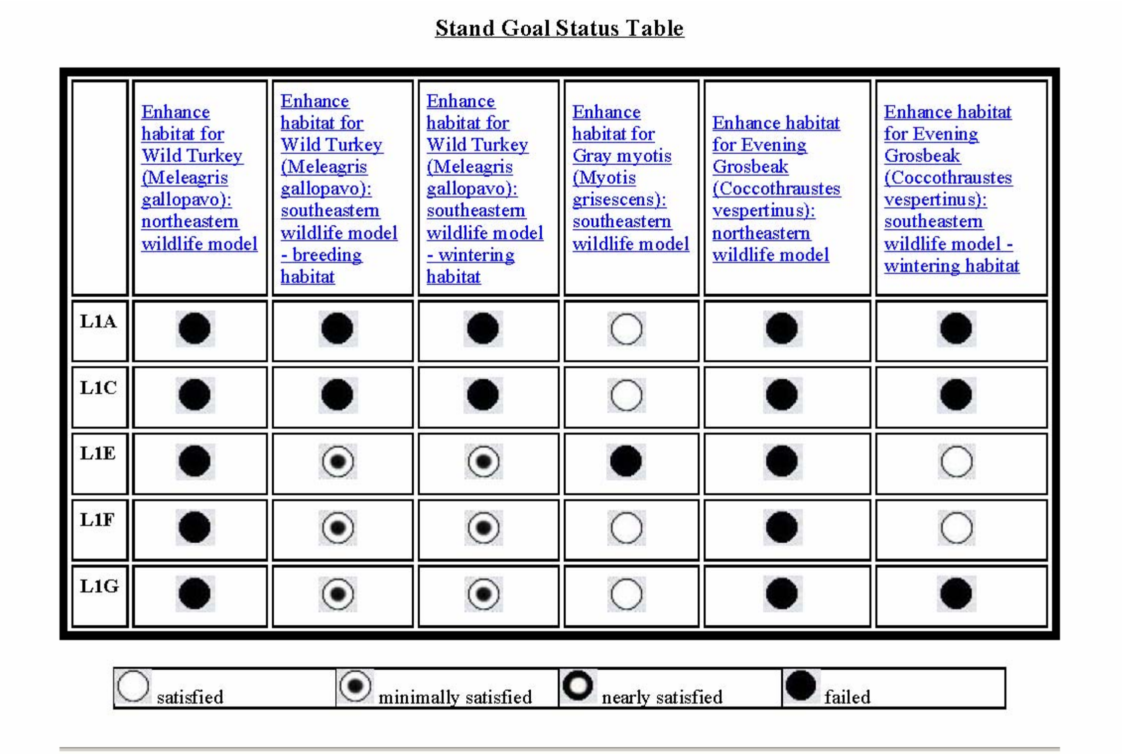
This Summary Analysis Report presents an overview of the goal analysis results for the management area of interest. Each management unit goal may be: fully satisfied, completely failed or not fully. This rating is found in the summary analysis table under the heading 'Status'. Here a management unit goal has DFCs that function at the stand level, the summary analysis report displays the percent of all the stands in the management unit that fall into each of the four rating categories: fully satisfied, minimally satisfied, nearly satisfied or failed. Some management unit goals are not defined at the stand level, only at the management unit level. Such goals, of course, have no stand analysis component and are shown in the table with dashes, eg.'---'.

The second table gives an overview of all stands and their goal status. Each of the displayed icons represents one of the four rating categories. Clicking on the goals themselves brings you to the individual goal reports.



Summary Analysis

Goal Name	Status	# Stands	Fully sat.	Min sat.	Nearly sat.	Failed
Enhance habitat for Wild Turkey (Meleagris gallopavo): northeastern wildlife model	completely failed	5	0	0	0	100
Enhance habitat for Wild Turkey (Meleagris gallopavo): southeastern wildlife model - breeding habitat	not fully	5	0	20.79	0	79.21
Enhance habitat for Wild Turkey (Meleagris gallopavo): southeastern wildlife model - wintering habitat	not fully	5	0	20.79	0	79.21
Enhance habitat for Gray myotis (Myotis grisescens): southeastern wildlife model	not fully	5	91.6	0	0	8.4
Enhance habitat for Evening Grosbeak (Coccothraustes vespertinus): northeastern wildlife model	completely failed	5	0	0	0	100
Enhance habitat for Evening Grosbeak (Coccothraustes vespertinus): southeastern wildlife model - wintering habitat	not fully	5	13.4	0	0	86.6

