

/COST EFFECTIVE PAD DESIGN FOR
OIL AND GAS DEVELOPMENT/

by

VAN F. POOL

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Major Professor

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Cost Effective Pad Design for Oil and Gas Development

Van F. Pool

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Elizabeth - "The day is near, as we shall share these past years in memories. Thanks for the love and constant encouragement."

To everyone - This is the long awaited finality.

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Oil and Gas Exploration

Chapter 1

CHAPTER 1

OIL AND GAS EXPLORATION

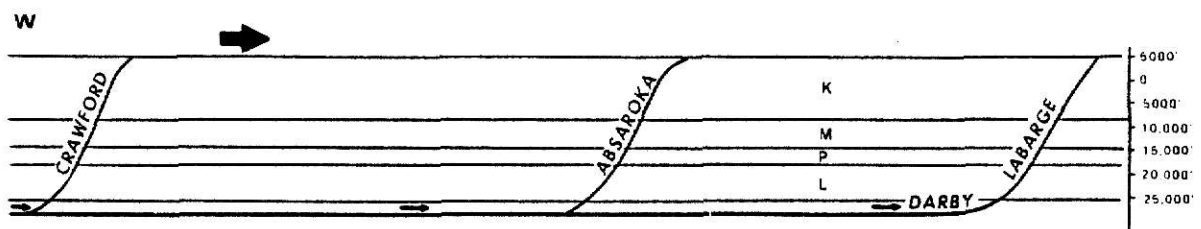
INTRODUCTION

Since the oil and gas embargo of the early 1970's, it has become increasingly apparent to our petroleum-oriented society that more domestic petroleum reserves are needed to maintain the current standards of living. This need along with the decontrol of oil prices has made it desirable and possible for the petroleum industry to explore in the more remote locations within the territorial boundaries of the U.S. including the Rocky Mountains. The article, "1980's Are to Be the Region's Most Active Decade" which appeared in the January 1980 issue of Western Oil Reporter, points out that drilling activity is increasing dramatically in the western states and especially in the Overthrust Belt encompassing the Rocky Mountain geological formations.¹² It could even extend into public lands once thought to be off limits to such activities. The Western Oil Reporter March 1980 issue points out in the article, "National Parks Could Be Freed For Exploration": that "Several other national parks and national monuments may contain oil or gas reserves and are being considered for public exploratory operations by the National Park Service and the U.S. Geological Survey."⁸

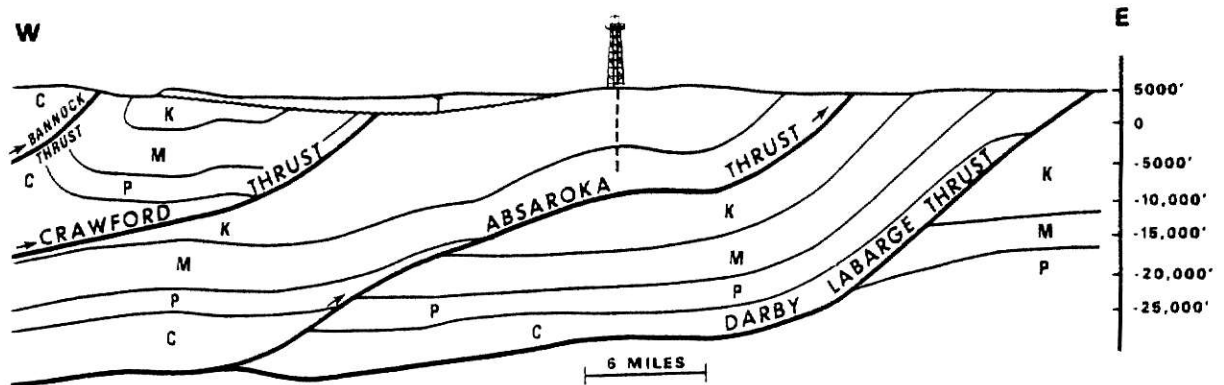
The Overthrust Belt is a descriptive geological term for the complex series of folded and faulted rock formations. This narrow belt of upthrust in the earth's crust extends from Alaska through western North America into Mexico as shown in illustration 1. One hundred fifty million years ago, these sedimentary rock formations were horizontal (illustration 2).

FIGURE 1⁹**OVERTHRUST**FIGURE 2⁹**THRUST BELT - Pre Thrusting**

150 MILLION YEARS AGO



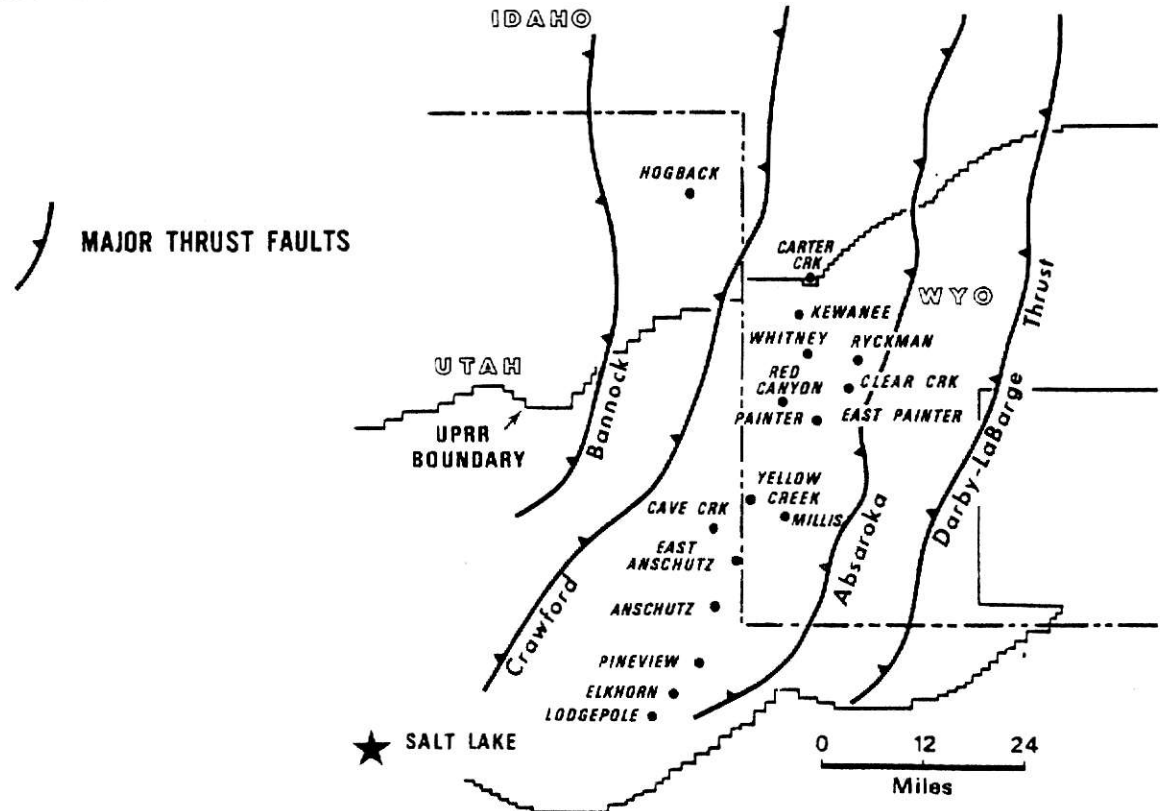
Then the Crawford, Absaroka, and Darby-Labarge faults became active due to extensive earthquake and volcanic activity, overlapping one another creating the Overthrust Belt and the right geological conditions for oil and gas to accumulate in the pools within the rock layers (illustration 3).

FIGURE 3⁹**THRUST BELT-Typical Cross Section**

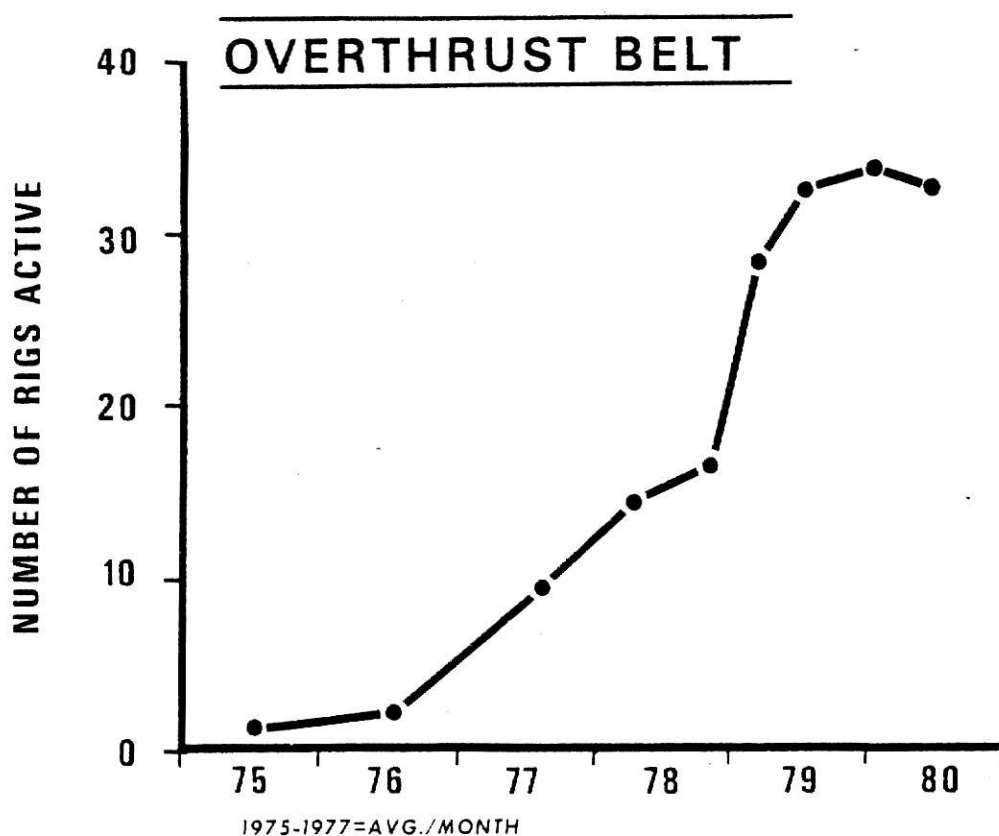
Recently, the Utah-Wyoming Overthrust Belt has evolved from a driller's graveyard to the most significant petroleum region since the discovery in Alaska's Prudhoe Bay more than a decade ago. Following the first overthrust region discovery near Calgary, Alberta, Canada, in 1936, some 500 dry holes were drilled in the belt before the 1975 discovery by American Quasar at the Pineview Field, Utah (illustration 4).

FIGURE 4⁹

OVERTHRUST BELT Utah-Wyoming



In 1976, Standard Oil Company discovered the Ryckman Creek Field (40 miles north) and Yellow Creek midway between Pineview and Ryckman Creek, triggering an acceleration of exploration activity. Between 1975 and 1980, 33 wells were drilled between Pineview and Ryckman Creek with 22 wildcat discoveries (illustration 4). The increased number of drilling operations present in the belt during this period is indicative of the petroleum industry's increased activity in the region. See illustration 5.

FIGURE 5⁹

This recent success is primarily due to the sophisticated data processing of seismic information through previously unavailable computer technology. Also, tremendous strides have been made in obtaining seismic information through use of helicopter-transported lightweight shot-hole rigs, increasing the quality of information.

ISSUES

Today, many believe the major impact of oil and gas site development is caused by the drilling rig because the drilling structure, the most visible element in the development process, spends between one month to one year or more on the site depending upon location, weather, and hardness of formations being drilled. An understandable misjudgment due to the public's lack of education or exposure to the oil and gas

development. However, there are several factors (e.g. stimulation activities, safety regulations, steep topography, etc.) which affect the size of the oil and gas development and the amount of impact on the environment within the mountainous regions of the Overthrust Belt. These factors created minor concern in the Great Plains since each was virtually non-existent as an impact.

Documented history of drill pad design and development is nearly nonexistent. Early drilling activity occurred in regions of very flat terrain (e.g., Texas, Oklahoma), obviously influencing the lack of attention to or concern for functional and compact drill pad design. Recent observation of the energy development activity in the mountainous Overthrust Region of western Wyoming reveals that these traditional pad layouts are still being used as if the drilling operations were taking place in the Great Plains states. The rectangular patterns of traditional pad design covered approximately four acres, caused little visual impact, and were easy to reclaim in the flat areas of Kansas, Oklahoma, and Texas. However, placing these pads in steeper terrain is disturbing large areas of the environment, resulting in extensive environmental damage and higher cost associated with pad construction and reclamation of the pad area after drilling operations have been completed. This raises an issue:

Can an alternative drilling pad design, adapting better to the natural slope reduce the earthwork and visual impact, but still provide the required work space needed during the life of the well?

OBSERVATIONS

During 1979, the author visited the Wyoming State Office of Bureau of Land Management to review current regulations governing the operations and reclamation of energy related properties. Based on this visit and subsequent discussions with BLM personnel in the compliance division, it was determined that there was a potential to reduce environmental damage and visual impact of oil and gas drilling pads. It was thought both may be accomplished by redesign of the drilling pads to better accommodate the steep terrain of the Overthrust Region without sacrificing safety and operational efficiency.

This premise - accommodation with less environmental impact and lower reclamation costs - served as the basis of this research effort culminating in the following outline of study.

1. Investigate the reasons for using the traditional pad layout.
2. Investigate the drilling and production activities currently affecting pad layout.
3. Investigate regulations affecting pad layout.
4. Investigate alternate pad layouts which might accommodate drilling and production activities while reducing the area of disturbance.

HYPOTHESIS

There is a better, more cost efficient, environmentally sound method of designing pads for the exploration and production of petroleum resources in the mountainous regions of the Western U.S. than is currently being utilized.

METHODOLOGY

As with any research undertaking, one must utilize a sound procedure to identify the parameters of the problem and generate sound alternatives for comparative purposes. As there was little familiarity with the issues and activities affecting oil and gas development, and since this information was critical to the success of the study, arrangements were made to gather this information in the field. The author was employed with BLM in the Kemmerer Resource Area during the summer of 1980 with ample opportunity to observe at first-hand the phases of drilling development and operations. Furthermore, preliminary concepts were developed for addressing the problems and the various concepts were reviewed by the oil companies and service companies for practicality. The author returned to Kansas State University where documentation of the various operations, equipment and regulations affecting the petroleum development was completed and the preliminary concepts refined. Finally, an additional summer was spent in the Wyoming State Office completing the research, verifying previous information and developing final proposals.

Any proposal brought forward suggesting revision of the traditional pad layout has to be responsive to the problems and spatial requirements of the various drilling and operational activities. These proposals were applied to existing well locations. Comparisons between the proposals and the existing pads were made to determine if significant reduction can be made in area disturbance and earthwork quantities without sacrificing the space needed for safe and efficient operations of the drilling and production facilities.

Regulation

Chapter 2

CHAPTER 2

REGULATION

Three levels of regulations govern the oil and gas industry in Wyoming: (1) Federal, (2) State, and (3) private. Each has developed regulations aimed at protecting the health and safety of workers as well as the visual and environmental quality of public lands (e.g. national parks, national forests, etc.).

Federal Regulations

Administration of oil and gas leases in Wyoming may involve several Federal agencies: the Bureau of Land Management (BLM), U.S. Geological Survey (GS), U.S. Fish and Wildlife Service, National Park Service, and the Bureau of Reclamation, all in the Department of Interior; the Forest Service in the Department of Agriculture; or the Corps of Engineers of the Department of the Army. GS and BLM play the greatest roles in the administration of oil and gas leases in Wyoming.

"The State of Wyoming is almost equally divided in its land ownership between federal and private, although the Federal Government manages close to seventy percent of the mineral estate. Of the nearly 63 million acres in the state, 30 million are administered by the federal agencies. Of this federal land, 17.5 million acres are administered by BLM, 9.25 million acres by the Forest Service, and 2.3 million acres by the Park Service. An additional 13 million acres of federal minerals are overlain by private lands."¹¹

U.S. Geological Survey

"Secretarial Order 2948 establishes Geological Survey (GS) as the Secretary of the Interior's representative for drilling operations, conservation of minerals, royalty matters, and safety."⁷ GS oversees the following sequence of actions or events:

1. GS issues Notice to Leasees (NTL) which explain proper operational procedures regarding "Federal oil and gas leases. The NTL-6 (Approval of Operations) describes the procedure for obtaining a permit to explore on a Federal lease."⁷
2. Operator files an Application for Permit to Drill (APD). The APD is a permit and development plan filed with GS's district engineer for federal minerals, and with the Wyoming oil and gas supervisor for private and/or state minerals.
3. After receiving the APD, prepared in accordance to NTL-6, GS reviews it for compliance and forwards a copy to BLM.
4. GS, in its role as lead agency, conducts the joint field examination (includes BLM staff, surface owner, and driller, etc.) to determine if the proposed construction and surface protection measures for the well site and access road comply with regulations.
5. GS serves as "final approving authority"⁷.
6. Once construction has started, GS is responsible for regulating emergency conditions and downhole matters (pertaining to the wellbore), (e.g. protection of geological formations encountered, facility layout, and safety).⁷

Although GS regulations do not address site design specifically, NTL-6 is one of the most important elements in the oil and gas

development planning process. NTL-6 identifies major planning issues: (1) drilling operations, (2) multi-purpose surface use and operations planning guidelines, (3) environmental analysis, (4) subsequent operations, (5) rehabilitation of privately owned surface, (6) well abandonment, and (7) water well conversion.

1. Drilling operations section identifies the future well location and describes equipment and operations the company anticipates using.
2. The multi-point surface use and operations plan offers sufficient detail of development, operation and rehabilitation of the drill location to permit a complete appraisal of the environmental effects associated with the proposed project.
3. The environmental analysis outlines methods for mitigating the potential adverse environmental effects associated with the proposed operation.
4. A written statement describing the work plan for subsequent operations such as deepening, or conditioning, a well, etc. is submitted for approval.
5. When a well is located on privately owned land, a plan for rehabilitation of surface disturbance must be submitted. This protects the private landowners who do not have established rehabilitation requirements.
6. The well abandonment section requires a sketch plan of the rehabilitation practices to be applied to the disturbed surface areas of government lands.
7. The water well conversion section provides an agreement for reimbursing the operator for any equipment, casing, etc. left

in the hole which can be used to convert it to complete a water well.¹⁵

Bureau of Land Management

"BLM is the Secretary of Interior's representative for mineral leasing, mitigation of development impacts, and rehabilitation."⁷ BLM is responsible for insuring that oil and gas operations are carried out in accordance with the terms and conditions of the lease, an approved APD, or an operative field plan. The responsibility is shared with GS and is conducted in full cooperation with GS. BLM is responsible for:

1. Maintaining stipulations requiring "the operator to submit a Preliminary Environmental Review (PER) to GS and BLM" [before entering onto the lease. This] "consists of a letter and map of the proposed well location"⁷ (optionally including approximate location of the access road). BLM reviews the PER to determine if conflicts exist between proposed development and resources. The review and a response must be completed within 15 days.
2. Reviewing the APD for completeness determining if "corrections or additions are needed." [If either] "are needed, GS requests the operator to supply the necessary data."⁷

BLM's primary concern is the 13-point surface use and operations plan in the APD.¹⁵ This "...contains the operator's plans for surface disturbance, handling of waste material, reclamation, etc." [It provides] "...sufficient detail to permit a complete analysis of environmental impacts, ...protection of resources..., [and includes plans for] ...reclamation of the disturbed areas."⁷ These are reviewed

and a list of questions prepared for discussion at the presite meeting.

3. Reviewing, at the presite meeting, proposed construction, operation and reclamation methods with the operator to determine their impact on the surface.

Wyoming Occupational Health and Safety Design Standards

The major regulatory agency affecting the spatial requirements of well sites is the Wyoming Occupational Health and Safety Administration (WOSHA). The following is a list of the major design standards approved on December 27, 1977 and enforced by WOSHA.¹³

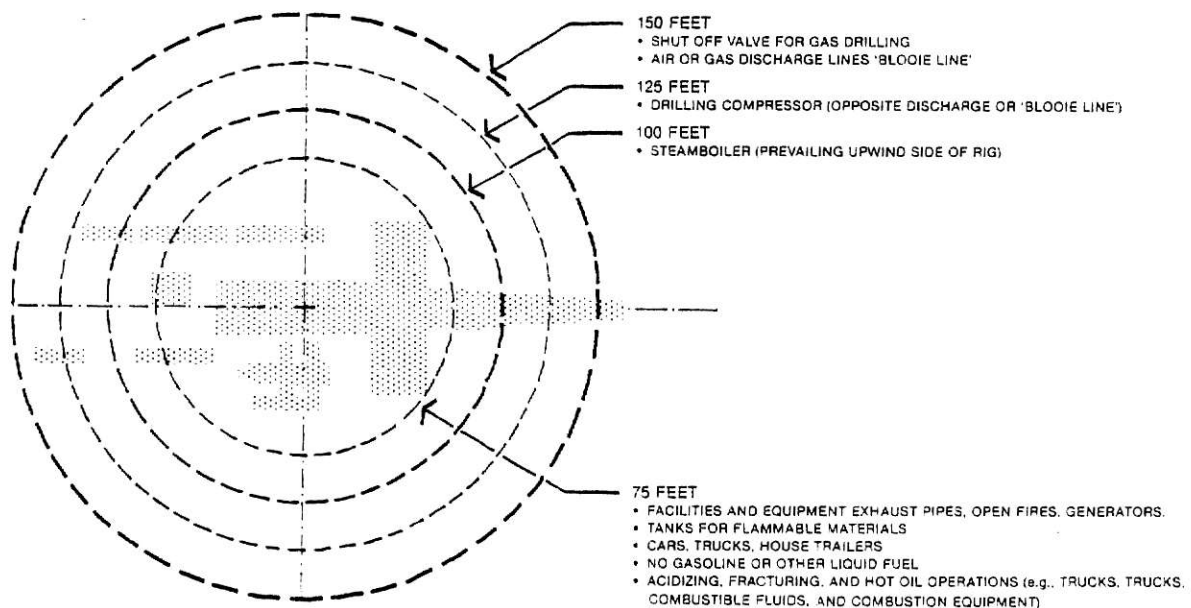
1. Site size - the submitting operator shall request in the APD "...an area large enough to accommodate any operations [expected to occur and] shall include provisions for a second escape route from the site."
2. Reserve pit location - the operator shall locate "...the reserve pit so that it does not interfere with the placement and testing of the anchor" for the workover rig mast. The reserve pit is a mud pit in which a supply of drilling fluid was stored usually an excavated, earthen walled pit. The anchor is a device that secures or fastens equipment. The workover rig is a portable service equipment usually mounted on a wheeled chassis with a self-erecting mast, substructure with rotary, pumps, pits and other auxiliaries to permit handling and working a drill string.
3. Diking, sloping, or ditching of above ground storage tanks (a tank in which oil is stored pending transfer to a pipeline or purchase) - the "tanks must either be diked with sufficient

area to contain the amount of liquid in the tank in case of an accident, be on a slope so liquid drains away from personnel or equipment, or ditched and drained away from the personnel or equipment."

