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AN APPLICATION OF KNOWLEDGE ENGINEERING
TO PETROLEUM PARTNERSHIP NEGOTIATIONS:
An Expert System for Evaluating
Petroleum Projects

by

Connie Kenward

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A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Mineral Economics).

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ABSTRACT

High investments, numerous variables, and uncertainty are common in petroleum projects. Consequently, the evaluation process requires high levels of diversified expertise. A quick, accurate way to anticipate the financial impact of a particular project is needed. This work creates a system that combines cost estimating expertise and an understanding of contract terms, incorporated with a knowledge of the company's financial situation.

The Evaluation System for Petroleum (ESP) uses a knowledge-based tool to accumulate and process incomplete project information, giving financial projections and advice to the user. ESP combines the expertise of the petroleum engineer, the landman, and the financial advisor in an expert system that can immediately provide: (1) a short-term financial analysis of cost, (2) a long-term project evaluation of costs and revenues, (3) support to the existing decision structure by providing access to timely, expert knowledge, and (4) advice on viable alternatives.

ESP is a prototype system demonstrating how an expert system can be used to connect an engineering database to an accounting application for interactive project evaluation.

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GLOSSARY

Actions Block: in VP-Expert program, the area that controls the order of the rule processing.

Algorithm: A clearly defined procedure (Hesse and Woolsey 1980).

Artificial Intelligence: Man-made capacity to acquire and apply knowledge (Arnold and Bowie 1986). The part of computer science concerned with design of computer systems which exhibit human intelligence: understanding language, learning new information, reasoning, and solving problems (Smutz 1989).

Backward Chaining: Starts with the goal and follows inference paths back to the facts (Siegel 1986)

Discounted Cash Flow: Method that represents the cash inflows and outflows of a project at a common point in time so they can be compared in an appropriate way (Horngreen and Foster 1987).

Estimated Reserves: Estimated amount of recoverable oil at a prospect.

Expert System: "A computer system which simulates the interaction of an expert with a user in resolving a particular problem. The standard interaction format is computer-generated questions and user-specified answers, followed by a computer-generated recommendation (Smutz 1989).

Expert System Shell: Specialized software package which facilitates development of expert systems (Lessenger 1988).

Heuristics: "A trick, rule of thumb, or strategy people can use to solve a problem (Arnold and Bowie 1986).

Inference Engine: "A program that determines how rules and other knowledge in a knowledge base are selected and used to solve problems (Arnold and Bowie 1986).

Intelligence: The capacity to acquire and apply knowledge. The faculty of thought and reason. The work of gathering information (Arnold and Bowie 1986).

Knowledge Engineer: The person who analyzes how experts make decisions and transfers that knowledge to a computer program (Lessenger 1988).

Knowledge Engineering: The process (generally manual) of collecting, organizing, and representing knowledge about the subject. This task includes both administrative and design responsibilities. It requires skills in interviewing and coordinating the work of the experts identified for the project as well as technical skills necessary for program design and implementation (Buehler 1987).

Knowledge Mapping: Analysis of how experts make decisions, often represented in flowchart format.

Landman: Individual who puts together drilling partnerships.

Plays: Refers to geological plays, potential oil producing zones.

Prospect: An area that potentially contains economically recoverable hydrocarbons.

Risk Reserves: Estimated reserves multiplied by the probability of success.

Rule Block: In VP-Expert program, the area that contains the basic logic structure.

Shell: A framework used to build and run an expert system or other AI-based system. Expert-system shells typically consist of a development environment, knowledge-representation schemes to store knowledge (e.g., rule, objects), and inference engines which algorithmically search and link the stored knowledge (Smutz 1989).

Statement Block: in VP-Expert program, the area that provides the means to assign a value to a parameter.

LIST OF ABBREVIATIONS

AFE:	authority for expenditure
AI:	artificial intelligence
CWDB:	completed well database
DCF:	discounted cash flow
DWDB:	default well database
ESP:	evaluation system for petroleum
KBS:	knowledge-based system
ORRI:	overriding royalty interest
PPSS:	pending projects spreadsheet
RI:	royalty interest (landowners interest)
SS:	spreadsheet
WI:	working interest

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Chapter 1

INTRODUCTION

The oil and gas industry is renowned for high investment, high risk, and potentially high returns. Consequently, financing arrangements designed to spread the cost, the risk, and the returns of each project have evolved. The evaluation of each project, with the numerous variables inherent in petroleum exploration and the complexities in the financial agreements, quickly becomes cumbersome.

Background

A typical project evaluation scenario in a petroleum company begins with the landman (the individual who puts together the drilling partnerships) getting a call from an associate who is soliciting partners in a drilling project. The landman needs to know if this drilling project meets company objectives and what the company's financial situation will be during the months of the proposed project. The landman will go to the financial advisor and ask if this project could be considered in the time frame specified and according to particular agreement terms.

These questions initiate a sequence of events for the financial advisor. To answer the landman, the financial advisor must know the approximate total cost of the proposed well, the pending and committed projects for the time frame under consideration, and the financial guidelines of the company. The financial advisor consults the company's petroleum engineer to obtain an estimate of total well costs and the duration of the drilling and completion process. Using these estimates, he will project the cash-flow requirements of the drilling project and compare them with the financial guidelines and financial commitments of the company during the project. Only then can he advise the landman on the viability of the project. The financial advisor may also suggest alternate ways to structure the deal or to schedule the project to better meet corporate objectives.

Given each individual's expertise and availability, the rough estimate may take an hour. Often one expert or another is not available, however, and, because of the interdependent nature of the information needed, the evaluation process cannot proceed.

An expert system is a "computer system designed to represent and use knowledge of specific areas of expertise" (Michaelson 1988). Expert systems, also called knowledge-

based systems, rely on facts and heuristics stored in the system to give advice on a particular problem.

This research explores the use of an expert system to capture the expertise needed to evaluate a petroleum project into one system. It uses the expert system to interact with other software programs and as a user interface to advise on the viability of a particular project.

The Evaluation System for Petroleum (referred to as ESP) captures the interactive-heuristic processes of the landman, the petroleum engineer, and the financial advisor needed to evaluate a petroleum project. Based on the information available from the user, the system may select analogous information from the engineer's databases, advise the user of corporate guidelines, or merely calculate and output information onto a spreadsheet. It gives a short-term and long-term analysis, advice on how the project fits into the corporate financial situation, and advice on how well the project meets the corporate objectives.

The ESP prototype was developed as a demonstration of how an expert systems tool could be utilized to assist in evaluating petroleum projects.

How Petroleum Projects Are Evaluated

A petroleum company employs individuals with four different areas of knowledge--geology, engineering, land, and finance--to properly evaluate if a petroleum project is compatible with the objectives and financial situation of a company. These individuals examine

1. the relationship of cost and risk to return
2. the timing and amount of investment
3. the corporate financial situation and criteria
4. the corporate goals regarding growth and expansion

The first stage in the evaluation process of a project is the geological risk assessment (Lessenger 1988). After a project is deemed worthy of further consideration by the geologist, it takes a minimum of three specialists to determine if the project is currently viable for the company. The petroleum engineer projects the expected costs of drilling and completing the well. The landman solicits partners to share in the financing and considers various ways to structure an agreement. The financial advisor verifies the financial situation of the company and determines how the project will fit into the company's objectives.

The evaluation process is a time-consuming, complex, and difficult task. Each of the parties involved brings a

high degree of professional judgment and knowledge to the process. Since information from each is required for analysis, scheduling is added to the problem of getting a timely project evaluation.

It would be much more efficient if a proposed project could be turned over to one person for the preliminary evaluation. That person would have the ability to initially estimate the well costs, know the effect of the various terms of the agreement, and be familiar with the company's financial condition and corporate objectives.

Unfortunately, that comprehensive expertise and understanding is rarely found in a single individual.

The Evaluation System for Petroleum may be used as an alternative to having such an individual on staff. ESP uses an expert system's rules and goals to link a database (input) to a spreadsheet (output). The expert system emulates the expertise of the engineer, the landman, and the financial advisor (Table 1). With ESP the user has access to much of the experience and expertise of the three petroleum experts in one system.

Meeting a Need with ESP

The desirability of such a system is obvious. Why hasn't the need been met?

Table 1
How the Evaluation System for Petroleum
Emulates the Knowledge of
Company Experts

COMPANY PERSONNEL	EXPERTISE NEEDED FOR EVALUATION	REPRESENTATION IN ESP
Petroleum Engineer	Knowledge of Well Costs	Information from CWDB* and DWDB*
Landman	Knowledge of Agreement Terms	Term Definition Structure of Calculations
Financial Advisor	Knowledge of Financial Situation	Pending Project Database
	Knowledge of Goals and Constraints	Corporate Objectives Corporate Guidelines
	Knowledge of Commitments	Pending Projects Database
	Knowledge of Tax Requirements	Rules and Structure of Calculations
	Knowledge of Evaluation Tools	Structure of Calculations

*CWDB--completed well data base;

*DWDB--default well data base.

Without the vast improvements in computer hardware and software of this decade, a system that guided the selective accessing of large databases and output the information to a spreadsheet would not have been economically feasible. In the past, computer memory and storage was limited or awkward to maintain. Packaged software was not available to interactively query the user, search the database, and extract only the relevant information. The hardware and software that was available was expensive and required extensive computer knowledge to operate. Even now, few computer systems are cost effective in handling the complexities of the petroleum project evaluation.

Computer use and software flexibility have greatly increased in the last decade. Business applications software is becoming more powerful, usable, and cost effective. Database managers and spreadsheet software are both very useful products of the 1980s, but previously lacked the ability to interact with each other.

One of the currently useful aspects of artificial intelligence research is the development of the concept of the expert system. MYCIN, one of the original expert systems, was designed to capture the diagnostic expertise of medical doctors, and assisted in the diagnosis of meningitis and blood infections (Arnold and Bowie 1986). Later the

reasoning process was extracted, and EMYCIN (empty MYCIN), the first empty expert system shell, was born (Simons 1984).

The expert system shell is computer software designed to mimic any expert's decision-making process. When a specific expert's knowledge is embedded in the expert system shell it becomes an expert system. An expert system is programmed to assist with tasks requiring judgment in specific areas. Numerous expert system shells are currently available and expert systems are being developed in areas such as emergency treatment, safety, and training.

Business people are becoming increasingly aware of expert system applications, and business problems are providing more opportunities for expert systems to assist with decision-making (Michaelson 1988). Since expert systems software is relatively new and only recently affordable and available, little has been done to integrate management information systems using expert systems. An enhanced version of the ESP prototype presented here is a step toward an integrated management information system.

Explanation of Research

The purpose of this thesis is to show an expert system to be a valid model and method to capture the necessary expertise for the petroleum project evaluation process.

Hence the goal is for the system to provide information to evaluate a project, given corporate guidelines and objectives.

There are three fundamental assumptions in this thesis:

1. Experienced individuals are able to evaluate a petroleum project, and, based on their projections, proper decisions can be made for a specific company.
2. A portion of this experience can be documented and encapsulated in an expert system, and information necessary to project cash flows for a proposed well can be captured in a historical database for completed wells.
3. The company's objectives, constraints, and preferences can be documented in an expert system and used to generate advice about how well this project meets corporate guidelines.

To build an expert system to capture the expertise needed to evaluate petroleum projects, one must be familiar with the problem and the expert system model. Chapter 2 introduces the three specialists and their role in the

evaluation process and the expert system model and its benefits.

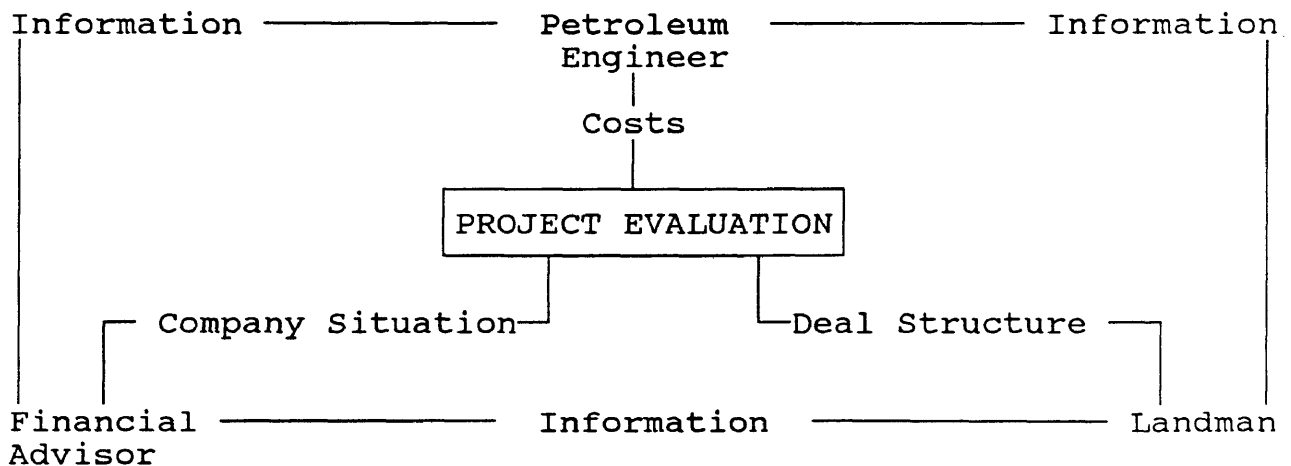
The process of capturing expertise in an expert system is called knowledge engineering. The general knowledge engineering process and how it relates to traditional problem solving is discussed in Chapter 3. The knowledge engineering process for ESP is explained in Chapter 4.

Chapter 5 outlines what ESP does from the perspective of the user. Chapter 6 discusses how the ESP system works by describing a condensed program which references the complete program listings in Appendix B. The limitations and potential enhancements of ESP and the conclusions from this research are in Chapter 7.

Chapter 2

CONCEPTUAL OVERVIEW

Part of the difficulty and the time-consuming nature of the petroleum project evaluation process stems from the inability of any one person to complete the job without input from others (Figure 1). For instance, a person versed in the financial implications of the operating agreement cannot estimate the cost of the well, nor can the landman know how much flexibility he has in negotiations to better contend with the future corporate situation. As a result, the petroleum industry is notorious for its "wheeler-dealer"



The Interaction Necessary to Evaluate a Project

Figure 1

and "fly by the seat of the pants" operators. When accurate, timely information is not available, instinct is the only thing on which to operate.

The Two-Stage Process

Because of the difficulty of projecting petroleum revenues, traditional priority-based financial ranking techniques, such as return on investment, earnings growth, discounted cash flow, and internal rate of return are intuitively or explicitly adapted to investigate the possibility of no revenue. Hence a two-stage project selection process has emerged:

1. Sort projects by probability of success.
Eliminate from further consideration now those projects which are below the hurdle rate as set by management.
2. Sort projects by other criteria such as location, cost, and timing of costs to be evaluated with respect to the company's current situation, objectives, and other pending opportunities.

The focus of this project is on the second stage of the evaluation process. (There is an expert system, Georisk, written by Margaret Lessenger at Colorado School of Mines

using the PC Plus expert system shell which determines the probability of success). Overall corporate objectives are not limited to evaluating return on investment; they include optimizing on when, how, and where to invest. The comprehensive investment environment focuses attention on the timing of the investment, the potential exposure of the deal, and the location of the well, after the probability of success from the first stage of the evaluation process is satisfied.

The primary goal of any company is to make money (Goldratt and Cox 1984). This requires numerous decisions aimed at satisfying this directive. For the petroleum company this means producing revenues from the sale of oil which are larger than the costs to find and produce the oil. Naturally, each project must be evaluated to select the ones that best meet the set of criteria for the company at this time.

A variety of evaluation tools are used, particularly in the second stage of the evaluation process. The most common ones are applications of cash-flow analysis discounted at the required rate of return, such as net present value and the present value ratio. An old rule-of-thumb from pre-discounted cash flow days is the payback ratio. Other methods, such as accounting rate of return and methods

calculating an average (annual) rate of return, are not applicable to the petroleum project because of the inherent assumptions of these models. See Stermole (1982) or Thompson and Wright (1985) for a complete discussion of decision models.

There are no decision method that can eliminate or even reduce risk and uncertainty. The utility of these methods is

to evaluate, quantify and understand risk and uncertainty so that the explorationist and manager can devise a decision strategy that will minimize the firm's exposure to risk and uncertainty (Ikoku 1980).

Thompson and Wright (1985) in their book Oil Property Evaluation indicate two categories of evaluation tools: those that incorporate the time value of money (discounted cash flow) and those that ignore the time value of money. Table 2 is a synopsis of the methods explained in their book. The more commonly used methods of the two categories are explained below.

Discounted-cash-flow techniques start with the concept of comparing investment dollars and revenue dollars at a common point in time (present, future, or annual). Present value analysis is most commonly used in the petroleum industry. The required rate of return of the company is normally used as the discount rate to bring the future dollars to a present value equivalent. If the discounted

Table 2

Yardsticks for Petroleum Project Evaluation

Yardsticks that Ignore the Time Value of Money

Urgency

Payback

Bail-Out Factor

Accounting Rate of Return

Undiscounted Profit to Investment Ratio

Yardsticks that Incorporate the Time Value of Money

Net Present Value

Present Value Profile

Discounted Profit-to-Investment Ratio

Discounted Cash-Flow Rate of Return (DCFROR)

Modified DCFROR

Appreciation-of-Equity Rate of Return

Source: From Thompson and Wright (1985), Oil Property Evaluation. Chapter 3. Thompson-Wright Associates.

future revenues are larger than the discounted costs, the net present value is positive and the project generates a return on investment that is higher than the required rate of return of the company. The present value ratio is discounted future revenues divided by the discounted costs. If this is larger than one, the project is above the required rate of return. "Because the discounted cash-flow model explicitly and routinely weighs the time value of money, it is usually the best model to use for long-range decisions" (Horngreen and Foster 1987).

Rule-of-thumb evaluations have the advantage of being easily calculated and understood, but they ignore the time value of money. One rule-of-thumb still employed for preliminary petroleum project evaluation is called either payout or payback. To calculate it, simply measure the time it takes to recoup the initial dollars invested.

Advocates of payback argue that it is a handy measure (a) where precision in estimates of profitability is not crucial and preliminary screening of many proposals is necessary, and (b) where the contemplated project is extremely risky (Horngreen and Foster 1987).

Several reserve evaluation computer programs are commercially available and a few spreadsheet templates are public domain. These packages for the most part concentrate on annual cash flow projections using production data

towards reserve reporting. Packages such as WHATIF2 and ECON are also useful for sensitivity analysis.

Expert systems are being used to drive computer applications in drilling decisions such as mud selection, trouble shooting, and refinery scheduling. ESP differs from other evaluation packages in that it provides monthly financial information for short-term cash budgeting, and it uses an expert system to interface between an engineering database and an accounting applications package.

The Expertise

Currently, at least three individuals employ heuristics to resolve the conflict of multiple objectives and select specific projects. Under the best conditions, the comparison and ranking of alternatives is difficult; even compiling a list of alternatives with the pros and cons of each process is time consuming. The specialists involved in the second stage of the evaluation process are the petroleum engineer, the landman, and the financial advisor.

The petroleum engineer's contribution to the project decision is a well budget, often called an "Authority for Expenditure." It includes an estimate of the cost of each component of the drilling and completion process. He relies on past experience, well files, or contractors and suppliers

for information toward making each estimate. As the depth, formations, and type of well vary, so do cost projections for the project.