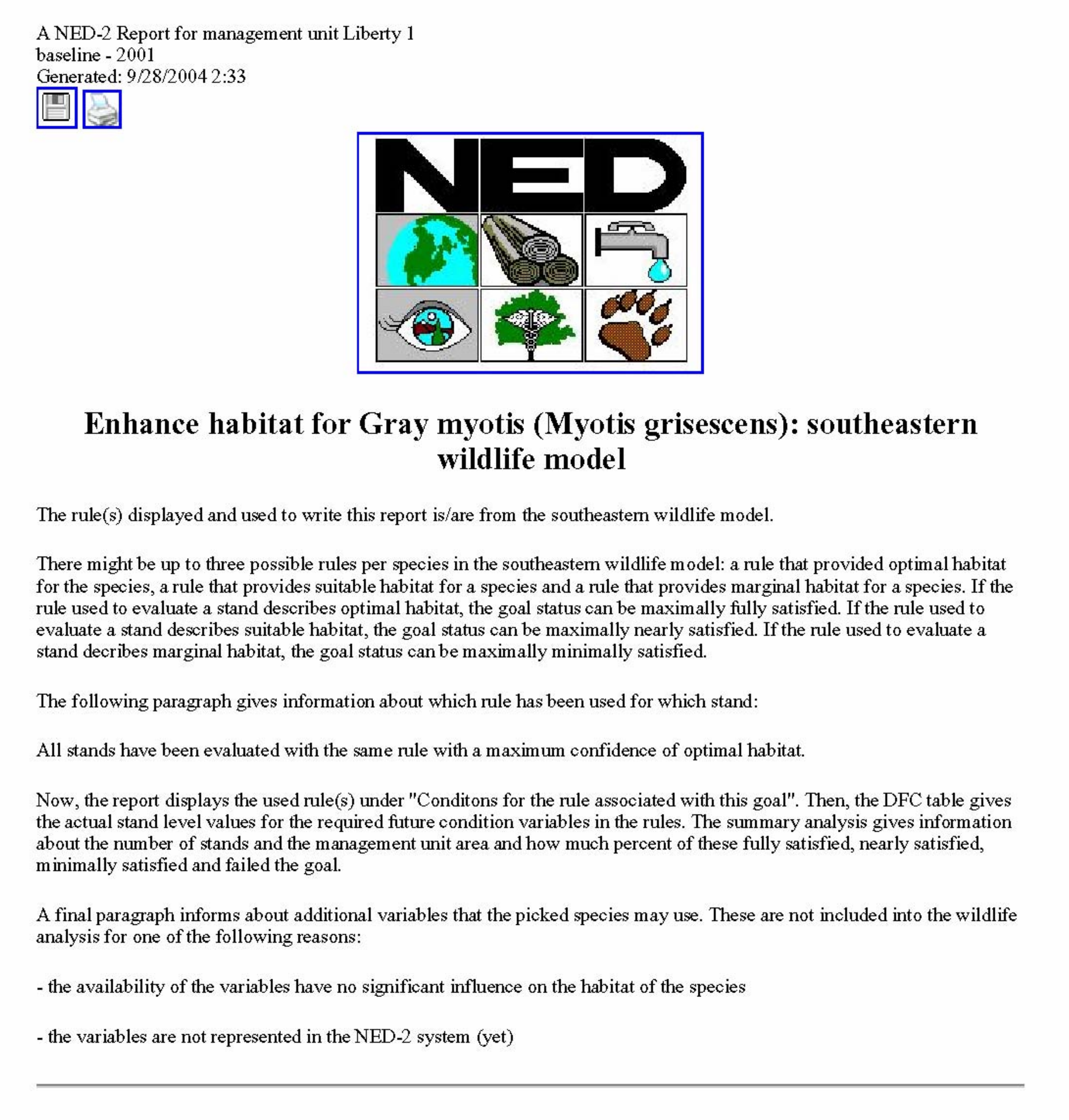


Stand Goal Status Table

	Enhance habitat for Wild Turkey (Meleagris gallopavo): northeastern wildlife model	Enhance habitat for Wild Turkey (Meleagris gallopavo): southeastern wildlife model - breeding habitat	Enhance habitat for Wild Turkey (Meleagris gallopavo): southeastern wildlife model - wintering habitat	Enhance habitat for Gray myotis (Myotis grisescens): southeastern wildlife model	Enhance habitat for Evening Grosbeak (Coccothraustes vespertinus): northeastern wildlife model	Enhance habitat for Evening Grosbeak (Coccothraustes vespertinus): southeastern wildlife model - wintering habitat
L1A	●	●	●	○	●	●
L1C	●	●	●	○	●	●
L1E	●	◉	◉	●	●	○
L1F	●	◉	◉	○	●	○
L1G	●	◉	◉	○	●	●

○ satisfied	◉ minimally satisfied	⭘ nearly satisfied	● failed

2. Individual Goal Report for Gray Myotis



A NED-2 Report for management unit Liberty 1
baseline - 2001
Generated: 9/28/2004 2:33

Enhance habitat for Gray myotis (Myotis grisescens): southeastern wildlife model

The rule(s) displayed and used to write this report is/are from the southeastern wildlife model.