4. Distances from source of ignition - "...drilling and service personnel should ensure a minimum distance of 120 feet is maintained between any source of ignition and any flammable or combustible substance."¹³

The following is a condensed list of required distances the Wyoming Occupational Health and Safety Administration regulations currently specify for servicing, drilling equipment and operations as delineated in illustration 6. (References are to Regulation Section of the WOSHA Handbook.)¹³

ILLUSTRATION 6
WOSHA - REQUIRED SAFETY DISTANCES



Chapter VI, Facilities

Minimum Distance From
Wellhead (in feet)

Section 8, Area Classification

C. Facilities and Equipment

1. Exhaust Pipes. 75
2. Open Fires 75
3. Generators 75

Chapter VII, Special Services and Operation

Section 1, Safety Procedures for Special Services and Operations

A. General Requirements

16. Tanks for Flammable Materials. 75

Section 2, Safety Procedures for Drill Stem Test

A. Specific Requirement

8. Smoking or Open Fires. 75

Section 4, Safety Procedures for Air and Gas Drilling

A. Specific Requirements

1. Drilling Compressor. 125
2. Air or Gas Discharge Line ("Blooney" Line). 150
6. Cars, Trucks, House Trailers 75
12. Shut-off Valve 150

Section 6, Acidizing, Fracturing, and Hot Oil Operation

A. Specific Requirements

7. Trucks and Tanks 75
12. Combustible Fluids, Combustion Equipment,
All Fires 75

Section 7, Safety Procedures for Fuel Tanks

A. Specific Requirement

1. No Gasoline or Other Liquid Fuel 75

Chapter IX, Hydrogen Sulfide (H_2S) Gas

Section 2, H_2S Safety Equipment and Procedures

C. Two Means of Egress on Each Location in a High Hazard Area Shall Be Provided.

Chapter X, Safety Procedures for Boilers and Pressure Vessels

Section 1, Boilers

E. Steam Boilers (Upwind). 100

Private Company

Although private companies adhere to State and Federal regulation, several publish their own rules and regulations for equipment placement. The following is a condensed list of regulations published by Dowell and Halliburton.

Dowell ⁵	Minimum Distance From Wellhead (in feet)
Bloocey and Bleed Off Lines.	150
All Parts of the Truck.	60
Spot Tanks.	150
Spot CO_2 Pumper, Booster Pump and CO_2 Transport	50
Spot N_2 Pumper and Transport.	50
Oil or Backwash Tanks	150
No Equipment With High Risk Oil	60

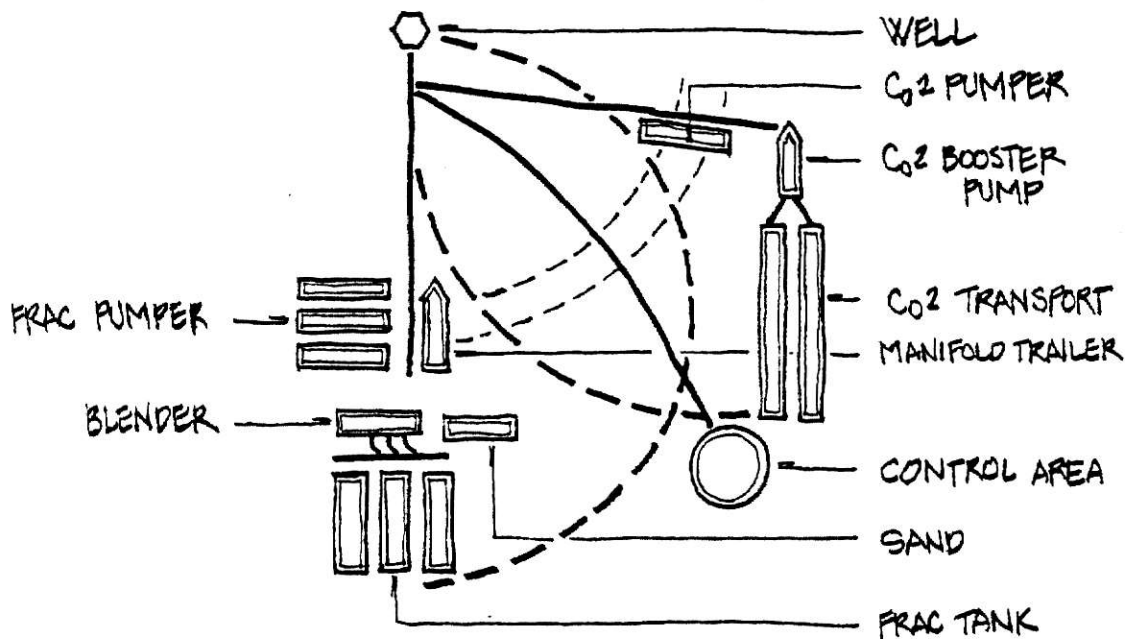
Halliburton¹⁴

Flammable Fluid Storage Tanks	75
Pumping Equipment	75
Vehicles Not Directly Involved in Operations.	150

One of the major concerns of the private companies is the potential hazard presented if one of the high pressure lines were to rupture. The potential swing radius of these lines are the major determinate in equipment layout (illustration 7).

FIGURE 7

SWING RADIUS SAFETY ZONES



Conclusion

Of all the regulating agencies, the two which affect site design most are WOSHA and the private companies. Although GS and BLM are the primary administrators, each creates regulatory parameters for surface activity but provide little guidance with actual dimensions or equipment configuration.

Equipment

Chapter 3

CHAPTER 3

EQUIPMENT

Drilling techniques have varied drastically over time, and pad designs have changed to accommodate these improvements. Edwin L. Drake first used an oaken battering ram with a simple windlass to drive the pipe into the ground at Titusville, Pennsylvania. A windlass prototype led to the stationary cable-tool drilling rig with pyramid-shaped wooden derricks. The cable-tool drilling was used from 1860 until the 1920's when the portable cable-tool rig became standard. However, because injecting drilling fluid was not part of the early drilling system, the the drilling operations was frequently interrupted to remove cuttings and debris from the drill hole. The cable-tool method was based on the percussion produced by the bits impact against the rock, loosening the soil and rock with each thrust.

Cable-tool methods gave way to the rotary, fluid-circulating drilling system, developed in France in the 1880's. The system is based on the rotating motion of the bit against the drilling surface in the wellbore in contrast to the less efficient percussion impact method. This system did not gain popularity until it was discovered that rotary drilling with circulating fluid, which removes cuttings from bore holes and cools the bit, could be used in areas where percussion drilling was inefficient. Drillers using the rotary drill method to search for water accidentally discovered oil in what became the Corsicana (Texas) Oil Field. However, the Great Weas Well at Spindletop (Texas) is recognized as the first major discovery by a rotary drill.

At the present time, the petroleum industry is experimenting with several new drilling systems: (a) jet-erosional drilling system, (b) continuous chain drill, (c) stratofax, (d) spark drilling and (e) electrodrill system. These new methods may revolutionize the process.

COMPONENTS

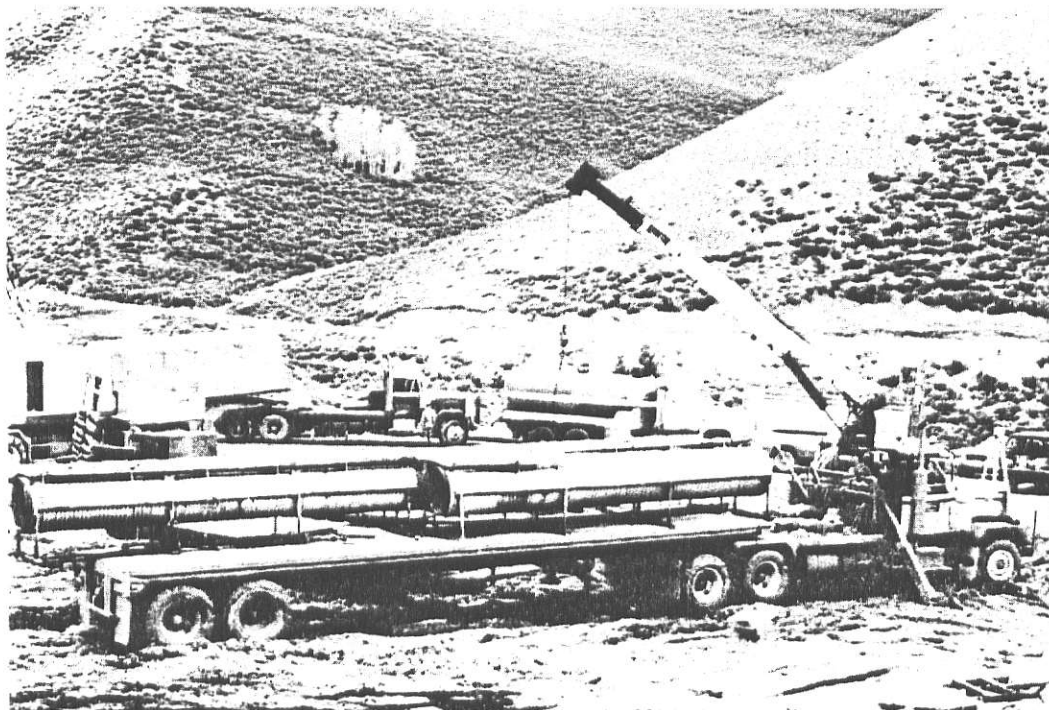
The spatial requirements of a drilling pad are determined by the various pieces of equipment, required service operations, and the functional relationships of the drilling equipment and operation safety standards. The following is a description of the basic elements found in an oil and gas operation and their spatial needs.

Rotary Rig and its Components

The rotary drilling rig is the major equipment used for oil and gas drilling. A prerequisite of any drilling equipment is that it must have some degree of portability since it is moved frequently. Federal and state transportation regulations set maximum gross weights which can be moved over public roads. This requires that the rig be disassembled and that each component be transported separately. (Plate 1).

PLATE 1

TRANSPORT OF EQUIPMENT



The drilling equipment can be divided into four main systems: power, hoisting, rotating, and circulating systems. Of these, the power, hoisting, and circulating systems have major impacts on the site size requirements.

Power System

Each rig structure houses a power plant sufficient to drill to specified depths. Two or more diesel or gas engines power the rotary table (principal component used to turn the drill stem), drawworks (the hoisting mechanism), and mud pumps (a large pump used to circulate the drilling mud) by either mechanical or electrical means. These engines are 1,000 to 3,000 horsepower (HP) depending on well depth and rig design. Auxiliary power for lighting is generally available from smaller generating units with engines ranging from 100 to 500 HP.

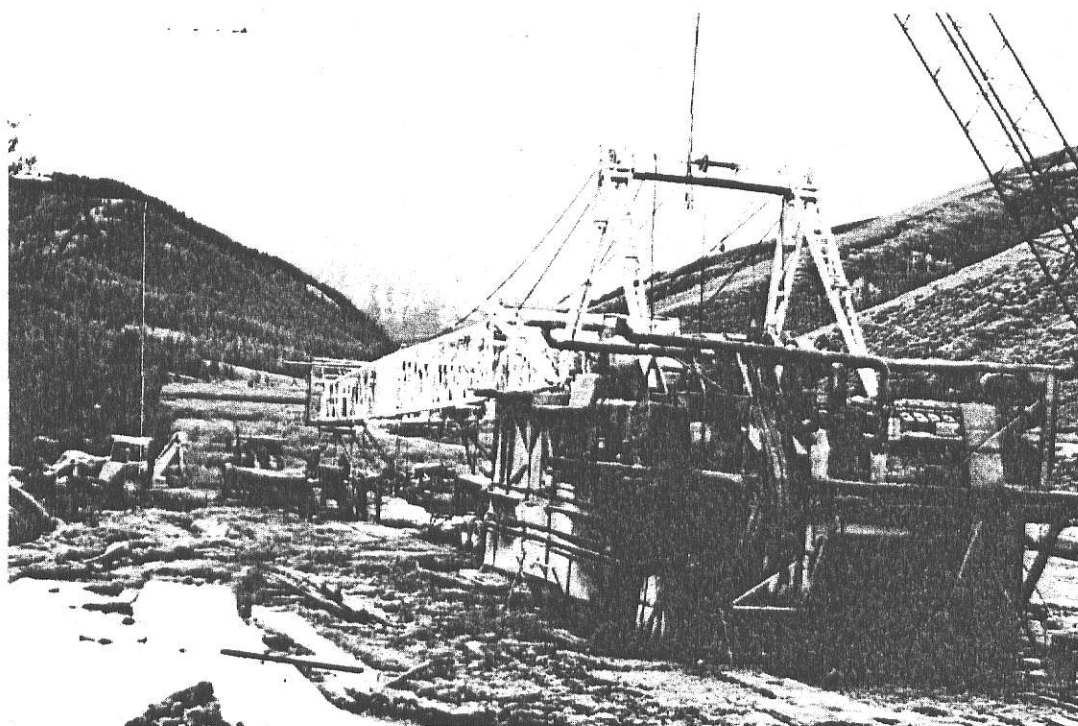
The power system sits next to the drilling structure on an engine foundation approximately 27 feet long, 38 feet wide, and 10 feet high. One of two methods are used to install the engines on the foundation: (1) hoisting by crane, and (2) sliding up a 100 foot ramp. The method chosen will influence the site width. The use of a crane does not require expansion of the pad because of the maneuverability of the truck and its boom. The ramp method requires that an additional 160 feet be added to the side of the structure to accommodate the ramp and allow ample room for the trucks to maneuver.

Hoisting System

Most of the wells in the Overthrust Belt reach depths of 15,000 feet. Long strings of pipe and drill collars are run in and out of the hole, requiring a large hoisting system. Hoisting system components include the mast or derrick, drawworks, catheads (winch used as a power source for unscrewing drill pipe), crown (top of a derrick), traveling block (an arrangement of pulleys which moves up and down in the derrick), and the drilling line (a wire cable used to support the drilling tools). The mast and derrick have considerable impact in pad design.

Recent trends indicate the mast is replacing the derrick primarily due to (1) ease of moving without disassembly, (2) ease of lowering when the job is complete and (3) ease of erecting it on a new location. The standard derrick must be assembled piece by piece on each site. Both are available in various heights, ranging from about 95 to 165 feet, with 136 and 145 feet being the most common. The mast or derrick is set on the substructure, a steel structure which averages 20 feet by 50 feet and 25 feet in height. (Plate 2).

PLATE 2
RIG STRUCTURE



The substructure supports the weight of the drill stem, usually requiring a support capacity between 250,000 pounds and 1,500,000 pounds. Generally, the derrick or mast is assembled and hoisted into place on the substructure. Although the maximum height is 165 feet and the average is 145 feet, the petroleum industry recommends at least 175 feet in lay-down area to allow for truck mobility in aligning the mast or derrick with the substructure before erecting.

The substructure serves two main purposes:

1. To support the rig floor, and rotary table and provide work space for the accessory equipment and labor on the floor,
2. To provide space below the floor for the blowout preventer.

Circulating System

One of the essential features of rotary drilling is its circulating system of drilling fluid usually called mud. Mud is a mixture of clay,

chemicals, and water carefully formulated to provide specific service characteristics in each of the geologic formations being drilled. The major portion of equipment and cost of drilling a deep well is devoted to handling the mud. Its principle functions are:

1. Cleaning and flushing cuttings from the hole.
2. Cooling the bit.
3. Supporting the walls of the borehole preventing a cave in.
4. Preventing entry of fluids from the formations into the borehole.

The components of a mud-circulating system are the pump, mud tanks, mud conditioning equipment and the reserve pits. The pump forces the drilling fluid through the drill stem and back to the mud tanks. The fluid is circulated through such mud-conditioning equipment as the shale shaker, desander, and the desilter which have little affect on the pad size since each are mounted on the mud-circulating tanks. Finally, the fluid is drained into the reserve pit containing two linked chambers. The first chamber acts as a settling basin allowing the cuttings brought up from the hole to settle out. The mud then circulates into the second chamber and is recirculated into the wellbore. An average reserve pit occupies approximately 200 feet by 200 feet with a holding capacity of more than 40,000 barrels.

Area Requirements

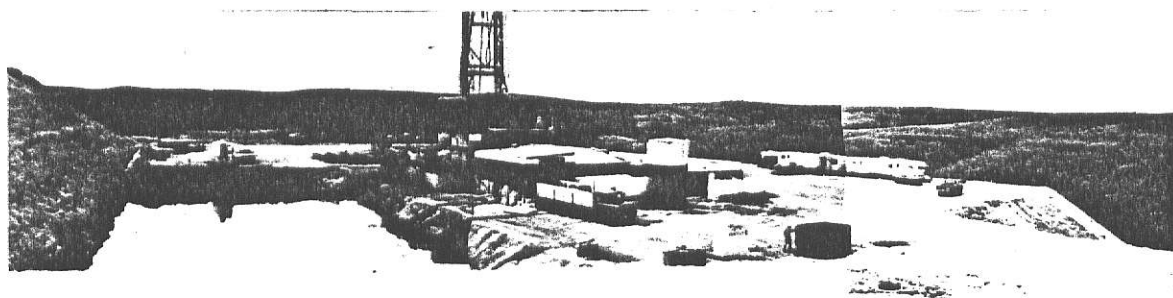
Following is a list of the area components and the land use required for the typical drilling equipment used in the Overthrust Region. These dimensions and areas do not include the allowances for vehicular circulation.

Substructure - 30' X 40' Area.	1,710 sq. ft.
Pipe Racks - 30' X 85' Area (2,500 sq. ft. each) . .	7,650 sq. ft.
Pump Mat with Pump House (Two Pumps) - 22' X 23' Area (506 sq. ft. each). . .	1,012 sq. ft.
Mud Storage - 8' X 28' Area.	224 sq. ft.
Water Tanks (Average 2 Per Site) (500 Barrels Per Tank) - 10' X 42' Area (420 sq. ft. each)	840 sq. ft.
Generators (1 to 3 Per Well) (Depending on Rig) - 10' X 41' Area (410 sq. ft. each)	1,230 sq. ft.
Boiler (Average 2 Per Well) 10' X 26' Area (260 sq. ft. each).	520 sq. ft.
Mud Tanks (Average 2 Per Site) (500 Barrels Per Tank) - 10' X 42' Area (420 sq. ft. each)	840 sq. ft.
Fuel Tank - 8' X 15' Area.	120 sq. ft.
Boiler Water - 10' X 26'	260 sq. ft.
Mud Mixing House - 10' X 24' Area.	240 sq. ft.
Parts House - 10' X 34' Area	340 sq. ft.
Crew House - 8' X 28' Area	224 sq. ft.
Dog House - 8' X 28' Area.	224 sq. ft.
Small Reserve Pit - 125' X 125' Area	15,625 sq. ft.
Large Reserve Pit - 200' X 200' Area	40,000 sq. ft.
Derrick Lay Area - 165' X 30' Area	4,950 sq. ft.

Subtotal with Small Reserve Pit	36,009 sq. ft. (or .83 acres)
Subtotal with Large Reserve Pit	60,384 sq. ft. (or 1.38 acres)

PLATE 3

TYPICAL DRILLING STRUCTURE AND EQUIPMENT



Once oil or gas has been found, the exploration phase of development is complete. The drilling equipment is removed and is replaced by production equipment. The typical oil and gas production equipment and its spatial requirements are as follows:

CELLAR: (A pit in the ground dug to provide adequate height between rig floor and the wellhead to accommodate blowout preventer, rathole, mousehole, etc. It also houses the Christmas tree after the well is completed. A Christmas tree is the control valves, pressure gauges, and chokes assembled at the top of a well to control the flow of oil and gas after the well has been drilled and completed. (Plate 4).

12' X 12' area 144 sq. ft.

PLATE 4

CELLAR WITH CHRISTMAS TREE

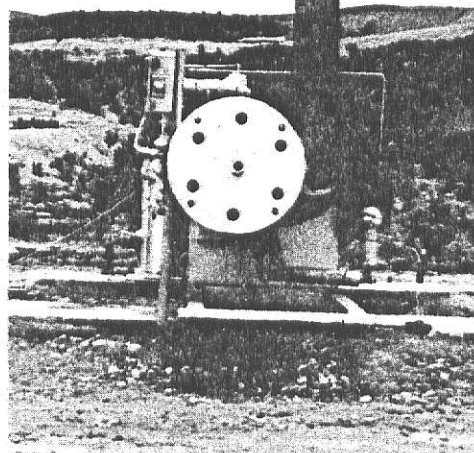


PLATE 5

TREATER

TREATER: (A vessel in which oil is treated for the removal of sediment and water, by the addition of chemicals, heat, electricity, or all three.)

15' X 30' area 450 sq. ft.

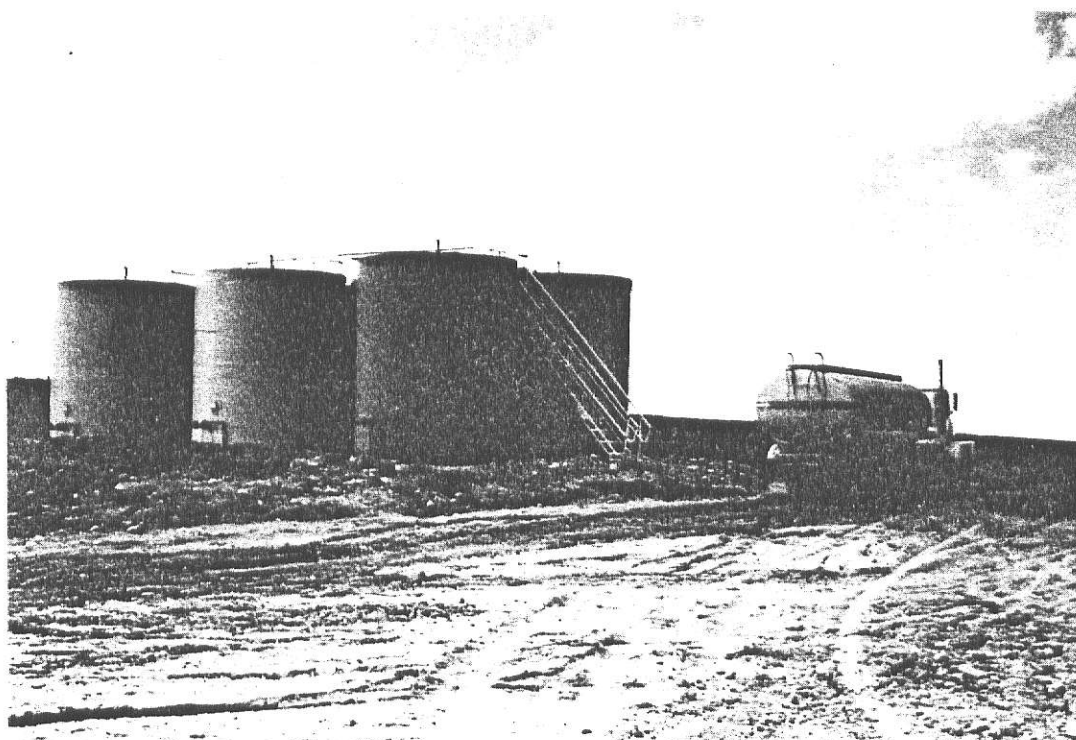


TANK BATTERY: (A group of tanks located in the field that store crude oil.)

Group of 3 at 20' in diameter - 314 sq. ft. each. . . 943 sq. ft.

PLATE 6

TANK BATTERY



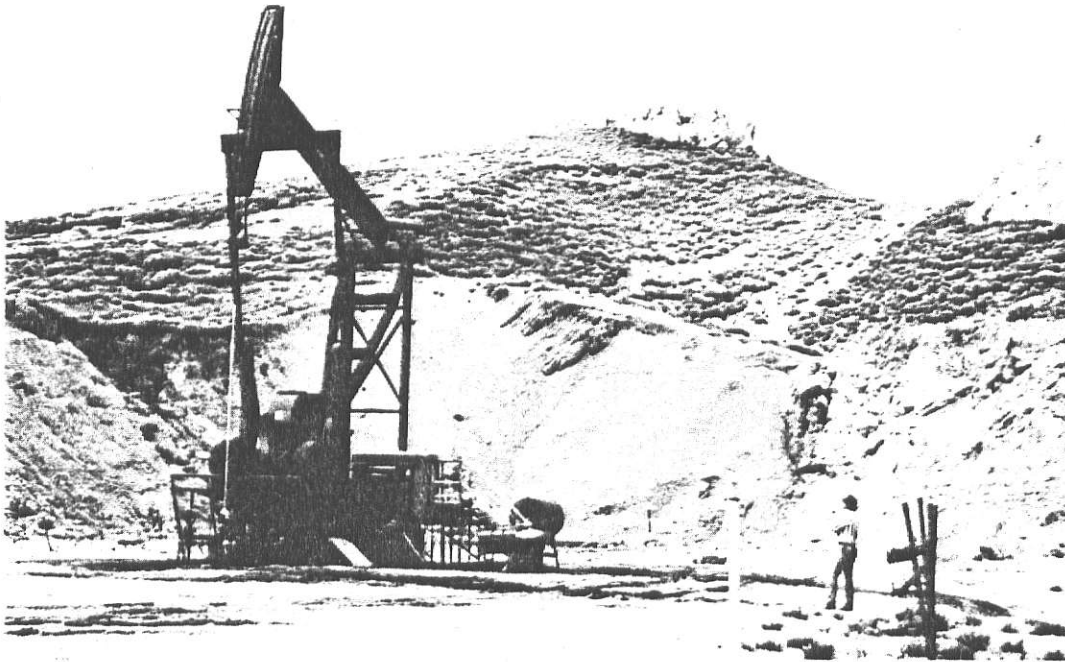
PUMP JACK OR ROD-SUCKER PUMPING:

(A method of artificially lifting fluid to the surface.)