The landman uses the explorationist's evaluation and the engineer's budget to become familiar with the project. Then, if he is putting the deal together, he selects potential partners and develops various scenarios of how the deal could be structured. If he is coming in on someone else's deal, he considers what portion of the deal is in his company's best interest. This will probably involve discussing the company's situation with the financial advisor.

The financial advisor considers how the agreement terms will fit with the financial condition, the corporate situation, and the corporate objectives. He is aware of other financial commitments of the company. Based on these criteria, the landman may need to rewrite his agreement terms to fit within the financial constraints or better meet the goals of the company.

The evaluation process is done for each potential project throughout the year. It requires a high level of experience and current knowledge from the personnel performing the evaluation process. An expert system could represent much of the necessary knowledge and experience in

an environment such as this one where constraint-directed reasoning is required.

The Expert System Model

Humans use heuristics, empirical strategies, to break a problem into smaller and more manageable subproblems until there is an answer available, then build back up to the original problem. Their decision tree and search process searches only the branches that lead to desirable results. The expert system's inference engine applies the knowledge base to the problem situation, consolidating relevant data to meet goals set in the program.

The sets of knowledge required of each of the three experts involved in the evaluation process are different and specialized. The expertise of these individuals is developed from experience as well as textbooks. After several years of college training, and by referencing previous analogous wells, the engineer estimates the well cost. The landmen who negotiate these conveyance agreements often have years of experience and have developed an intuition and insight into the type of deal that will suit the objectives of the investor(s) they represent. Along with the industry expertise, the landman must be informed of the company's constantly changing financial situation and

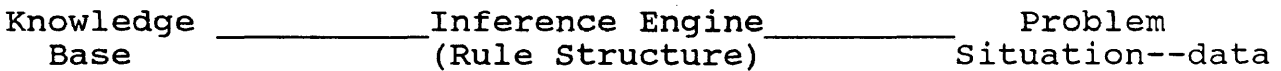
the progress of current exploration projects. Each of these affect the company's perspective of this deal and how it will meet corporate long- and short-term goals.

An expert system emulates human expertise in its knowledge base. The knowledge base consists of facts and rules which relate the facts to each other.

Humans use heuristics to relate knowledge to a problem.



Expert systems use the inference engine to relate knowledge to a problem.



Management research shows that the quality of human performance is best when the problem is well defined and well structured and the goal is specific. Expert systems require such organization, often the greatest benefit of the effort. A computer system has the advantages of being fast and able to deal with vast amounts of data efficiently. Rather than relying on memory for its indexing functions, a computer sorts on specific data within each record. An expert system uses its domain knowledge to analyze a

specific (user) problem. The domain knowledge must be acquired, engineered, and encoded into the system. Then the user is queried for data on his specific problem. It "creates" knowledge in the form of updating the knowledge base, sorting for relevant data and selecting from alternatives. The expert system uses the domain knowledge to give a solution or advice for the user's problem.

An expert system is designed to handle problems within a specific area or domain. Table 3 summarizes some introductory remarks on expert systems.

Humans use various reasoning methods to group, relate, or search through information. An expert system can be programmed to deal with some forms of human expertise relatively well. Expert systems can deal with problems that involve logic, reasoning, specialized knowledge, and/or complex skills, but they do not yet emulate other human attributes such as creativity, imagination, and emotion. Some forms of common sense can be captured, other common sense applications are not efficiently implemented using an expert system.

Among other forms of knowledge, expert systems provide a means for managing structured knowledge. Structured knowledge "consists of well-understood logical paths, where sets of conditions result in particular conclusions" (Smutz 1989).

Table 3
Characteristics of an Expert System

It is designed to represent and use knowledge of specific areas, of expertise to solve problems.

Its purpose is to assist with tasks requiring judgment.

It performs tasks normally performed by experts, arriving at solutions similar to those reached by experts.

It includes a data base, a knowledge base (used to process the data), an inference engine (guides the knowledge base to process the data), and a user interface.

It functions from known facts to conclusions (forward chaining) or proceeds from conclusions back to facts confirming them (backward chaining). Most can represent uncertainty in facts and conclusions.

It is useful for increasing the availability of expertise, organizing decisions, and training novices.

Its limits are the narrow range of expertise and the fact that a system may not detect that a problem is outside the range.

Sources: From Michaelson, Robert H. 1988, Development of an expert computer system to assist in the classification of estate tax returns. Accounting Horizons. (December): 63-70.

From Borthick, A. F. and O. D. West. 1987. Expert systems: A new tool for the professional. Accounting Horizons. (March): 9-16.

Both the problem and the form of knowledge required to evaluate a petroleum project are well suited to the expert systems abilities as described by Lessenger (1988):

Essential Elements of an Expert System

- o Complex problem
- o Specialized knowledge required to solve the problem
- o Many different kinds of information used
- o Task effectively performed by experienced personnel

Benefits of Expert System Development and Use

Numerous benefits are realized in the development process and use of an expert system. Table 4 lists several benefits, but three are particularly important to this research.

To build ESP required capturing the expertise of the three experts. The combination of knowledge in ESP is one of its strengths, giving a novice or any one expert the ability to do the complete petroleum project evaluation. That alone will speed up the evaluation process.

An expert system has the ability to guide the user along a natural path of reasoning by the order of its questions. Hence it is often used as a learning tool, helping the user to develop orderly thought processes. Inexperienced personnel may produce a more comprehensive

Table 4
Benefits of Expert Systems

Distribution of knowledge

- Human experts may not be available in all situations needing their expertise

Preservation of knowledge

- Articles and textbooks do not capture the full detail of an expert's problem-solving techniques
- A knowledge-based system does so

Analysis of knowledge

- If an Expert System is to work correctly, the human expert's problem-solving strategies must be fully understood

Combination of knowledge

- Combining the knowledge of several human experts into a single integrated system

Educational knowledge bases

- An expert system gives students a dynamic, functioning model of human expertise to study, critique and emulate.

Source: From Knowledge-Based Systems and Artificial Intelligence by George Luger (1986). Integrated Computer Systems.

analysis with the assistance of ESP. Also, their training in the process would be supplemented by the experience captured in ESP's knowledge base.

Another benefit of developing an expert system is that the development process tends to focus attention on the decision-making process. Documentation of the decision process may also encourage experts to more thoroughly consider all the relevant factors in the analysis by using the expert system as a reminder or as an outline. Specific uses of the ESP system are given in Chapter 5.

Any practical tool must be able to justify itself in a cost/benefit evaluation. Development cost of expert systems are high. It is time consuming to interview experts, organize the knowledge, encode their knowledge into a computer system, and test the system.

Nevertheless, on this particular application the author believes the frequency of use, the time savings, and the ability to use less experienced personnel would easily justify full development of the prototype expert system demonstrated in this study.

Chapter 3

KNOWLEDGE ENGINEERING METHODOLOGY

The expert system concept has roots in a technology called "General Problem Solving." This was an effort to build a computer system whose logical procedures . . . would mimic how the human mind solves a problem (True 1989).

Typical problem solving consists of recognizing a problem, applying task operations, and ending with a desired result. To solve a problem using a computer system requires that well-defined knowledge be captured in the system. Care must be taken to define explicitly what information is available and how it relates to the problem and the desired result.

Knowledge engineering is the art/science specifically concerned with gathering, representing, and organizing knowledge to be used in searching for solutions with a defined system logic. It requires a style of thinking about the problem which allows the computer to implement the decision-making process. Obviously, the problem, alternatives, and solutions must be in a form the computer can handle. The problem must be stated according to the form of the model, in this scenario the expert system's requirements.

The knowledge engineering process has three steps: knowledge acquisition, knowledge organization and representation, and encoding knowledge into the expert system (so it can later be retrieved and interpreted). The device used by an expert system for utilizing the knowledge logically is called the "inference engine." A rule-based expert system shell typically provides one or two forms of system logic: backward chaining, forward chaining, or both. Each step is described in this chapter; they are illustrated in Chapter 4 specifically with respect to the petroleum project evaluation process.

Problem Solving

Decision sciences use models as a means to organize information and as a vehicle for problem formulation. Once the problem is formulated according to the assumptions and requirements of the model, programs are available which allow the model to be solved efficiently, effectively, and accurately by a computer. If a linear programming model were selected to represent a situation, the user would expect to have at least one objective function and probably some constraints. The terms would be described as "coefficients" and "variables." Inherent in any model are some assumptions and some requirements. The model provides

a particular structure for thinking about the problem, the situation, and the solution.

Similarly, an expert system can be thought of as a model. It provides a structure for thinking about a problem, the situation, and the solution. A rule-based expert system requires at least one goal. The terms are described as "parameters," and rules set the values of the parameters. Inherent in the expert system are some assumptions which limit its application to a domain of specific problems. It provides a particular structure for finding a particular solution, and it works well for decisions which are based on reasoning and comparisons. True (1989) described the role of the expert decision maker and the parallel process of the expert system as follows:

Experts in a field start with a wealth of general knowledge about a subject--that's what makes them experts--and can thereby deal with limited, more focused sets of information.

In expert-system software . . . this general knowledge of a field becomes a "knowledge base." To this is added a "fact base," consisting of data specific to a situation or problem which the system is to analyze and about which it must reach conclusions.

The mechanism performing this analysis--an "inference engine"--is a programmed procedure for combining relevant data from the knowledge base with all the data from the fact base to reach a conclusion or solve a specific problem.

The knowledge engineering process builds the knowledge base by supplying general knowledge to the expert system. The user supplies the fact base for the specific problem, and the expert system's program (inference engine) is designed to combine the relevant information from the knowledge base and the fact base to reach a conclusion. Chapter 4 describes the knowledge engineering steps for ESP, Chapter 5 views ESP interaction with the user, and Chapter 6 looks at ESP from the perspective of the programmer.

The fundamental difference between conventional computer-modeling processes and the use of an expert system shell is that, by using an expert system shell, the knowledge engineer can focus on the decision process rather than on the exact procedure that the computer will follow during its processing. Conventional (procedural) programming, according to Buehler (1987),

requires the programmer to lay out, in series, each step that will be processed in the program.

Declarative programming allows the programmer to focus on the concepts of symbols (knowledge) that the program addresses without concentrating on the program's processing flow.

Knowledge acquisition involves interviewing experts to determine the logic of their decision-making techniques. Often this is more difficult than originally anticipated because experts solve problems without explicitly defining their thought process, and, although the knowledge engineer

is experienced at encoding knowledge into the system, he may have little domain knowledge of the industry or little understanding of the problem being addressed. The difficulty of the task is apparently in direct proportion to the amount of qualitative information in the decision process. The assessment procedures have not been explicitly defined by the experts in a step-like process; therefore, they have difficulty explaining the procedures to a novice in that domain, the knowledge engineer.

The Delphi approach to gather information involves asking for opinions, tallying the results, then telling the participants what others thought and asking for their revised opinion based on the new information. The advantage of this approach is that it also looks to the future, whereas databases typically collect only past experience.

The knowledge engineering process incorporates the Delphi approach by initially gathering information, building a prototype expert system, and validating the expert system by having the experts evaluate it. The prototype acts as feedback of what others thought to the participants.

Knowledge Acquisition

Knowledge acquisition, as in any information-gathering process, is time consuming and expensive. For expert system development this involves repeatedly questioning the expert(s) about the information they rely on and the process they use to make a decision. The knowledge engineer must sometimes "devise stratagems that get people to reveal thought processes that have become second nature" (Kupter 1987). It requires organizing and structuring complex decisions, checking for consistency and completeness, and resolving conflicts. Also, explanations for the reasoning process are normally included as a part of the system.

Knowledge Representation and Organization

There are three primary forms of knowledge representation used in various expert system shells:

1. Rules--describe the action, reason, and the conclusions given a particular situation; i.e.,
 If: conditions are met
 Then: take specified action.
2. Frames/Objects--describe a hierarchy of objects or concepts with a particular relationship suggested by the location in the hierarchy.

3. Neural Networks--patterns of connections between components.

These three forms provide the structure for the encoding of the knowledge in the expert system shell. Some of the more powerful shells use more than one form of knowledge representation. More flexibility in the form of the knowledge representation may be acquired by opting to use a programming language designed for use with artificial intelligence applications, such as Lisp or Prolog, but the required level of programming skills will also increase.

The inference engine controls how rules and facts are used for solutions. The two principal inference mechanisms used in rule-based expert systems are backward chaining and forward chaining. Backward chaining, the most common, works backward from a goal to seek circumstances that will satisfy the goal conditions. Conversely, forward chaining works forward from a set of facts to reach conclusions based on those facts. The two processes are parallel to inductive and deductive reasoning.

Coding

An expert system can be programmed using either third-, fourth-, or fifth-generation languages (tools). Although there is some overlap, a third-generation tool is designed for professional programmers, a fourth-generation tool is

designed for end users (nonprogrammers), and a fifth-generation tool is designed to be used by AI specialists.

An expert system shell is commonly a fourth-generation tool providing the framework to build and run an expert system. It includes knowledge representation schemes, built-in inference engine(s), and the ability to transfer information between its components. It is designed for the nonprogrammer, but, like most software packages, it requires a set format for instructions.

Prototyping Learning Curve

Knowledge engineering is, in itself, a learning process as the knowledge engineer and expert become more familiar with the problem domain, information, and decision process. A learning curve develops, with the participants at each step becoming more effective and efficient at the tasks and processes necessary to develop an expert system. Frequently the expert becomes more clear on his decision process as well as on how the system can handle his thought pattern. The knowledge engineer, on the other hand, learns much about the problem domain and how to best represent the information and processes of the expert's decision making.

The amount of learning in the development of a prototype expert system is substantial, and the improvement in the efficiency of the expert system is usually so

significant that the completed prototype is abandoned in favor of a new expert system, developed using the improved representation and coding skills of the knowledge engineer. The new system is tremendously more efficient.

Such are the expectations of this thesis. Once the expert system is shown to be a valid approach to the petroleum evaluation process and a prototype is built to demonstrate that point, the skills developed during the prototyping process can be used to capture the decision process more efficiently and effectively in another expert system. Part of that learning process is incorporated into ESP's prototyping process in the two-stage Delphi approach (Table 5) taken in the knowledge engineering process. This is explained in Chapter 4.

Similarities to other Problem-Solving Approaches

The expert systems approach has parallels to that of PERT (program evaluation review technique). In PERT, experts' opinions are solicited and used together to establish a "weighted average" of required information, and the goal of management is to minimize the bottlenecks in cash flow and operations load by evening out the timing of the cash requirements and the work flow.

Table 5

Steps in the Knowledge Engineering Process
(Two-Stage Delphi Process)

Knowledge Engineering: to transfer knowledge from human to
computer

Initial Stage

General knowledge, logic structure, relationships and
definitions

1. Gather-- extract from human expert
2. Represent and organize--define objects
describe characteristics
indicate operations or functions
classify
3. Load into computer-- via expert system shell
via programming language

Verify and Improve Stage

Specific knowledge, logic structure, relationships and
definitions

1. Gather-- extract from human expert
2. Represent and organize--define objects
describe characteristics
indicate operations or functions
classify
3. Load into computer-- via expert system shell
via programming language

Motivation

One motive for keeping the knowledge engineering process (for ESP) simple is the recognition that ESP must be understandable and verifiable to management.

[T]he simple techniques should be used first. . .
(1) As they are simpler, there is a higher probability that they will be used; (2) there is a good chance that the user will understand what he or she is doing; and (3) simpler techniques are usually cheaper. Hesse and Woolsey (1980).

ESP's simple approach improves the probability that an enhanced version of this prototype will be accepted and implemented in a corporate setting.

Chapter 4

KNOWLEDGE ENGINEERING FOR THE EVALUATION SYSTEM FOR PETROLEUM PROJECTS

The petroleum project evaluation process meets many of the criteria for an expert system application: it is a complex problem requiring specialized knowledge, and it is a task performed by experienced personnel using different kinds of information.

The knowledge engineering process for ESP (Table 6) used a two-stage Delphi-like process to draw on the intuition and expertise of petroleum experts. First, to extract the general approach, each expert was asked what information was absolutely essential for an off-the-cuff or rule-of-thumb estimate of costs and revenues in petroleum project evaluations. This approach to defining the decision space was used to utilize the intuition of the experts but to stay within their range of experience. Second, specific information was gathered in a more formal interview. Finally, ESP was demonstrated to the experts and each evaluated the system.

Specifically the expertise to evaluate a petroleum project was sought from the three specialists. The evaluation process requires the manipulation of complex knowledge within the domains of engineering, negotiation,

Table 6

Steps in the Knowledge Engineering Process (ESP)

ESP's Knowledge Engineering Process

The domain knowledge for ESP was gathered in two stages: first, generally, in conversations; and second, more specifically, in interviews with three experts. After each round of gathering information, the information was programmed and loaded into the computer.

Initial (general)

1 & 2 Gather and Represent

Develop interview sheet--to find out necessary information for rules of thumb, data bases, defaults, corporate guidelines, logic, and calculations.

Interview selected experts for fundamental information and process.

2 & 3 Represent and Load

Develop Concept Demonstration of how system interacts

to capture fundamental information and process

to know how system interacts

User with system
 Organization, indexing and accessing information
 Database, rules and spread sheet

to know what additional information is needed from each expert

(continued)

Table 6 (continued)

Verify and Improve (specific)

1 Gather

Revise interview sheet
Interview petroleum experts

3 Load

Code information and process in expert system shell

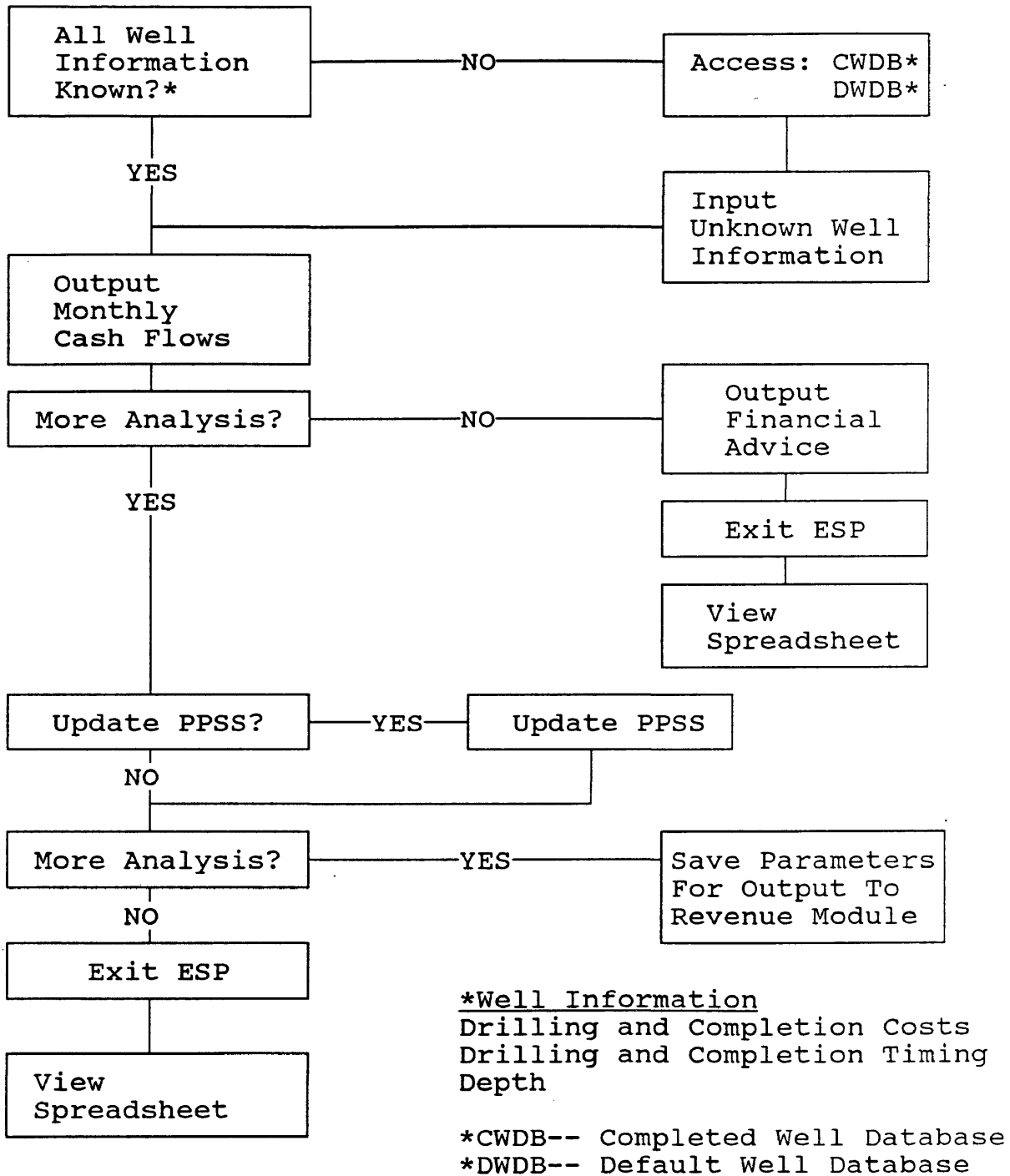
and finance. The expert system developed for this thesis is a way to mimic the evaluation process.