There might be up to three possible rules per species in the southeastern wildlife model: a rule that provided optimal habitat for the species, a rule that provides suitable habitat for a species and a rule that provides marginal habitat for a species. If the rule used to evaluate a stand describes optimal habitat, the goal status can be maximally fully satisfied. If the rule used to evaluate a stand describes suitable habitat, the goal status can be maximally nearly satisfied. If the rule used to evaluate a stand decribes marginal habitat, the goal status can be maximally minimally satisfied.

The following paragraph gives information about which rule has been used for which stand:

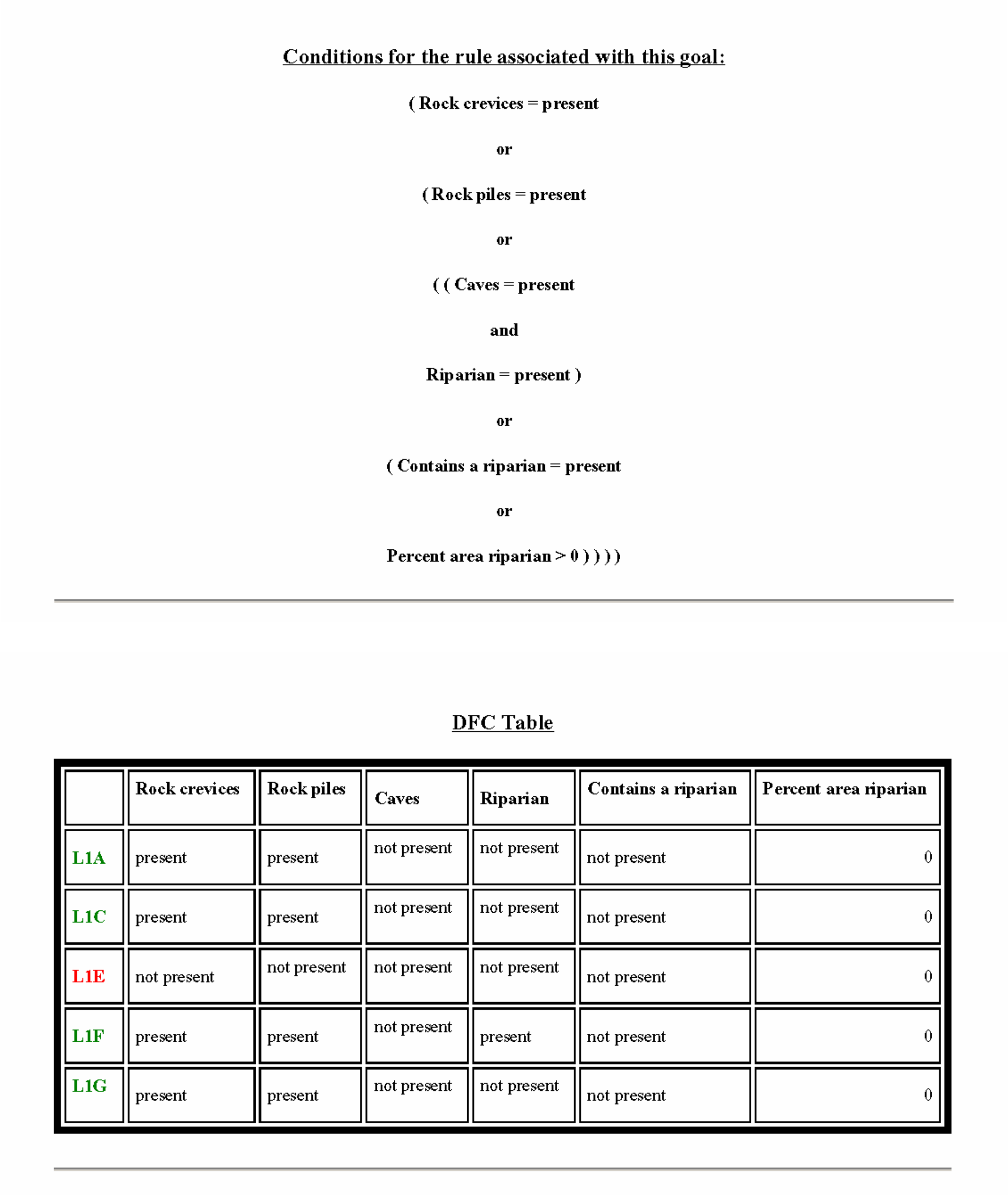
All stands have been evaluated with the same rule with a maximum confidence of optimal habitat.