20' X 40' area 800 sq. ft.

PLATE 7

PUMP JACK



The areas listed above do not include pedestrian or vehicular circulation, but show that the drilling equipment occupies from 25 to 42 percent of the total surface area on a 3.3 acre pad surface area or 21 to 35 percent of a 4-acre surface area. The production equipment occupies from 2 to 1 percent of the total site, respectively. Small overlaps are possible, but would not significantly decrease the required surface area.

Sequence of Activities

Chapter 4

CHAPTER 4

SEQUENCE OF ACTIVITIES

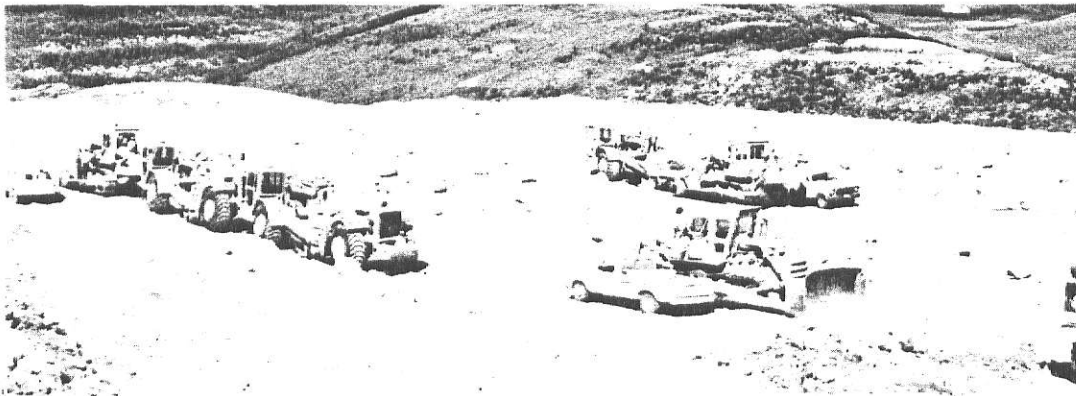
Oil and gas fields are developed in five phases: 1) preconstruction, 2) site preparation, 3) drilling, 4) production, and 5) reclamation.

Once a lease is secured and the APD and NTL-6 are approved by the appropriate agencies (preconstruction), the operator begins by constructing an access road to the location. This route is selected and staked by an engineer, identifying the cut and fill areas from which all vegetation and topsoil are stripped and stockpiled.

After the access route is completed, work on the pad begins. Vegetation and topsoil are stripped and stockpiled, then bulldozers rip the cut zones so the material can be excavated easily by scrapers. Scrapers move large quantities efficiently and their rubber tires increase compaction of the fill zone compared to track vehicles. However, from field observation, there remains a question as to whether scraper tire compaction is sufficient.

PLATE 8

SITE PREPARATION



Once the pad (often 3.4 acres of flat surface area) is graded, a gravel bed is placed over the entire site and access road in preparation for the drilling structure. (Plate 9).

PLATE 9

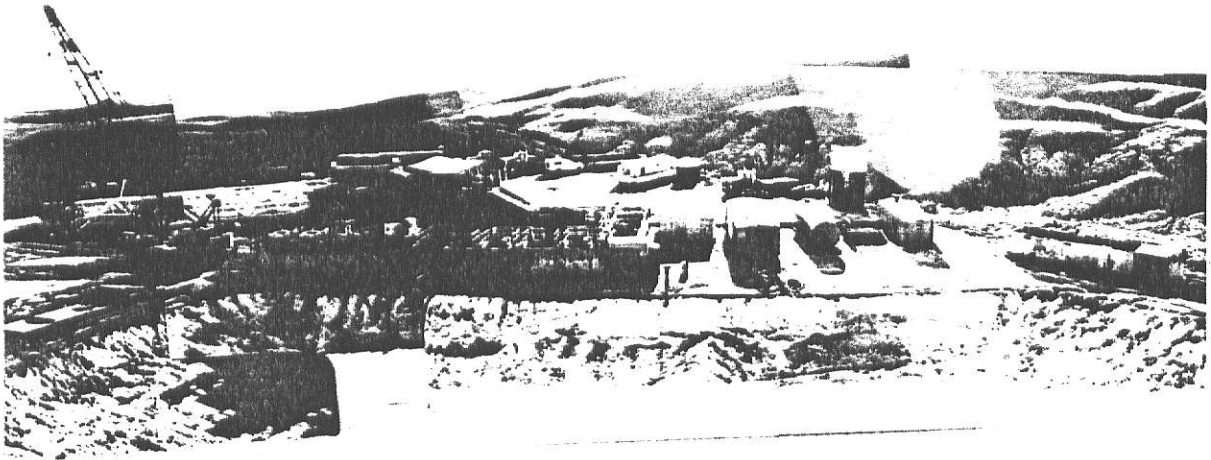
SITE PREPARATION - WELL SITE



The reserve pit is excavated in the cut zone to reduce the possibility of a breach. It is lined with a colloidal clay (bentonite) or a synthetic liner to act as a seal. This prevents the mud and fluids from seeping into the soil and/or water table, streams, etc. Assembly begins with the placement of the substructure. Next the derrick or mast is hoisted into place and this operation is followed by placing the pipe, drawworks, and engines on the substructure.

PLATE 10

ASSEMBLY OF DRILLING STRUCTURE



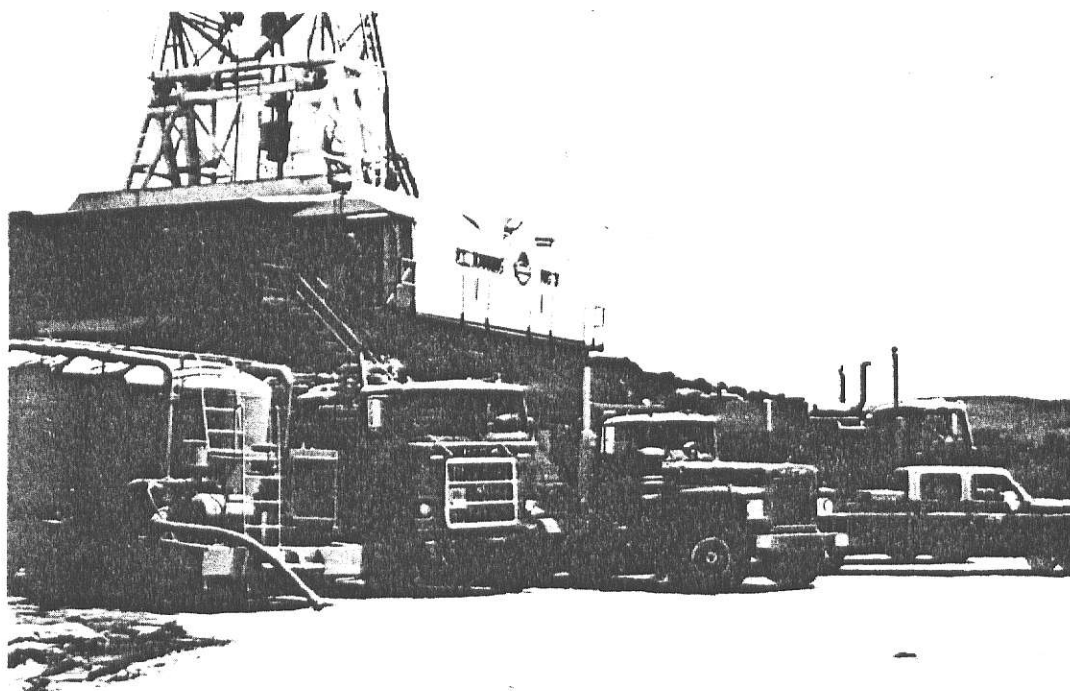
The mud storage tanks, mixing house, dog house, crew house, boiler, fuel tanks, etc. are placed on location and drilling begins. (Plate 10).

After drilling activity begins, the operation often requires that as much as 125,000 gallons of water be stored in the water tanks daily. The water is hauled in by truck or a water well is drilled on site and water is piped to the operation.

The drill company usually places the drill stem in storage tubs or to one end of the pipe rack while casing is delivered and placed on the opposite end of the pipe racks. After initial drilling operations have penetrated through the upper formation, protective casing is placed and grouted by the service company to ensure against groundwater pollution, bore hole collapse, and fluid exfiltration.

PLATE 11

DRILLING - CASING OPERATION



The service company stocks large quantities of cement and the necessary mixing equipment requiring a sizable area on site. The grouting is tested and if it meets oil company standards, a blowout-preventer is installed and drilling resumes with a smaller bit. This process is repeated several times in deep formations. (Plate 11).

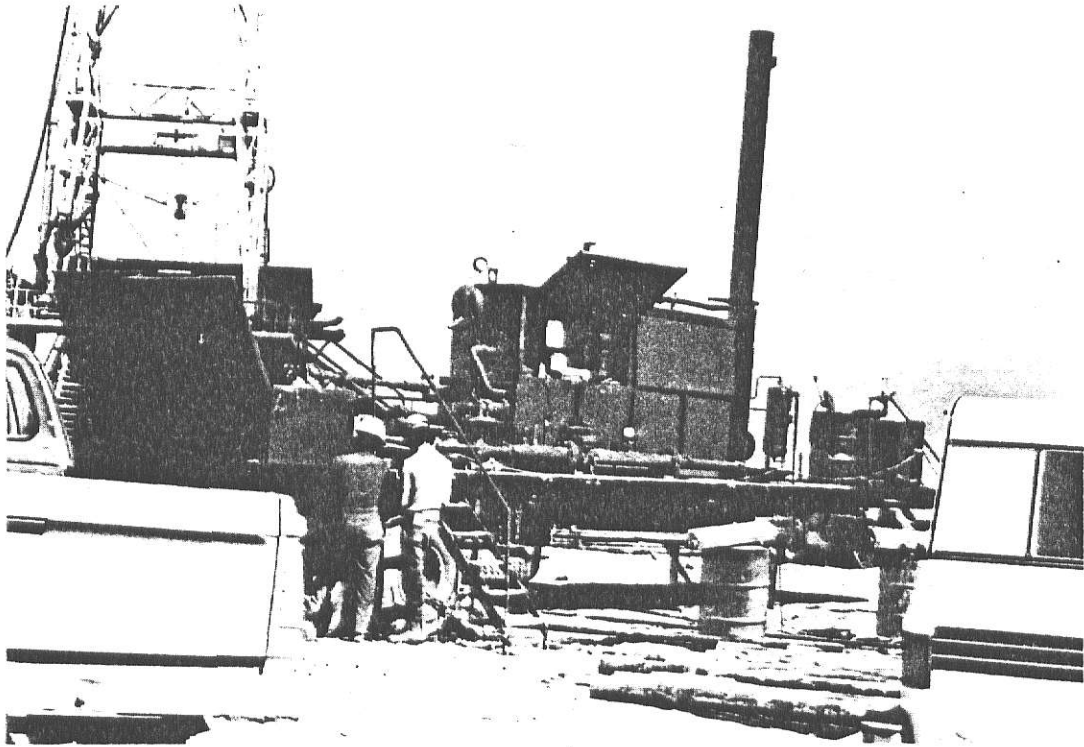
Cuttings are continually examined and analyzed in a portable laboratory on site to determine the presence of hydrocarbons. Other methods of analyzing the downhole formations include well logging, drill stem test, and core samples. After analyzing the formation and available hydrocarbons at the final depth, the operating company decides to either prepare the well for production or plug the well. If the well is not capable of producing oil and gas in commercial quantities, it will be abandoned. If the well is expected to be productive, production casing is run to the final depth of the borehole and capped. Once

production casing is installed, the drilling equipment is removed and the site is prepared for the workover rig by placing anchors and perforating the casing at the production formation. The workover rig or completion rig moves on location, the wellbore casing cap is removed, the Christmas tree (page 25) is placed (primarily used for gas wells), and production tubing is run in the protective casing down to the production formation. A separator (production equipment used to separate liquid components of the well stream from the gaseous elements) or heater treater (a vessel that heats an emulsion and removes water and gas from the oil) is placed on location to bring the product to a marketable quality acceptable for pipeline transmission from the wellhead. Frequently, if a large amount of condensate fluid is available, additional tank batteries (used to store separated oil or condensate) are placed on location with vehicular access to accommodate sales by the truckload.

Occasionally, drilling fluid is lost into the formation and a service company is hired to flow the well and monitor productivity until maximum quality production is reached (ideally 98 percent oil and gas and 2 percent fluid). (Plate 12). Well productivity is monitored for three or four months. If, in the operator's or petroleum geologist's judgment, the productivity is low, the formation may be stimulated in an attempt to increase production.

PLATE 12

PRODUCTION - SERVICE COMPANY MONITORING PRODUCTIVITY



Formation stimulation has been used for 40 years, but current technology uses injection of fluids under high pressure (high pressure fluid injection) to hydraulically fracture the formation instead of using explosives as was used with earlier methods. Stimulation is a very specialized service performed by very select, specialized companies. Stimulation services are often used for both new and old wells. The well may be stimulated by fracturing, acidizing, or a combination of both. Large volumes of highly pressurized fluids are pumped into the well reaching a peak of 15,000 psi. The highly pressurized fluid literally cracks or fractures the production formation. These fissures are held open by sand or bauxite which has been mixed with the fluid and carried into the cracks, allowing oil and gas to flow from the well more readily. In acidizing methods, sands are

pumped into the formation with an acid solution again under high pressures. This acid solution dissolves the rock formation and allows the oil and gas to flow from the well, increasing the recovery rate. There are two major types of stimulation: (1) high pressure stimulation with small quantities of fluids (Type 1), and (2) high pressure stimulation with large quantities of fluids (Type 2). Both use acid or condensate (a light hydrocarbon liquid) mixed with sand or bauxite to create the stimulation fluids referred to as "gelatin fluids."

Stimulation equipment requires the following areas (Plate 13 and 14):

14 truck pumps, each 500 horsepower, for recirculating the gel fluid	
9' X 50' (450 sq. ft. each)	6300 sq. ft.
4 to 6 intensifiers	
4 at 9' X 30' (270 sq. ft. each)	1080 sq. ft.
6 at 9' X 30' (270 sq. ft. each)	1620 sq. ft.
6 to 40 gelatin fracture tanks (500-barrel capacity), quantity dependent on type of stimulation	
4 at 9' X 40' (360 sq. ft. each)	1440 sq. ft.
40 at 9' X 40' (360 sq. ft. each)	14400 sq. ft.
4 upright gelatin fracture tanks (400-barrel)	
20' diameter (314 sq. ft. each)	1256 sq. ft.
2 to 4 CO ₂ trucks	
9' X 50' (450 sq. ft. each)	900 sq. ft.
2 to 6 bauxite or sand trucks	
2 at 9' X 50' (450 sq. ft. each)	900 sq. ft.
6 at 9' X 50' (450 sq. ft. each)	2700 sq. ft.
1 back-pressure pumper	
9' X 50'	450 sq. ft.
2 to 4 mixer blenders	
2 at 9' X 50' (450 sq. ft. each)	900 sq. ft.
4 at 9' X 50' (450 sq. ft. each)	1800 sq. ft.
150' radius safety zone from wellhead.	70686 sq. ft.

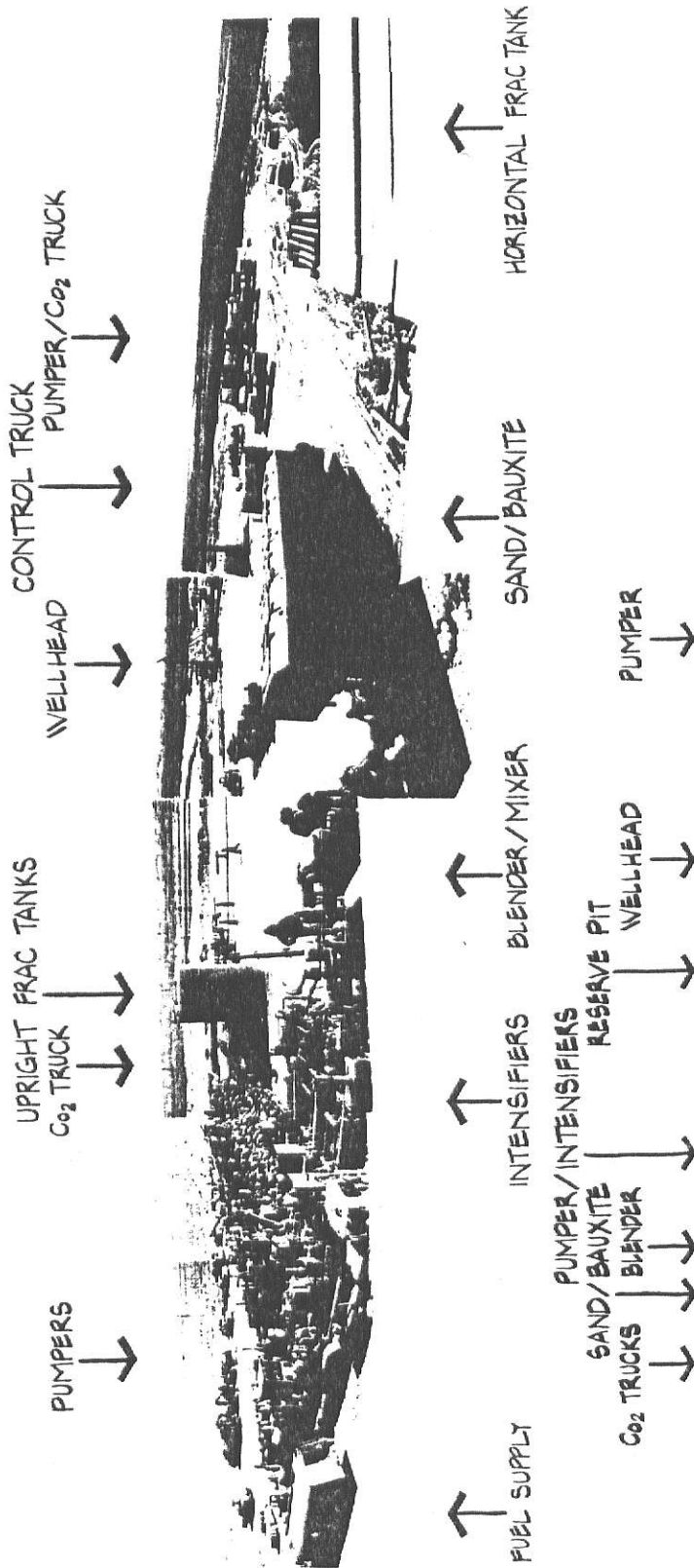


PLATE 13

PRODUCTION - TYPE 1 STIMULATION

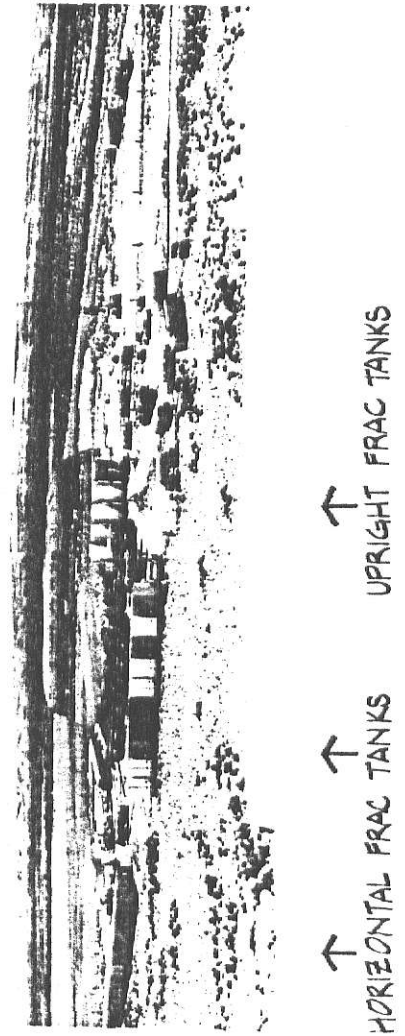


PLATE 14

PRODUCTION - TYPE 2 STIMULATION

The major difference between Type 1 and Type 2 stimulation is the different amounts of gelatin fluid pumped into the formation. Type 2 may require 40 gelatin fracture tanks and Type 1 as few as 10. Preplanning of stimulation activity is virtually non-existent. Although it is mentioned in the APD, in reality no considerations are given to the stimulation activity in the initial pad construction. Of all operations, stimulation requires the maximum surface area to meet safety regulation (page 16) and to accommodate the required equipment. Stimulation requires only 3 days, one for assembly, a second for fracturing, and a final day to disassemble. (Plate 13 and 14).

After stimulation, some fluids are required for flowback from the well to release pressure. A small pit is excavated to store these fluids.

Once the well is producing, partial reclamation of the site can be initiated. During the reclamation, scrapers excavate the fill area and place the material along the cut wall on benches. Then bulldozers level the surface to match the previous grade. (Plate 15 and 16).