Knowledge Acquisition

Many individuals had input into the domain knowledge of ESP. The general problem domain and overall petroleum evaluation process were the topic of numerous casual conversations with petroleum industry personnel. Informal interviews were conducted with individuals to elicit the abilities the system would need to deal with the form of data each expert uses.

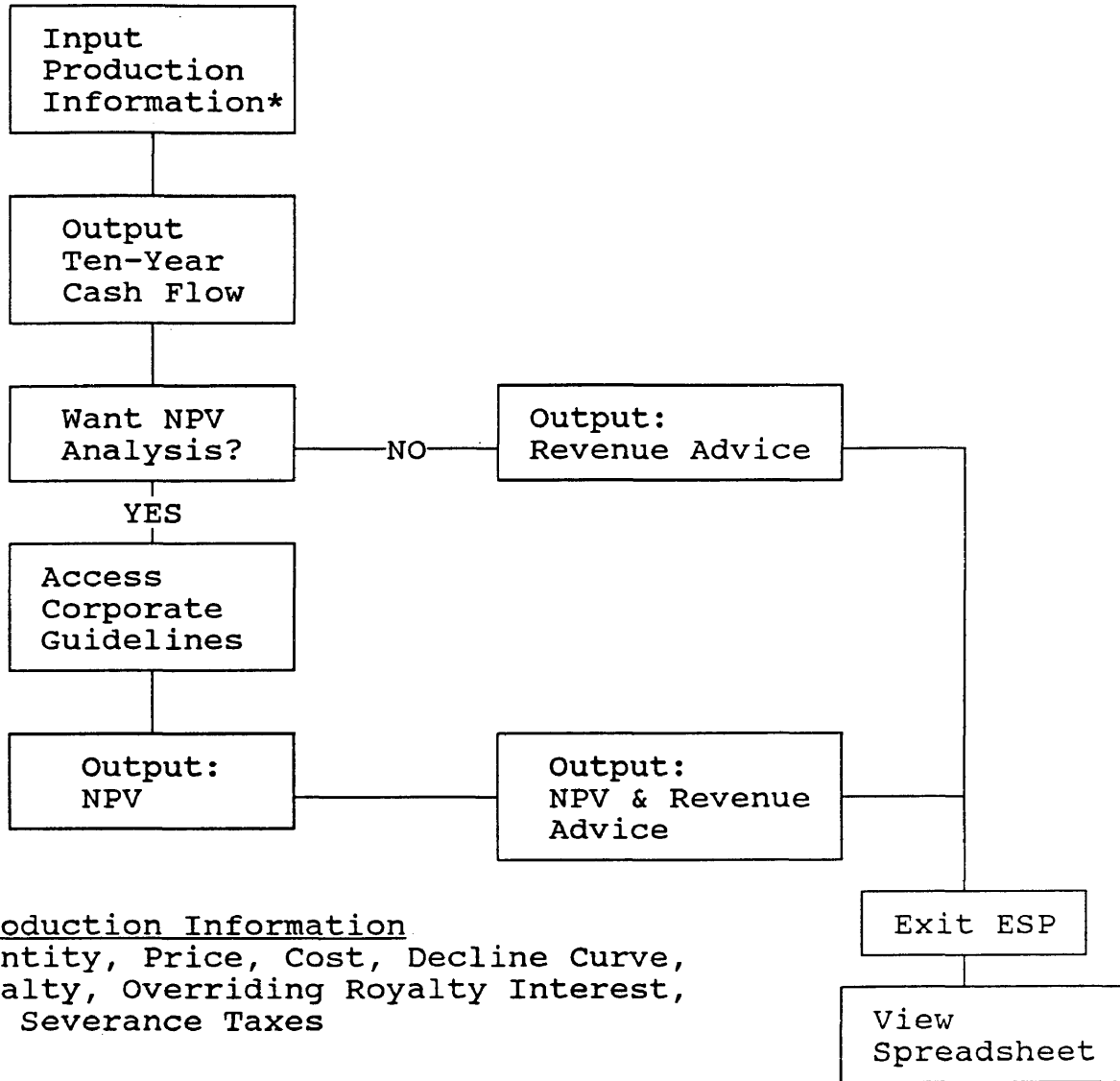
From these informal interviews a skeleton of the cost and revenue module was constructed as a concept demonstration. This was designed to test the VP-Expert system shell, as well as to demonstrate the fundamental construction and use of ESP.

Although the recommendation is to use only one expert during the expert systems development stages, three experts were selected to be interviewed because of the diverse subject areas included in the petroleum project evaluation process. At the interviews, each expert saw the knowledge maps and the spreadsheet developed for ESP. The knowledge maps (Figures 2 and 3) show the basic system structure and actions. The spreadsheet format (Table 7) showed the



Knowledge Map of Cost Module

Figure 2



*Production Information
Quantity, Price, Cost, Decline Curve,
Royalty, Overriding Royalty Interest,
and Severance Taxes

Knowledge Map of Revenue Module

Figure 3

desired results. Each expert was asked for more data and relationships using the interview sheets shown in Appendix E as a guide. Interview questions were specific to the role of the expert in the assessment process, with a good deal of overlap on the shared areas of knowledge to capture vocabulary differences for the glossary and help statements. Responses to the questions determined the form of the database search and the system defaults (necessary if database information is not available).

After several hours of interviews, it became increasingly apparent that care must be taken to allow much flexibility in the user's ability to adapt the program for specific corporate objectives and guidelines. The differences in the size and focus of each firm made this mandatory. Individual preferences were also noted in the way the database was structured and searched.

The knowledge maps (Figures 2 and 3) were constructed during the preliminary design of ESP to graphically illustrate the structural framework of the system and to help the experts see the impact of their advice on the system. The maps illustrate the essence of the ESP logic. Table 7 illustrated the results to be obtained from the consultation with ESP. It was used to demonstrate the relationship between user or expert input and the

calculations for the output. These graphic representations of system logic and output proved to be excellent tools for quickly communicating to the experts the assessment process the system would capture.


Knowledge Representation

The tasks of the knowledge engineering process are not distinct. There is a significant learning process involved just to be able to represent and search through the generic system, then, to use the system to get the desired results.

The framework of the thought process defines possible paths and a hierarchy of rules and goals given values by the system, when the evidence (information necessary to solve the problem) is given by the user. Fundamentally, ESP is a simple, decision-tree structure with two end results: short-term or long-term spreadsheets and advice to the user.

VP-Expert Software

Ideally the expert system shell should be selected to best implement the solution of the particular problem. However, VP-Expert was selected with a two-part objective: (1) the shell needed to interface directly (both ways) with independent database and spreadsheet software, and (2) it needed to be documented well enough for a novice programmer



to use it. Consequently the constraints in VP-Expert influenced the design of the problem statement and the order of the steps toward the solution.

VP-Expert is an expert system shell currently available at a reasonable cost with the ability to access and process the information needed for this research. The following are the principle criteria for the selection of VP Expert:

1. The ability to output data to and receive data from a spreadsheet and a database
2. Availability of the necessary hardware for the system in a portable computer
3. Simplicity of the programming
4. Cost

A paper presented at the ORSA/TIMS conference in October by Patrick Lyons (1988) demonstrated the existence of a two-way interface between the database and the spreadsheet. His applications did not require both interfaces in the same system, but his demonstration showed that VP-Expert did have the features needed for this research and that it was a suitable software package from which to develop a prototype.

Since the purpose of this project is to demonstrate the ability of an expert system to capture the human expertise needed to evaluate petroleum projects, the expert system

shell selection process was neither complete nor exhaustive. Other expert system shells may be equally suitable for illustrating how an expert system can emulate three experts. VP-Expert was selected because it was available and affordable. It was large enough to deal with the databases for the prototype and offered expandability for practical use (without adapting the rule base). The interface with the spreadsheet went both ways, and VP-Expert promised to be usable to a novice knowledge engineer.

The software package, VP-Expert, is a user friendly, expert system shell. It was used for the prototype ESP developed in this thesis. The knowledge base within VP-Expert is defined with rules, parameters, and statements. The system will ask the user, or search an information base (database), to set values for the parameters which will then match a rule's goal. The Actions Block determines the order of the rule testing with instructions to find values for particular parameters. The system then tests any rule that could assign a value to that parameter. The system uses a goal-directed inference scheme based on a backward-chaining process, which is explained in Chapter 6.

Encoding of the specific experts' knowledge was parallel to the two knowledge-acquisition stages. The general functional relationships of costs, percentages, and

delays were encoded initially for the concept demonstration. The specific information from the formal interviews (such as ranges of values and specific calculations) were put into the system. Then, after the system was demonstrated to each expert, their suggestions were encoded into the system when possible.

Chapter 5

CONSULTING THE EVALUATION SYSTEM FOR PETROLEUM

ESP has two perspectives. The consult mode is used to process a project evaluation. The develop mode is used by the knowledge engineer to change the knowledge base. This chapter covers the consult mode and has a section discussing the input and output from the user's perspective. Chapter 6 looks at the ESP knowledge base from the developers perspective. The limitations and possible enhancements of ESP are discussed in Chapter 7.

The expert system is able to access database and spreadsheet software. The database provides the ability to store, select, and display relevant information, and the spreadsheet provides the ability to update numerous calculations based on new information and to display the results. The ESP accomplishes the following in its evaluation process:

1. Gives the amount and timing of the well costs on a monthly schedule, potential revenues on an annual basis, and expected tax implications.
2. Gives immediate access to the well costs of previously completed projects and selects and

displays only those projects analogous to the project under consideration.

3. Allows the user to run a variety of well interest scenarios and advises the user if the project is outside the current corporate objectives.
4. Maintains a database of all pending projects, both those in process and those currently under consideration.
5. Displays current projects with their financial database (contains the amount of funds available by month) while commenting and advising the user on alternatives.

ESP uses database software to supply analogous well information to the user as input suggestions and spreadsheet software for calculations to generate cash flows and advice as output. The expert system selects relevant data from the database to display to the user and processes user input for transfer to the spreadsheet. Appendix A supports the Input section with a complete listing of parameters and database format and the Output section with a listing of spreadsheet formulas.

A Consulting Session

When consulted, ESP will guide the user in a structured but adaptable evaluation of the petroleum project. The user first enters the Cost Module. The advice generated tells the user whether the cash requirements of the project are compatible with the cash flows expected during that time frame and the corporate guidelines. If the user elects to continue the consultation, the Revenue Module is opened, expected production information is requested (of the user) and an annual analysis of revenue is available. Net present value is calculated in the revenue module using selected data imported from the cost module and corporate guidelines.

When the user begins the dialog with ESP (see Appendix C for system requirements), he is instructed on how to work with the system (Figure 4). In the Short Cost Module, he is prompted for eight answers. He will type in the answers or select from the available menu choices as the questions appear on the screen, Figure 5. If the user is unable to supply necessary information, he types in a "?", then the system queries the Completed Well Database for analogous information or queries the Corporate Defaults Database so that the evaluation can proceed (Figure 6).

ESP will use the domain knowledge in the knowledge base to generate advice (Figure 7) to the user about his proposed

WELCOME TO E.S.P.
The Evaluation System for Petroleum

This Knowledge Based Expert System will assist you in determining the impact of a proposed drilling project on your company's financial situation. First, a monthly cash flow spreadsheet is produced, then it is compared with pending and committed projects for the general analysis and advice.

E.S.P. interacts with database files and spreadsheet files to provide information and final analysis.

PRESS ANY KEY TO CONTINUE

TO ANSWER A PROMPT:

Type in your answer or, when presented with a menu, use the direction keys to position the light bar over your selection in the menu, and then press the ENTER or RETURN key.

TO INDICATE AN UNKNOWN:

Whenever you are confronted with a prompt, and you are unsure of the answer, enter a question mark (?). This tells E.S.P. that the information is unknown.

TO INDICATE UNCERTAINTY:

If you are not 100% confident of an answer to a prompt you may indicate your uncertainty by entering your answer then pressing the HOME key and a number from 0-100. (This is called your degrees of confidence. A 0 indicates total uncertainty and 100 indicates total confidence)

PRESS ANY KEY TO CONTINUE

ESP Introduction Screens

Figure 4

What is the name of the proposed well?

Colorado Rose

What is the identification number of the proposed well?

25-2

What type of well will this be?

OIL

GAS

DEV

W-C

UNKNOWN

What is the projected depth of this well?

6500

Will you be drilling with your own crew or a hired contractor?

CREW

CONTRACTOR

PRESS ANY KEY TO CONTINUE

What is your estimate for drilling cost?

600,000

What are your tangible drilling costs?

(Enter as a dollar amount excluding the dollar sign or as a percentage in decimal format)

.34

What are your intangible drilling costs?

(Enter as a dollar amount excluding the dollar sign or as a percentage in decimal format)

.66

PRESS ANY KEY TO CONTINUE

ESP Sample Prompt Screens

Figure 5

This data has been provided from a well previously drilled in Garfield county.

Name: Cameo 1

Depth: 4574

Days to drill: 43

Spud date: 05/20/85

Rig release date: 07/02/85

Well type: Wildcat

Status: Producer

Drilling cost: \$903,520.00

Total cost: \$1,104,170.00

PRESS ANY KEY TO CONTINUE

Corporate Defaults for Garfield county:

Well	Depth	Cost/Foot	Days to Drill	Days to Complete	Cost to Complete
----	-----	-----	-----	-----	-----
Shallow	7000	\$30.00	19	10	\$200,000
Medium	8000	\$35.00	30	11	\$220,000
Deep	9000	\$40.00	40	12	\$250,000

PRESS ANY KEY TO CONTINUE

Completed Well Database and Default Well Database

Figure 6

project. The analysis includes information on how this agreement will affect the overall cash position of the company and advice as to other terms and timing that should be considered to better fit with corporate objectives. The user may opt to view the spreadsheet generated by ESP (Figure 8). A monthly or annual spreadsheet indicates specifically when the costs and/or revenues are expected.

Input

Three sources of information are available for ESP to use to evaluate petroleum projects. The listing is in order of priority and level of confidence:

1. The interactive user query
2. The analogous well information in the Completed Well Database
3. The Corporate Defaults Database, which provides average estimates for a variety of parameters.

The interactive user query is presumed to be the best source of specific well information because the user has given thought to the specific situation associated with that well. ESP asks the questions (Figure 5), then processes the information gathered to output to the spreadsheet. If any question cannot be answered, that is indicated by inserting a "?" rather than the answer. ESP then selects and displays

Potential investment in Colorado Rose exceeds corporate guidelines.

Suggest:

Reduce working interest.

AUTHORIZATION REQUIRED FROM V.P. FINANCE BEFORE
COMMITMENT ON Colorado Rose PROJECT!

PRESS ANY KEY TO CONTINUE

Corporate monthly cash flow exceeds the \$100,000.00 limit
in the following
month(s): January
February

Suggest:

Change spud date or
Become a non operator or
Reduce your working interest.

PRESS ANY KEY TO CONTINUE

Corporate policy is to keep working interest below 25%

Suggest:

Reduce working interest.

AUTHORIZATION REQUIRED FROM V.P. FINANCE BEFORE
COMMITMENT ON Colorado Rose PROJECT!

PRESS ANY KEY TO CONTINUE

Sample Advice Screens Generated by ESP

Figure 7

Well Data		Well Costs			
-----		-----			
Well Name:..JDs Deceiver		Drilling Cost:..		\$437,825	
Well Number:	36.00	Tangible:.....		\$170,752	
State:.....	Colorado	Intangible:...		\$267,073	
County:.....	DOLORIS				
Township:...	39	Completion Cost:		\$102,175	
Section:....	20	Tangible:.....		\$12,261	
Range:.....	36	Intangible:...		\$89,914	
Strata:....	DESSERT CREEK				

12 month cash flow projection:					
	January	February	March	April	
Drilling Days					
Per Month.....	10	12	0	0	
Drilling					
Out.....	\$0	\$199,017	\$238,813	\$0	
Drilling					
Reimbursement..	\$0	\$0	\$179,115	\$214,931	
IF PRODUCER:					
Completion Days:					
Per Month.....	0	14	0	0	
Completion					
Out.....	\$0	\$0	\$102,175	\$0	
Completion					
Reimbursement..	\$0	\$0	\$0	\$113,527	

Segment of Cost Module Spreadsheet

Figure 8

relevant domain knowledge on analogous wells.

The Completed Well Database and the Corporate Defaults Database are part of the domain knowledge of the expert system (Figure 6). Both are used to help the user supply necessary input to the system. The Completed Well Database is a list of facts about previously drilled wells. Companies accumulate this information in well files. The petroleum engineer retains some of this detail in his memory, but if he does not remember the details of an analogous well, he knows how and where to look for the information. ESP parallels this process by selecting wells in the same county to display to the user. ESP displays only the nine items in Figure 6 (top) that are relevant to this project evaluation. The other items in the database may be accessed for other purposes. If there are no wells in the Completed Well Database for that county, Corporate Defaults (Figure 6 bottom) suggest average time and costs by depth for each county so that the user can estimate the necessary input items.

The format for the Completed Well Database is shown in Appendix A. Accumulating this information in a standard database package allows each company more flexibility on which information to include, and the same information can be used for a variety of purposes. ESP can be adapted to

parameters and fields; for instance, township and range could be used instead of county. The defaults, similarly are flexible. They should be reviewed and updated at least annually because they are estimates.