Now, the report displays the used rule(s) under "Conditons for the rule associated with this goal". Then, the DFC table gives the actual stand level values for the required future condition variables in the rules. The summary analysis gives information about the number of stands and the management unit area and how much percent of these fully satisfied, nearly satisfied, minimally satisfied and failed the goal.

A final paragraph informs about additional variables that the picked species may use. These are not included into the wildlife analysis for one of the following reasons:

- the availability of the variables have no significant influence on the habitat of the species

- the variables are not represented in the NED-2 system (yet)



Conditions for the rule associated with this goal:

(Rock crevices = present

or

(Rock piles = present

or

((Caves = present

and

Riparian = present)

or

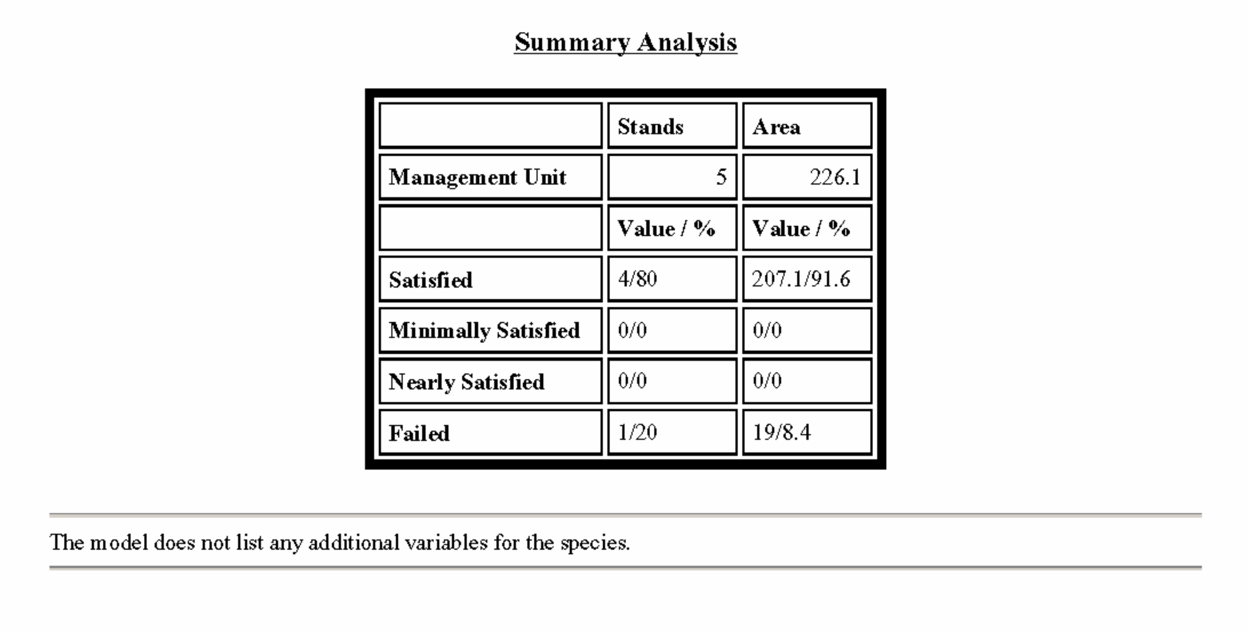
(Contains a riparian = present

or

Percent area riparian > 0))))

DFC Table

	Rock crevices	**Rock piles**	**Caves**	**Riparian**	**Contains a riparian**	**Percent area riparian**
L1A	present	present	not present	not present	not present	0
L1C	present	present	not present	not present	not present	0
L1E	not present	not present	not present	not present	not present	0
L1F	present	present	not present	present	not present	0
L1G	present	present	not present	not present	not present	0