PLATE 15

RECLAMATION - SCRAPER OPERATION

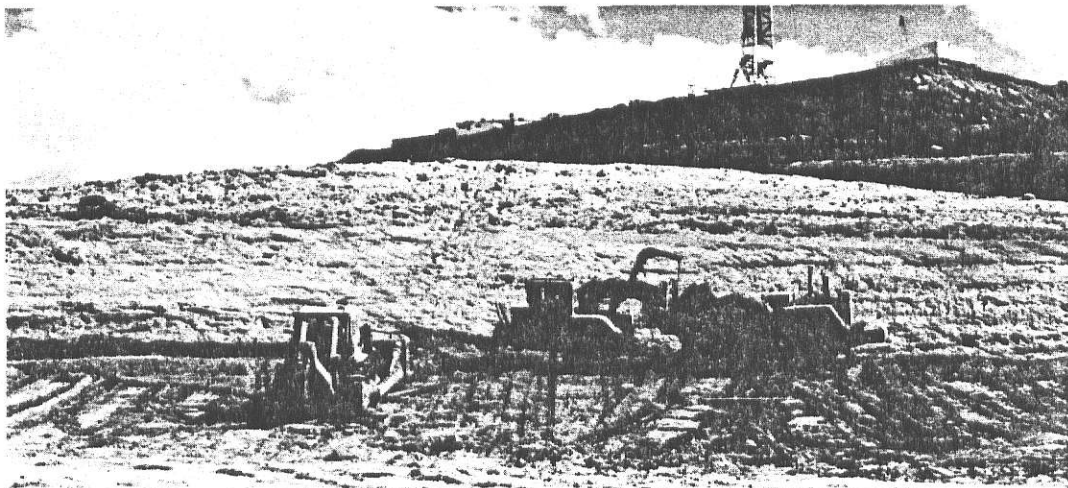


PLATE 16

RECLAMATION - BULLDOZER OPERATION

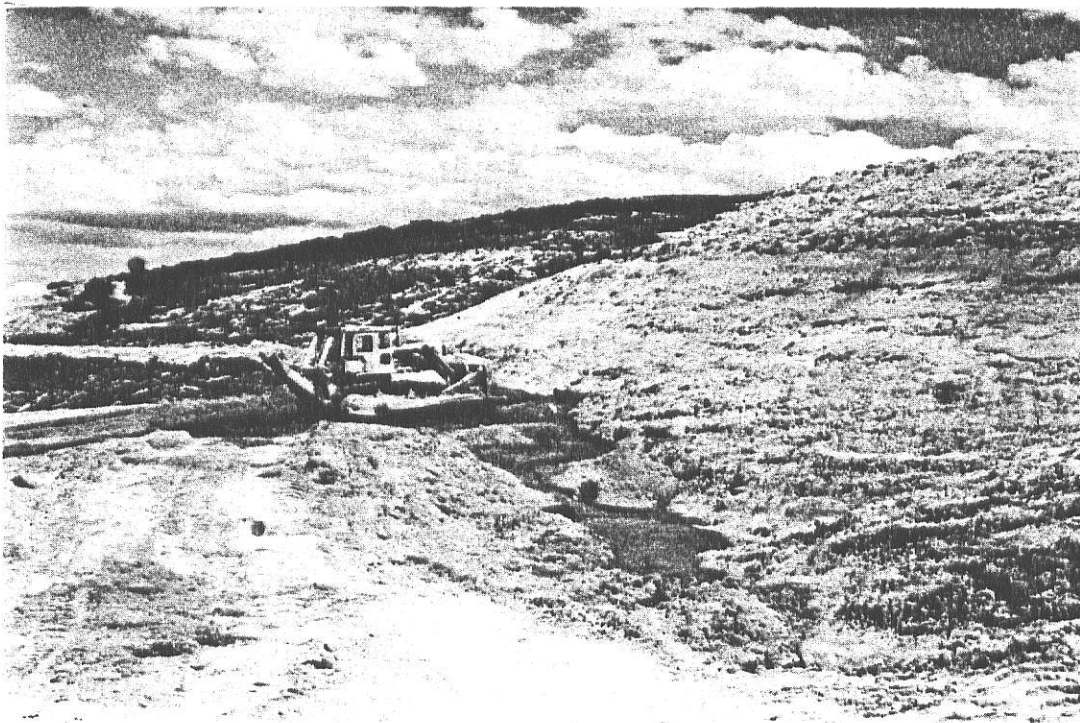


PLATE 17

RECLAMATION - RECLAIMED WELL LOCATION



Once the disturbed location is reshaped to conform to adjacent terrain, waterbreaks are prepared and seeding together with mulch, fertilizers, etc. is done. This prevents erosion of fill material and reestablishes desirable vegetation. (Plate 17).

Observation

Chapter 5

CHAPTER 5

OBSERVATION

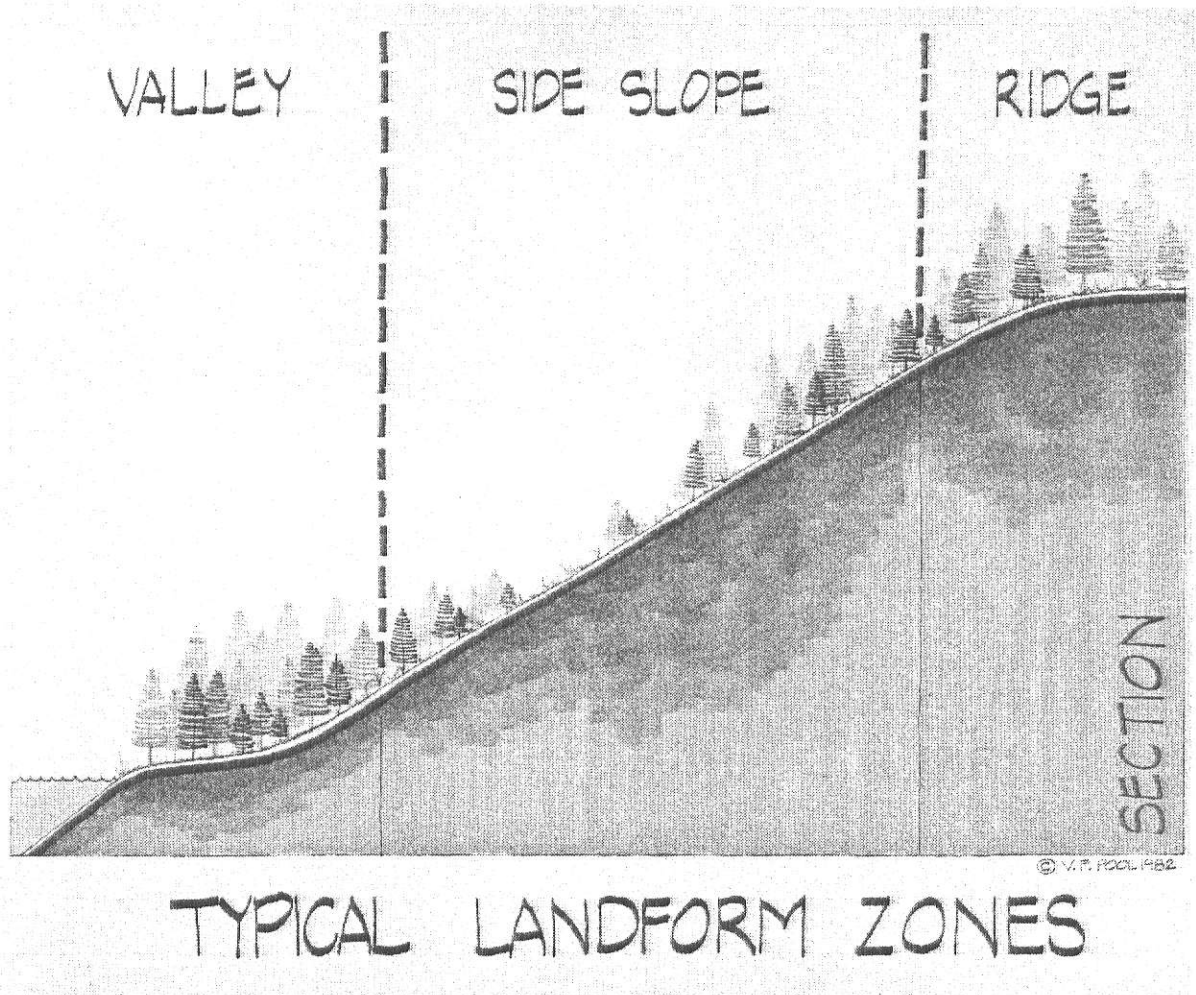
Oil and gas development involves several sequential phases of activity, all of which occur within the pad area throughout the well's life. Initial site design of the drilling pad must accommodate these necessary activities even though some of the activities may prove unnecessary after the drilling operations are completed. The primary influences on the area requirement for the drilling site are the service activity (e.g., stimulation) and the safety regulations (Illustration 6).

Assuming a mountainous region, a drill site may occur in one of three geographical zones (1) ridge, (2) side slope, and (3) valley. The ridge is usually a relatively flat area extending from the summit or hilltop to the side slope, the point where the landform drops off in a continuous steep slope. In the Overthrust Belt the side slope is a continuous 15 percent to 70 percent slope which occurs between the ridge and valley zones. The valley, another relatively flat area, begins at the base of the side slope (Figure 8).

Twelve case study sites were identified within the three geographic zones. These included drilling structures on location, production wells, wells under emergency conditions, and reclaimed sites. Each site was visited to identify the location, to observe operations, problems, and other factors that might influence the pad design.

It became apparent very quickly that development on the steep side slope produced more negative impacts than development on the ridge or

FIGURE 8



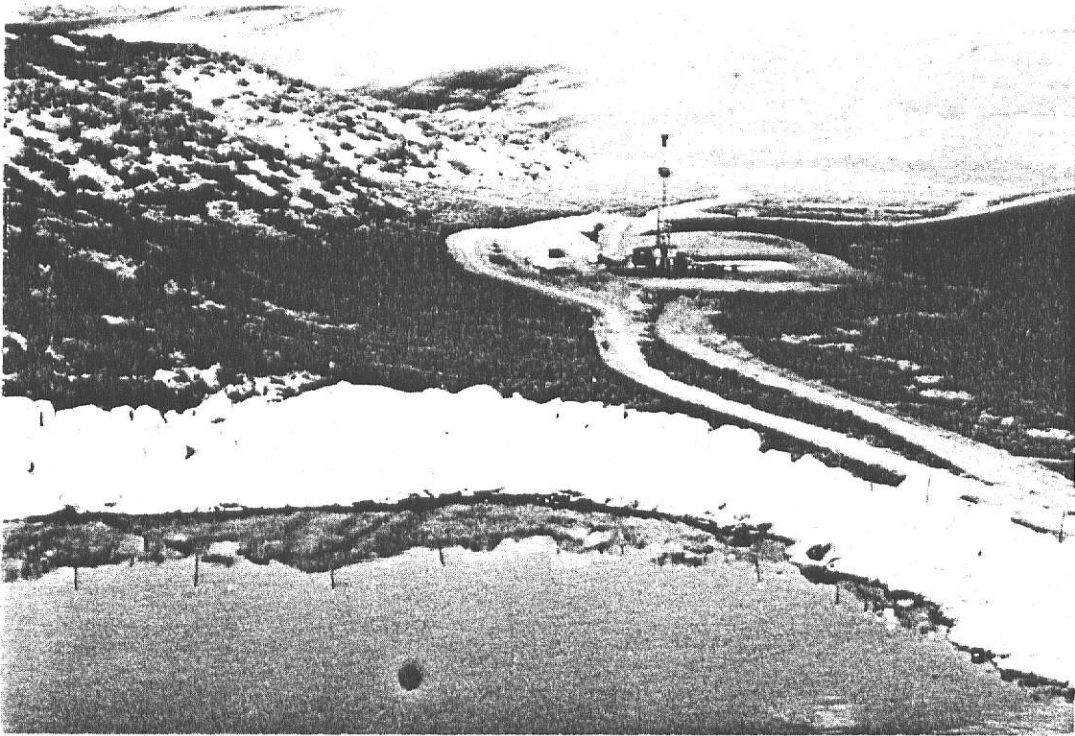
the valley. The most significant impacts - erosion/siltation runoff and visual disruption - were a direct result of the large quantities of earthwork needed to build the traditional geometric, relatively flat pads on the steep side slopes. Traditional pad construction techniques contribute to the siltation and sedimentation problems which in turn add to the continuing cost of maintenance and repair needed during the life of the well. The continued use of these traditional techniques of pad construction suggest an inherent resistance within the industry to recognize the need for change. It is apparent there are alternative approaches to pad construction that would reduce the negative environmental impacts and also reduce the cost of construction and

reclamation. Some of the traditional practices causing the more severe problems are: (1) poorly compacted dikes around reserve pits, (2) reserve pit placement on fill or within the flowline of offsite surface drainage channels, (3) broadcasting of large boulders and fill downgrade from the pad shelf, (4) obstruction of drainage channels, (5) improper backfill of reserve pits with topsoil or automobiles, and (6) poor surface grading.

It is apparent that drilling operators are concerned with the stability of the drill structures as the drill structures are located in the cut zone ensuring a stable foundation without further compaction. However, many operators overlook the importance of foundation stability when constructing reserve pits. Although regulation requires: (1) that seventy percent of its holding capacity be within a cut zone, (2) the dike be constructed with a keyway excavated in the existing grade, and (3) the dike should be free of debris and large boulders to ensure compaction, these requirements are often not adhered to. Poor compaction and insufficient soil stability often cause the dike to breach or leak, allowing the toxic mud and fluids to contaminate the environment. At an absolute minimum, compaction of fill areas in general and reserve pit dikes in particular should be given top priority during earthwork operations in direct contrast to the present approach. (Plate 18).

PLATE 18

PROBLEM - POOR CONSTRUCTION TECHNIQUES



At the same time, in steep terrain the reserve pit should not be placed at the toe of the high wall. If it is, subsoil can become unstable, give way and cause the high wall to slide into the pit reducing the volume of the pit (referred to as squeezing) forcing drilling fluids onto the hillside. (Plate 19).

If pits are placed in drainage swales, there's a strong possibility that the drilling fluids will be washed out by runoff from rain storms and snow melt. (Plate 20). Another problem often plaguing reserve pits are the advent of springs within the pit or adjacent high wall, flooding the pit. (Plate 21).

PLATE 19

PROBLEM - UNSTABLE HIGHWALL WITHIN CUT ZONE

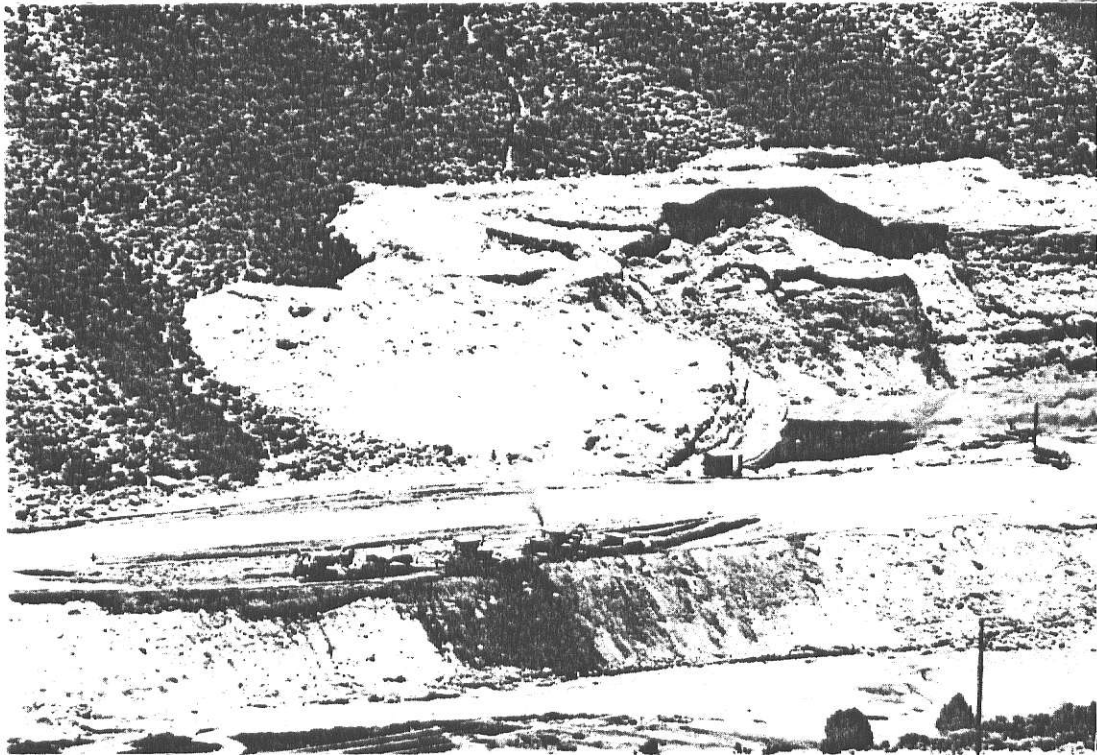


PLATE 20

PROBLEM - PLACEMENT OF RESERVE PIT WITHIN SURFACE RUNOFF

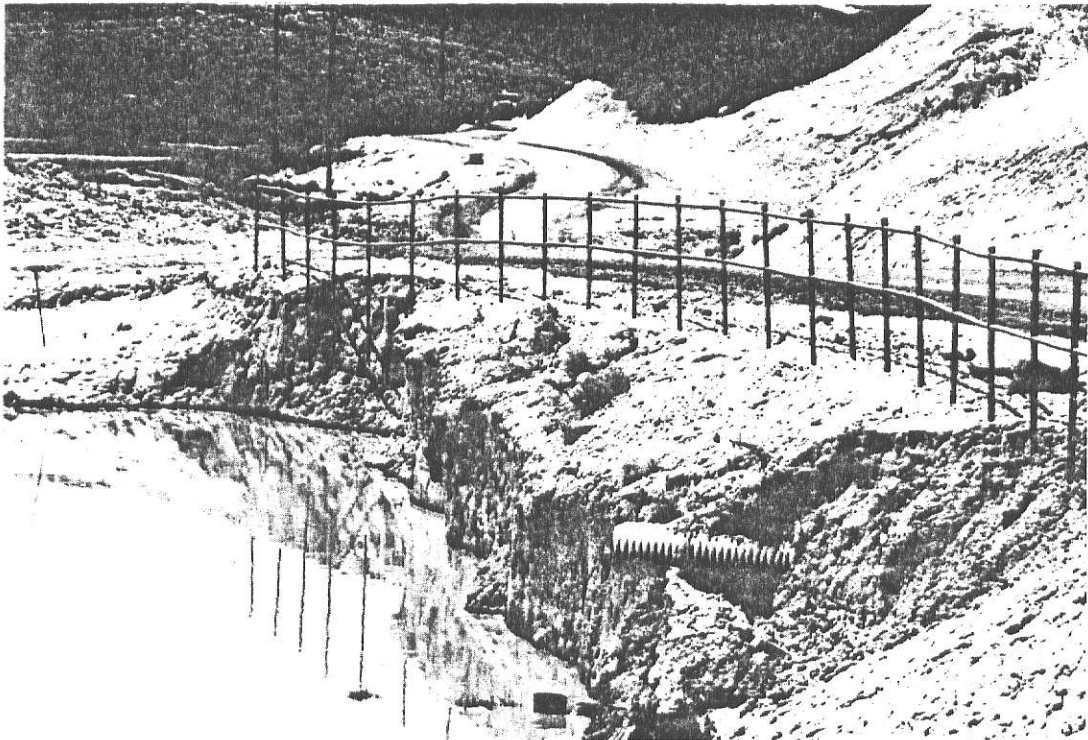


PLATE 21

PROBLEM - ACTIVE SEASONAL WATER TABLE SQUEEZES PIT FLUIDS

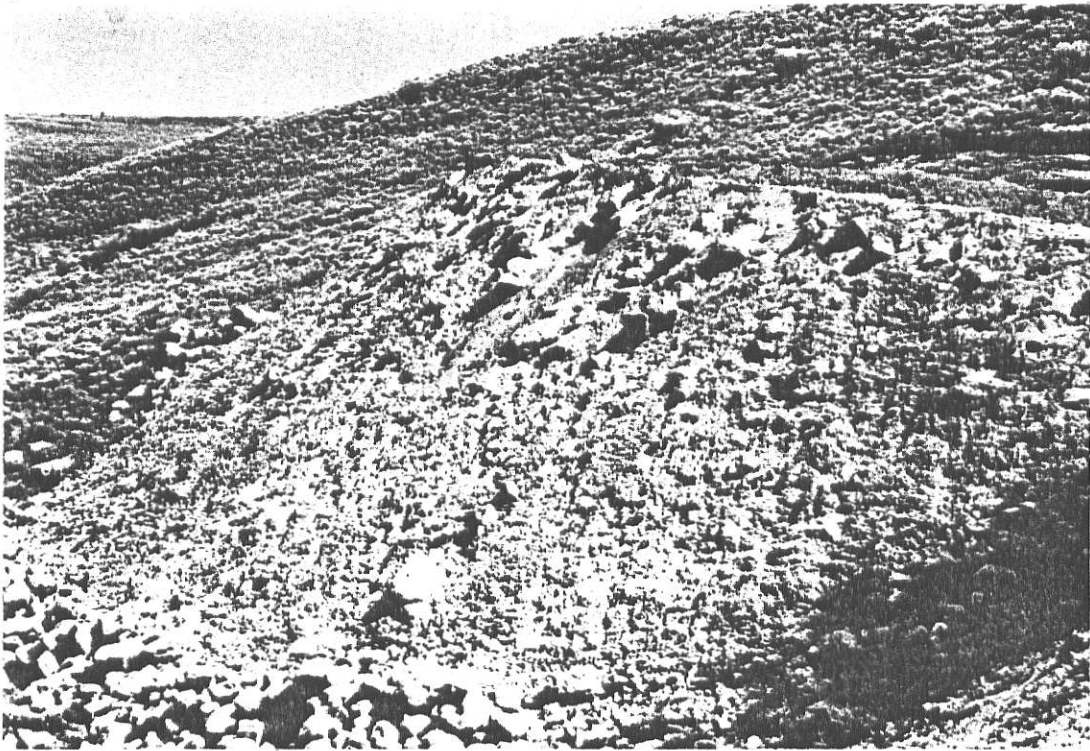


Furthermore, it is not uncommon to observe overcast fill zones which completely obstruct drainage channels (Plate 22 and 23), resulting in increased sedimentation within the streams and ultimately within reservoirs (Plate 24 and 25) significantly compromising water quality of the area and region.

Once an area is disturbed, it is apparent that sedimentation will occur without the proper controls. Control methods exist which, when properly implemented, would help alleviate sedimentation. One such method is to outline the perimeter of the disturbed area with rows of

PLATE 22

PROBLEM - ROCK OVERCAST



hay bales, which allows percolation of the water and acts as a filter to contain the sediment. (Plate 26). Another consideration is positive grading of pad surfaces to alleviate poor working conditions and decrease siltation runoff. (Plate 27).

The boulder and debris should be stockpiled on site and used later during reclamation of the reserve pit. However, it has been observed as a common practice that most boulders were overcast on the fill. (Plate 22).

Since the scrapers are unable to lift these large boulders and it is impossible to push these boulders upgrade by bulldozer, a dragline is used to reclaim the boulders increasing the reclamation cost

considerably. If the boulders are not recovered and used in the reclamation of the reserve pit, the topsoil stockpile is often used resulting in the loss of the only organic base material to support revegetation. If the boulders are not reclaimed, these add to the visual disturbance and are considered as a noncompliance toward reclamation. If used properly, the boulders contribute considerable stability to the fill zone during the reclamation process.

The problems (e.g. stream sedimentation, channel blockage, poor construction practices, etc.) have surfaced because of specific conditions in the Overthrust Region not addressed heretofore by the oil industry. A number of the problems stated can be minimized through more considerate prelaning of the pad design.