Output

ESP generates two forms of output: the cash flow spreadsheet and the advice.

ESP Spreadsheet. The preprogrammed spreadsheets for the Cost Module and the Revenue Module handle many of the calculations typically made by the landman. The output form of the spreadsheets are shown as Figure 8. A complete listing of the spreadsheet formulas is included in Appendix C. The cost spreadsheet uses the spud dates, days drilling, and completion days to calculate how much and in what month the costs are incurred. The working interest percentage and operator status then determine how much and in what month the costs are paid. The revenue spreadsheet uses production data, tax data, corporate guidelines, and revenue interest percentages to project annual revenue estimates. The net present value of the project is calculated using a corporate guideline, rate of return, as the discount factor.

ESP Advice. The advice given by ESP is triggered by a comparison of information calculated on the spreadsheet and corporate guidelines set up in the rules. Based on the relationship of the corporate guidelines and objectives to parameter values or to specific cells on the spreadsheet, specific advice is displayed to the user. Basically, if the amount is within the acceptable range, the advice indicates that. If the amount is outside the corporate guidelines, the advice states possible remedies to the situation along with who to contact for further authorization of the project as it is currently stated.

User Interaction

ESP provides several tutorial-style screens to advise the user of helpful information, such as drilling cost indices, average well costs, and the relationship between working interest and revenue interest (Figure 9). This feature could be enhanced to supplement an employee training program. The user can get information about why a particular conclusion was reached by asking "why (/y)". ESP displays the "because" portion of that rule.

ESP Features

Each ESP module was designed to demonstrate the expert

ESP has determined that one or more of your cost breakdowns falls outside a given range:

Tangible drilling costs are low.
 Intangible drilling costs are high.
 Tangible completion costs are OK.
 Intangible completion costs are OK.

The following relationships are common in Colorado:

Of Total -----		Tangible -----	Intangible -----
60-70%	Drilling Costs = 100%	30-35%	65-70%
30 40%	Completion Costs = 100%	90%	10%

100%			

PRESS ANY KEY TO CONTINUE

ESP needs to know the working interest percentage.
 The following revenue and working interests are common:

	COSTS	DIVISION OF REVENUE
Landowner Royalty	0%	12.5-15%
Overriding Royalty	0%	0-3%

Net Revenue Interest (NRI)	100%	82-87%
Working Interest of NRI (1/3 for 1/4)		
Drilling		
For each of 3 partners	33%	25%
For Managing Partner	0%	25%
Completion		
For each of 3 partners	25%	25%
For Managing Partner	25%	25%

ESP Sample User Information and Help Screens

Figure 9

system in a different role. The Short Cost Module is a smart front-end for a preprogrammed spreadsheet. The Long Cost Module demonstrates giving the user access to only relevant information from an unfamiliar database. The Revenue Module illustrates one expert system supplying data for another expert system.

Structure. The ESP structure is in the organization of the knowledge base and the order of the questions asked. The system uses backward chaining, so only questions necessary to meet specific goals are asked. If the user has incomplete information (as is often the case), the program will select and display analogous well information from the completed well database, and inform the user of corporate defaults for estimating the amount. The user can indicate his level of confidence about the accuracy of the estimate. If this confidence factor is exceptionally low the advice will reflect that fact.

Flexibility. Flexibility is incorporated into the system allowing the evaluation to continue even if all information is not available. ESP suggests alternative ways to estimate it; for example, if the user does not know the approximate well cost, the system will query the database

for costs from similar projects or will display the corporate defaults for that area so that the evaluation can continue.

Two other realms of flexibility are built into the modular approach of the system:

1. The user can select the extensiveness of the analysis from the modules. The first module focuses on the short-term cash flow impact of this project by showing the timing of payment of the well's cost considering operator status and percentage of ownership on a monthly spreadsheet. The second module focuses on the long-term financial impact of this project. It produces an annual revenue spreadsheet, from the production data for the well and pricing data supplied by corporate defaults. Discounted cash flow and returns on investment are among the other analysis options.
2. The user can select the magnitude of the database accessed and built by the system, from using only corporate defaults to integrating corporate engineering and accounting systems.

Utility. Although a complete preliminary analysis is available to the novice, an expert can fully utilize the system's abilities. Other experts' knowledge can be accessed to do more goal-directed specific analysis. With ESP the engineer has easy access to analogous well data and the effects of agreement terms and the financial advisor has a powerful evaluation tool and a Pending Projects database.

ESP is probably the most useful to the negotiator. It gives immediate feedback on how this project and its agreement terms may affect the overall cash and risk position of the company. By running various scenarios, the negotiator could know the impact of each point of negotiation on the company and on each of the investors. Contract terms can be negotiated that would suit the financial situation and objectives of the company. Also known is the relative cost for the other investors. Therefore, with better information, the possibility of reaching a Pareto optimal solution (a solution or compromise where there are no losers) is increased.

Chapter 6

DEVELOPING THE ESP KNOWLEDGE BASE

The result of the knowledge engineering processes described in Chapter 4 is the ESP program. ESP is based on a rule-based expert system shell which provides the complex programming necessary to emulate the decision-making process. Examples of the programming terms used in ESP are briefly described in the Glossary. Appendix B contains a complete listing of the program instructions for the Short Cost Module, the Long Cost Module, and the Revenue Module.

A Developing Session

The VP-Expert inference engine navigates through the knowledge base to solve the problem. The knowledge base consists of three blocks (Figure 10):

- o Actions--the controller
- o Rules--the expertise
- o Statements--pertinent information

To add to or change the knowledge base from ESP, the knowledge engineer must have selected "Develop" in the initial menu. To change either the databases or the software.

VP Expert Program Blocks -----	VP Expert Terms and Clauses -----	Explanation -----
ACTIONS	MENU	Creates menu of choices from a field's values in a selected database file.
	FIND	Initiates search for value.
	parameter=	Assigns value to parameter.
	PWKS	Writes to spreadsheet.
	WKS	Retrieves value(s) from spreadsheet.
	WHILEKNOWN	Initiates Whileknown-End loop.
	END	Terminates Whileknown-End loop.
RULES	IF	Premise of rule.
	THEN	Conclusion of rule.
	ELSE	Assigns the value of else if premise is false.
STATEMENTS	ASK	User query for parameter.
	CHOICES	List of menu choices for parameter.
	PLURAL	Allows a parameter to have more than one value.

ESP Program Construction

Figure 10

Actions

The Actions Block controls the order of rule processing. The primary goal of ESP's rule order is to lead the user in a logical thought progression. The secondary goal is to allow the system to operate as quickly as possible.

The Actions Block specifies the goals of the consultation, along with commands to display the results and other commands. . . . [It] provides a procedural framework that allows for the presentation of output and, interfacing to spreadsheets and databases. . . . [It] invokes the inference engine to search the rules in the Rules Block for a given goal (Hicks and Lee 1988).

Figure 11 illustrates several of the terms in the Actions Block of ESP.

Rules

The basic logic structure is contained in the rules. ESP is backward chaining. It works backwards from goals, through the THEN clauses of the rules, then tests the IF clauses of the rules to set values for parameters. If there is no rule to set the value, ESP uses the ASK clause to query the user for a value (Figure 12). The Actions Block determines the order of the rule testing by the order of the FIND clauses. The rule format is

```
    If:      Conditions exist
    Then:    Conclusion is
```

ACTIONS

```
MENU C_O_COUNTY,ALL,A:\DATABASE\CWELINFO,COUNTY
FIND C_O_WELL_NAME
FIND C_O_COUNTY
CLS
FIND I_Q_DRILLING_COST
FIND D_C_TANG & INTANG
FIND Provide_info
PWKS C_O_WELL_NAME,C4,A:COST
PWKS C_O_COUNTY,C7,A:COST
PWKS C_O_DRILLING_COST,E4,A:COST
PWKS C_O_TANG_DRILLING_COST,K4,A:COST
PWKS C_O_INTANG_DRILLING_COST,K5,A:COST
WKS MCFI,C41..Z41,A:COST
WKS MCFI_TOTAL,AA41,A:COST
WKS COMMITTED_AND_CURRENT,C56,A:COST
WKS MCFI,C41..Z41,A:COST
WKS MCFI_TOTAL,AA41,A:COST
WKS COMMITTED_AND_CURRENT,C56,A:COST
FIND TANG_D_C_PERCENT
FIND INTANG_D_C_PERCENT
FIND TANG_C_C_PERCENT
FIND INTANG_C_C_PERCENT
FIND RECOMMENDATIONS_01
FIND RECOMMENDATIONS_02
```

ESP Actions Block

Figure 11

```
RULE 001
  IF      RISK_ADJUSTMENT = YES
  THEN    R_O_RISK_ADJUSTMENT =
          (PERCENT_RISK_ADJUSTMENT)
          FIND PERCENT_RISK_ADJUSTMENT
  ELSE    R_O_RISK_ADJUSTMENT = 1;

RULE 002
  IF      OVERRIDE_ROYALTY_INTEREST = YES
  THEN    R_O_OVERRIDE_ROYALTY_INTEREST =
          (PERCENT_OVERRIDE_ROYALTY_INTEREST)
          FIND PERCENT_OVERRIDE_ROYALTY_INTEREST
  ELSE    R_O_OVERRIDE_ROYALTY_INTEREST = 0;

RULE 003
  IF      C_O_STATE = COLORADO
  THEN    R_O_STATE_TAX = .0775;

RULE 004
  IF      C_O_STATE = WYOMING
  THEN    R_O_STATE_TAX = .1279;

RULE 005
  IF      C_O_STATE = NEW_MEXICO
  THEN    R_O_STATE_TAX = .0808;
```

ESP Rule Block

Figure 12

Statements

The Statements Block provides the means to assign a value to any parameter whose value was not set by a rule (Figure 13).

This block contains the ASK statements and any special conditions associated with them. . . . Any variable not assigned a value in a rule needs an ASK statement in order to have a value assigned by the user (Hicks and Lee 1988).

The Statements block of ESP contains the user query and sets up the CHOICES available for some questions (other choices are set up through the database records using the term MENU).

ESP Program Construction

ESP starts with the first FIND clause, checks the then portion of the rules, then proceeds to ASK the user for parameter values in the order of the remaining FIND clauses in the ACTIONS BLOCK. When applicable, ESP lists the available responses (using CHOICES or MENU). After the user selects (or inputs) a response, the program moves to the next question, and so on, until values have been assigned to all necessary parameters (goal variables).

The parameter values are then transferred to a preprogrammed spreadsheet for cashflow projections and tax implications. Certain information from the spreadsheet is then fed back into the expert system for comparison to corporate

guidelines, and the user is given advice on how well this project fits into the corporate plan and within the financial constraints. The more disparity there is between this project's attributes and the corporate business plan, the less desirable the project.

Figure 14 is an abbreviated illustration of the ESP program provided in full in Appendix B. The abbreviated program FINDs the value of one parameter (goal variable) "F_O_DRILLING_COSTS" and traces the program's route through the rules to the ASK statement. The Short Cost Module asks for values for eight parameters. The Long Cost Module and the Revenue Module follow the same basic route for numerous variables. Fundamentally ESP finds F_O_DRILLING_COSTS by testing Rules 001, and if necessary, Rule 002 which ask the user "What are the expected drilling costs?" then puts F_O_DRILLING_COST in cell D4 of the spreadsheet file, Auto 123.Wks. The majority of the calculations take place on the spreadsheet, which then feeds information back from selected cells to the rules to generate advice based on the corporate guidelines and objectives.

Special Features

From a larger perspective, ESP was constructed as a

```
ASK C_O_WELL_NAME:      "What is the name of the proposed
                        well?";
ASK C_O_DRILLING_COST:  "What is your projected drilling
                        cost?";
ASK C_O_COMPLETION_COST:"After rig release, what is your
                        projected completion cost?";
ASK C_O_SPUD_MONTH:     "What month do you expect to start
                        drilling?";
ASK C_O_SPUD_DAY:       "What day {C_O_SPUD_MONTH} do you
                        expect to start drilling?
                        (ie 1-30)";
ASK C_O_DRILLING_DAYS:  "How many days do you expect to be
                        drilling? (max 90)";
ASK C_O_COMPLETION_DAYS:"After rig release, How many days
                        will it take to complete this
                        well?";

CHOICES C_O_SPUD_MONTH: January, February, March, April,
                        May, June, July, August, September,
                        October, November, December;
PLURAL: RECOMMENDATIONS_01,RECOMMENDATIONS_03;
PLURAL: MONTH;
```

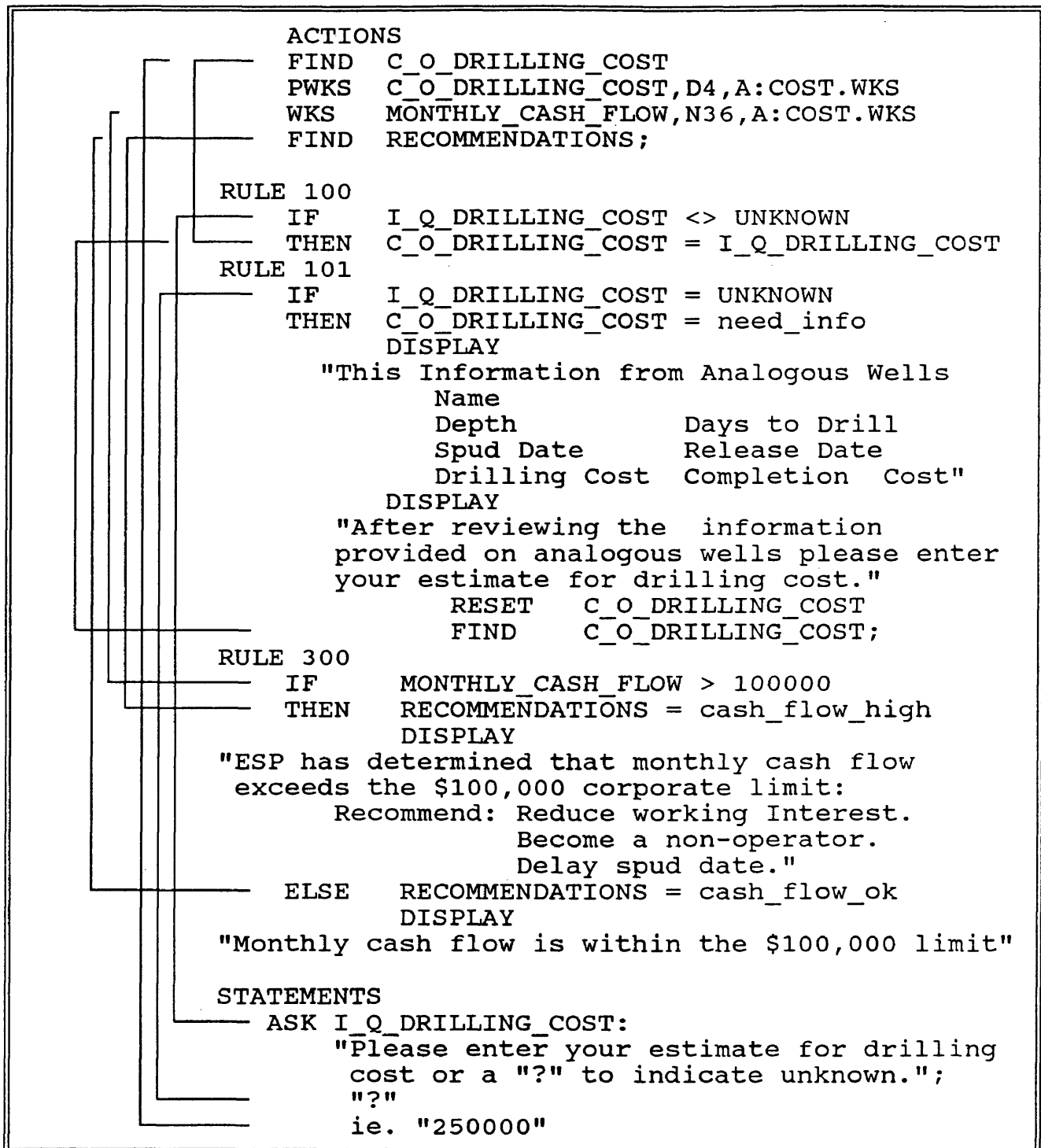
ESP Statements Block

Figure 13

concept demonstration to illustrate three roles an expert system can play in the management information system of a company. The purpose was use an expert system to link individual databases and computer applications to one another.

Empirical evidence indicates that independent data gathering systems have developed from focused needs of particular departments. Pockets of specialized knowledge exist in most companies. For example, in the petroleum company, engineering departments have data systems focused on drilling and production information. Accounting departments have an accounting system focused on inflows and outflows of dollars; land departments have a data system focused on maintaining land rights, ownership, leasing, and deal structures.

For specific functions, such as the petroleum project evaluation, information is needed from several departments, but since the information systems are not compatible, shared information must go through people. (Linking the databases directly or merging all information into a single common database has met with limited success.) One individual must extract the information from his system, physically hand it to another person who enters the information into his system. Expert systems provide a means of extracting



Abbreviated ESP Program Format

Figure 14

relevant information from one area and linking it to applications in another area.

ESP demonstrates the expert system's ability to link an expert systems to a spreadsheet, an expert system to a database, an expert system to an expert system and a combination of the above. Linking one step towards an integrated management information system.

Adaptability. ESP is adaptable to specific company situations. From the develop mode, the knowledge engineer can easily update or change the Corporate Objectives or the Corporate Guidelines in the Rule Base or the Corporate Defaults in the Default Well Data Base (Table 8). The importance of this adaptability is widely recognized as Quick and Schuyler (1988) state:

The operating strategies must complement the company's financial strategies. This involves evaluating future investment opportunities in the light of the company's financial condition and basic business strategies in order to develop exploration strategies that will complement the company's overall business strategies. . . . The exploration planning process needs to tie into the company's strategic planning process.

Security. One concern may be to protect files from user manipulation. ESP is designed to allow the user to input or to view information but does not allow the user to update or change information from the consulting mode.

Therefore the rule base, database and preprogrammed spreadsheet are protected from user update or change.

The Corporate Objectives or Corporate Guidelines are in the rule base, the Corporate Defaults are in a database, and the calculations in the spreadsheet are all protected from inadvertent manipulation while the user is in the consult mode.

Flexibility. For maximum flexibility, ESP uses three independent methods to capture the expertise needed to evaluate a petroleum project: the database, the rules, and the spreadsheet. Since these have been discussed previously, suffice it to say that the expert system can be readily adapted to gather information from many in-place databases and can output information to numerous spreadsheet software packages.

Another realm of flexibility is in the form of the advice generated by the expert system. ESP includes examples of three forms of advice in Figure 8 of Chapter 5, a warning, instructions, and suggestions for change.