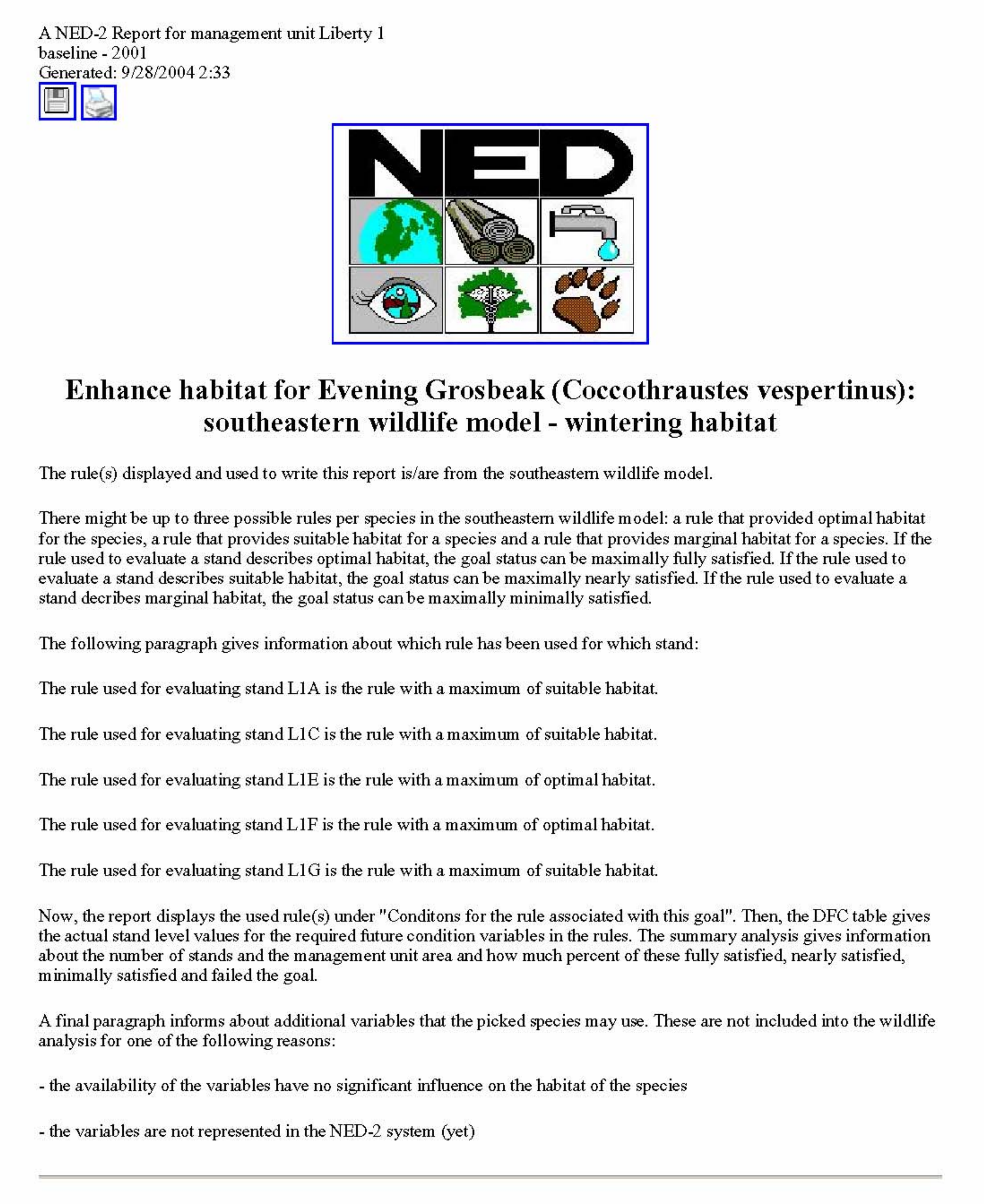


Summary Analysis

	Stands	Area
Management Unit	5	226.1
	Value / %	**Value / %**
Satisfied	4/80	207.1/91.6
Minimally Satisfied	0/0	0/0
Nearly Satisfied	0/0	0/0
Failed	1/20	19/8.4

The model does not list any additional variables for the species.

3. Individual Goal Report for Evening Grosbeak



A NED-2 Report for management unit Liberty 1
baseline - 2001
Generated: 9/28/2004 2:33

Enhance habitat for Evening Grosbeak (Coccothraustes vespertinus): southeastern wildlife model - wintering habitat

The rule(s) displayed and used to write this report is/are from the southeastern wildlife model.

There might be up to three possible rules per species in the southeastern wildlife model: a rule that provided optimal habitat for the species, a rule that provides suitable habitat for a species and a rule that provides marginal habitat for a species. If the rule used to evaluate a stand describes optimal habitat, the goal status can be maximally fully satisfied. If the rule used to evaluate a stand describes suitable habitat, the goal status can be maximally nearly satisfied. If the rule used to evaluate a stand decribes marginal habitat, the goal status can be maximally minimally satisfied.

The following paragraph gives information about which rule has been used for which stand:

The rule used for evaluating stand L1A is the rule with a maximum of suitable habitat.

The rule used for evaluating stand L1C is the rule with a maximum of suitable habitat.

The rule used for evaluating stand L1E is the rule with a maximum of optimal habitat.

The rule used for evaluating stand L1F is the rule with a maximum of optimal habitat.