PLATE 23

PROBLEM - FILL OVERCAST OBSTRUCTS DRAINAGE CHANNEL



PLATE 24

PROBLEM - STREAM SEDIMENTATION



PLATE 25

PROBLEM - SEDIMENTATION ACCUMULATION WITHIN RESERVOIRS

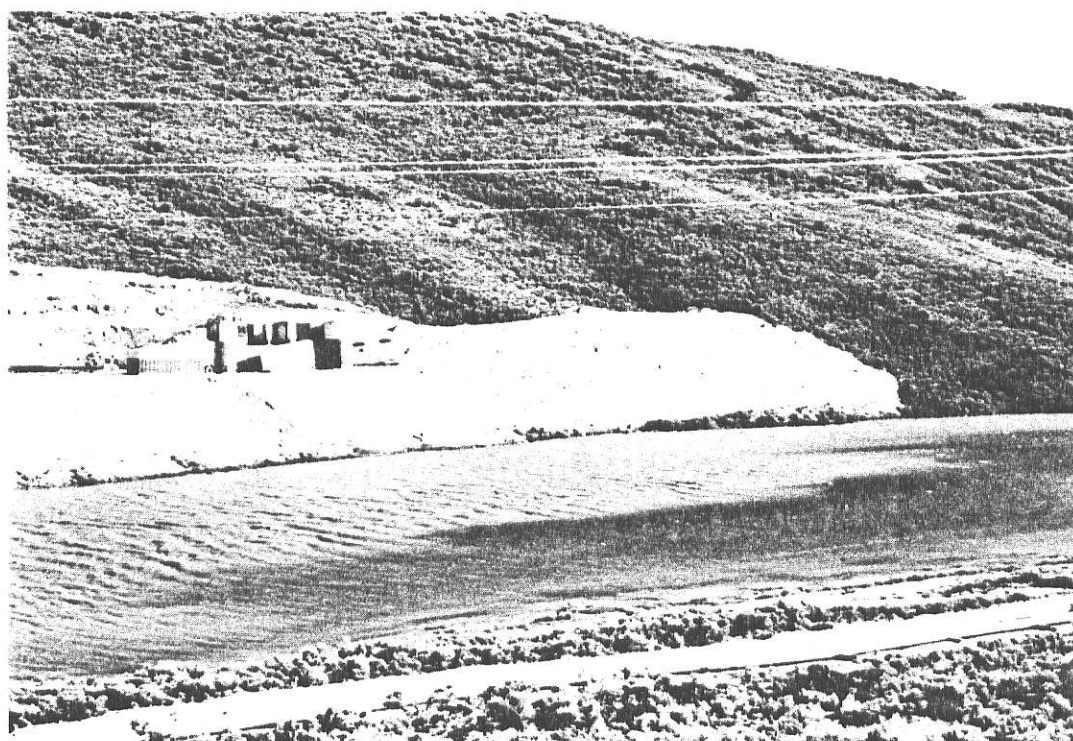


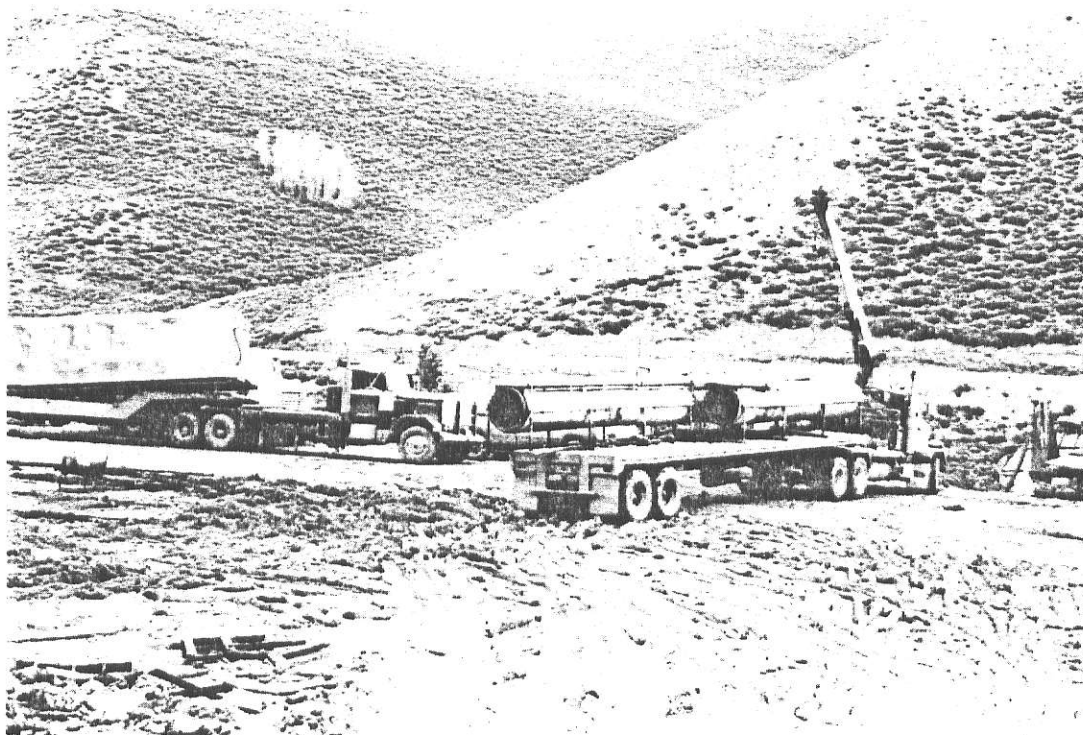
PLATE 26

STRAW BALES TO CONTROL SEDIMENTATION



PLATE 27

PROBLEM - INADEQUATE SURFACE DRAINAGE



Concepts

Chapter 6

CHAPTER 6

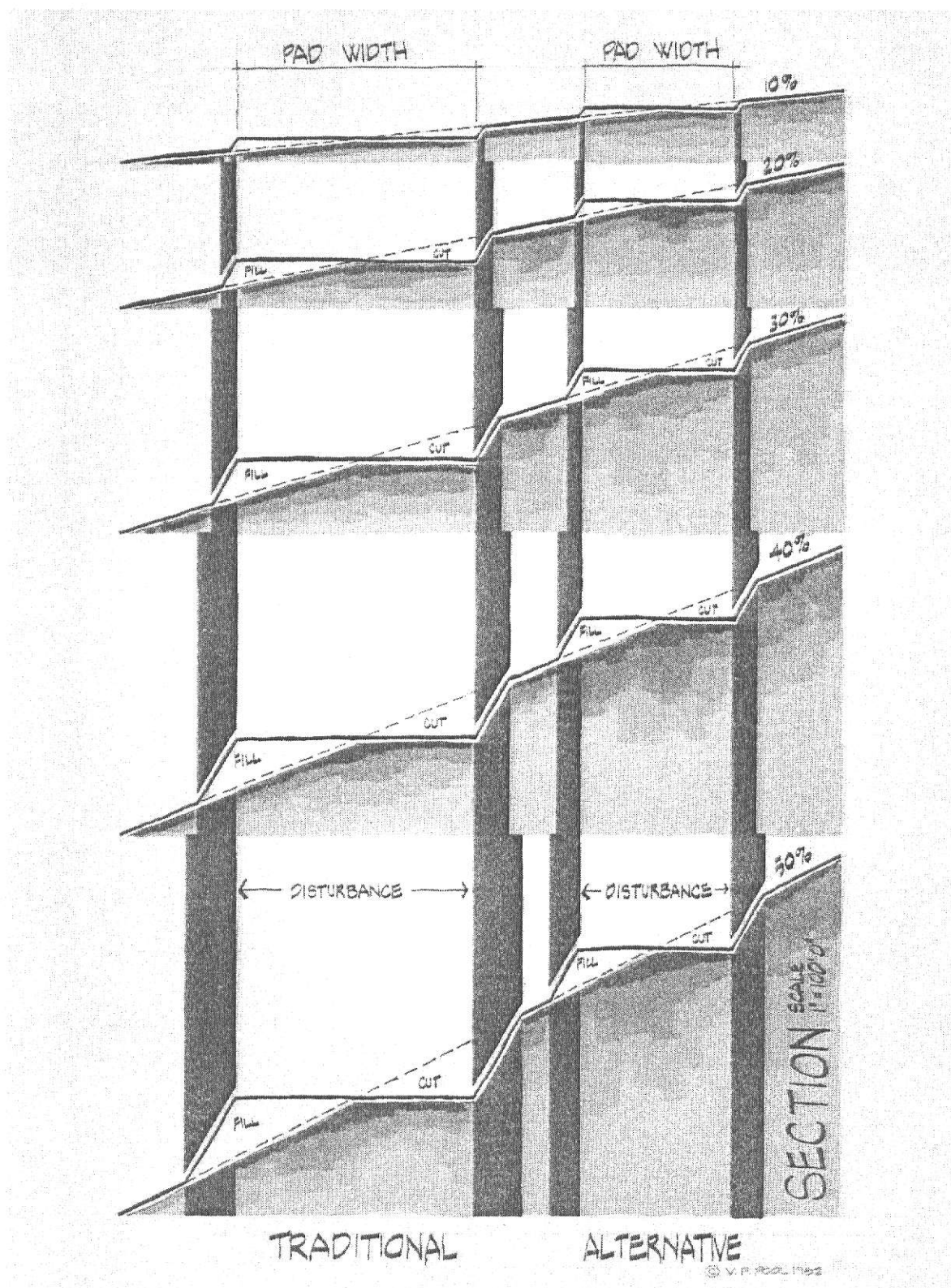
CONCEPTS

Many factors can have major influence over pad design: site location, slope, soil type, surface and subsurface hydrology, existing roads, and prevailing winds to mention a few. It's very rare for any two sites to share the same characteristics and design priorities, therefore, it is important to address each drill site location independently. As indicated in the previous chapter, the various problems encountered are a direct outgrowth of existing conditions and lack of appropriate construction considerations. However, the amount of disturbance caused by a drilling pad is directly proportional to the slope of the existing terrain and width of pad (the greater the slope and width of pad, the larger the disturbance).

Since the slope of the existing terrain is a given, pad width is the only variable available for the designer to manipulate in considering the pad layout. Figure 9 illustrates the amount of disturbance caused by the use of a narrower pad in terrain with slopes of 10, 20, 30, 40, and 50 percent and suggest that narrower pads would cause much less disturbance. This in turn, sets reduced width as the major criteria for designing a pad that will be more compatible with the existing terrain. Since site conditions in the Overthrust Region vary greatly, the following assumptions regarding existing site conditions and design criteria were established so that accurate comparisons could be made between nontraditional drilling pad concepts and their ability to successfully meet industry operation and safety standards.

FIGURE 9

INCREASE SLOPE PERCENTAGE AND PAD WIDTH EQUALS INCREASED DISTURBANCE



Existing Site Conditions:

1. Continuous uniform 50 percent slope.
2. Favorable subsoil conditions.
3. Non-forest vegetation.
4. No surface or subsurface problems
5. Prevailing winds parallel the slope.

Design Criteria:

1. Sheet surface drainage.
2. Cut and fill slopes should be maintained at a maximum ratio of 1.5:1.
3. Reserve pit to accommodate 40,000 barrels of fluid and 70 percent of it to be placed in cut area.

First, a pad employing the traditional layout was applied to the site conditions to establish a basis for comparing nontraditional concepts with those presently in use. The size and configuration of this pad (Figure 10) was based on the average dimension of twelve case studies in the Overthrust Region and it does not reflect the largest or smallest pads studied. The pad is rectangular and has a surface area of approximately 3.3 acres. This area will accommodate all of the drilling, service, and production activities except stimulation. Assuming stimulation, with its condensate tanks, requires that the area be enlarged to 11.7 acres (including backslopes fill and cut zones) to meet safety regulations. This large disturbance is the result of stimulation activities requiring a flat site in steeply sloping terrain.

As stated previously, the slope of the terrain is a given and width of the pad is a variable. Therefore, if a narrower pad could be used, the amount of disturbance would be reduced. To narrow the pad width,

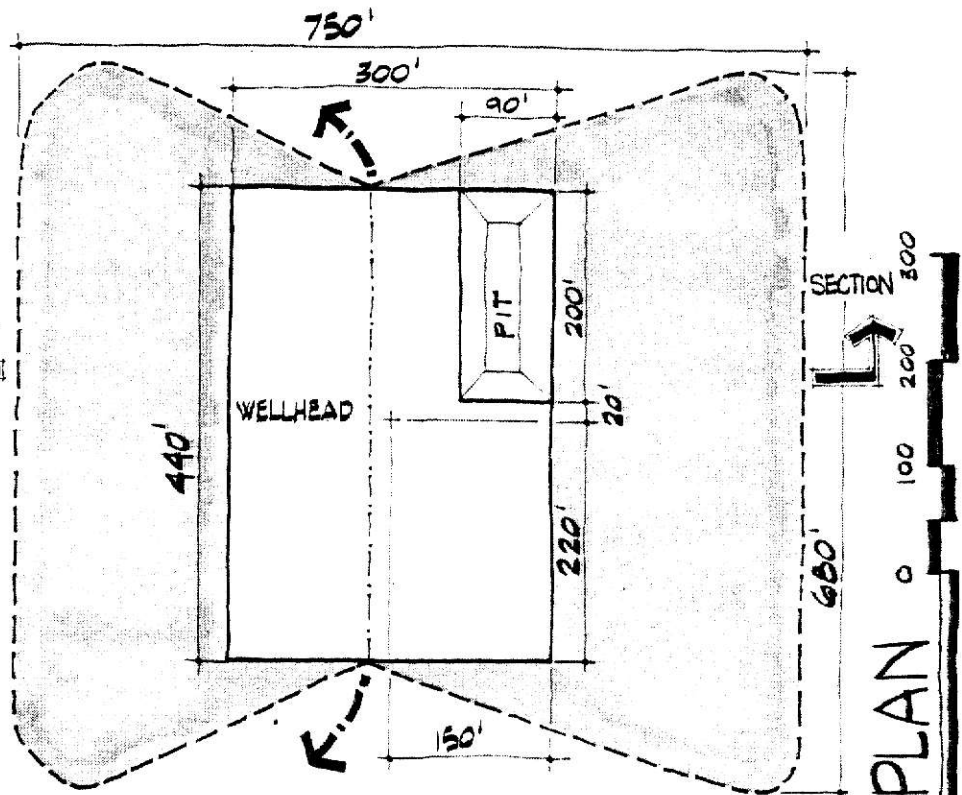
FIGURE 10

TRADITIONAL DRILL PAD DESIGN

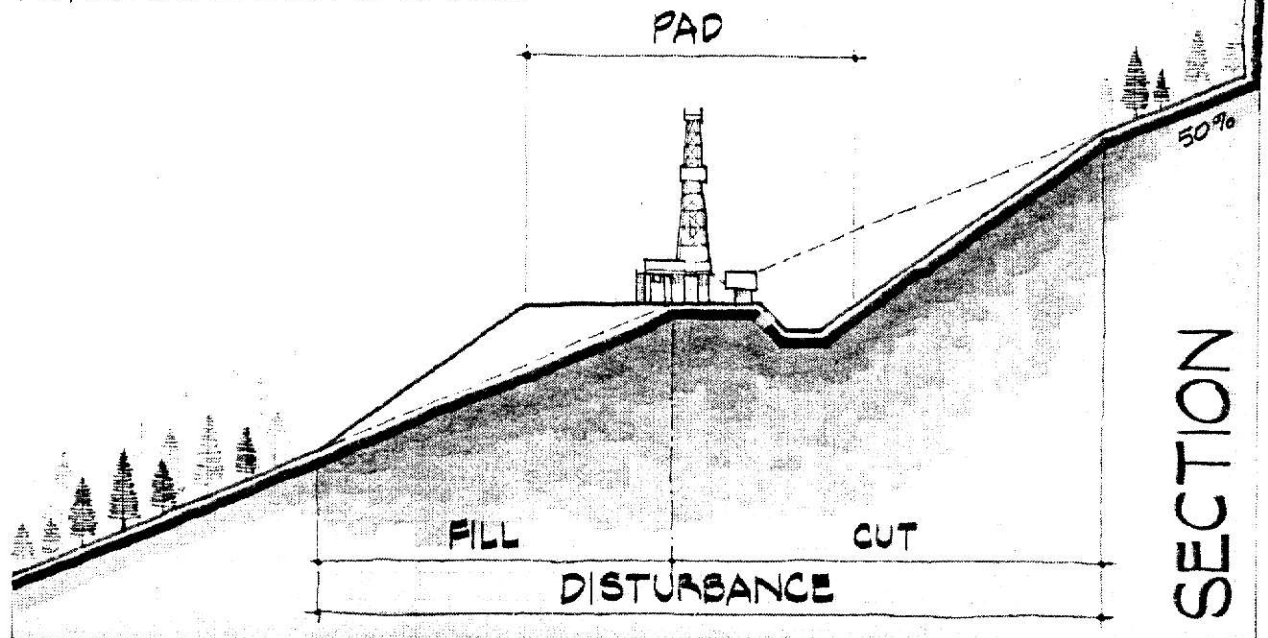
LEGEND

- DISTURBANCE
- - - NO CUT, NO FILL
- ← ROAD ACCESS

SECTION



3.3 AC. PAD AREA
11.7 AC. TOTAL DISTURBANCE



the reserve mud pit was relocated to the end of the site and a drainage swale excavated next to a high wall to allow fluid movement into the pit from the mud tanks. The drainage swale provides adequate gradient and width to accommodate a small tractor with blade to assist the movement of fluid and cuttings outcast into the pit if necessary (Alternative 1 Figure 11). The reduced width of the pad may range from 110 to 200 feet (depending on the reserve pit size) which proportionately reduces the area of disturbance $\pm 44\%$ on the average.

Three alternative pad design concepts were developed based on the following design objectives:

- * Reduce the environmental and ecological damage.
- * Reduce the visual damage.
- * Reduce the pad construction cost.
- * Preplan reclamation activities.
- * Reduce the cost of reclamation.
- * Accommodate safety or industry operating standards.

Alternative 1 Pad Design

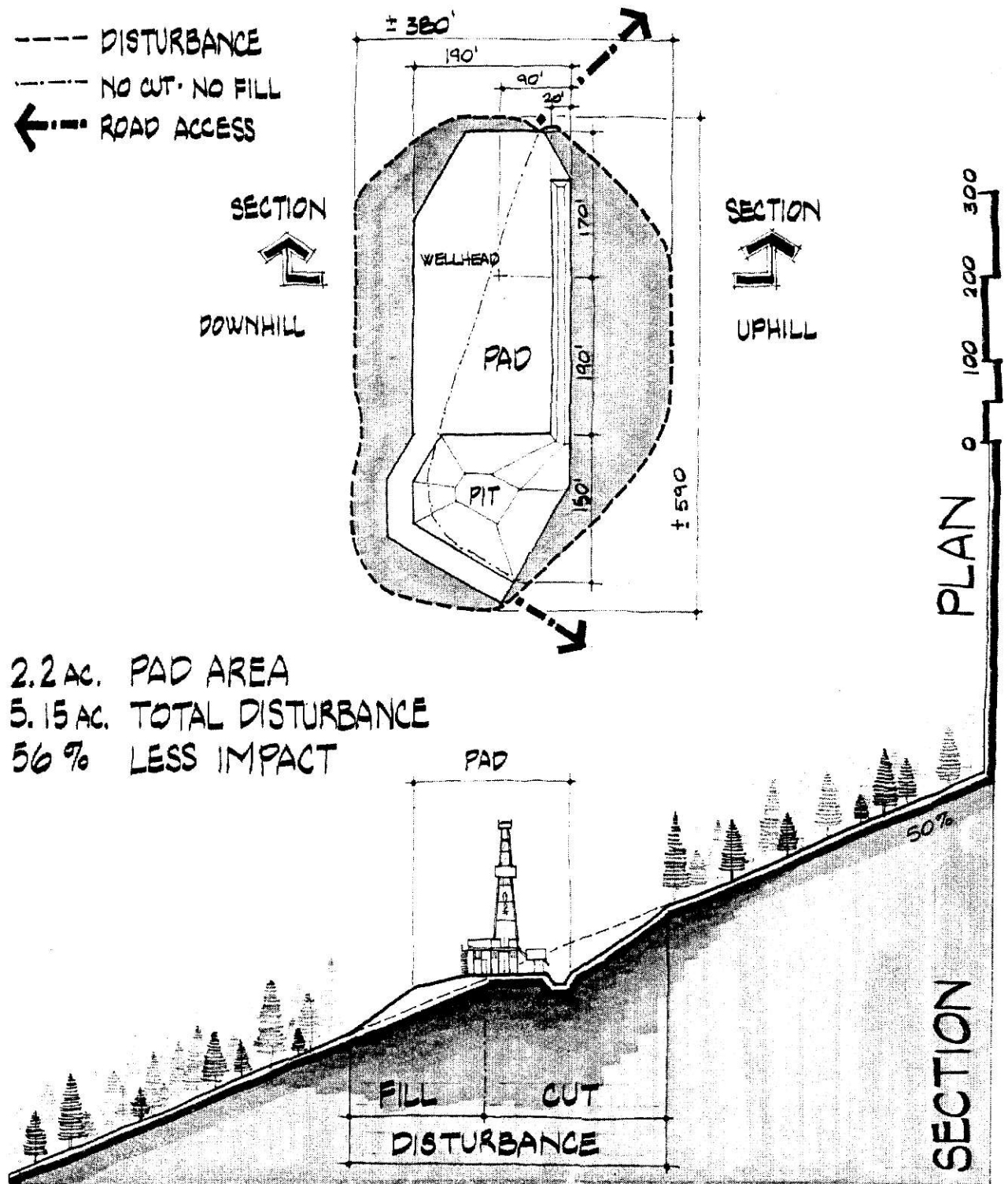
Alternative 1 applies the principle of narrowing the width and lengthening the pad area to fit the contour and to minimize the total disturbance (Figure 11). As compared to the traditional pad design (11.7 acres total disturbance), Alternative 1 (5.15 acres total disturbance) decreases the total disturbance by 56 percent. The pad surface (2.2 acres) meets all safety regulations for drilling and various service activities. However, it is unable to accommodate the 150' safety radius for either type of stimulation. Seventy percent of the reserve pit is located in the cut zone, reducing the potential of breaching or slippage of material from the cut wall which has a minimum

FIGURE 11

ALTERNATIVE 1 PAD DESIGN

LEGEND

- DISTURBANCE
 -.-.-.- NO CUT, NO FILL
 ←--- ROAD ACCESS



height. A bench, of adequate width to handle a tractor with blade, is provided as an additional precaution. The retention dike is reinforced by the additional width required for the roadway. The road follows the no cut/no fill line which makes possible the early reclamation of part of the site. Once drilling is complete, the outer edge of the pad can be regraded back to original grade and still allow room for the production facilities (Figure 14). The no cut/no fill line also bisects the site to maximize an attempt to reduce the stockpile of spoils material by balancing the cut and fill quantities. Furthermore, this provides a stable base for the drill structure and other equipment. The topsoil stripped should be stockpiled on the opposite side of the site from the reserve pit to minimize the chance of it being used as backfill during reclamation. Since this alternative cannot accommodate service activities, its use should be limited to regions where it is known that stimulation will not be required.

Alternative 2 Pad Design

Alternative 2, which is similar to Alternative 1, offers increased surface length to accommodate Type 1 stimulation (high pressure/low fluid mixture - Plate 14). Compared to the traditional pad design, Alternative 2 (5.32 acres total disturbance) decreases the total disturbance as much as 55 percent (Figure 12 compared to Figure 11). This pad design should be used in regions with geologic formations that require Type 1 stimulation service activity.