Table 8

Corporate Guidelines, Objectives, and Defaults

CORPORATE GUIDELINES (in spreadsheet and/or rule base)Economic

Price/bbl by year
Decline curve percentage
Escalation percentage--cost, revenue
Discount factor (ROR)
Corporate income tax rate

Financial

Monthly cashflow limits--total, by project
Cashflow by time--total, by project
Maximum working interest percentage

CORPORATE OBJECTIVES (in Rule Base)

Type of well--oil or gas, wildcat or development
Locations--states, counties, formations

CORPORATE DEFAULTS (in Default Well Database)

Well Information - by location shallow, middle and deepest
well, drilling cost/foot, completion cost

Chapter 7

ESP LIMITATIONS, ENHANCEMENTS, AND CONCLUSIONS

ESP is a prototype. A prototype is a necessary first step in defining the problem and the solution path for expert systems development. Prototypes are expected to be replaced, but the lessons learned during development are excellent guides toward future improvements. ESP shows an expert system as a valid method of capturing the expertise of three petroleum experts towards project evaluation.

Each of the three ESP modules demonstrated a different role that an expert system can play in the information system of a company. The Short Cost Module performed like a "smart" front end to a preprogrammed spreadsheet. The Long Cost Module allowed the user access to only relevant data from an unfamiliar database, and provided estimated information when the user had incomplete data. The Revenue Module demonstrated how one expert system can supply information to another expert system.

Limitations and Enhancements

During the knowledge engineering process, it is necessary to stay directed towards the primary goal. Of

necessity, there were numerous instances of delaying the "nice-to-have" items to implement the "must-have" items.

ESP's present form is relatively simple and small, but it was specifically designed to be easily expanded. The form of the knowledge base, using independent databases and spreadsheets as the main sources of domain knowledge, makes the system readily adaptable to database systems already in place with minimum changes to the inference engine which accesses those databases.

Although ESP can implement many of the enhancements discussed below, further consideration should be given to starting a new expert system rather than continuing to build on the prototype. The new system should be substantially more efficient.

Petroleum projects are typically evaluated in two stages. First, the probability of success is determined by the explorationist and evaluated against a risk hurdle rate (Lessenger 1988). Then the well's location, cost, and schedule is evaluated with respect to the company's situation, objectives, and other opportunities. ESP addresses the second-stage evaluation, beginning after the explorationist has investigated and approved the probability of success of a prospect. In ESP, no attempt has been made to evaluate or determine the potential for hitting oil

reserves. An expansion into the first evaluation stage has been done by Lessenger (1988) using Personal Consultant (an expert system shell).

Realistically, information from other than the three principal experts may be solicited for the decision. Much of this information can be included in a database or in the rules coded into the system.

Databases. In the demonstration system, care has been taken to limit the databases to the most essential information for the evaluation. Throughout the report, numerous enhancements have been mentioned. Many could be included in an enhanced version of ESP. A user should determine what other information would be useful for specific needs and incorporate that information into a database or into the heuristics of the system.

For the demonstration system that accompanies this thesis, the databases are limited to the Colorado portion of the Denver Julesberg Basin. The Denver Julesberg Basin includes three geologic plays or strata: Cretaceous Stratigraphic, Fractured Niobrara, and Pennsylvania Stratigraphic Carbonate. Since the Completed Well Data Base and the Default Well Data Base are independent databases, they are easily expandable. Since ESP can access virtually

any database information, the Completed Well Data Base could include numerous improvements, such as item-by-item estimates of well cost, contrasted to the actual cost by range of depths.

Heuristics and Algorithms. The algorithmic portion of the landman's knowledge of the agreement terms is limited to the basic agreement terms. The algorithms include calculations using a working interest percentage and an operator/nonoperator status in the Costs Module. The Revenue Module includes a royalty interest and an overriding royalty interest. Other terms such as farmouts, dry hole contributions, carried working interests, and production payments could be incorporated but have not been included.

A financial advisor should be aware of the current and near-future financial situation as well as potential financial commitments and pending financial opportunities. This data is included in the Pending Projects Database. The ability to predict the timing of cash flows is included in the heuristics and calculations of the system.

Corporate Objectives, Guidelines, and Defaults (Table 8) provide a means to set cash-flow limits, location preferences, and basic calculation instructions in the demonstration system. These limits can be expanded to

include other objectives, guidelines, and defaults to suit individual company situations.

Output and Advice. The Evaluation System for Petroleum assumes the oil (not gas) is sold when produced at the well site. Transportation issues, although obviously important, are not included in the demonstration system. The tax implications advice is limited to federal income tax for deductibility of costs. The Revenue Module deals with the state and local severance taxes applicable in 1988. Numerous decline curve models are available and could be incorporated into the Revenue Module calculations. For the demonstration system, only a constant decline percentage calculation is included.

Expert systems traditionally include some form of confidence factors which allow the evaluation of soft information such as "gut" reactions or intuitive feelings. Such "information" is very useful in the selection of partners and the negotiation process. Unfortunately, some of the intuitive expertise associated with petroleum evaluation is necessarily excluded from the ESP prototype for simplicity.

Environmental issues are important in any extraction industry. State and local regulations can be included in

the location database. Spacing requirements can be offered as advice, triggered by the location, state, county, or township and the fact that this is a development well. Or, if additional surface casing is required to protect ground water, the system could also advise the user of that additional cost. The ESP prototype does not address these factors, but the rule structure, the database, and the advice can be expanded to incorporate environmental requirements.

For years, computer systems personnel have talked of fully integrated management information systems. ESP demonstrates the usability of an expert system to link two unrelated software packages to provide specific management information. Further expansions and improvements are necessary for ESP to be a system accessing and updating the management information system of a company, but this is the first step.

Conclusions

Petroleum contract negotiations exhibit many of the characteristics of an environment in which an expert system can be useful. By nature the terms are complex and the timing of cash outflow is vulnerable to a multitude of influences. As with most negotiations, petroleum contract

negotiations take place between individuals with diverse backgrounds, different objectives, and unique abilities. These differences must be reconciled often in an environment where time is a critical factor.

The Evaluation System for Petroleum uses expert system technology to select, access, or process relevant information to evaluate a project. It gives useful cash-flow information and advice to the user. ESP demonstrates that the expert system is a valid means of capturing much of the expertise required for the second stage of the petroleum project evaluation.

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APPENDIX A
INPUT AND OUTPUT

COST MODULE (SHORT)
ESP INPUT PARAMETERS AND USER QUERY

Parameter Listing

Cost Output Parameters: Final value output to spreadsheet
(C_O_) Set either input by user or deduced
by rule base.

<u>Number</u>	<u>Name</u>	<u>Value</u>
001	C_O_WELL_NAME	Well name
002	C_O_WELL_NUMBER	Well number
003	C_O_WELL_TYPE	Well type: Oil, Gas, W/C, Dev.
004	C_O_DRILL_CREW	Drilling crew: Contractor, Own crew
005	C_O_STATE	State of proposed well
006	C_O_COUNTY	County of proposed well
007	C_O_TOWNSHIP	Township of well, alpha- numeric input ie 27-W
008	C_O_SECTION	Section of well location, alpha-numeric input ie 14-N
009	C_O_RANGE	Range location of proposed well
010	C_O_GEOLOGY	Expected geology at drill site
011	C_O_BASIN	Basin location of proposed well. Menu provided by access to completed wells database, also OTHER.
012	C_O_STRATA	Expected Strata. Menu provided by access to

		completed wells database, also OTHER
013	C_O_SPUD_MONTH	Month of first drilling day. Choices provided: January through December, also UNKNOWN
014	C_O_SPUD_DAY	First day of drilling in Spud Month
015	C_O_OPERATOR	Is user the operator. Choices: Yes, No
016	C_O_LANDOWNER_ROYALTY	The percentage of landowner royalties. Expressed as a decimal value.
017	C_O_OTHER_BURDENS	Total percentage of all other carried revenue interests in addition to royalty and overriding royalty
018	C_O_CASH_CALL	Is the user planning a cash call option. Choices: Yes, No
019	C_O_DEPTH	Projected depth of well
020	C_O_DRILLING_DAYS	Number of days to drill this well
021	C_O_COMPLETION_DAYS	Number of days to complete this well
022	C_O_DRILLING_COST	Projected drilling cost
023	C_O_COMPLETION_COST	Projected completion cost
024	C_O_WORKING_INTEREST	Costs to bear
025	C_O_REVENUE_INTEREST	Revenue received

Initial Query Parameters: Initial Query for these
(I_Q_) parameters. If user enters

unknown (?) rule base will access
databases then second query
(S_Q_).

026	I_Q_DEPTH	Well depth
027	I_Q_DRILLING_COST	Drilling cost
028	I_Q_COMPLETION_COST	Completion cost
029	I_Q_DRILLING_DAYS	Days to drill
030	I_Q_COMPLETION_DAYS	Completion days
031	I_Q_WORKING_INTEREST	Working interest
032	I_Q_REVENUE_INTEREST	Revenue interest

Second Query Parameters: Second query for unknown database
(S_Q_) accessible parameters

033	S_Q_DEPTH	Well depth
034	S_Q_DRILLING_COST	Drilling cost
035	S_Q_COMPLETION_COST	Completion cost
036	S_Q_DRILLING_DAYS	Days to drill
037	S_Q_COMPLETION_DAYS	Completion days
038	S_Q_WORKING_INTEREST	Working interest
039	S_Q_REVENUE_INTEREST	Revenue interest

Recommendation Parameters: Parameters whose values trigger
recommendation screens. Set
either from worksheet access or
calculated from user input

040	MCFI	Monthly Cash Flow Individual. Monthly cost cash flow totals for this well only.
041	MCFI_TOTAL	Monthly Cash Flow

		Individual and Total. Total twenty-four month cash flow
042	COMMITTED_AND_CURRENT	Total cash flow of this well and all other committed and current wells
043	TANG_D_C_PERCENT	Percentage of tangible drilling cost
044	INTANG_D_C_PERCENT	Percentage of intangible drilling cost
045	TANG_C_C_PERCENT	Percentage of tangible completion cost
046	INTANG_C_C_PERCENT	Percentage of intangible completion cost
047	T_D_C_HIGH_OR_LOW	Value of tangible drilling cost: HIGH, LOW, or OK
048	I_D_C_HIGH_OR_LOW	Value of intangible drilling cost: HIGH, LOW, or OK
049	T_C_C_HIGH_OR_LOW	Value of tangible completion cost: HIGH, LOW, or OK
050	I_C_C_HIGH_OR_LOW	Value of intangible completion cost: HIGH, LOW, or OK

Dummy Parameters: Parameters used to trigger rules, other
parameters or prompts for other
parameters

051	D_C_TANG_&_INTANG	Triggers prompts for tangible and intangible drilling costs
052	C_C_TANG_&_INTANG	Triggers prompts for

		tangible and intangible completion costs
053	WORK_&_REV_INTEREST	Triggers help screen if working interest OR revenue interest is unknown
054	Provide_info	Triggers database search if any key parameters are entered as unknown (?) by the user
055	RECOMMENDATIONS_01	Triggers primary recommendation search
056	RECOMMENDATIONS_02	Triggers secondary recommendation search, if any tangible or intangible percentages are out of bounds

Completed Wells Information

Well Name	Number	State	County	Township	Range	Section	Formation	Depth	Days to Drill	Spud Date
ALTA MARTIN	1-33	CO	MOFFAT	10N	93W	33	LEWIS	7652	19	01/05/79
CAMEO 1	20-4	CO	GARFIELD	7S	91W	20	PICE.	4574	43	05/20/85
ETTA THOMAS	16-6	CO	DOLORES	39N	51W	36	DESERT CREEK	6309	20	12/19/85
FASSETT	2-13	CO	LA PLATA	34N	9W	13	FRUITLAND COAL	2675	6	01/27/85
FULTON	1-19	CO	KIT CARSON	9S	48W	19	ARBUCKLE	6600	15	01/09/86
LARSEN	1-12	CO	LA PLATA	34N	9W	12	FRUITLAND COAL	2400	6	01/22/85
PAYNE	1-8	CO	LA PLATA	32N	6W	8	MESA VERDE	5580	11	12/10/82
POMEROY	4-26	CO	LOGAN	7N	54W	26	WFCP	7909	21	02/02/83
ROGER PILGRIM	1-10	CO	MOFFAT	10N	93W	10	LEWIS	9402	38	06/19/79
TRAVIS PARK	1-15	CO	MOFFAT	10N	93W	15	LEWIS	8906	47	02/14/81
OTHER	OTHER	OT	OTHER				OTHER	0	0	

Rig Release Date	Well Type	Status	Basin	Rig Release Cost	Final Cost	\$/ft to Drill	\$/ft to Rig Release	\$/ft Final
01/24/79	DEV	PROD	GREAT DIVIDE	307417	520000	30.27	40.17	67.96
07/02/85	W/C	PROD	WILDCAT	903520	1104170	124.96	197.49	241.35
01/08/86	DEV	PROD	PAPOOSE CANYON	437825	540000	50.73	69.40	85.59
02/02/85	DEV	PROD	IGNATIO	132270	304000	26.65	49.45	113.64
01/24/86	W/C	P&A	WILDCAT	209020	209020	26.28	31.67	31.67
01/28/85	DEV	PROD	IGNATIO	160210	343000	43.92	66.75	142.92
12/21/82	DEV	PROD	IGNATIO	287150	406955	39.70	51.46	72.93
02/23/83	W/C	P&A	WILDCAT	328040	328040	29.46	41.48	41.48
07/27/79	DEV	PROD	GREAT DIVIDE	507463	1300000	39.83	53.97	138.27
04/02/81	DEV	P&A	BIG HOLE	622878	622878	45.56	69.93	69.93
OTHER	OTHER	OTHER	OTHER	0	0	0.00	0.00	0.00

Corporate Defaults by County

County	Depth (S)	\$/foot (S)	Days to Drill (S)	Days to Complete(S)	Cost to Complete(S)
LA PLATA	3000	20.00	9	6	340000
MOFFAT	7000	30.00	19	10	200000
GARFIELD	4000	40.00	25	10	160000
DOLORES	5500	47.00	18	10	100000
KIT CARSON	6000	22.00	15	10	100000
LOGAN	7500	28.00	20	10	120000
OTHER	3000	30.00	10	10	75000

Depth (M)	\$/foot (M)	Days to Drill (M)	Days to Complete (M)	Cost to Complete (M)
4000	28.00	10	6	380000
8000	35.00	30	11	220000
5000	50.00	30	10	180000
6000	50.00	20	10	100000
6500	25.00	16	10	100000
8000	30.00	21	10	120000
6000	40.00	15	12	100000

COST MODULE SPREADSHEET

Well Data		Well Costs		Well Timing		Agreement Terms		Month									
Well Name	JDs Deceiver	Drilling Cost	Intangible	Spud Month	Days to Drilling	Days to Complete	Operator Interest	January	February	March	April	May	June	July	August	September	October
Well Number	36	\$137,825	\$120,740	March	9	0	0.09										
State	Colorado	\$267,073	\$240,804			\$197,021											
County	DOLORES																
Township																	
Section																	
Range																	
State																	
12 month cash flow projection:																	
Drilling Days Per Month	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drilling Out	\$0	\$0	\$240,804	\$197,021	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Drilling Reimbursement	\$0	\$0	\$0	\$219,131	\$179,289	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
IF PRODUCER:																	
Completion Days Per Month	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Completion Out	\$0	\$0	\$0	\$102,175	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Completion Reimbursement	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Revenue In																	
Net Cash Flow (In)	\$0	\$0	\$240,804	\$60,665	(\$272,269)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Completed Projects:																	
Northern Success M 151 C	\$12,000																
Pending Projects:																	
Donna's Whis OPERATOR	\$0	\$0	\$110,000	\$23,000	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0

30.001

REVENUE MODULE SPREADSHEET

Revenue information for:.....TEST		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Well production (BBL's/year):...	91250.00	Royalty:.....	0.13	Revenue							
Decline curve:...	45,000	overriding		NPV:.....	\$1,107,960.70	Drilling costs:..					
Risk adjustment:..	0.90	Royalty interest:	2,500,000	Revenue		Completion costs:					
Annual well cost:	4000.00	Net revenue:	50.00%	Cost escalation:	6.00%	NPV of Well:.....	\$1,107,960.70				
Income tax rate:	28.00%	Interest:.....	1.12	Escalation:	5.00%						
Corporate Guidelines											
Average annual price/BBL											
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Price/BBL:.....	\$20	\$20	\$21	\$22	\$22	\$22	\$22	\$22	\$24	\$24	\$25
Production (BBL's):.....	45,000	40,500	36,450	32,805	29,324	26,372	23,915	21,522	19,371	17,434	15,691
Revenue:.....	\$900,000	\$810,000	\$765,450	\$721,710	\$649,539	\$584,585	\$550,041	\$515,562	\$464,904	\$418,414	\$392,263
State tax:.....	\$45,000	\$40,500	\$38,272	\$36,085	\$32,477	\$29,329	\$27,502	\$25,823	\$23,245	\$20,921	\$19,613
Net revenue:.....	\$855,000	\$769,500	\$727,177	\$685,624	\$617,062	\$555,256	\$522,539	\$490,733	\$441,659	\$397,493	\$372,650
Royalty & ORR:.....	\$128,250	\$115,425	\$109,077	\$102,844	\$92,559	\$83,301	\$78,381	\$73,612	\$66,249	\$59,624	\$55,897
Well costs (Annually):.....	\$4,000	\$4,200	\$4,110	\$4,630	\$4,862	\$5,105	\$5,360	\$5,623	\$5,910	\$6,205	\$6,516
Net revenue	\$722,750	\$649,875	\$613,691	\$578,150	\$519,641	\$466,947	\$438,798	\$411,495	\$369,501	\$331,864	\$310,237
Our net revenue	\$361,375	\$324,937	\$306,845	\$289,075	\$259,820	\$233,474	\$219,399	\$205,747	\$184,750	\$165,832	\$155,118
Our after tax	\$260,190	\$233,955	\$220,929	\$208,134	\$187,071	\$168,101	\$157,967	\$148,138	\$133,020	\$119,399	\$111,685

APPENDIX B
PROGRAM CODE

Program Listing: LONGESP.KBS

*KBX Long Analysis computer
assisted input

*C_0_ indicates final Cost
Output

*I_Q_ indicates Initial
Query

*Immediately starts KB

EXECUTE;

*Single window instead of three

RUNTIME;

*Eliminates need to press end after each entry

ENDOFF;

*Block

ACTIONS

*Program finds values for
the parameters by user input
or by database query according
to the rules

*Display on screen

DISPLAY "

Please enter the following general well information:

PRESS ANY KEY TO CONTINUE~"

*Clears screen

CLS

*Creates menus from Data Bases

```

MENU C_O_COUNTY,ALL,A:\DATABASE\CWELINFO,COUNTY
MENU C_O_BASIN,ALL,A:\DATABASE\CWELINFO,BASIN
MENU
C_O_STRATA,ALL,A:\DATABASE\CWELINFO,FORMATION

```

*Need to know the values of these parameters

```

FIND C_O_WELL_NAME
FIND C_O_WELL_NUMBER
FIND C_O_WELL_TYPE
FIND I_Q_DEPTH
FIND C_O_DRILL_CREW
CLS
DISPLAY "

```

Please enter the following information about well location:

PRESS ANY KEY TO CONTINUE~"

CLS

*Need to know the value of these parameters

```

FIND C_O_STATE
FIND C_O_COUNTY
FIND C_O_TOWNSHIP
FIND C_O_SECTION
FIND C_O_RANGE
CLS
FIND C_O_GEOLOGY
FIND C_O_BASIN
FIND C_O_STRATA
CLS
DISPLAY "

```

Please enter the following information about well costs:

PRESS ANY KEY TO CONTINUE~"

CLS

*Need to know the value of these parameters

```

FIND I_Q_DRILLING_COST

```

```

FIND D_C_TANG_&_INTANG
CLS
FIND I_Q_COMPLETION_COST
FIND C_C_TANG_&_INTANG
CLS
DISPLAY "

```

Please enter the following information about timing:

PRESS ANY KEY TO CONTINUE~"

```

CLS
FIND C_O_SPUD_MONTH
FIND C_O_SPUD_DAY
FIND I_Q_DRILLING_DAYS
FIND I_Q_COMPLETION_DAYS
CLS
DISPLAY "

```

Please enter the following information about
the proposed agreement:

PRESS ANY KEY TO CONTINUE~"

```

CLS

```

*Need to know the value of these parameters

```

FIND I_Q_WORKING_INTEREST
FIND I_Q_REVENUE_INTEREST
FIND WORK_&_REV_INTEREST
FIND C_O_OPERATOR
FIND C_O_LANDOWNER_ROYALTY
FIND C_O_OTHER_BURDENS
CLS
FIND C_O_CASH_CALL
FIND Provide_info
FIND C_O_DEPTH
FIND C_O_DRILLING_DAYS
FIND C_O_COMPLETION_DAYS
FIND C_O_DRILLING_COST
FIND C_O_COMPLETION_COST
FIND C_O_WORKING_INTEREST
FIND C_O_REVENUE_INTEREST

```

DISPLAY "

ESP is now transferring information to the monthly cash flow worksheet.