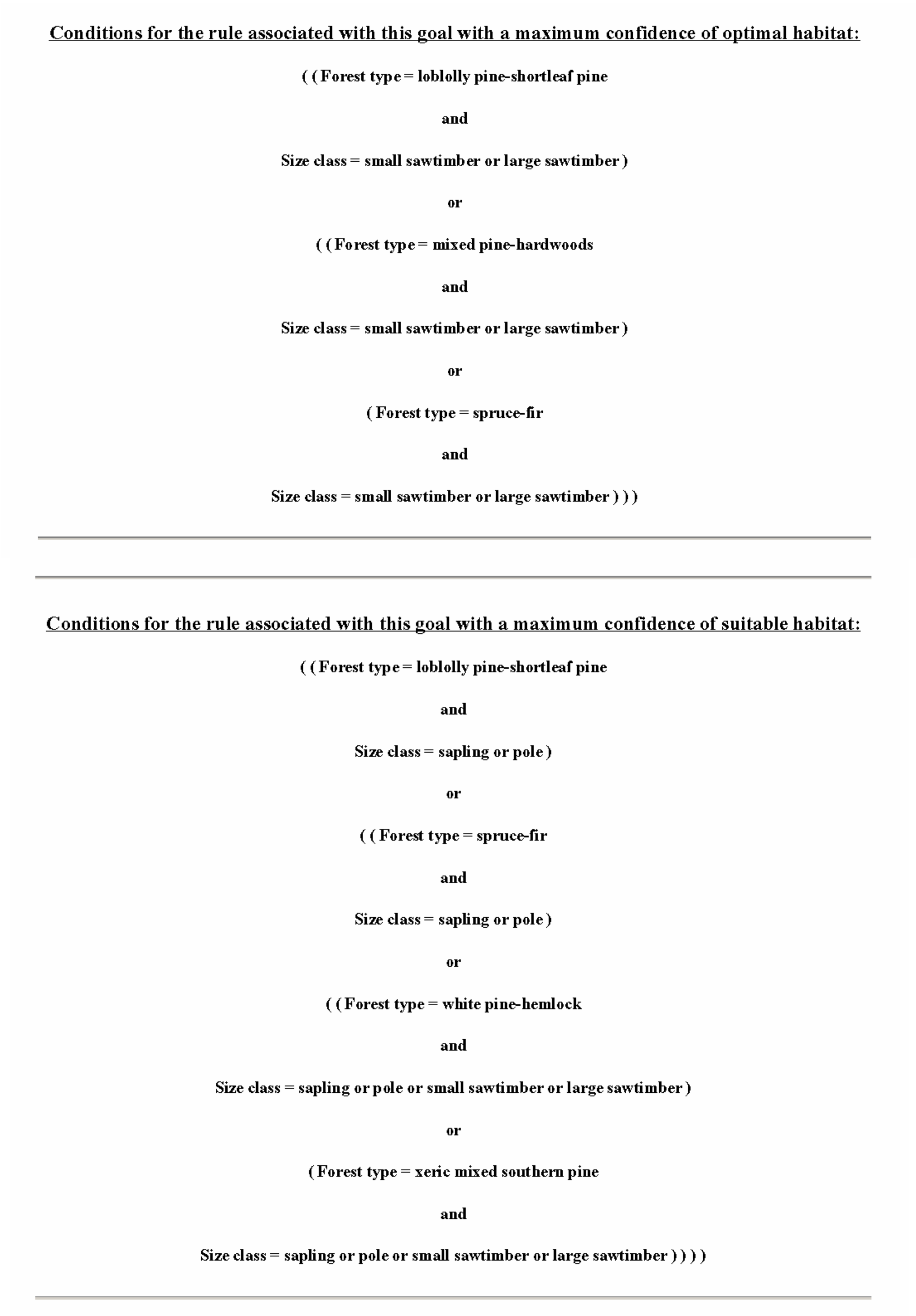
The rule used for evaluating stand L1G is the rule with a maximum of suitable habitat.

Now, the report displays the used rule(s) under "Conditons for the rule associated with this goal". Then, the DFC table gives the actual stand level values for the required future condition variables in the rules. The summary analysis gives information about the number of stands and the management unit area and how much percent of these fully satisfied, nearly satisfied, minimally satisfied and failed the goal.