Alternative 3 Pad Design

The addition of an upper bench area (.85 acres surface area or 2.27 acres total disturbance) to Alternative 2 creates Alternative 3, which

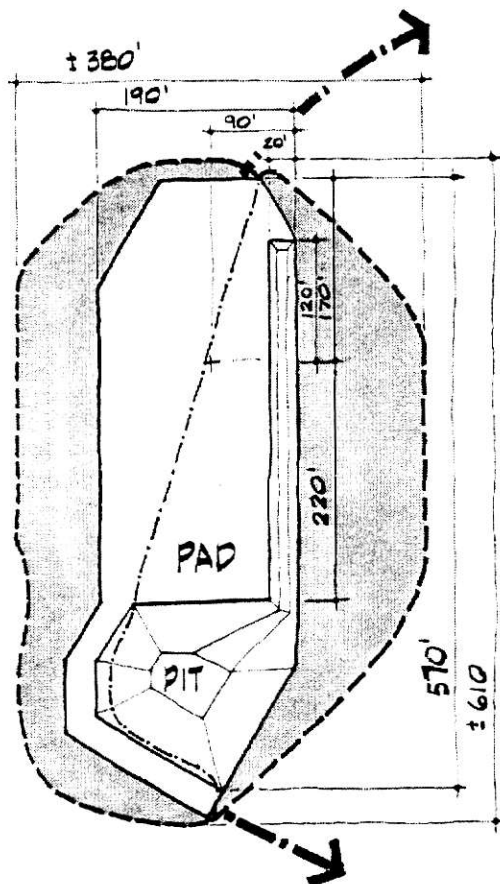
FIGURE 12

ALTERNATIVE 2 PAD DESIGN

LEGEND

- DISTURBANCE
 - - - NOCUT, NO FILL
 ← ROAD ACCESS

SECTION
 ↑
 DOWNHILL



SECTION
 ↑
 UPHILL

PLAN 0 100 200 300

2.49 AC. PAD AREA
 5.32 AC. TOTAL DISTURBANCE
 55% LESS IMPACT

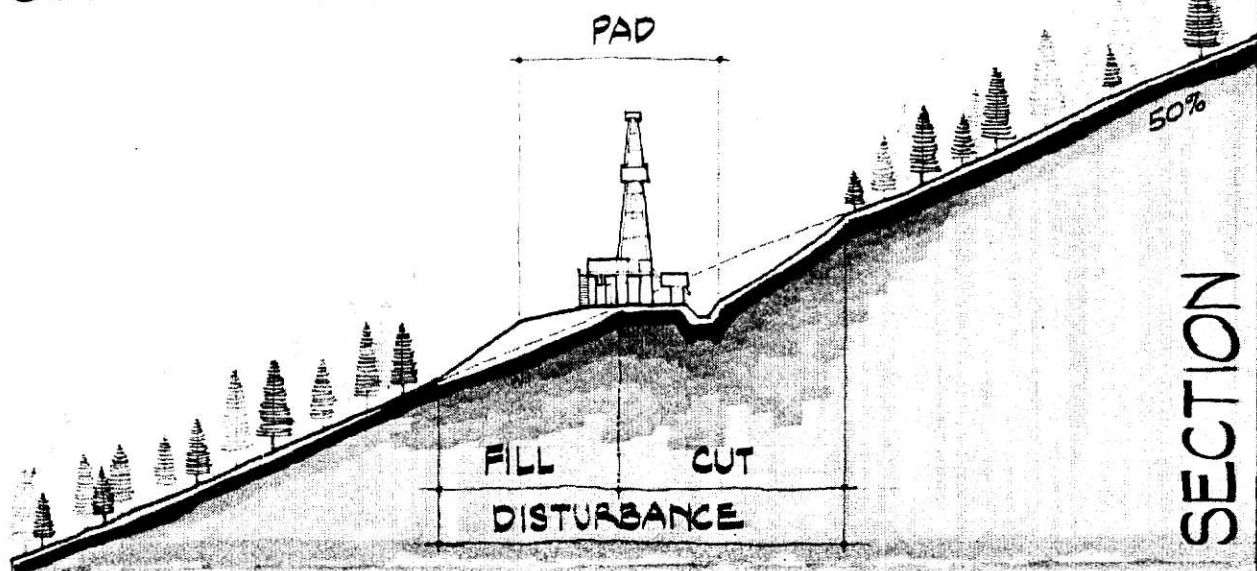


FIGURE 13

ALTERNATIVE 3 PAD DESIGN

LEGEND

--- DISTURBANCE

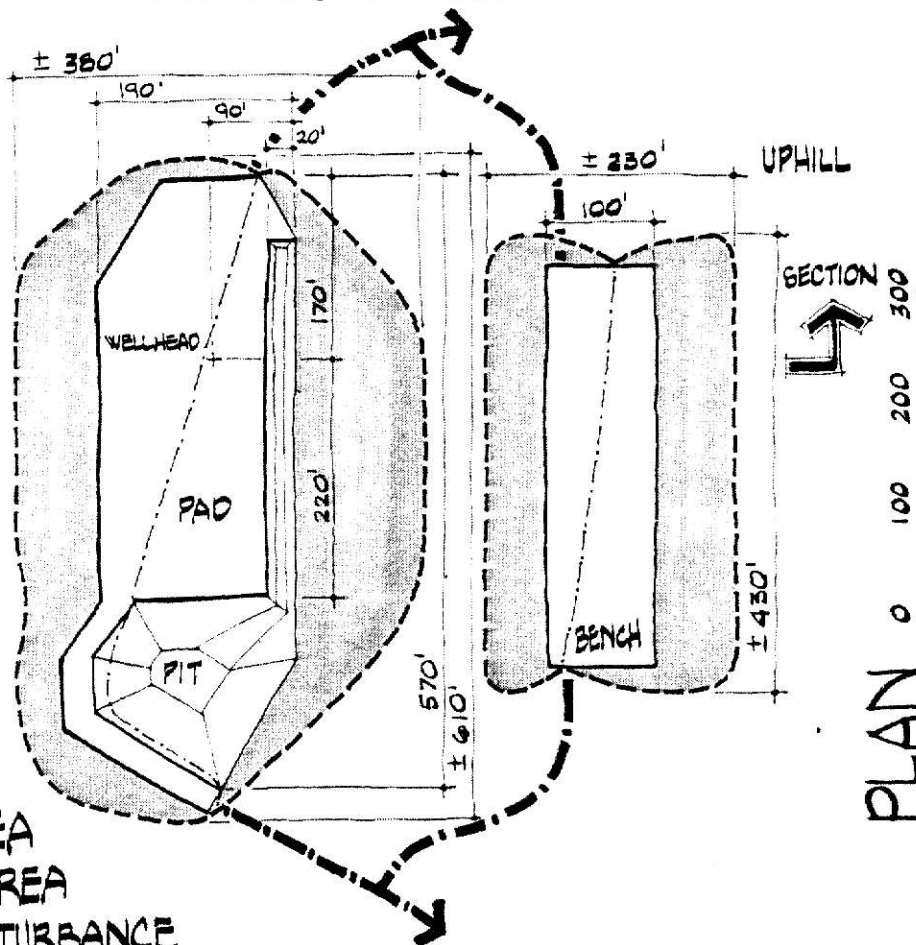
- - - NO CUT, NO FILL

← ROAD ACCESS

SECTION

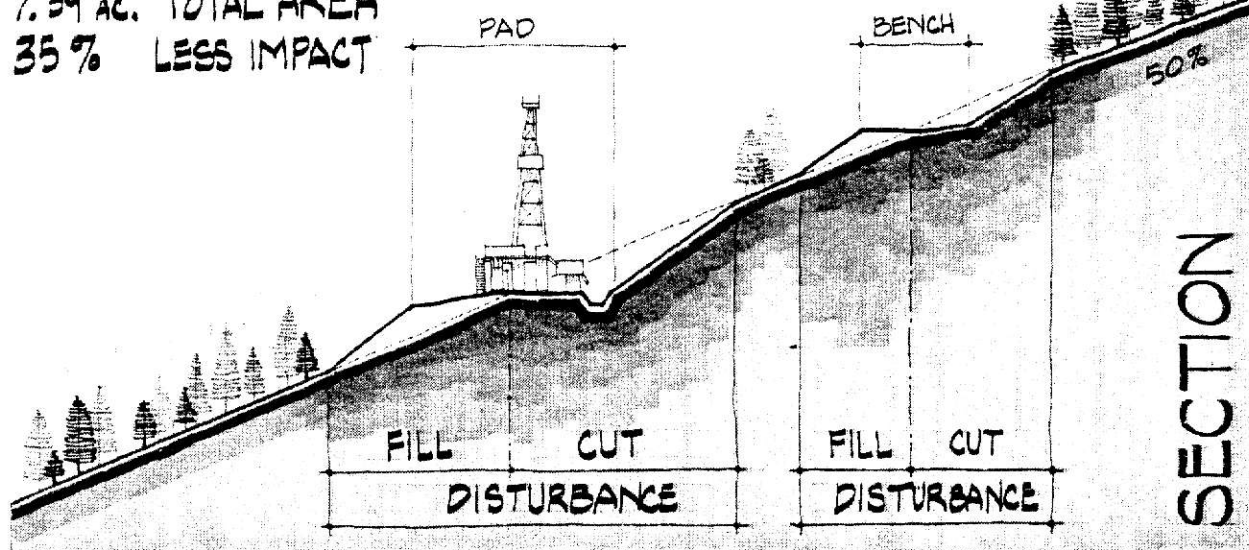


DOWNHILL



PLAN

2.49 AC. PAD AREA
 .85 AC. BENCH AREA
 5.32 AC. PAD DISTURBANCE
 2.27 AC. BENCH DISTURBANCE
7.59 AC. TOTAL AREA
 35% LESS IMPACT



SECTION

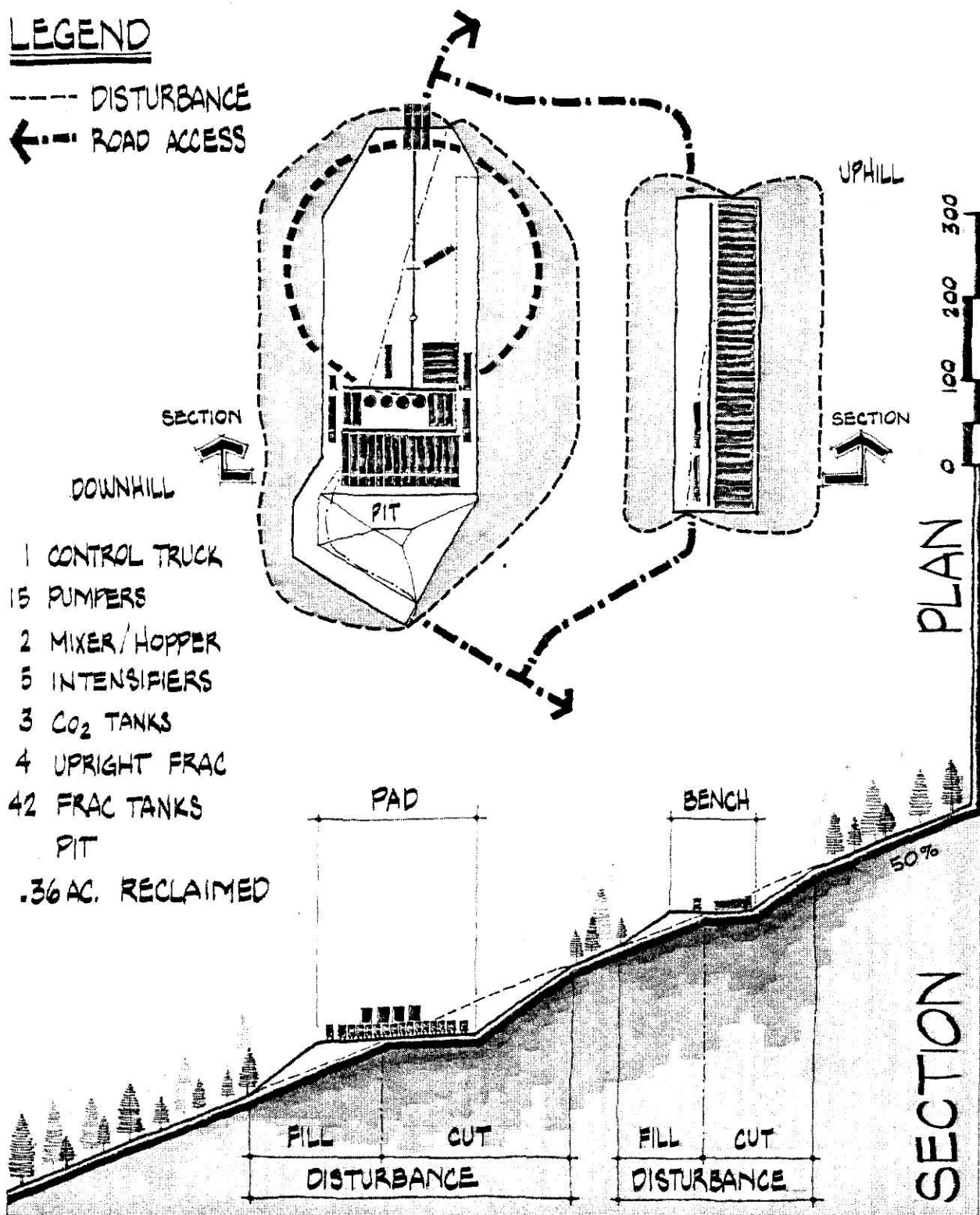
FIGURE 14

STIMULATION LAYOUT

LEGEND

----- DISTURBANCE

←--- ROAD ACCESS



is able to accommodate the maximum Type 2 stimulation (high pressure/high fluid mixture (Plate 14 and Figure 13)). Compared to the traditional pad design, Alternative 3 (7.59 acres total disturbance including the bench area) can reduce the total disturbance as much as 35 percent (Figure 13). Alternative 3 has several advantages over the traditional design.

1. The work surface areas total 3.3 acres each, but Alternative 3 meets safety regulations for all stimulation types and provides dual access routes which are required when drilling within formations that may contain H_2S .
2. The dual access routes can serve as future access routes to new drill pad sites.
3. Proper drainage beside the fracturing tanks (which contain condensate fluid) on the upper bench may direct leakage or spillage away from combustion engines.
4. Hydraulic pressure by gravity flow of gelatin or condensate fluids is increased when flowing downhill to the pad.
5. The dike of the reserve pit is safer due to increased width and increased compaction via constant traffic load.
6. The chance of cut or fill slopes sliding downhill into streams or reserve pits is reduced due to decreased height.

Alternative 3 pad design is recommended assuming the maximum type of service activity is needed or if the need for stimulation is unknown. Once alternative 3 pad design is staked out and approved, the driller then should proceed with construction of the pad only. When drilling is complete, if stimulation is needed, the permit has already been approved and the driller can continue with the necessary site work to accommodate

stimulation activities, thus avoiding costly delays in redesigning, staking, applying for and receiving approval for the additional work. If stimulation is not needed, the area can be left untouched.

Production/Reclamation

Reclamation may begin immediately upon completion of drilling operations, depending on expected service activities required such as stimulation, etc. However, most stimulation activities require flow back pits with approximately 5,000-barrel capacities. Therefore, reclamation activities are usually phased in two stages with portions of the pad, cut slope, and reserve pit areas reclaimed immediately after drilling operations and the remaining reclamation completed after stimulation.

All three alternatives can easily be converted into production pads and more than 90 percent of the original pad can be reclaimed. The remaining 10 percent can be used to accommodate the road, wellhead, heater treater, and tank battery. The cut zone offers the most stable support for this equipment, so it is placed in the cut area close to the no cut/no fill line (Figure 15). This also makes it possible to reclaim the greatest percentage of the site by moving the fill material back into the cut zones using balanced quantities.

Implications

In addition to reducing the various problems, the redesign of the traditional drilling pads suggest the petroleum industry could reduce up to 56 percent of site preparation and reclamation cost associated with earthwork. This can be verified by comparing the earthwork quantities of the traditional pad to the alternative concepts. Although not

FIGURE 15

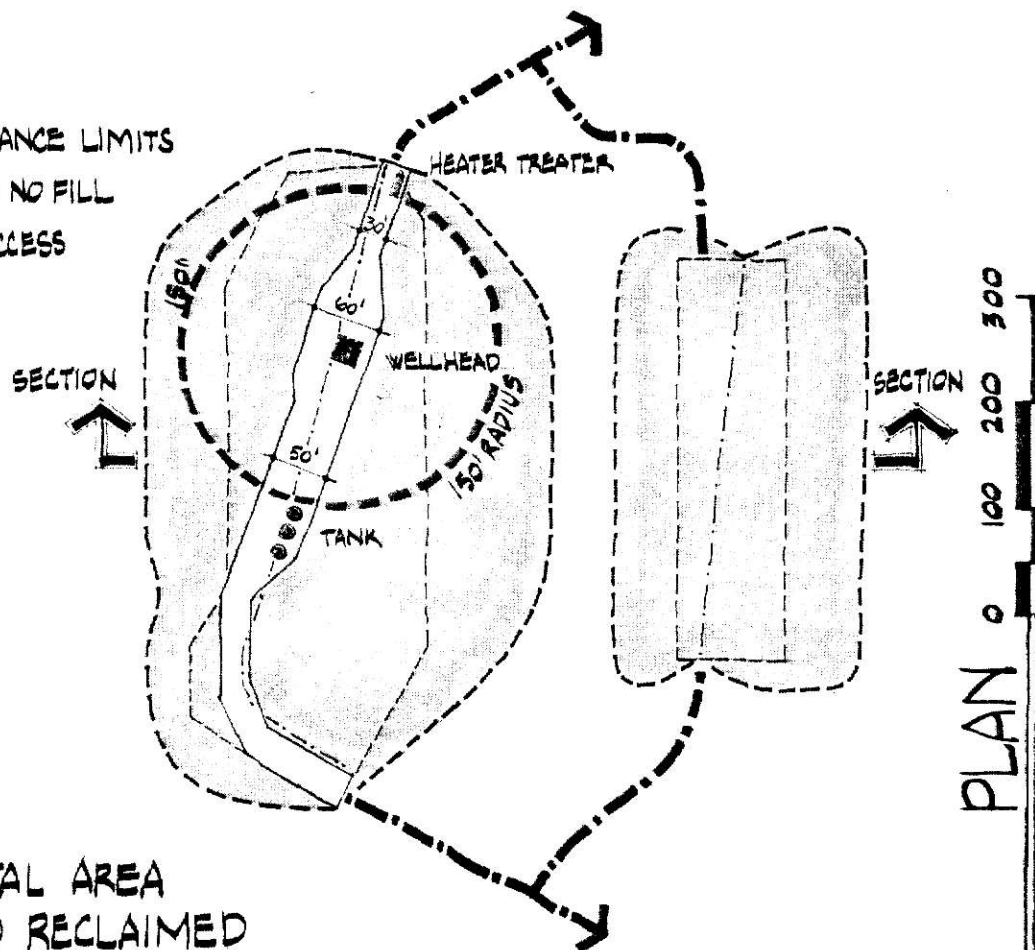
PRODUCTION DESIGN LAYOUT

LEGEND

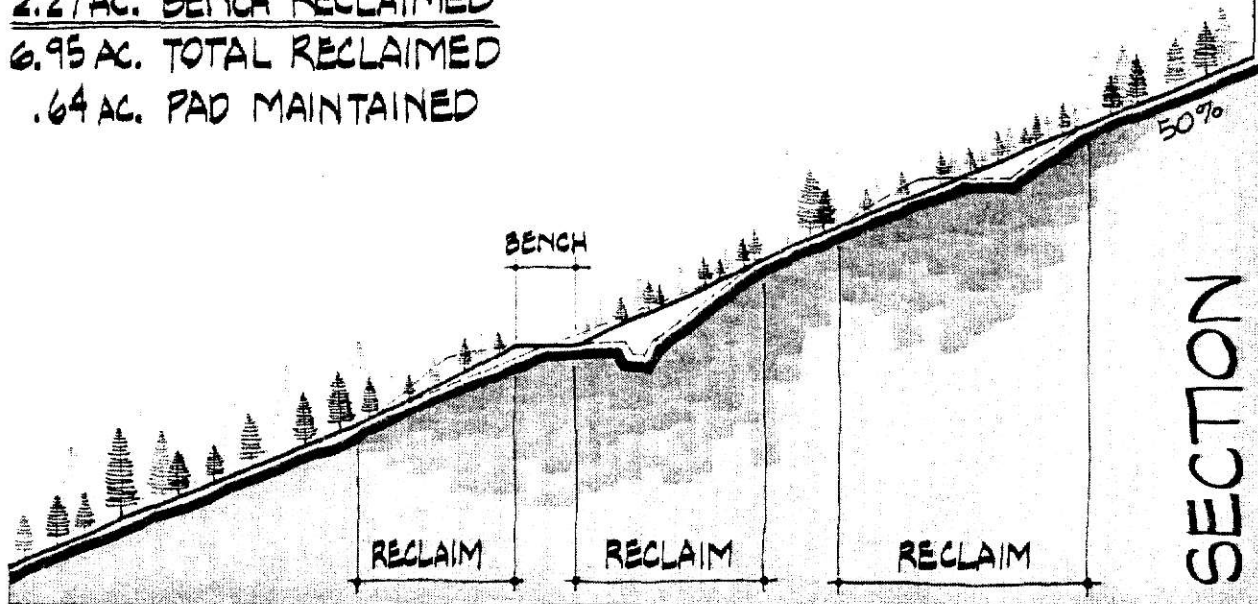
----- DISTURBANCE LIMITS

----- NO-CUT - NO FILL

←--- ROAD ACCESS



7.59 AC. TOTAL AREA
 4.68 AC. PAD RECLAIMED
2.27 AC. BENCH RECLAIMED
 6.95 AC. TOTAL RECLAIMED
 .64 AC. PAD MAINTAINED



encompassed in this study, general observations suggest that reduced earthwork will produce:

1. Less environmental damage.
2. A savings in pad construction and maintenance cost.
3. A reduction in manhours needed for additional approvals of stimulation activities.
4. A savings in reclamation cost.

Earthwork quantities, however, can be estimated in advance of construction with some accuracy. The alternative pad design concept implies that a significant reduction of the disturbance is possible for side slopes of 50 percent or greater. Therefore, to verify this, the concepts were applied to and compared to ten sites; 3 ridge, 3 side slope, and 4 valley locations in the Overthrust Region. These comparisons show that earthwork quantities could have been reduced on any of the location indicated. In fact, earthwork quantities could have been reduced an average of 56 percent on ridge sites, 40 percent in the valley, and 66 percent on sites located on the side slopes. The quantities for ridge sites appear high, since ridges are typically flat. However, placement of the wider traditional pad on the relatively narrow ridges forced encroachment onto the side slopes increasing the earthwork considerably.

The application of Alternatives 1, 2, and 3 to the existing three landforms indicates a larger savings when compared to the initial conceptual studies (Figure 16 and Appendix).

These alternatives offer the industry a wide range of designs suitable for oil and gas development within the Overthrust Belt. The industry may select the most appropriate alternative during the planning stages and reduce expense and problems in future years.