This will take a few minutes. Please be patient."

*Transfers Parameter values into selected cells of cashflow spreadsheet

PWKS C_O_WELL_NAME,C4,A:COST
 PWKS C_O_WELL_NUMBER,C5,A:COST
 PWKS C_O_STATE,C6,A:COST
 PWKS C_O_COUNTY,C7,A:COST
 PWKS C_O_TOWNSHIP,C8,A:COST
 PWKS C_O_RANGE,C10,A:COST
 PWKS C_O_SECTION,C9,A:COST
 PWKS C_O_STRATA,C11,A:COST
 PWKS C_O_DRILLING_COST,E4,A:COST
 PWKS C_O_TANG_DRILLING_COST,K4,A:COST
 PWKS C_O_INTANG_DRILLING_COST,K5,A:COST
 PWKS C_O_COMPLETION_COST,E8,A:COST
 PWKS C_O_TANG_COMPLETION_COST,K6,A:COST
 PWKS C_O_INTANG_COMPLETION_COST,K7,A:COST
 PWKS C_O_SPUD_MONTH,G4,A:COST
 PWKS C_O_SPUD_DAY,G5,A:COST
 PWKS C_O_DRILLING_DAYS,G6,A:COST
 PWKS C_O_COMPLETION_DAYS,G7,A:COST
 PWKS C_O_OPERATOR,I4,A:COST
 PWKS C_O_WORKING_INTEREST,I5,A:COST
 PWKS C_O_CASH_CALL,I6,A:COST
 CLS

*Retrieves values form worksheet

WKS MCFI,C41..Z41,A:COST
 WKS MCFI_TOTAL,AA41,A:COST
 WKS COMMITTED_AND_CURRENT,C56,A:COST

*Finds tangible and intangible percentages

FIND TANG_D_C_PERCENT
 FIND INTANG_D_C_PERCENT
 FIND TANG_C_C_PERCENT
 FIND INTANG_C_C_PERCENT

*Locates advice bases on financial comparisons

```

FIND RECOMMENDATIONS_01
FIND RECOMMENDATIONS_02
CLS

```

*Questions link to revenue module

```

FIND REVENUE_QUERY;

```

*End of ACTIONS block

=====

*Begin RULES block

*100 series rules decide whether to query for tangible and intangible drilling and completion costs, based on whether drilling costs and completion costs are known.

```

RULE 100
  IF      I_Q_DRILLING_COST <> UNKNOWN
  THEN    D_C_TANG_&_INTANG = YES
          FIND C_O_TANG_DRILLING_COST
          FIND C_O_INTANG_DRILLING_COST
  ELSE    D_C_TANG_&_INTANG = NO;

RULE 101
  IF      I_Q_COMPLETION_COST <> UNKNOWN
  THEN    C_C_TANG_&_INTANG = YES
          FIND C_O_TANG_COMPLETION_COST
          FIND C_O_INTANG_COMPLETION_COST
  ELSE    D_C_TANG_&_INTANG = NO;

RULE 102
  IF      I_Q_DRILLING_COST = UNKNOWN
  THEN    S_Q_D_C_TANG_&_INTANG = YES
          FIND C_O_TANG_DRILLING_COST
          FIND C_O_INTANG_DRILLING_COST
  ELSE    S_Q_D_C_TANG_&_INTANG = NO;

RULE 103
  IF      I_Q_COMPLETION_COST = UNKNOWN
  THEN    S_Q_C_C_TANG_&_INTANG = YES
          FIND C_O_TANG_COMPLETION_COST
          FIND C_O_INTANG_COMPLETION_COST
  ELSE    S_Q_C_C_TANG_&_INTANG = NO;

```



```

END
CLOSE A:\DATABASE\DWELINFO
GET C_O_COUNTY=COUNTY,A:\DATABASE
\DWELINFO,ALL
DISPLAY "

```

Corporate Defaults for {C_O_COUNTY} county:

Well	Depth	Cost/Foot	Days to Drill	Days to Complete	Cost to Complete
----	-----	-----	-----	-----	-----
Shallow	{sdepth}	\$(scstft)	{sdtodril}	{sdtocomp}	\$(scompst)
Medium	{mdepth}	\$(mcstft)	{mdtodril}	{mdtocomp}	\$(mcompst)
Deep	{ddepth}	\$(dcstft)	{ddtodril}	{ddtocomp}	\$(dcompst)

PRESS ANY KEY TO CONTINUE~"

```

CLS
DISPLAY "

```

After reviewing the information provided by E.S.P., please enter information for the following missing values.

PRESS ANY KEY TO CONTINUE~"

```

CLS

```

*Second query for necessary information

```

FIND S_Q_DEPTH
FIND S_Q_DRILLING_DAYS
FIND S_Q_COMPLETION_DAYS
FIND S_Q_DRILLING_COST
FIND S_Q_D_C_TANG_&_INTANG
FIND S_Q_COMPLETION_COST
FIND S_Q_C_C_TANG_&_INTANG;

```

RULE 201

```

IF      I_Q_DEPTH = UNKNOWN OR
        I_Q_DRILLING_COST = UNKNOWN OR
        I_Q_COMPLETION_COST = UNKNOWN OR
        I_Q_DRILLING_DAYS = UNKNOWN OR
        I_Q_COMPLETION_DAYS = UNKNOWN AND

THEN    C_O_COUNTY = OTHER
        Provide_info=ONLY_GENERICDEFAULTS
        CLOSE A:\DATABASE\DWELINFO
        GET C_O_COUNTY=COUNTY,A:\DATABASE
        \DWELINFO,ALL

        DISPLAY "

```

There are no previous records in this database for the county where you are drilling. You may, however use the generic corporate defaults listed below as a source of information for the missing values.

Well Depth	Cost/Foot	Days to Drill	Days to Complete	Cost to Complete
-----	-----	-----	-----	-----
Shallow {sdepth}	#{scstft}	{sdtodril}	{sdtocomp}	#{scompst}
Medium {mdepth}	#{mcstft}	{mdtodril}	{mdtocomp}	#{mcompst}
Deep {ddepth}	#{dcstft}	{ddtodril}	{ddtocomp}	#{dcompst}

PRESS ANY KEY TO CONTINUE~"

```

CLS
DISPLAY "

```

After reviewing the information provided by E.S.P., please enter information for the following missing values.

PRESS ANY KEY TO CONTINUE~"

```

CLS

```

*Second query for necessary information
FIND S_Q_DEPTH

```

FIND S_Q_DRILLING_DAYS
FIND S_Q_COMPLETION_DAYS
FIND S_Q_DRILLING_COST
FIND S_Q_D_C_TANG_&_INTANG
FIND S_Q_COMPLETION_COST
FIND S_Q_C_C_TANG_&_INTANG;

```

```

RULE 202
  IF      I_Q_DEPTH <> UNKNOWN AND
          I_Q_DRILLING_COST <> UNKNOWN
          AND I_Q_COMPLETION_COST <>
          UNKNOWN
          AND I_Q_DRILLING_DAYS <> UNKNOWN
          AND I_Q_COMPLETION_DAYS <>
          UNKNOWN
  THEN    Provide_info = NO;

```

*300 series rules set output values from first or second query

```

RULE 300
  IF      I_Q_DEPTH <> UNKNOWN
  THEN    C_O_DEPTH = (I_Q_DEPTH)
  ELSE    C_O_DEPTH = (S_Q_DEPTH);

RULE 301
  IF      I_Q_DRILLING_DAYS <> UNKNOWN
  THEN    C_O_DRILLING_DAYS =
          (I_Q_DRILLING_DAYS)
  ELSE    C_O_DRILLING_DAYS =
          (S_Q_DRILLING_DAYS);

RULE 302
  IF      I_Q_COMPLETION_DAYS <> UNKNOWN
  THEN    C_O_COMPLETION_DAYS =
          (I_Q_COMPLETION_DAYS)
  ELSE    C_O_COMPLETION_DAYS =
          (S_Q_COMPLETION_DAYS);

RULE 303
  IF      I_Q_DRILLING_COST <> UNKNOWN
  THEN    C_O_DRILLING_COST =
          (I_Q_DRILLING_COST)
  ELSE    C_O_DRILLING_COST =
          (S_Q_DRILLING_COST);

RULE 304
  IF      I_Q_COMPLETION_COST <> UNKNOWN

```

```
THEN      C_Q_COMPLETION_COST =
          (I_Q_COMPLETION_COST)
ELSE      C_Q_COMPLETION_COST =
          (S_Q_COMPLETION_COST);
```

*400 series rules set values for second query if first query is known

```
RULE 400
  IF      I_Q_DEPTH <> UNKNOWN
  THEN    S_Q_DEPTH = ASK_NOT;

RULE 401
  IF      I_Q_DRILLING_DAYS <> UNKNOWN
  THEN    S_Q_DRILLING_DAYS = ASK_NOT;

RULE 402
  IF      I_Q_COMPLETION_DAYS <> UNKNOWN
  THEN    S_Q_COMPLETION_DAYS = ASK_NOT;

RULE 403
  IF      I_Q_DRILLING_COST <> UNKNOWN
  THEN    S_Q_DRILLING_COST = ASK_NOT;

RULE 404
  IF      I_Q_COMPLETION_COST <> UNKNOWN
  THEN    S_Q_COMPLETION_COST = ASK_NOT;
```

*500 series rules trigger recommendations.

```

RULE 500
  IF      MCFI[1] > 100000 OR MCFI[2] >
          100000 OR MCFI[3] > 100000 OR
          MCFI[4] > 100000 OR MCFI[5] >
          100000 OR MCFI[6] > 100000 OR
          MCFI[7] > 100000 OR MCFI[8] >
          100000 OR MCFI[9] > 100000 OR
          MCFI[10] > 100000 OR MCFI[11] >
          100000 OR MCFI[12] > 100000 OR
          MCFI[13] > 100000 OR MCFI[14] >
          100000 OR MCFI[15] > 100000 OR
          MCFI[16] > 100000 OR MCFI[17] >
          100000 OR MCFI[18] > 100000 OR
          MCFI[19] > 100000 OR MCFI[20] >
          100000 OR MCFI[21] > 100000 OR
          MCFI[22] > 100000 OR MCFI[23] >
          100000 OR MCFI[24] > 100000
  THEN   RECOMMENDATIONS_01=CASH_FLOW_HIGH

```

```

CLS
FIND MONTH

```

```

DISPLAY "

```

Corporate monthly cash flow exceeds the \$100,000.00 limit
in the following month(s): {MONTH}

Suggest:

Change spud date or
Become a non-operator or
Reduce your working interest.

PRESS ANY KEY TO CONTINUE~"

BECAUSE "A corporate guideline of
not more than \$100,000
has been set for monthly
cash flow.";

```
RULE 501
  IF      MCFI_TOTAL > 50000
  THEN    RECOMMENDATIONS_01 =
          INVESTMENT_HIGH
          CLS
          DISPLAY "
```

Potential investment in {C_O_WELL_NAME} exceeds corporate guidelines.

Suggest:

Reduce working interest.

AUTHORIZATION REQUIRED FROM V.P. FINANCE BEFORE
COMMITMENT ON {C_O_WELL_NAME} PROJECT!

PRESS ANY KEY TO CONTINUE~";

```
RULE 502
  IF      COMMITTED_AND_CURRENT > 100000
  THEN    RECOMMENDATIONS_01 =
          COMMITTED_AND_CURRENT_HIGH
          CLS
```

DISPLAY "

Monthly outflow for committed projects combined with this project exceeds corporate limit.

Suggest:

Changing spud date or
becoming a non-operator or
taking a smaller working interest position.

PRESS ANY KEY TO CONTINUE~";

```

RULE 503
  IF      TANG_D_C_PERCENT < .30 OR
          TANG_D_C_PERCENT > .35
  THEN    RECOMMENDATIONS_03 =
          TANGIBLE_D_C_OUT_OF_RANGE
          FIND T_D_C_HIGH_OR_LOW
  ELSE    T_D_C_HIGH_OR_LOW = OK;

RULE 504
  IF      TANG_D_C_PERCENT < .3
  THEN    T_D_C_HIGH_OR_LOW = low;

RULE 505
  IF      TANG_D_C_PERCENT > .35
  THEN    T_D_C_HIGH_OR_LOW = high;

RULE 506
  IF      INTANG_D_C_PERCENT < .65 OR
          INTANG_D_C_PERCENT > .70
  THEN    RECOMMENDATIONS_04 =
          INTANGIBLE_D_C_OUT_OF_RANGE
          FIND I_D_C_HIGH_OR_LOW
  ELSE    I_D_C_HIGH_OR_LOW = OK;

RULE 507
  IF      INTANG_D_C_PERCENT < .65
  THEN    I_D_C_HIGH_OR_LOW = low;

RULE 508
  IF      INTANG_D_C_PERCENT > .70
  THEN    I_D_C_HIGH_OR_LOW = high;

RULE 509
  IF      TANG_C_C_PERCENT < .85 OR

```

```

                TANG_C_C_PERCENT > .95
THEN            RECOMMENDATIONS_05 =
                TANGIBLE_C_C_OUT_OF_RANGE
                FIND T_C_C_HIGH_OR_LOW
ELSE            T_C_C_HIGH_OR_LOW = OK;

RULE 510
IF              TANG_C_C_PERCENT <.85
THEN            T_C_C_HIGH_OR_LOW = low;

RULE 511
IF              TANG_C_C_PERCENT > .95
THEN            T_C_C_HIGH_OR_LOW = high;

RULE 512
IF              INTANG_C_C_PERCENT < .05 OR
                INTANG_C_C_PERCENT > .15
THEN            RECOMMENDATIONS_06 =
                INTANGIBLE_C_C_OUT_OF_RANGE
                FIND I_C_C_HIGH_OR_LOW
ELSE            I_C_C_HIGH_OR_LOW = OK;

RULE 513
IF              INTANG_C_C_PERCENT <.05
THEN            I_C_C_HIGH_OR_LOW = low;

RULE 514
IF              INTANG_C_C_PERCENT > .15
THEN            I_C_C_HIGH_OR_LOW = high;

RULE 515
IF
RECOMMENDATIONS_03 <> UNKNOWN OR
RECOMMENDATIONS_04 <> UNKNOWN OR
RECOMMENDATIONS_05 <> UNKNOWN OR
RECOMMENDATIONS_06 <> UNKNOWN
THEN            RECOMMENDATIONS_02 = NEED_INFO_01
                DISPLAY "
```

ESP has determined that one or more of your cost breakdowns falls outside a given range:

Tangible drilling costs are {T_D_C_HIGH_OR_LOW}.
 Intangible drilling costs are {I_D_C_HIGH_OR_LOW}.
 Tangible completion costs are {T_C_C_HIGH_OR_LOW}.
 Intangible completion costs are {I_C_C_HIGH_OR_LOW}.

The following relationships are common in Colorado:

Of Total -----		Tangible -----	Intangible -----
60-70%	Drilling Costs = 100%	30-35%	65-70%
30 40%	Completion Costs = 100%	90%	10%
----- 100%			

PRESS ANY KEY TO CONTINUE~";

```

RULE 516
IF          C_O_WORKING_INTEREST > .25
THEN       RECOMMENDATIONS_01 =
           WORKING_INTEREST_HIGH
           CLS
           DISPLAY "
    
```

Corporate policy is to keep working interest below 25%

Suggest:

Reduce working interest.

AUTHORIZATION REQUIRED FROM V.P. FINANCE BEFORE
 COMMITMENT ON {C_O_WELL_NAME} PROJECT!