A final paragraph informs about additional variables that the picked species may use. These are not included into the wildlife analysis for one of the following reasons:

- the availability of the variables have no significant influence on the habitat of the species

- the variables are not represented in the NED-2 system (yet)



Conditions for the rule associated with this goal with a maximum confidence of optimal habitat:

((Forest type = loblolly pine-shortleaf pine

and

Size class = small sawtimber or large sawtimber)

or

((Forest type = mixed pine-hardwoods

and

Size class = small sawtimber or large sawtimber)

or

(Forest type = spruce-fir

and

Size class = small sawtimber or large sawtimber)))

Conditions for the rule associated with this goal with a maximum confidence of suitable habitat:

((Forest type = loblolly pine-shortleaf pine

and

Size class = sapling or pole)

or

((Forest type = spruce-fir

and

Size class = sapling or pole)

or

((Forest type = white pine-hemlock

and

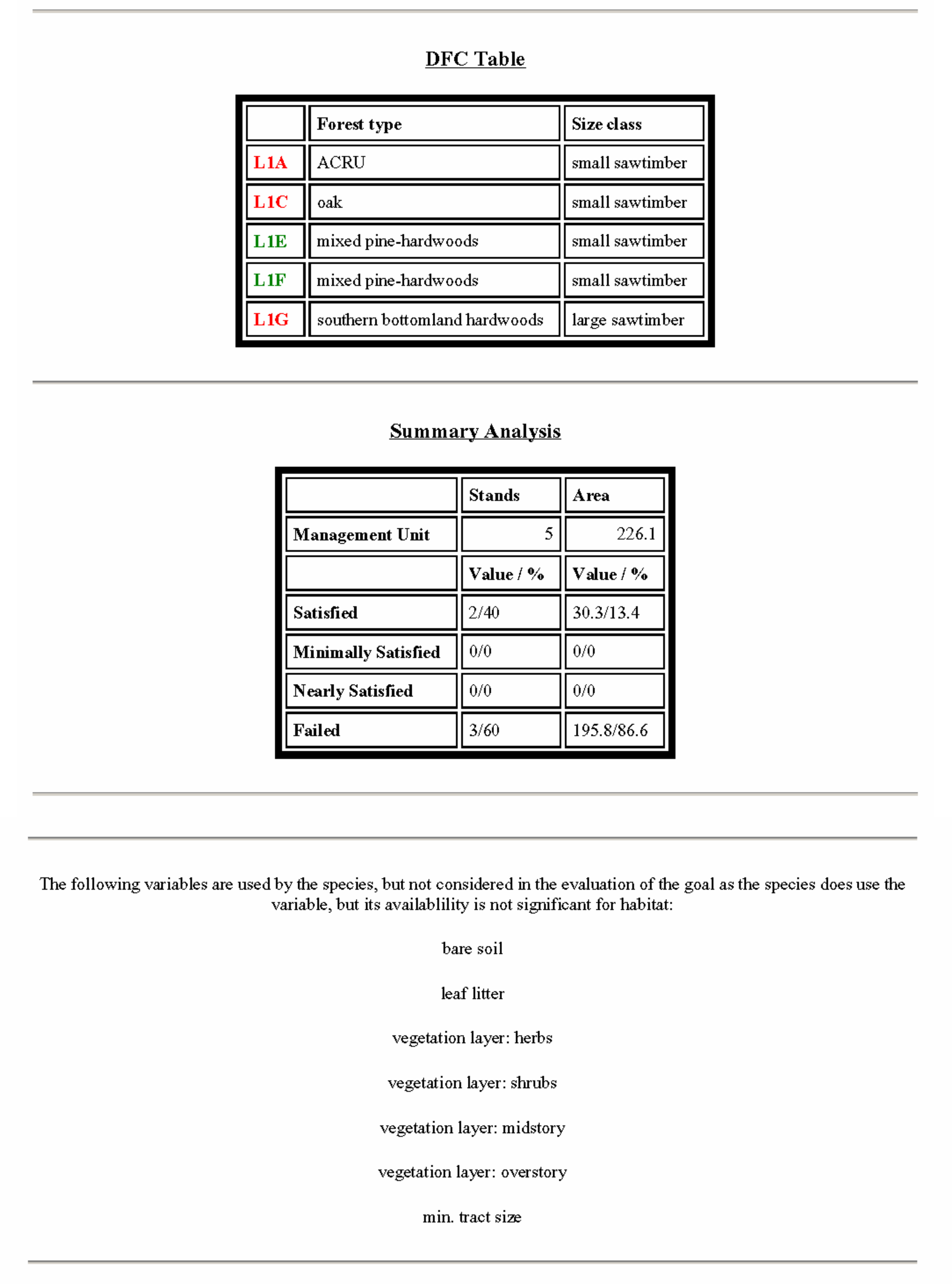
Size class = sapling or pole or small sawtimber or large sawtimber)

or

(Forest type = xeric mixed southern pine

and

Size class = sapling or pole or small sawtimber or large sawtimber))))



DFC Table

	Forest type	Size class
L1A	ACRU	small sawtimber
L1C	oak	small sawtimber
L1E	mixed pine-hardwoods	small sawtimber
L1F	mixed pine-hardwoods	small sawtimber
L1G	southern bottomland hardwoods	large sawtimber