FIGURE 16

INDUSTRY TRADITIONAL DESIGN COMPARED WITH ALTERNATIVE DESIGNS
ON THE THREE LANDFORMS

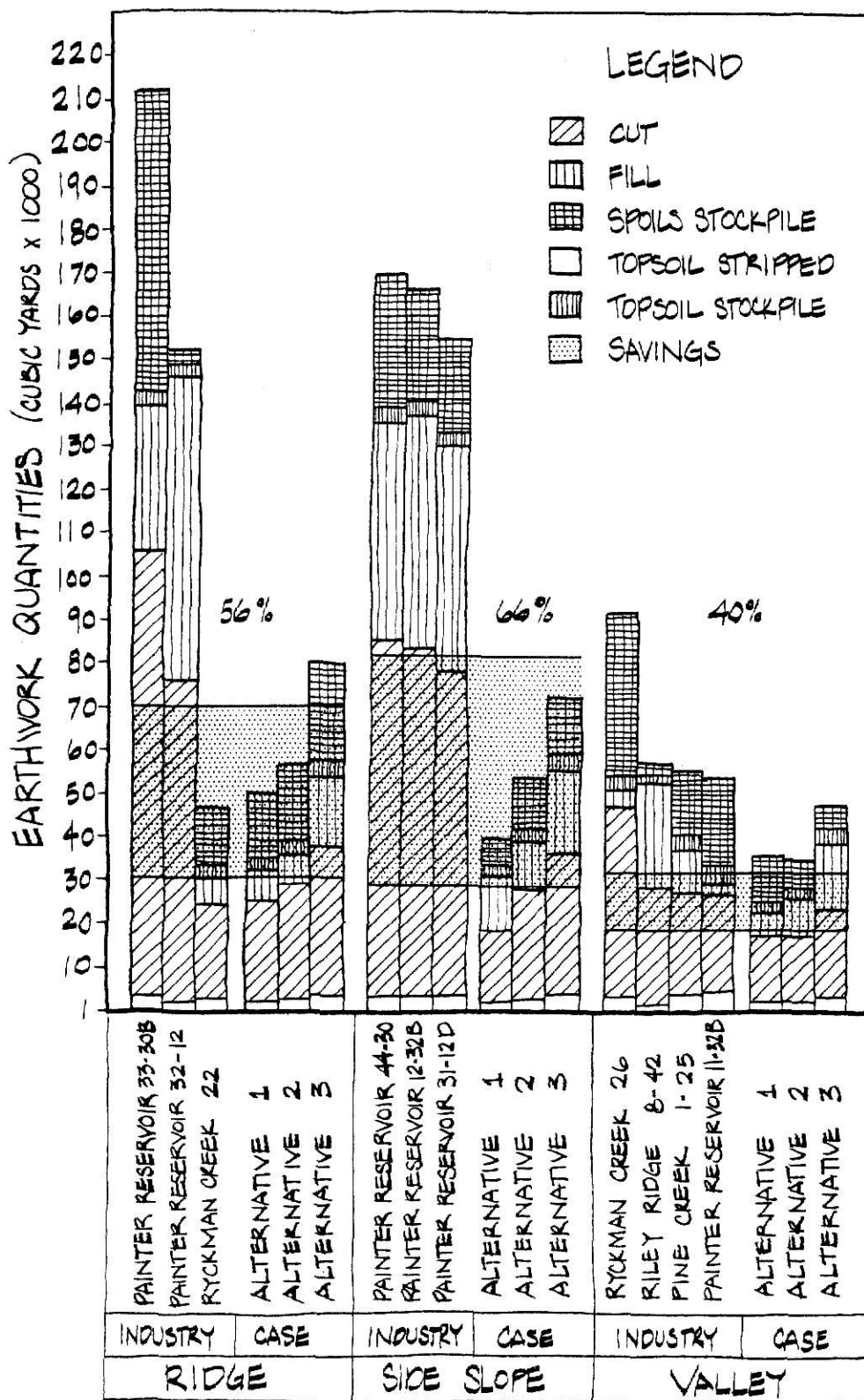
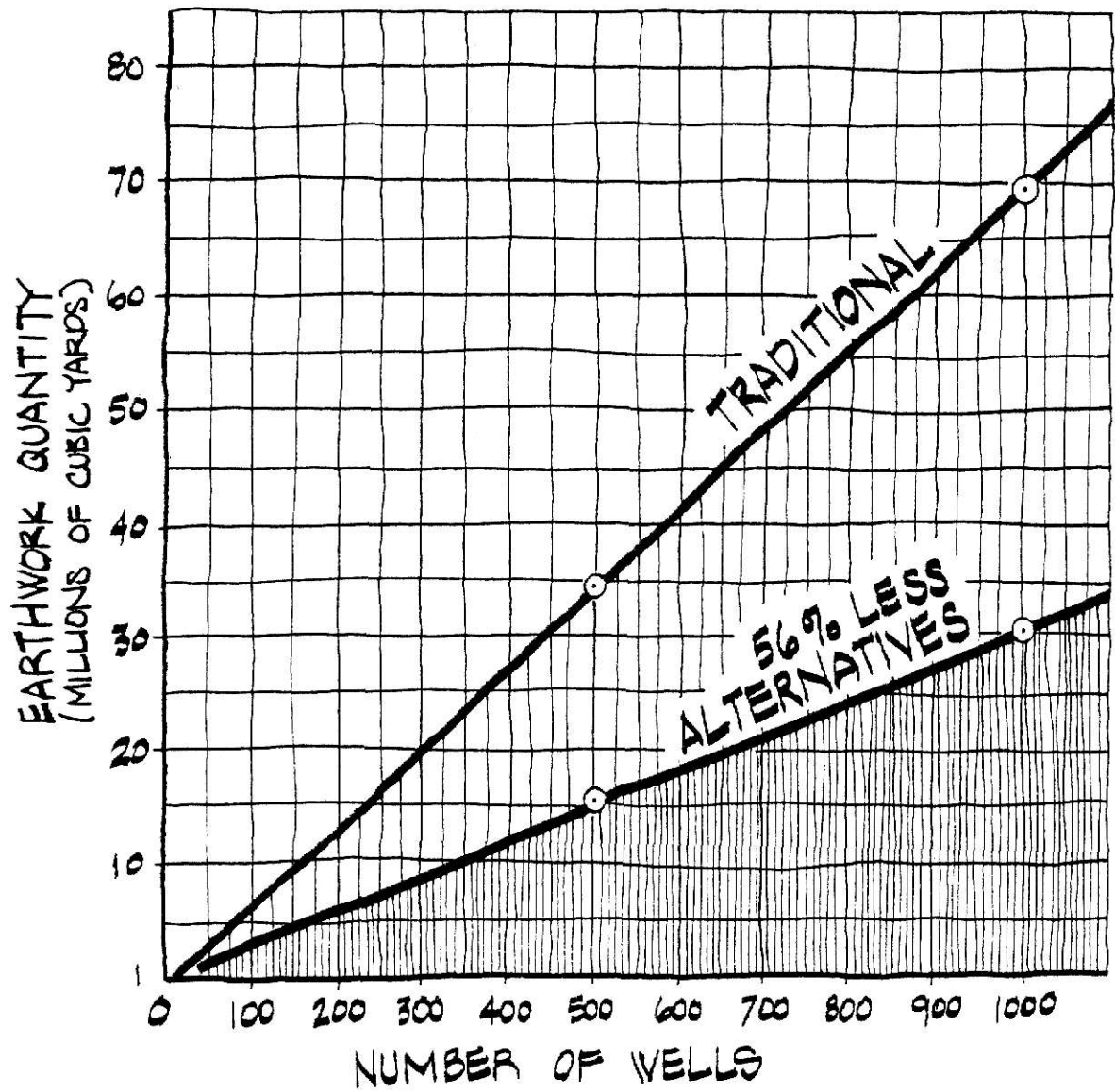


FIGURE 17

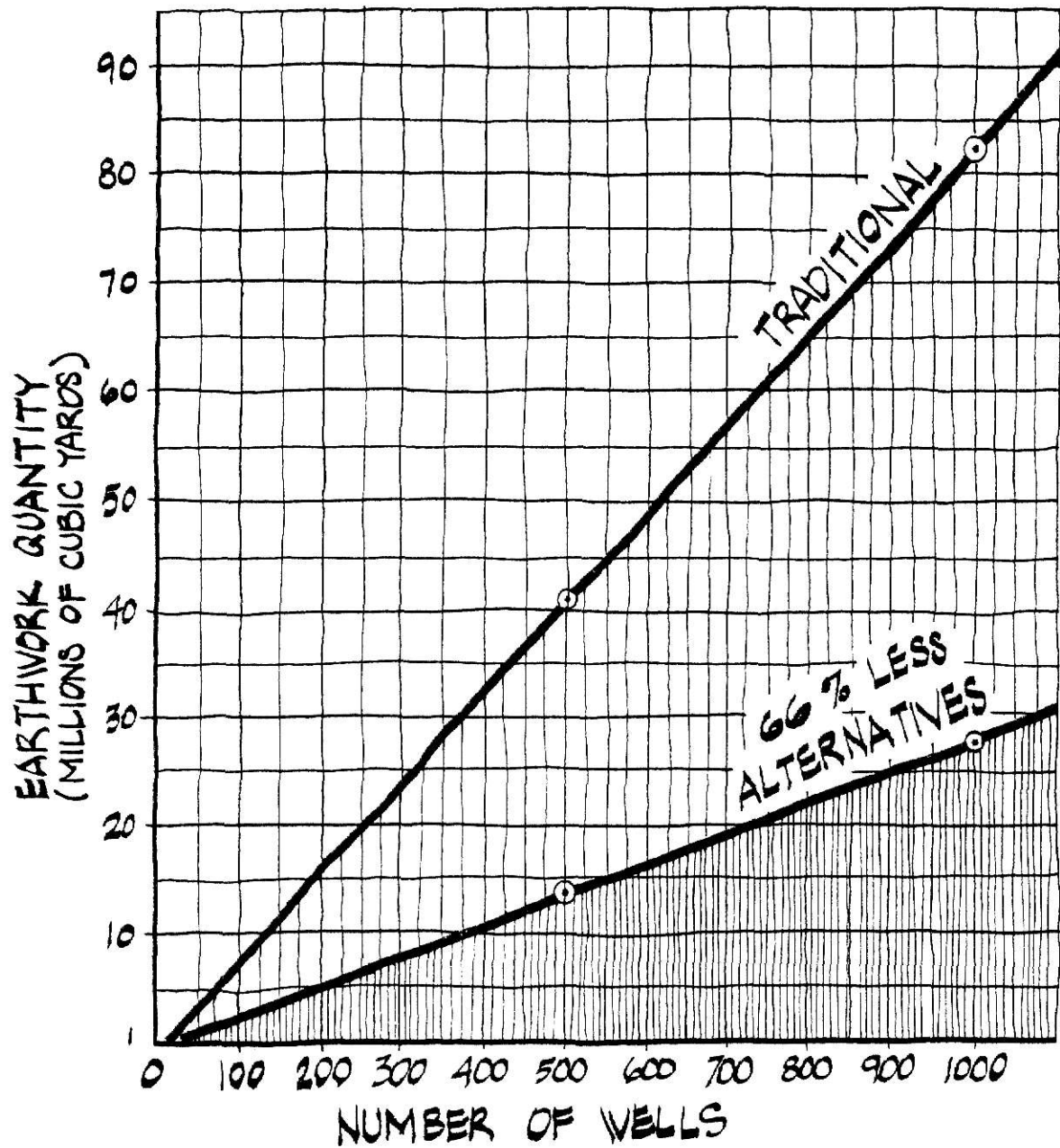
COMPARISON OF MEAN AVERAGE EARTHWORK QUANTITY OF TRADITIONAL
PAD DESIGN TO ALTERNATIVE PAD DESIGN OVER LARGE QUANTITY OF WELLS



RIDGE
© V. F. POOL 1982

FIGURE 18

COMPARISON OF MEAN AVERAGE EARTHWORK QUANTITY OF TRADITIONAL
PAD DESIGN TO ALTERNATIVE PAD DESIGN OVER LARGE QUANTITY OF WELLS

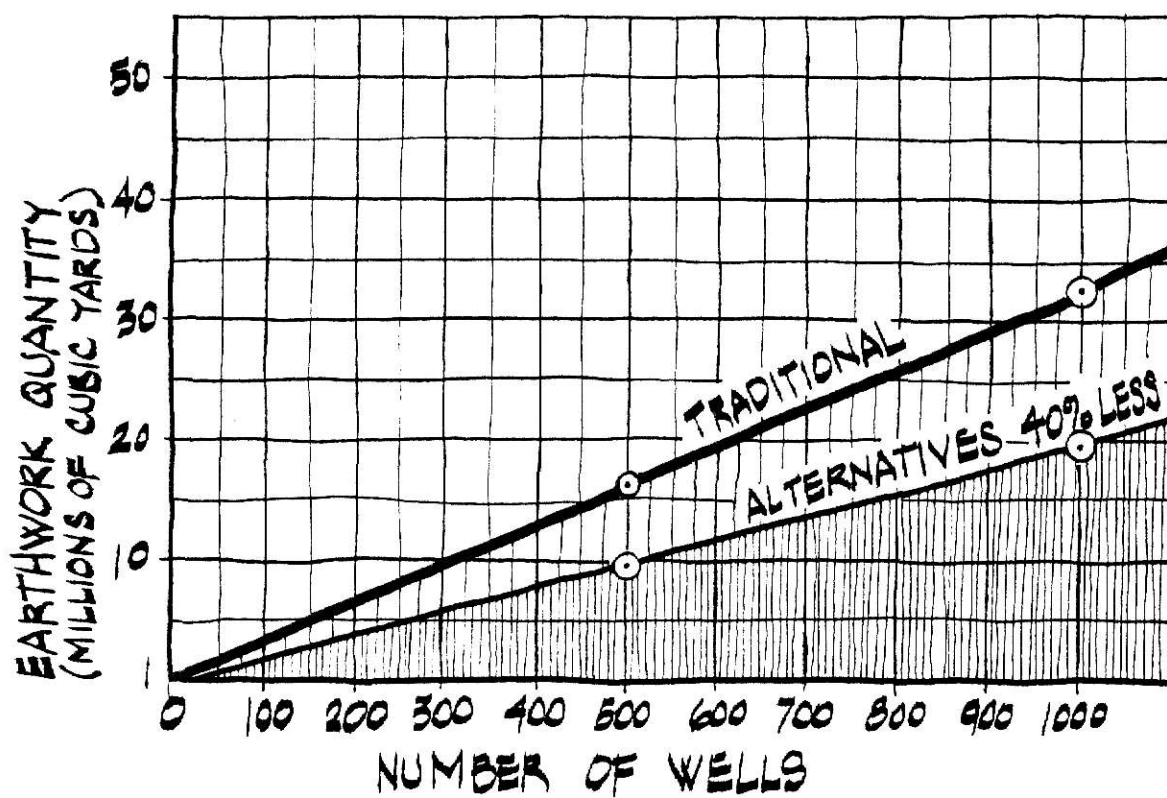


SIDE SLOPE

© V. F. POOL 1982

FIGURE 19

COMPARISON OF MEAN AVERAGE EARTHWORK QUANTITY OF TRADITIONAL
PAD DESIGN TO ALTERNATIVE PAD DESIGN OVER LARGE QUANTITY OF WELLS



VALLEY
© V.F. POOL 1982

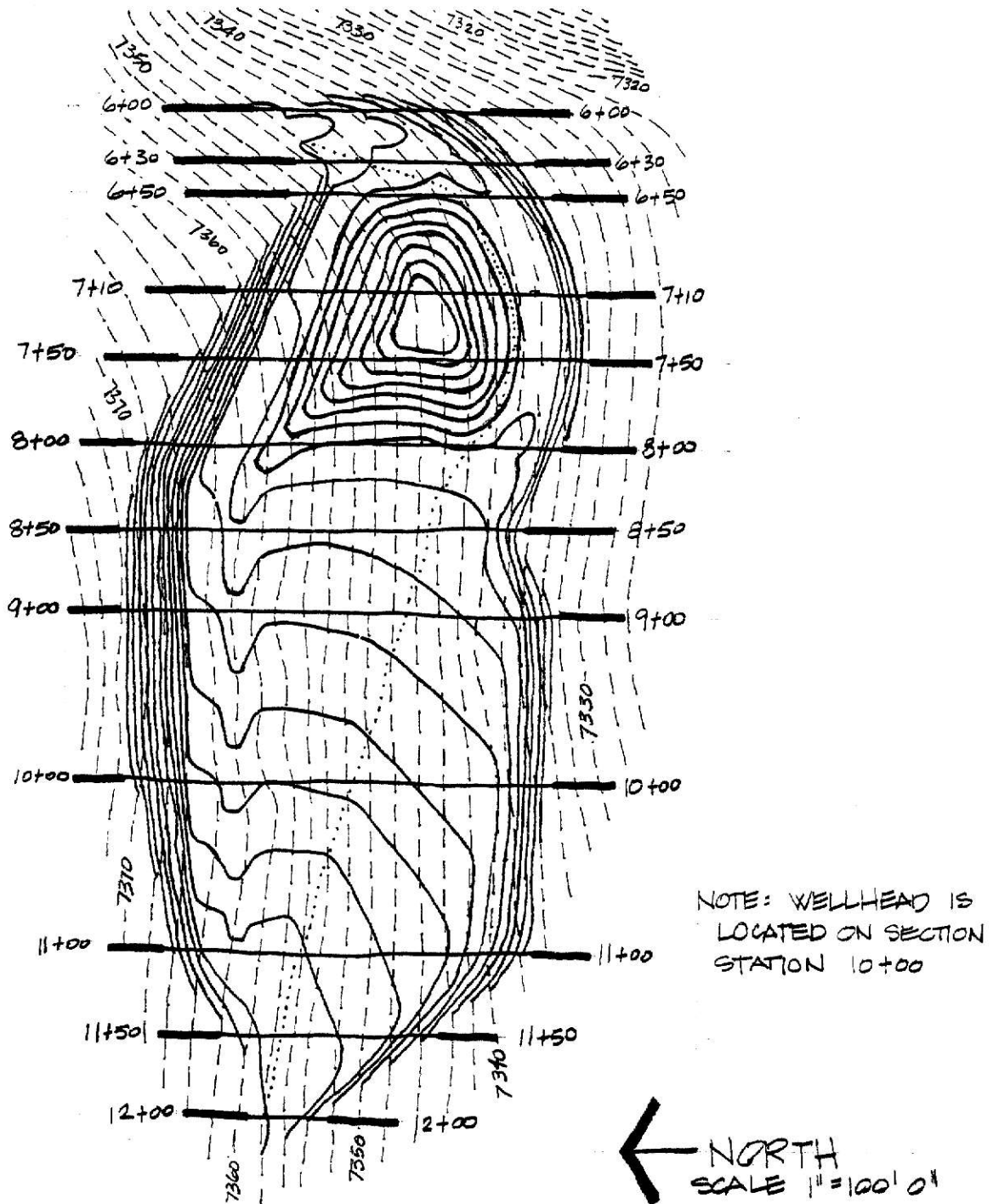
Conclusions

As shown in the comparative studies, significant reductions can be made in the size of pads used for exploration and production of oil and gas without sacrificing safety and operation standards of the industry. These reductions result from the use of a linear pad which can fit more sympathetically to the steep topography. This type of pad design offers the additional benefits of:

1. Less visual damage.
2. Less potential for environmental damage.
3. Less cost to the industry.

The potential savings to the industry are very significant when applying these concepts to a large number of wells. Looking at each type of landform the potential savings for 500 wells range from approximately 10 million cubic yards for the valley locations, to 20 million cubic yards for the ridge locations, to 28 million cubic yards for the side slope.

Appendix



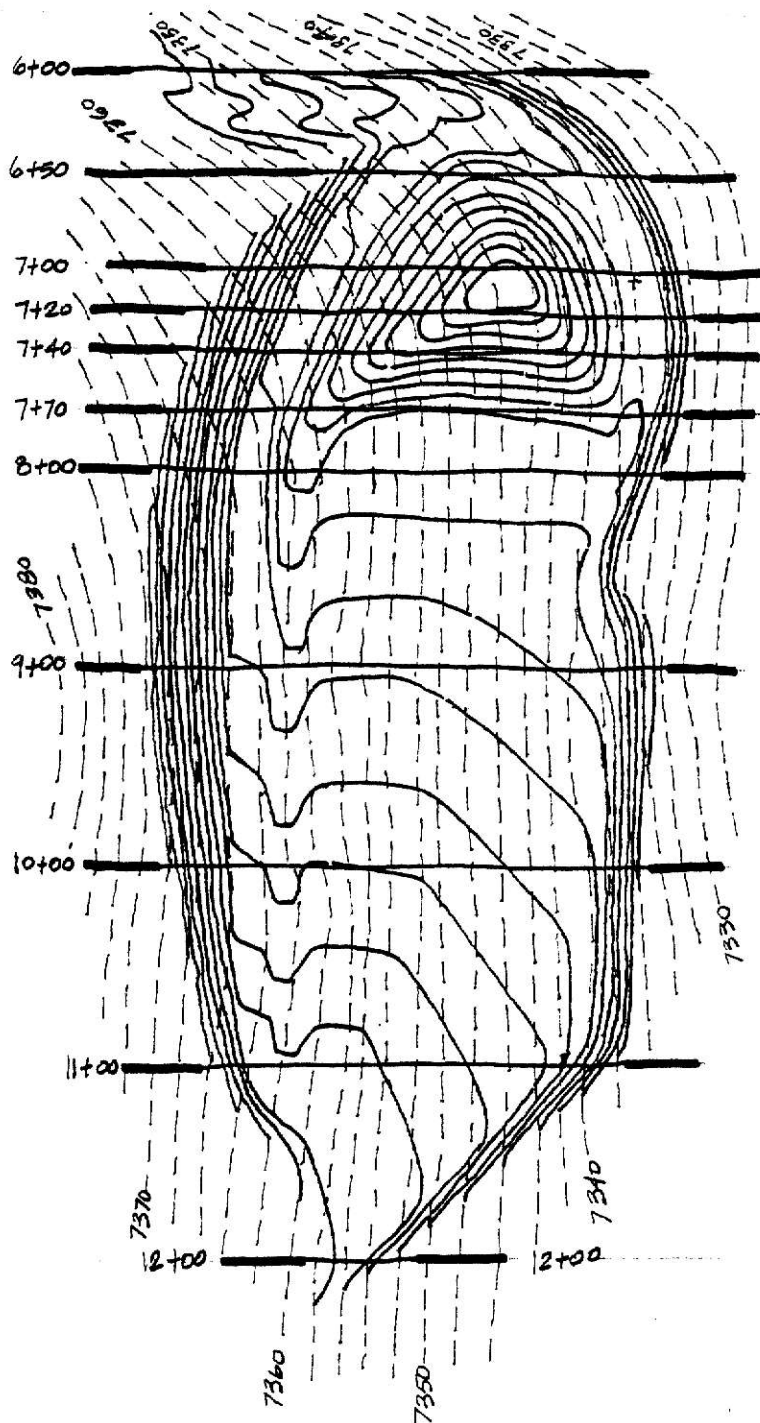
LEGEND

- SECTION
- - - EXISTING CONTOUR
- PROPOSED CONTOUR
- NO CUT/NO FILL

RIDGE

ALTERNATIVE 1

© V. F. POOL 1982



NOTE: WELLHEAD IS
LOCATED ON SECTION
STATION 10+00

← NORTH
SCALE 1" = 100' 0"