PRESS ANY KEY TO CONTINUE~"

BECAUSE "A working interest percentage (the percentage of costs which you will bear) is necessary in order to calculate the monthly cash flow. Working interest is usually kept

below 33 percent.";

```

RULE 517
  IF      I_Q_WORKING_INTEREST = UNKNOWN OR
          I_Q_REVENUE_INTEREST = UNKNOWN
  THEN    WORK_&_REV_INTEREST= NEED_INFO_02
          DISPLAY "

```

ESP needs to know the working interest percentage.
 The following revenue and working interests are common:

	DIVISION OF	
	COSTS	REVENUE
Landowner Royalty	0%	12.5-15%
Overriding Royalty	0%	0-3%

Net Revenue Interest (NRI)	100%	82-87%
Working Interest of NRI (1/3 for 1/4)		
Drilling		
For each of 3 partners	33%	25%
For Managing Partner	0%	25%
Completion		
For each of 3 partners	25%	25%
For Managing Partner	25%	25%

PRESS ANY KEY TO CONTINUE~"

```

CLS
FIND S_Q_WORKING_INTEREST
FIND S_Q_REVENUE_INTEREST

```

BECAUSE "Working interest (the percentage of costs you will bear) is necessary in order to calculate the monthly cash flow.";

```

RULE 518
  IF      I_Q_WORKING_INTEREST <> UNKNOWN
          AND I_Q_REVENUE_INTEREST <>
          UNKNOWN
  THEN    WORK_&_REV_INTEREST =
          NOT_NEED_INFO_02;

```

```

RULE 519
  IF      I_Q_WORKING_INTEREST <> UNKNOWN
  THEN    C_O_WORKING_INTEREST =
          (I_Q_WORKING_INTEREST)
  ELSE    C_O_WORKING_INTEREST =
          (S_Q_WORKING_INTEREST);

RULE 520
  IF      I_Q_REVENUE_INTEREST <> UNKNOWN
  THEN    C_O_REVENUE_INTEREST =
          (I_Q_REVENUE_INTEREST)
  ELSE    C_O_REVENUE_INTEREST =
          (S_Q_REVENUE_INTEREST);

RULE 521
  IF      I_Q_WORKING_INTEREST <> UNKNOWN
  THEN    S_Q_WORKING_INTEREST = ASK_NOT

RULE 522
  IF      I_Q_REVENUE_INTEREST <> UNKNOWN
  THEN    S_Q_REVENUE_INTEREST = ASK_NOT

```

*600 series rules find value for month(s) of overextension

```

RULE 600
  IF      MCFI[1] > 1000 OR MCFI[13] >
          100000
  THEN    MONTH = JANUARY;

RULE 601
  IF      MCFI[2] > 100000 OR MCFI[14] >
          100000
  THEN    MONTH = FEBRUARY;

RULE 602
  IF      MCFI[3] > 100000 OR MCFI[15] >
          100000
  THEN    MONTH = MARCH;

RULE 603
  IF      MCFI[4] > 100000 OR MCFI[16] >
          100000
  THEN    MONTH = APRIL;

RULE 604
  IF      MCFI[5] > 100000 OR MCFI[17] >
          100000

```

```

        THEN          MONTH = MAY;

RULE 605
  IF          MCFI[6] > 100000 OR MCFI[18] >
             100000
  THEN       MONTH = JUNE;

RULE 606
  IF          MCFI[7] > 100000 OR MCFI[19] >
             100000
  THEN       MONTH = JULY;

RULE 607
  IF          MCFI[8] > 100000 OR MCFI[20] >
             100000
  THEN       MONTH = AUGUST;

RULE 608
  IF          MCFI[9] > 100000 OR MCFI[21] >
             100000
  THEN       MONTH = SEPTEMBER;

RULE 609
  IF          MCFI[10] > 100000 OR MCFI[22] >
             100000
  THEN       MONTH = OCTOBER;

RULE 610
  IF          MCFI[11] > 100000 OR MCFI[23] >
             100000
  THEN       MONTH = NOVEMBER;

RULE 611
  IF          MCFI[12] > 100000 OR MCFI[24] >
             100000
  THEN       MONTH = DECEMBER;

```

*700 series rules find values for tangible and intangible percentages

```

RULE 700
  IF          C_O_TANG_DRILLING_COST > 1
  THEN       TANG_D_C_PERCENT =
             (C_O_TANG_DRILLING_COST /
              C_O_DRILLING_COST)
  ELSE       TANG_D_C_PERCENT =
             (C_O_TANG_DRILLING_COST)

```

```

BECAUSE "Tangible drilling cost is
         necessary to calculate the tax
         implications on the cash flow
         spreadsheet.";

RULE 701
IF      C_O_INTANG_DRILLING_COST > 1
THEN    INTANG_D_C_PERCENT =
        (C_O_INTANG_DRILLING_COST /
         C_O_DRILLING_COST)
ELSE    INTANG_D_C_PERCENT =
        (C_O_INTANG_DRILLING_COST)

BECAUSE "Intangible drilling cost is
         necessary to calculate the tax
         implications on the cash flow
         spreadsheet.";

RULE 702
IF      C_O_TANG_COMPLETION_COST > 1
THEN    TANG_C_C_PERCENT =
        (C_O_TANG_COMPLETION_COST /
         C_O_COMPLETION_COST)
ELSE    TANG_C_C_PERCENT =
        (C_O_TANG_COMPLETION_COST)

BECAUSE "Tangible completion cost is
         necessary to calculate the tax
         implications on the cash flow
         spreadsheet.";

RULE 703
IF      C_O_INTANG_COMPLETION_COST > 1
THEN    INTANG_C_C_PERCENT =
        (C_O_INTANG_COMPLETION_COST /
         C_O_COMPLETION_COST)
ELSE    INTANG_C_C_PERCENT =
        (C_O_INTANG_COMPLETION_COST)

BECAUSE "Intangible completion cost is
         necessary to calculate the tax
         implications on the cash flow
         spreadsheet.";

```

*800 series rules chain to revenue module

RULE 800

```

IF          REVENUE_OR_QUIT = REVENUE_MODULE
THEN       REVENUE_QUERY = YES
          SAVEFACTS FACTS
          CHAIN A:REVENUE;

```

*End of RULES block

=====
*Begin STATEMENTS block

*Prompts to ask user to set values for parameters in rules

```

ASK C_O_WELL_NAME: "What is the name of the
                   proposed well?";
ASK C_O_WELL_NUMBER: "What is the identification
                     number of the proposed
                     well?";
ASK C_O_WELL_TYPE: "What type of well will this
                   be?";
ASK I_Q_DEPTH: "What is the projected depth of
               this well?";
ASK C_O_DRILL_CREW: "Will you be drilling with
                   your own crew or a hired
                   contractor?";
ASK C_O_STATE: "In what state are you
               drilling?";
ASK C_O_COUNTY: "In what county are you
                drilling?";
ASK C_O_SECTION: "In what section are you
                 drilling?";
ASK C_O_TOWNSHIP: "In what township are you
                  drilling?";
ASK C_O_RANGE: "In what range are you
               drilling?";
ASK C_O_GEOLOGY: "What geology do you expect to
                 find at the drill site?";
ASK C_O_BASIN: "In what basin are you
               drilling?";
ASK C_O_STRATA: "In what type of strata do you
                expect to find oil or gas?";
ASK C_O_SPUD_DAY: "What day of {C_O_SPUD_MONTH}
                  will you begin drilling? (ie
                  1-30)";
ASK C_O_SPUD_MONTH: "In what month will you
                    begin drilling";
ASK I_Q_DRILLING_DAYS: "How many days will this
                       well take to drill? (max

```

```
90)";  
ASK I_Q_COMPLETION_DAYS: "How many days will it  
take to complete this  
well?";  
ASK I_Q_WORKING_INTEREST: "What is your working  
interest in the  
proposed project?  
(please enter in  
decimal form. ie  
.07)";
```

ASK I_Q_REVENUE_INTEREST: "What is your revenue interest in the proposed project? (please enter in decimal form. ie .07)";

ASK C_O_OPERATOR: "Will you be the operator?";

ASK C_O_LANDOWNER_ROYALTY: "What is the landowner royalty?";

ASK C_O_OTHER_BURDENS: "What is the total percentage of all other burdens?";

ASK C_O_CASH_CALL: "Are you planning a cash call?";

ASK I_Q_DRILLING_COST: "What is your estimate for drilling cost?";

ASK I_Q_COMPLETION_COST: "What is your estimate for completion cost?";

ASK S_Q_DEPTH: "Please enter your estimate for depth";

ASK S_Q_DRILLING_DAYS: "Please enter your estimate for number of days to drill";

ASK S_Q_COMPLETION_DAYS: "Please enter your estimate for number of days to complete";

ASK S_Q_DRILLING_COST: "Please enter your estimate for drilling cost";

ASK S_Q_COMPLETION_COST: "Please enter your estimate for completion cost";

ASK REVENUE_OR_QUIT: "Would you like to analyze revenue for this project?";

ASK C_O_TANG_DRILLING_COST: "What are your tangible drilling costs? (Enter as a dollar amount excluding the dollar sign or as a percentage in decimal format)";

ASK C_O_INTANG_DRILLING_COST: "What are your intangible drilling costs? (Enter as a dollar amount

```

                                excluding the
                                dollar sign or
                                as a percentage
                                in decimal
                                format)";
ASK C_O_TANG_COMPLETION_COST: "What are your
                                tangible
                                completion costs?
                                (Enter as a
                                dollar amount
                                excluding the
                                dollar sign or as
                                a percentage in
                                decimal format)";
ASK C_O_INTANG_COMPLETION_COST: "What are your
                                intangible
                                completion
                                costs?
                                (Enter as a
                                dollar amount
                                excluding the
                                dollar sign or
                                as a percentage
                                in decimal
                                format)";

```

* Menu choices available in program

```

CHOICES C_O_WELL_TYPE: OIL,GAS,DEV,W-C,UNKNOWN;
CHOICES C_O_DRILL_CREW: CREW,CONTRACTOR;
CHOICES C_O_SPUD_MONTH:JANUARY,FEBRUARY,MARCH,
                        APRIL ,MAY,JUNE,JULY,
                        AUGUST,SEPTEMBER,OCTOBER,
                        NOVEMBER,DECEMBER,
                        UNKNOWN;
CHOICES C_O_OPERATOR: YES,NO;
CHOICES C_O_CASH_CALL: YES,NO;
CHOICES REVENUE_OR_QUIT: REVENUE_MODULE,QUIT;
CHOICES ACCESS_TO_COST: YES,NO;

PLURAL: RECOMMENDATIONS_01,RECOMMENDATIONS_03;
PLURAL: MONTH;

```

*END KBS Long Analysis

Program Listing: SHORTESP.KBS

*Begin KBS Short Analysis - use only if all input known
 *Immediately starts KB

EXECUTE;

*Single window instead of three windows

RUNTIME;

*Eliminates need to press end after each entry

ENDOFF;

*Actions Block

*Program finds values for the parameters by user
 input or rules

ACTIONS

The following values are set to "" to clear invalid
 spreadsheet information from last consultation

C_O_WELL_NUMBER = *
 C_O_STATE = *
 C_O_COUNTY = *
 C_O_TOWNSHIP = *
 C_O_SECTION = *
 C_O_RANGE = *
 C_O_STRATA = *

*The following items must be user input in the short
 analysis

FIND C_O_WELL_NAME
 CLS
 FIND C_O_DRILLING_COST
 CLS
 FIND C_O_TANG_DRILLING_COST
 FIND C_O_INTANG_DRILLING_COST
 CLS
 FIND C_O_COMPLETION_COST
 CLS
 FIND C_O_TANG_COMPLETION_COST
 FIND C_O_INTANG_COMPLETION_COST
 CLS

```

FIND C_O_SPUD_MONTH
FIND C_O_SPUD_DAY
CLS
FIND C_O_DRILLING_DAYS
FIND C_O_COMPLETION_DAYS
CLS
FIND C_O_WORKING_INTEREST
FIND C_O_OPERATOR_STATUS
FIND C_O_CASH_CALL
CLS
DISPLAY "

```

ESP is now transferring information to the monthly cash flow worksheet. This will take a few minutes. Please be patient."

*Transfers parameter values into selected cells of cash flow spreadsheet.

```

DISPLAY "Transferring well name"
PWKS C_O_WELL_NAME,C4,A:COST
DISPLAY "Transferring drilling cost"
PWKS C_O_DRILLING_COST,E4,A:COST
PWKS C_O_TANG_DRILLING_COST,K4,A:COST
PWKS C_O_INTANG_DRILLING_COST,K5,A:COST
DISPLAY "Transferring completion cost"
PWKS C_O_COMPLETION_COST,E8,A:COST
PWKS C_O_TANG_COMPLETION_COST,K6,A:COST
PWKS C_O_INTANG_COMPLETION_COST,K7,A:COST
DISPLAY "Transferring spud date"
PWKS C_O_SPUD_DAY,G5,A:COST
DISPLAY "Transferring drilling days"
PWKS C_O_DRILLING_DAYS,G6,A:COST
DISPLAY "Transferring completion days"
PWKS C_O_COMPLETION_DAYS,G7,A:COST
DISPLAY "Transferring working interest"
PWKS C_O_WORKING_INTEREST,I5,A:COST
DISPLAY "Transferring operator status"
PWKS C_O_OPERATOR_STATUS,I4,A:COST
DISPLAY "Clearing non-essential values"
PWKS C_O_WELL_NUMBER,C5,A:COST
PWKS C_O_STATE,C6,A:COST
PWKS C_O_COUNTY,C7,A:COST
PWKS C_O_TOWNSHIP,C8,A:COST
PWKS C_O_SECTION,C9,A:COST
PWKS C_O_RANGE,C10,A:COST
PWKS C_O_STRATA,C11,A:COST

```

```

PWKS C_O_SPUD_MONTH,G4,A:COST
PWKS C_O_CASH_CALL,I6,A:COST

```

```

DISPLAY "ESP is now checking the worksheet for
        problems"

```

```

WKS MCFI,C41..Z41,A:COST
WKS MCFI_TOTAL,AA41,A:COST
WKS COMMITTED_AND_CURRENT,C56,A:COST
FIND TANG_D_C_PERCENT
FIND INTANG_D_C_PERCENT
FIND TANG_C_C_PERCENT
FIND INTANG_C_C_PERCENT
FIND RECOMMENDATIONS_01
FIND RECOMMENDATIONS_02
CLS
FIND REVENUE_QUERY;

```

*End of ACTIONS Block

=====

*Begin RULES Block

*500 series rules offer recommendations

```

RULE 500
  IF      MCFI[1] > 100000 OR MCFI[2] >
          100000 OR MCFI[3] > 100000 OR
          MCFI[4] > 100000 OR MCFI[5] >
          100000 OR MCFI[6] > 100000 OR
          MCFI[7] > 100000 OR MCFI[8] >
          100000 OR MCFI[9] > 100000 OR
          MCFI[10] > 100000 OR MCFI[11] >
          100000 OR MCFI[12] > 100000 OR
          MCFI[13] > 100000 OR MCFI[14] >
          100000 OR MCFI[15] > 100000 OR
          MCFI[16] > 100000 OR MCFI[17] >
          100000 OR MCFI[18] > 100000 OR
          MCFI[19] > 100000 OR MCFI[20] >
          100000 OR MCFI[21] > 100000 OR
          MCFI[22] > 100000 OR MCFI[23] >
          100000 OR MCFI[24] > 100000
  THEN   RECOMMENDATIONS_01=CASH_FLOW_HIGH
          CLS
          FIND MONTH
          DISPLAY "

```

Corporate monthly cash flow exceeds the \$100,000.00 limit
in the following month(s): {MONTH}

Suggest:

Change spud date or
Become a non-operator or
Reduce your working interest.

PRESS ANY KEY TO CONTINUE~"

```
ELSE      RECOMMENDATIONS_01 = CASH_FLOW_OK
          CLS
          DISPLAY "
```

Monthly cash flow is within corporate guidelines for this
project.

PRESS ANY KEY TO CONTINUE~"

BECAUSE "A corporate guideline of not more
than \$100,000 has been set for
monthly cash flow.";

```
RULE 501
  IF      MCFI_TOTAL > 50000
  THEN    RECOMMENDATIONS_01 =
          INVESTMENT_HIGH
          CLS
          DISPLAY "
```

Potential investment in {C_O_WELL_NAME} exceeds corporate
guidelines.

Suggest:

Reduce working interest.

AUTHORIZATION REQUIRED FROM V.P. FINANCE BEFORE
COMMITTMENT ON {C_O_WELL_NAME} PROJECT!

PRESS ANY KEY TO CONTINUE~"

```
ELSE      RECOMMENDATIONS_01 = INVESTMENT_OK
          CLS
          DISPLAY "
```

Total potential investment in {C_O_WELL_NAME} is within corporate guidelines.

PRESS ANY KEY TO CONTINUE~"

BECAUSE "A corporate guideline of \$50,000 has been set for total expenditure.";

```

RULE 502
  IF      WORKING_INTEREST > .25
  THEN    RECOMMENDATIONS_01 =
          WORKING_INTEREST_HIGH
          CLS
          DISPLAY "

```

Corporate policy is to keep working interest below 25%

Suggest:

Reduce working interest.

AUTHORIZATION REQUIRED FROM V.P. FINANCE BEFORE
COMMITTMENT ON {C_O_WELL_NAME} PROJECT!

PRESS ANY KEY TO CONTINUE~"

BECAUSE "A working interest percentage (the percentage of costs which you will bear) is necessary in order to calculate the monthly cash flow. Working interest is usually kept below 33 percent.";

```

RULE 503
  IF      COMMITTED_AND_CURRENT > 100000 AND
          C_O_OPERATOR_STATUS = YES
  THEN    RECOMMENDATIONS_01 =
          COMMITTED_AND_CURRENT_HIGH
          CLS
          DISPLAY "

```

Monthly outflow for committed projects combined with this project exceeds corporate limit.

Suggest:

Changing spud date or
becoming a non-operator or
taking a smaller working interest position.

PRESS ANY KEY TO CONTINUE~"

```
ELSE      RECOMMENDATIONS_01 =
          COMMITTED_AND_CURRENT_OK
          CLS
          DISPLAY "
```

This project combined with committed projects falls within corporate cashflow guidelines

PRESS ANY KEY TO CONTINUE~"

BECAUSE "A total monthly expenditure of \$100000 has been approved for all committed projects.";

```
RULE 504
  IF      RECOMMENDATIONS_03 <> UNKNOWN OR
          RECOMMENDATIONS_04 <>
          UNKNOWN OR RECOMMENDATIONS_05 <>
          UNKNOWN OR RECOMMENDATIONS_06 <>
          UNKNOWN
  THEN   RECOMMENDATIONS_02 = NEED_INFO_01
          CLS
          DISPLAY "
```

ESP has determined that one or more of your cost breakdowns falls outside a given range:

Tangible drilling costs are {T_D_C_HIGH_OR_LOW}.
Intangible drilling costs are {I_D_C_HIGH_OR_LOW}.
Tangible completion costs are {T_C_C_HIGH_OR_LOW}.
Intangible completion costs are {I_C_C_HIGH_OR_LOW}.

PRESS ANY KEY TO CONTINUE~"

CLS
DISPLAY "

The following relationships are common in Colorado:

Of Total		Tangible	Intangible
-----		-----	-----
60-70%	Drilling Costs = 100%	30-35%	65-70%
30 40%	Completion Costs = 100%	90%	10%

100%			

PRESS ANY KEY TO CONTINUE~";

RULE 505
IF WORKING_INTEREST = UNKNOWN
THEN C_O_WORKING_INTEREST = NEED_INFO_02
DISPLAY "

ESP needs to know the working interest percentage.