Summary Analysis

	Stands	Area
Management Unit	5	226.1
	Value / %	Value / %
Satisfied	2/40	30.3/13.4
Minimally Satisfied	0/0	0/0
Nearly Satisfied	0/0	0/0
Failed	3/60	195.8/86.6

The following variables are used by the species, but not considered in the evaluation of the goal as the species does use the variable, but its availablility is not significant for habitat:

bare soil

leaf litter

vegetation layer: herbs

vegetation layer: shrubs

vegetation layer: midstory

vegetation layer: overstory

min. tract size

APPENDIX F

WILDLIFE MODEL FOR GAME SPECIES: WILD TURKEY HABITAT

2/9/2001

Turkey Rules for NED

Expert: Craig Harper, Univ. of Tennessee at Knoxville

Knowledge Elicitation by: H. M. Rauscher

Note that this rule set describes the absolute BEST/OPTIMUM conditions for the support of the best wild turkey populations. It is unlikely that any one area will measure up to all of these criteria. So we need to develop a rating system which allows partial success by reducing rating points for the area. Notice also, that failure to meet any of these conditions, implies knowledge of what we need to do in order to manage for better turkey habitat.

hmr

Highest Level Goal:

F	Special Needs are favorable
AND	Landscape pattern is favorable
AND	Food is favorable
Then	
	Habitat is favorable for turkey

** Rules for determining the favorability of special needs

```
IF      Winter snow covers ground <= 2 weeks at a time
AND     Roosting trees are present in management area
AND     Special conditions are favorable
THEN
Special needs are favorable
REM     Northern limit of turkey is function of duration of winter snow cover
        Western limit of turkey is function of lack of roosting trees due to drought
```

```
IF      Geographic area is Southern Appalachians
AND     (Coniferous stands are present
OR      Conifers are present in hardwood stands)
AND     Spring seeps are present
THEN
        Special conditions are favorable
REM     Each geographic region is likely to have some special unique features
```

```
IF      Geographic area is Coastal Plain Pine Belt
AND     Mature pine forests exist
AND     Mature hardwood forests along riparian zones exist
THEN
        Special conditions are favorable
```

```
IF      Not above
THEN
        Special conditions are favorable
```

**   Rules for determining the favorability of landscape pattern

```
IF      Herbaceous openings in the landscape are favorable
AND
        (Mature hardwoods are favorable
AND     Mature conifers are favorable)
OR      Mature mixed hardwood/conifers are favorable
Then
        Landscape pattern is favorable

IF      Total acres of herbaceous openings are between 25 – 50% of area
AND     Managed foodplots make up 5% of the area
AND     Herbaceous openings are dispersed throughout the area
THEN
        Herbaceous openings in the landscape are favorable
REM     Seeded roads also qualify for herbaceous opening area
        Herbaceous openings are those where forbs predominate

IF      Mature Oak and Beech >= 30% of basal area
AND     Woody understory is open
AND     Herbaceous understory  >= 30%
THEN
        Mature hardwoods are favorable
REM     Herbaceous understory is used for brood cover

IF      Mature conifers >= 5 and <= 15% of area
THEN
        Mature conifers are favorable

IF      Mature Oak and beech >= 30% of basal area
AND     Mature conifers are present
AND   Woody understory is open
AND   Herbaceous understory  >= 30%
THEN
      Mature mixed hardwood/conifers are favorable
REM   Herbaceous understory is used for brood cover


**  Rules for determining the favorability of food


IF    Mature hardwoods are favorable
AND   Herbaceous openings for food are favorable
AND   Managed food plots are favorable
AND   Wild grapes present in management area
THEN
      Food is favorable

IF    Vegetation is predominantly forbs
AND   Vegetation is NOT predominantly cool season perennial grasses
AND   Ground level vegetation structure is sparse or open NOT dense
AND   Vegetation height is between 1-2 ft
AND   Herbaceous openings contain small patches of brambles
AND   Scattered soft-mast producing trees are present
THEN
      Herbaceous openings for food are favorable

IF    Managed food plots make up 5% of the area
AND   50% of food plots are in grain (corn/millet/milo)
AND   50% of food plots are in forage (clover/wheat/oats/rye)
THEN
      Managed food plots are favorable
```

APPENDIX G

FUTURE VARIABLES IN NED-2

- stand_grassy_open
- stand_earth_bank
- stand_fresh_water
- stand_brackish_water
- stand_salt_water
- stand_shrub_thickets
- stand_moist_soil
- stand_rocky_outcrops
- stand_potholes
- stand_aquatic_vegetation