The following revenue and working interests are common:

	DIVISION OF	
	COSTS	REVENUE
Landowner Royalty	0%	12.5-15%
Overriding Royalty	0%	0-3%
	-----	-----
Net Revenue Interest (NRI)	100%	82-87%

PRESS ANY KEY TO CONTINUE~"

CLS
DISPLAY "

Working Interest of NRI (1/3 for 1/4)

Drilling		
For each of 3 partners	33%	25%
For Managing Partner	0%	25%
Completion		
For each of 3 partners	25%	25%
For Managing Partner	25%	25%

PRESS ANY KEY TO CONTINUE~"

```

RESET C_O_WORKING_INTEREST
FIND C_O_WORKING_INTEREST
BECAUSE "Working interest (the
         percentage of costs you
         will bear) is necessary in
         order to calculate the
         monthly cash flow.";

```

```

RULE 506
IF      WORKING_INTEREST <> UNKNOWN
THEN    C_O_WORKING_INTEREST =
        (WORKING_INTEREST)
FIND    C_O_WORKING_INTEREST
BECAUSE "Working interest (the
         percentage of costs you
         will bear) is necessary in
         order to calculate the
         monthly cash flow.";

```

*600 series rules provide a value for month of overextension

```

RULE 600
IF      MCFI[1] > 100000 OR MCFI[13] >
        100000
THEN    MONTH = JANUARY;

RULE 601
IF      MCFI[2] > 100000 OR MCFI[14] >
        100000
THEN    MONTH = FEBRUARY;

RULE 602
IF      MCFI[3] > 100000 OR MCFI[15] >
        100000
THEN    MONTH = MARCH;

RULE 603
IF      MCFI[4] > 100000 OR MCFI[16] >
        100000
THEN    MONTH = APRIL;

RULE 604
IF      MCFI[5] > 100000 OR MCFI[17] >
        100000

```

```

        THEN      MONTH = MAY;

RULE 605
  IF      MCFI[6] > 100000 OR MCFI[18] >
          100000
  THEN    MONTH = JUNE;

RULE 606
  IF      MCFI[7] > 100000 OR MCFI[19] >
          100000
  THEN    MONTH = JULY;

RULE 607
  IF      MCFI[8] > 100000 OR MCFI[20] >
          100000
  THEN    MONTH = AUGUST;

RULE 608
  IF      MCFI[9] > 100000 OR MCFI[21] >
          100000
  THEN    MONTH = SEPTEMBER;

RULE 609
  IF      MCFI[10] > 100000 OR MCFI[22] >
          100000
  THEN    MONTH = OCTOBER;

RULE 610
  IF      MCFI[11] > 100000 OR MCFI[23] >
          100000
  THEN    MONTH = NOVEMBER;

RULE 611
  IF      MCFI[12] > 100000 OR MCFI[24] >
          100000
  THEN    MONTH = DECEMBER;

```

*700 series rules find values for tangible and intangible percentages

```

RULE 700
  IF      TANG_D_C_PERCENT < .30 OR
          TANG_D_C_PERCENT > .35
  THEN    RECOMMENDATIONS_03 =
          TANGIBLE_D_C_OUT_OF_RANGE
          FIND T_D_C_HIGH_OR_LOW
  ELSE    T_D_C_HIGH_OR_LOW = OK;

```

```
RULE 701
  IF      TANG_D_C_PERCENT < .3
  THEN    T_D_C_HIGH_OR_LOW = low;

RULE 702
  IF      TANG_D_C_PERCENT > .35
  THEN    T_D_C_HIGH_OR_LOW = high;

RULE 703
  IF      INTANG_D_C_PERCENT < .65 OR
          INTANG_D_C_PERCENT > .70
  THEN    RECOMMENDATIONS_04 =
          INTANGIBLE_D_C_OUT_OF_RANGE
          FIND I_D_C_HIGH_OR_LOW
  ELSE    I_D_C_HIGH_OR_LOW = OK;

RULE 704
  IF      INTANG_D_C_PERCENT < .65
  THEN    I_D_C_HIGH_OR_LOW = low;

RULE 705
  IF      INTANG_D_C_PERCENT > .70
  THEN    I_D_C_HIGH_OR_LOW = high;

RULE 705
  IF      TANG_C_C_PERCENT < .85 OR
          TANG_C_C_PERCENT > .95
  THEN    RECOMMENDATIONS_05 =
          TANGIBLE_C_C_OUT_OF_RANGE
          FIND T_C_C_HIGH_OR_LOW
  ELSE    T_C_C_HIGH_OR_LOW = OK;

RULE 706
  IF      TANG_C_C_PERCENT < .85
  THEN    T_C_C_HIGH_OR_LOW = low;

RULE 707
  IF      TANG_C_C_PERCENT > .95
  THEN    T_C_C_HIGH_OR_LOW = high;

RULE 708
  IF      INTANG_C_C_PERCENT < .05 OR
          INTANG_C_C_PERCENT > .15
  THEN    RECOMMENDATIONS_06 =
          INTANGIBLE_C_C_OUT_OF_RANGE
          FIND I_C_C_HIGH_OR_LOW
  ELSE    I_C_C_HIGH_OR_LOW = OK;
```

```

RULE 709
  IF      INTANG_C_C_PERCENT < .05
  THEN    I_C_C_HIGH_OR_LOW = low;

RULE 710
  IF      INTANG_C_C_PERCENT > .15
  THEN    I_C_C_HIGH_OR_LOW = high;

RULE 711
  IF      C_O_TANG_DRILLING_COST > 1
  THEN    TANG_D_C_PERCENT =
          (C_O_TANG_DRILLING_COST /
           C_O_DRILLING_COST)
  ELSE    TANG_D_C_PERCENT =
          (C_O_TANG_DRILLING_COST)
  BECAUSE "Tangible drilling cost
          is necessary to
          calculate the tax
          implications on the
          cash flow
          spreadsheet.";

RULE 712
  IF      C_O_INTANG_DRILLING_COST > 1
  THEN    INTANG_D_C_PERCENT =
          (C_O_INTANG_DRILLING_COST /
           C_O_DRILLING_COST)
  ELSE    INTANG_D_C_PERCENT =
          (C_O_INTANG_DRILLING_COST)
  BECAUSE "Intangible drilling
          cost is necessary to
          calculate the tax
          implications on the
          cash flow
          spreadsheet.";

RULE 713
  IF      C_O_TANG_COMPLETION_COST > 1
  THEN    TANG_C_C_PERCENT =
          (C_O_TANG_COMPLETION_COST /
           C_O_COMPLETION_COST)
  ELSE    TANG_C_C_PERCRNT =
          (C_O_TANG_COMPLETION_COST)
  BECAUSE "Tangible completion
          cost is necessary to
          calculate the tax
          implications on the
          cash flow

```

spreadsheet.";

```

RULE 714
  IF      C_O_INTANG_COMPLETION_COST > 1
  THEN    INTANG_C_C_PERCENT =
          (C_O_INTANG_COMPLETION_COST /
           C_O_COMPLETION_COST)
  ELSE    INTANG_C_C_PERCRNT =
          (C_O_INTANG_COMPLETION_COST)
  BECAUSE "Intangible completion
           cost is necessary to
           calculate the tax
           implications on the
           cash flow
           spreadsheet.";
```

*800 series rules decide whether to chain to revenue module

```

RULE 800
  IF      REVENUE_OR_QUIT = REVENUE_MODULE
  THEN    REVENUE_QUERY = YES
          SAVEFACTS FACTS
          CHAIN A:REVENUE
  BECAUSE "ESP would like to know
           if you would like to
           examine the revenue for
           this project.  If you
           answer yes ESP will
           activate the revenue
           module.";
```

End of Rules Block

=====

Begin STATEMENTS block

*Prompts to ask user to set values for parameters

```

ASK C_O_WELL_NAME: "What is the name of the
                   proposed well?";
ASK C_O_DRILLING_COST: "What is your projected
                       drilling cost?";
ASK C_O_COMPLETION_COST: "After rig release,
                          what is your projected
                          completion cost?";
```


*END KBS Short Analysis

Program Listing REVENUE.KBS

*Immediately starts Knowledge Base

EXECUTE;

*Single window instead of three windows

RUNTIME;

*Eliminates need to press END after each entry

ENDOFF;

*Program finds values for the Parameters by user input or rules

ACTIONS

LOADFACTS FACTS

FIND R_O_WELL_PRODUCTION

FIND R_O_DECLINE_CURVE

FIND R_O_RISK_ADJUSTMENT

FIND R_O_ANNUAL_WELL_COSTS

FIND R_O_ROYALTY

FIND R_O_OVERRIDE_ROYALTY_INTEREST

*Assigns a value to R_O_NET_REVENUE_INTEREST with a calculation

R_O_NET_REVENUE_INTEREST = (1-
(R_O_OVERRIDE_ROYALTY_INTEREST - R_O_ROYALTY))

FIND R_O_STATE_TAX

DISPLAY "

<p>Now transferring data to the REVENUE spreadsheet. This will take a few minutes, please be patient."</p>
--

DISPLAY "Transferring Well Name"

PWKS C_O_WELL_NAME,C1,A:REVENUE

DISPLAY "Transferring Expected yearly production"

PWKS R_O_WELL_PRODUCTION,B4,A:REVENUE

DISPLAY "Transferring Decline Curve"

PWKS R_O_DECLINE_CURVE,B6,A:REVENUE

DISPLAY "Transferring Risk Adjustment"

PWKS R_O_RISK_ADJUSTMENT,B7,A:REVENUE

```

DISPLAY "Transferring Annual Well Costs"
PWKS R_O_ANNUAL_WELL_COSTS,B9,A:REVENUE
DISPLAY "Transferring Royalty"
PWKS R_O_ROYALTY,D4,A:REVENUE
DISPLAY "Transferring Overriding Royalty
Interest"
PWKS R_O_OVERRIDE_ROYALTY_INTEREST,D6,A:REVENUE
DISPLAY "Transferring Working Interest"
PWKS C_O_WORKING_INTEREST,D7,A:REVENUE
PWKS R_O_NET_REVENUE_INTEREST,D9,A:REVENUE
DISPLAY "Revenue module complete.";

```

End of ACTIONS Block

=====
Start Rules Block

```

RULE 001
IF      RISK_ADJUSTMENT = YES
THEN    R_O_RISK_ADJUSTMENT =
        (PERCENT_RISK_ADJUSTMENT)
        FIND PERCENT_RISK_ADJUSTMENT
ELSE    R_O_RISK_ADJUSTMENT = 1;

RULE 002
IF      OVERRIDE_ROYALTY_INTEREST = YES
THEN    R_O_OVERRIDE_ROYALTY_INTEREST =
        PERCENT_OVERRIDE_ROYALTY_INTEREST
        FIND
        PERCENT_OVERRIDE_ROYALTY_INTEREST
ELSE    R_O_OVERRIDE_ROYALTY_INTEREST=0;

RULE 003
IF      C_O_STATE = COLORADO
THEN    R_O_STATE_TAX = .0775;

RULE 004
IF      C_O_STATE = WYOMING
THEN    R_O_STATE_TAX = .1279;

RULE 005
IF      C_O_STATE = NEW_MEXICO
THEN    R_O_STATE_TAX = .0808;

```

End of RULES Block

=====

Begin STATEMENTS Block

```
ASK R_O_WELL_PRODUCTION: "What is projected well
                           production per year in
                           BBL's?";
ASK R_O_DECLINE_CURVE: "What percentage would
                        describe the decline in
                        production from one year
                        to the next? (decimal
                        format please)";
ASK RISK_ADJUSTMENT: "Do you wish to risk adjust
                     your expected production?"
ASK R_O_ANNUAL_WELL_COSTS: "What are your
                            projected annual
                            well costs?";
ASK R_O_ROYALTY: "What is the landowners royalty
                 interest?";
ASK OVERRIDE_ROYALTY_INTEREST: "Is there an
                                overriding
                                royalty
                                interest?";

ASK PERCENT_RISK_ADJUSTMENT: "What percentage
                              indicates the
                              probability of
                              success? (decimal
                              format please)";
ASK PERCENT_OVERRIDE_ROYALTY_INTEREST: "What
                                         percentage
                                         is the
                                         overriding
                                         royalty
                                         interest?

CHOICES RISK_ADJUSTMENT: YES,NO;
CHOICES OVERRIDE_ROYALTY_INTEREST: YES,NO;
```

APPENDIX C
CONSULTING ESP

The following instructions assume that VP Expert is installed on the C drive in a sub-directory called VPX and that ESP and all associated files are in the A drive.

Text in quotation marks is input by user. ENTER refers to the enter or return key on the computer. Select refers to using the cursor (arrow) keys to move the light bar over the desired menu item.

Screen	Input
C:>	CD VPX ENTER
C:\VPX>:	VPX ENTER
	F7
	A: ENTER
	F4
ESP Help screen 1	select ESP ENTER
ESP Help screen 2	ENTER
ESP help screen 3	ENTER
	select SHORT or LONG

A sample consultation with Short ESP

Well Name:	Input "Grand Inspiration" ENTER
Projected	
Drilling Cost:	Input "307417" ENTER
Tangible	
Drilling Cost:	Input ".34" ENTER
Intangible	
Drilling Cost:	Input ".66" ENTER
Completion Cost:	Input "212583" ENTER
Tangible	
Completion Cost:	Input ".90" ENTER
Intangible	
Completion Cost:	Input ".10" ENTER
Spud Month:	Select "January" ENTER
Spud Day:	Input "5" ENTER
Drilling Days:	Input "19" ENTER
Completion Days:	Input "10" ENTER
Working Interest:	Input ".08" ENTER
Operator:	Select "YES" ENTER
Cash Call:	Select "YES" ENTER

View advice screens.

Screen 1

Corporate monthly cash flow exceeds the \$100,000.00
limit in the following month(s):
February

Suggest:

Change spud date or
Become a non-operator or
Reduce your working interest.

Screen 2:

Monthly outflow for committed projects combined with this
project exceeds corporate limit.

Suggest:

Changing spud date or
becoming a non-operator or
taking a smaller working interest position.

Revenue or Quit

Select REVENUE_MODULE or QUIT

A Sample Consultation With Long ESP

```

ENTER
Well Name:      Input "JDs Deceiver"  ENTER
Well Number:   Input "36-6"    ENTER
Type of Well:  Select "OIL"    ENTER
Projected Depth: Input "?"    ENTER
Crew or Contractor: Select "CREW"  ENTER
ENTER
State:         Input "Colorado"  ENTER
County:       Select "Dolores"  ENTER
Township:     Input "39-N"    ENTER
Range:        Input "20-W"    ENTER
Section:      Input "36"     ENTER
Geology:      Input "Sandstone"
Basin:        Select "Papoose Canyon"  ENTER
Formation:    Select "Desert Creek"  ENTER
ENTER
Drilling Costs: Input "?"    ENTER
Completion Costs: Input "?"    ENTER
ENTER
Spud Month:    Select "December"  ENTER
Spud Day:     Input "19"    ENTER
Drilling Days: Input "?"    ENTER
Completion Days: Input "?"    ENTER
ENTER
Working Interest: Input "?"    ENTER
Revenue Interest: Input "?"    ENTER

```

View working interest and revenue interest advice screen.

ESP needs to know the working interest percentage.
The following revenue and working interests are common:

	DIVISION OF	
	COSTS	REVENUE
Landowner Royalty	0%	12.5-15%
Overriding Royalty	0%	0-3%

Net Revenue Interest (NRI)	100%	82-87%
Working Interest of NRI (1/3 for 1/4)		
Drilling		
For each of 3 partners	33%	25%
For Managing Partner	0%	25%
Completion		
For each of 3 partners	25%	25%
For Managing Partner	25%	25%

Working Interest: Input ".09" ENTER
Revenue Interest: Input ".0765" ENTER

Operator: Select "NO" ENTER
Landowner Royalty: Input ".125" ENTER
Other Burdens: Input ".025" ENTER
Cash Call: Select "NO" ENTER

View database of previously drilled wells in Dolores County.

This data has been provided from a well previously drilled
in Dolores county.

Name: {NAME}

Depth: {DEPTH} Days to drill: {DRILLDAYS}

Spud date: {SPUDDATE} Rig release date: {RRDATE}

Well type: {WELLTYPE} Status: {STATUS}

Drilling cost: \${RRCOST} Total cost: \${FINALCOST}

View database of corporate defaults for Dolores County.

Corporate Defaults for {C_O_COUNTY} county:

Well	Depth	Cost/Foot	Days to Drill	Days to Complete	Cost to Complete
----	-----	-----	-----	-----	-----
Shallow	{sdepth}	#{scstft}	{sdtodril}	{sdtocomp}	#{scompst}
Medium	{mdepth}	#{mcstft}	{mdtodril}	{mdtocomp}	#{mcompst}
Deep	{ddepth}	#{dcstft}	{ddtodril}	{ddtocomp}	#{dcompst}

Depth: Input "6309" ENTER
 Drilling Cost: Input "437825" ENTER
 Tangible Drilling Cost: Input ".39" ENTER
 Intangible Drilling Cost: Input ".61" ENTER
 Completion Cost: Input "102175" ENTER
 Tangible Completion Cost: Input ".12" ENTER
 Intangible Completion Cost: Input ".88" ENTER
 Drilling Days: Input "20" ENTER
 Completion Days: Input "12" ENTER

View advice screens.

Screen 1

Monthly cash flow exceeds the \$100,000.00 limit in the following month(s):

March
 April
 May

Suggest:

Change spud date or
 Become a non-operator or
 Reduce your working interest.

Screen 2

"ESP has determined that one or more of your cost breakdowns falls outside a given range:

Tangible drilling costs are high.
 Intangible drilling costs are low.
 Tangible completion costs are OK.
 Intangible completion costs are OK.

The following relationships are common in Colorado:

Of Total		Tangible	Intangible
-----		-----	-----
60-70%	Drilling Costs = 100%	30-35%	65-70%
30 40%	Completion Costs = 100%	90%	10%

100%			

Revenue or Quit

Select REVENUE_MODULE or QUIT

APPENDIX D
INTERVIEW SHEETS

INTERVIEW SHEET

for the

EVALUATION SYSTEM FOR PETROLEUM

Name _____
Company _____
Position _____

FOR CONTROL STRUCTURE AND RULE BASE

Engineer

What determines drilling costs? What information is essential for your "off the cuff" estimates of:

Drilling and Completion Costs?

Timing of Cash flows?

- _____ Location Notes:
- _____ Depth
- _____ Basin
- _____ Type(Oil)
- _____ W/C or Dev
- _____ WI% RI%
- _____
- _____

What risk can be accessed (after Probability of Success (Ps) by geologist)?

Is there any other criteria you consider? Importance ranking?

What makes one well analogous to another?

How long does it take to drill a well? or complete it?
Less than _____ days. less than _____ days.
Ft./day? Days per range?

What determines the likelihood of delays? How expensive are they? How significant are they?

What relationships exist between drilling and completion costs(in total or percent)?

		Tangible	Intangible
ie. Drilling	= \$100,000	_____	_____
Completion	= \$ _____	_____	_____

When are costs incurred to well site? % by month?
\$ by month?

Landman

How do terms affect the investment and timing of costs?

When are costs billed to operator? _____
 paid by operator? _____
 billed to partner? _____
 paid by partner? _____

Are there a portion of costs incurred up front? _____
 If so, what percentage and when?

Are cash calls common? _____ Amount or %? _____

What proportion of deals have only WI, RI and ORRI? _____
 Other frequent terms?

Do the percentages of WI, RI etc. change? _____
 How or when? Time? Activity?
 Carried WI?
 Bottom Hole Contribution?

What "rules of thumb" do you use in your position?

FOR CORPORATE GUIDELINES AND OBJECTIVES
 (Constraints and Desires)

Financial Advisor

What information is important about pending projects and potential cash flows?

How do you deal with differences between AFEs and actual costs? only in accounting reports? to well file?

What financial goals and constraints should be defined?

What objectives should be defined?

Expansion form, areas, types of deals

What advice is important for corporate goal congruency?

What is fundamental in setting up your corporate objectives for acceptable drilling projects?

Do you have a hurdle rate? How is it defined? (w/ w/o risk)

If two projects look financially the same what other criteria would you consider to select one over the other.

Location, type of expertise (of company)?

Compatible with other projects or agreements? Please give examples

Complementary with other projects or agreements?

Committed sales contracts?

Gathering system available?

Type of production? Oil or gas

Type of well? Development or wildcat

Timing earlier or later in fiscal year. Tax implications?

Corporate defaults (supplement to database for input to ES)

EVALUATION OF ESP

Rating System to answer the following questions

1	2	3	4	5
Not at All	Poorly	Acceptable	Quite well	Very well

Does the system accomplish its purpose?

1	2	3	4	5
No				Yes

Given the limited scope of ESP does it give a reasonable estimate of the timing of cash flows for a pending project?

1	2	3	4	5
No				Yes

How does the system's accuracy compare with the expert's.

1	2	3	4	5
---	---	---	---	---

Would your estimate differ from that of ESP given the original data? How?

1	2	3	4	5
No				Yes

What should be improved or included in the system?

- On input and form of input
- On heuristics or calculations
- On output and form of output