LEGEND

- SECTION
- - - EXISTING CONTOUR
- PROPOSED CONTOUR
- NO CUT/NO FILL

RIDGE

ALTERNATIVE 2

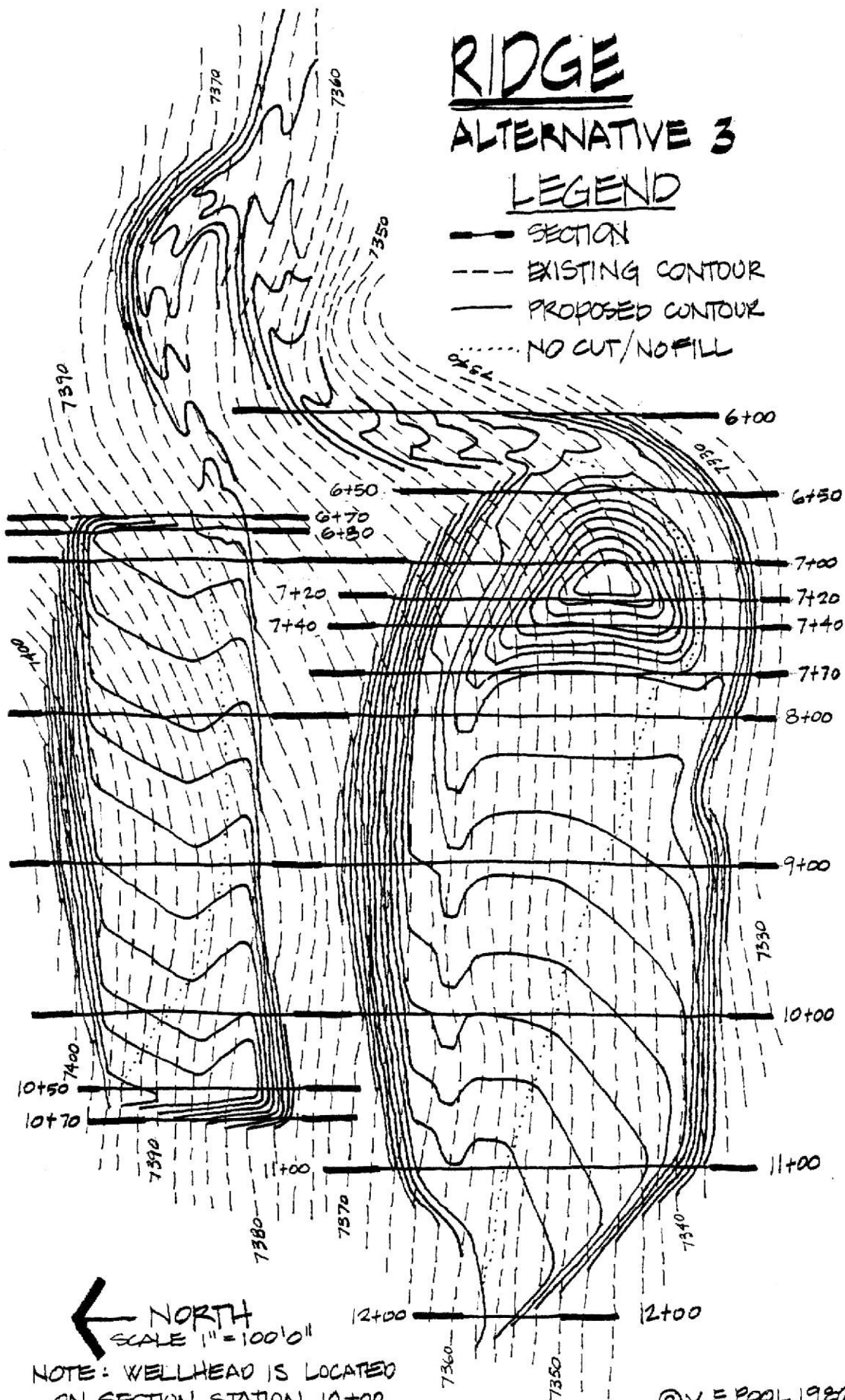
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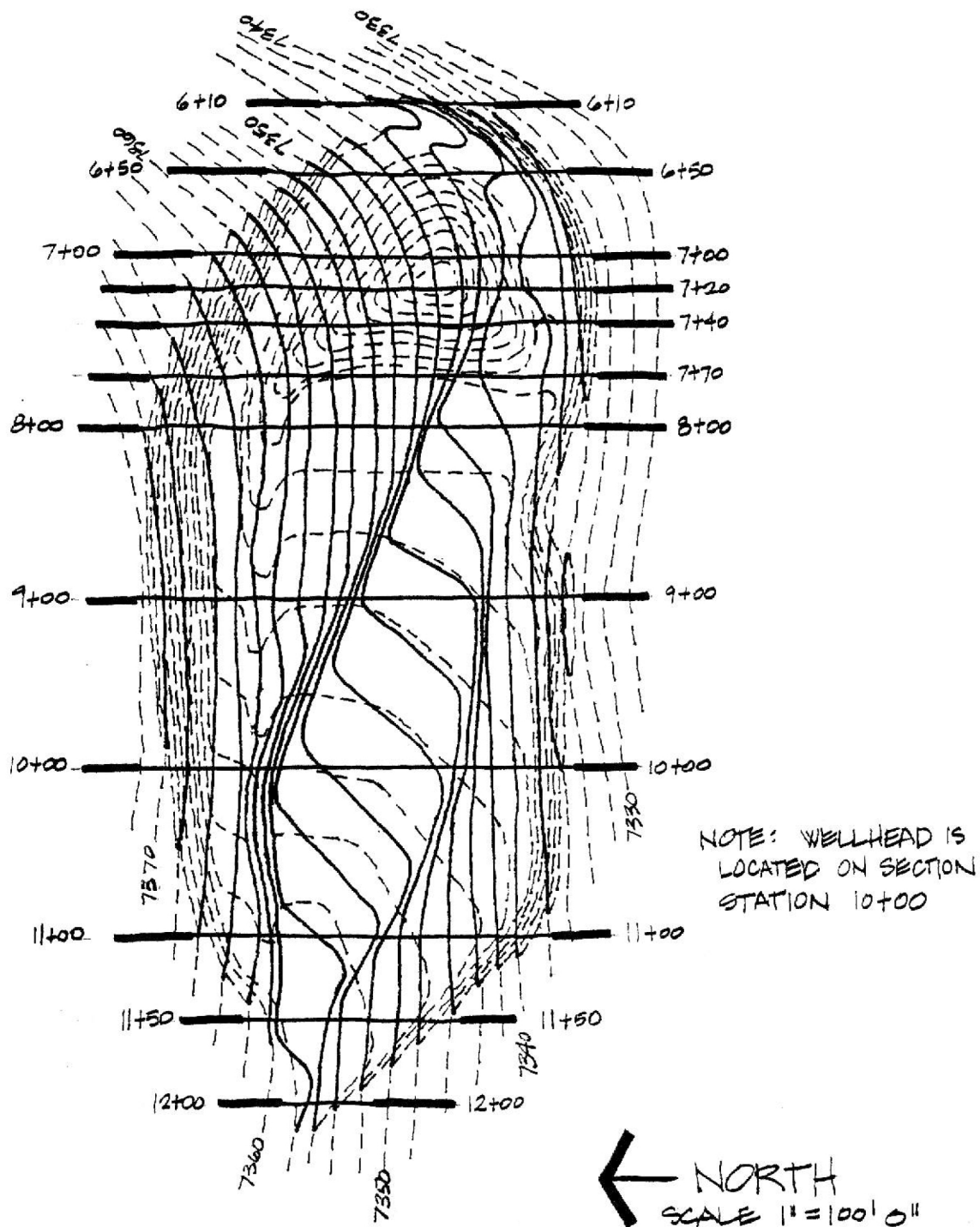
RIDGE

ALTERNATIVE 3

LEGEND

- SECTION
- EXISTING CONTOUR
- PROPOSED CONTOUR
- NO CUT/NO FILL



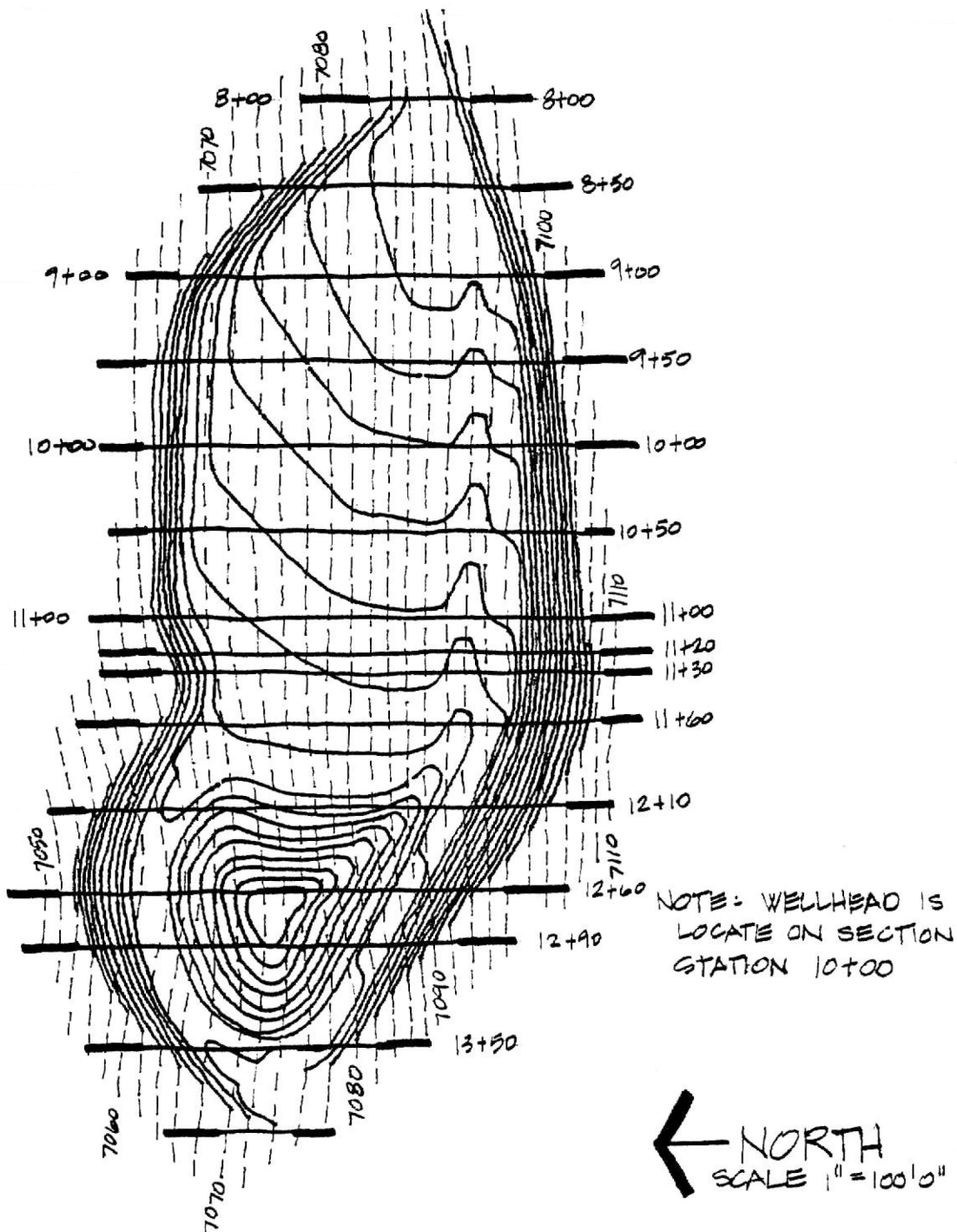


LEGEND

- SECTION
- - - EXISTING CONTOUR
- PROPOSED CONTOUR

RIDGE
PRODUCTION

© V. F. POOL 1982



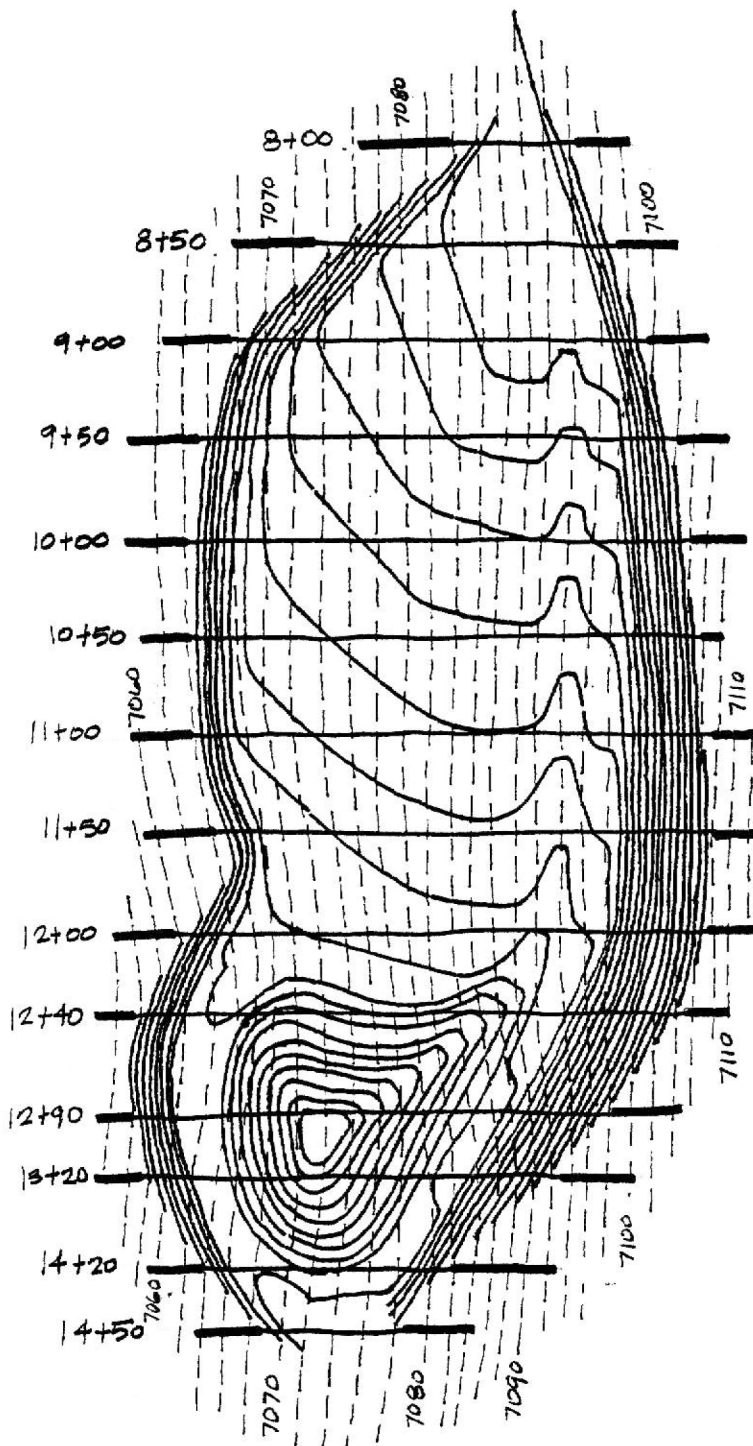
LEGEND

- SECTION
- - - EXISTING CONTOUR
- PROPOSED CONTOUR

SIDE SLOPE

ALTERNATIVE 1

© V. F. FOOL 1982



NOTE: WELLHEAD IS
LOCATED ON SECTION
STATION 10+00

← NORTH
SCALE 1"=100' 0"

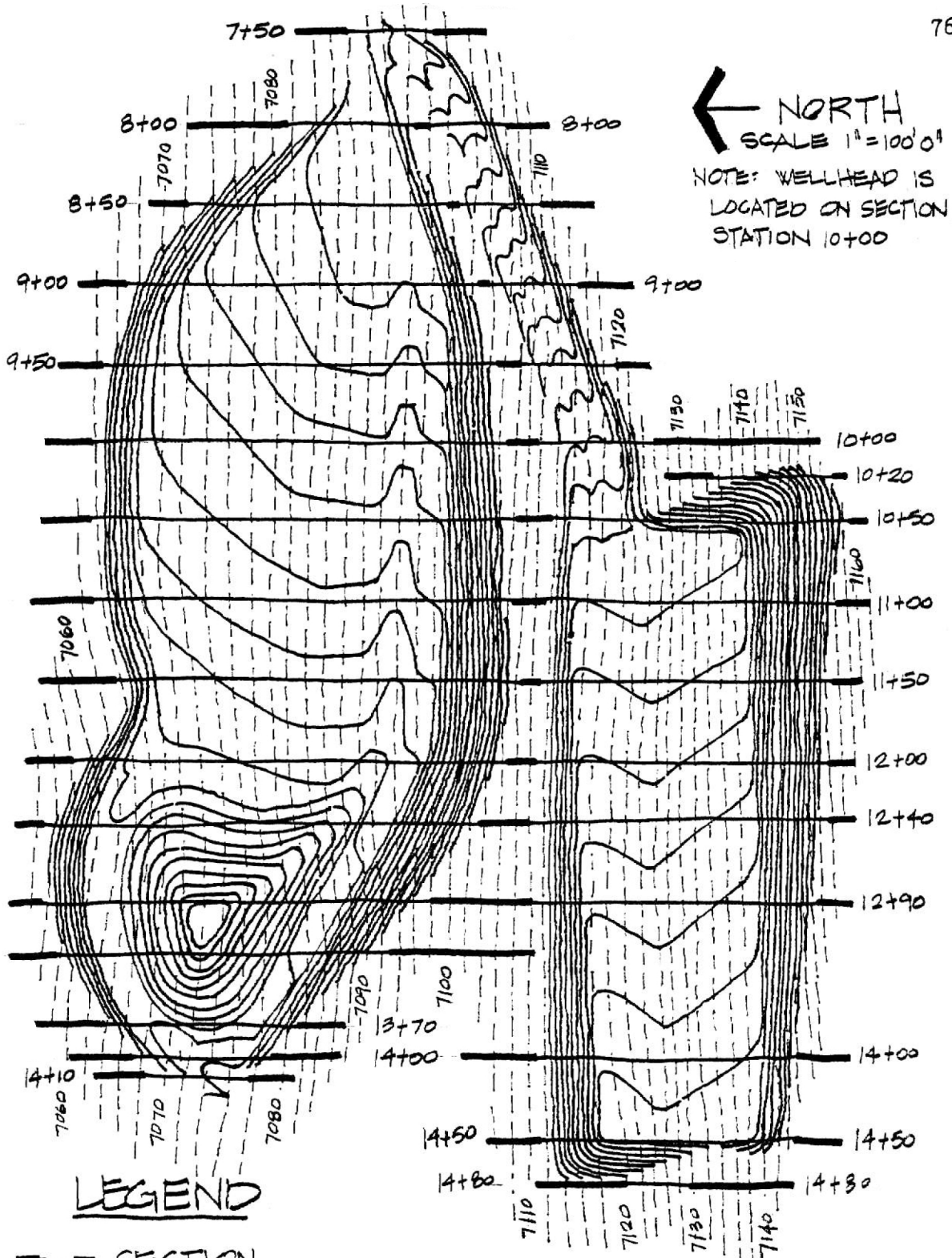
LEGEND

- SECTION
- EXISTING CONTOUR
- PROPOSED CONTOUR

SIDE SLOPE

ALTERNATIVE 2

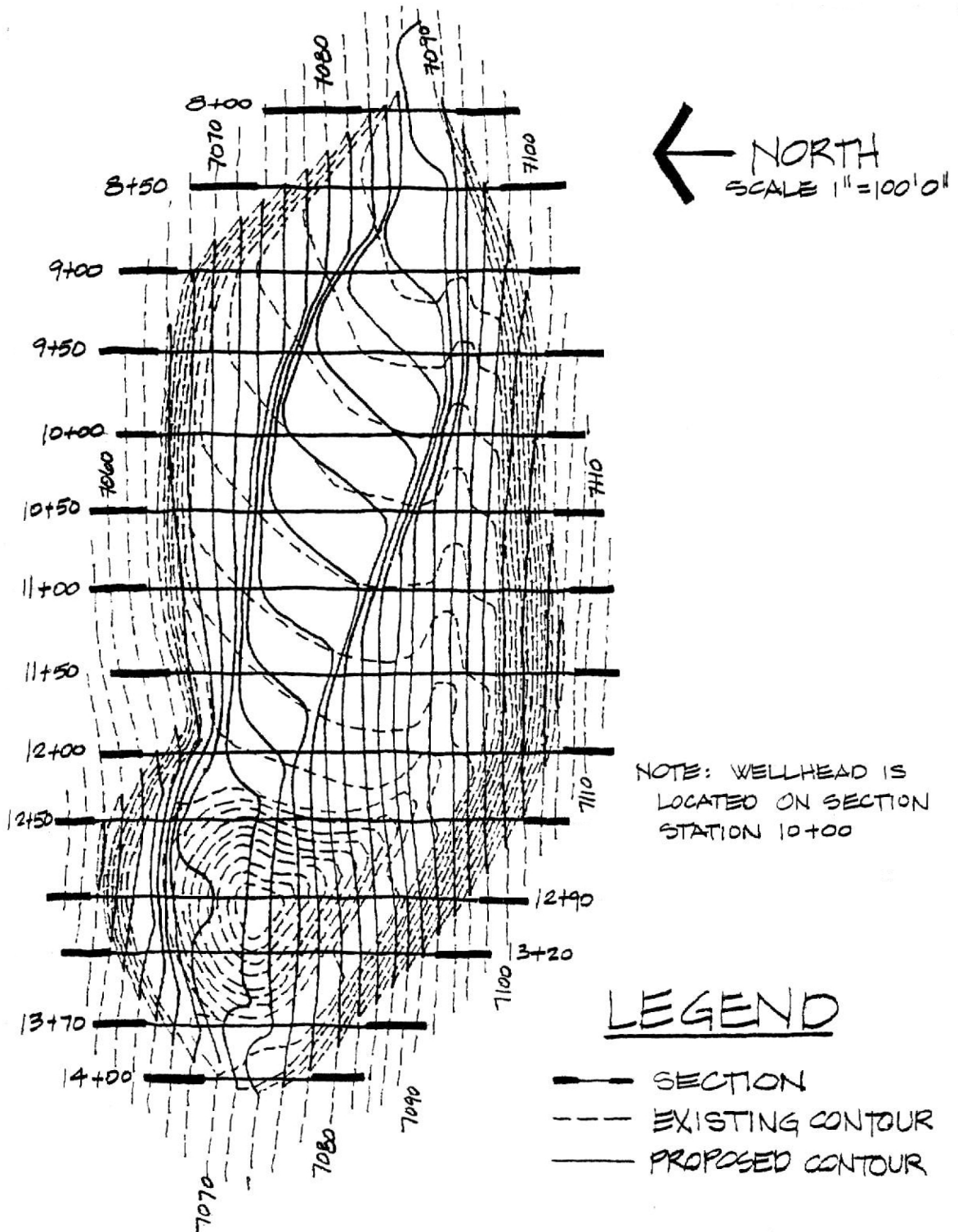
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SIDE SLOPE

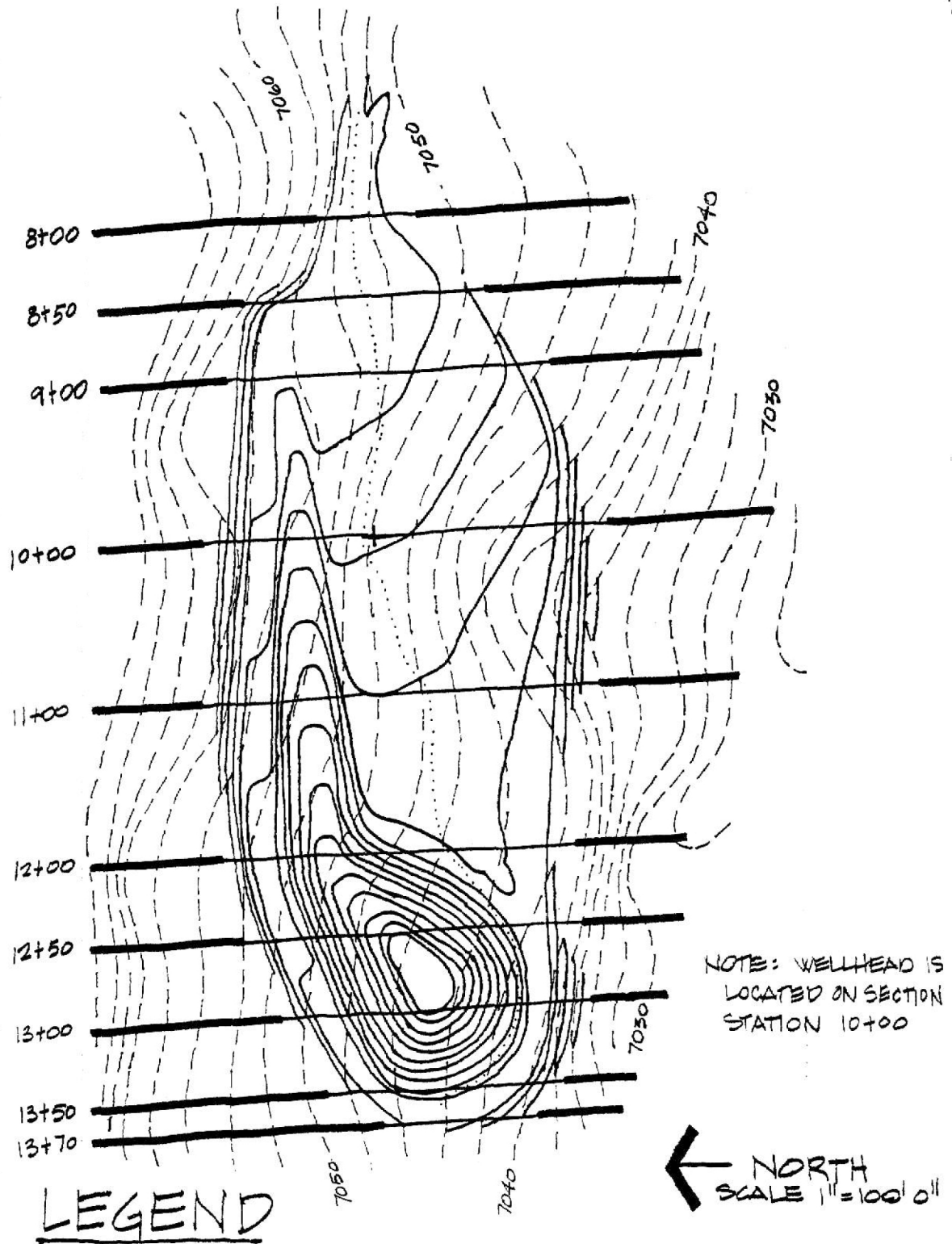
ALTERNATIVE 3

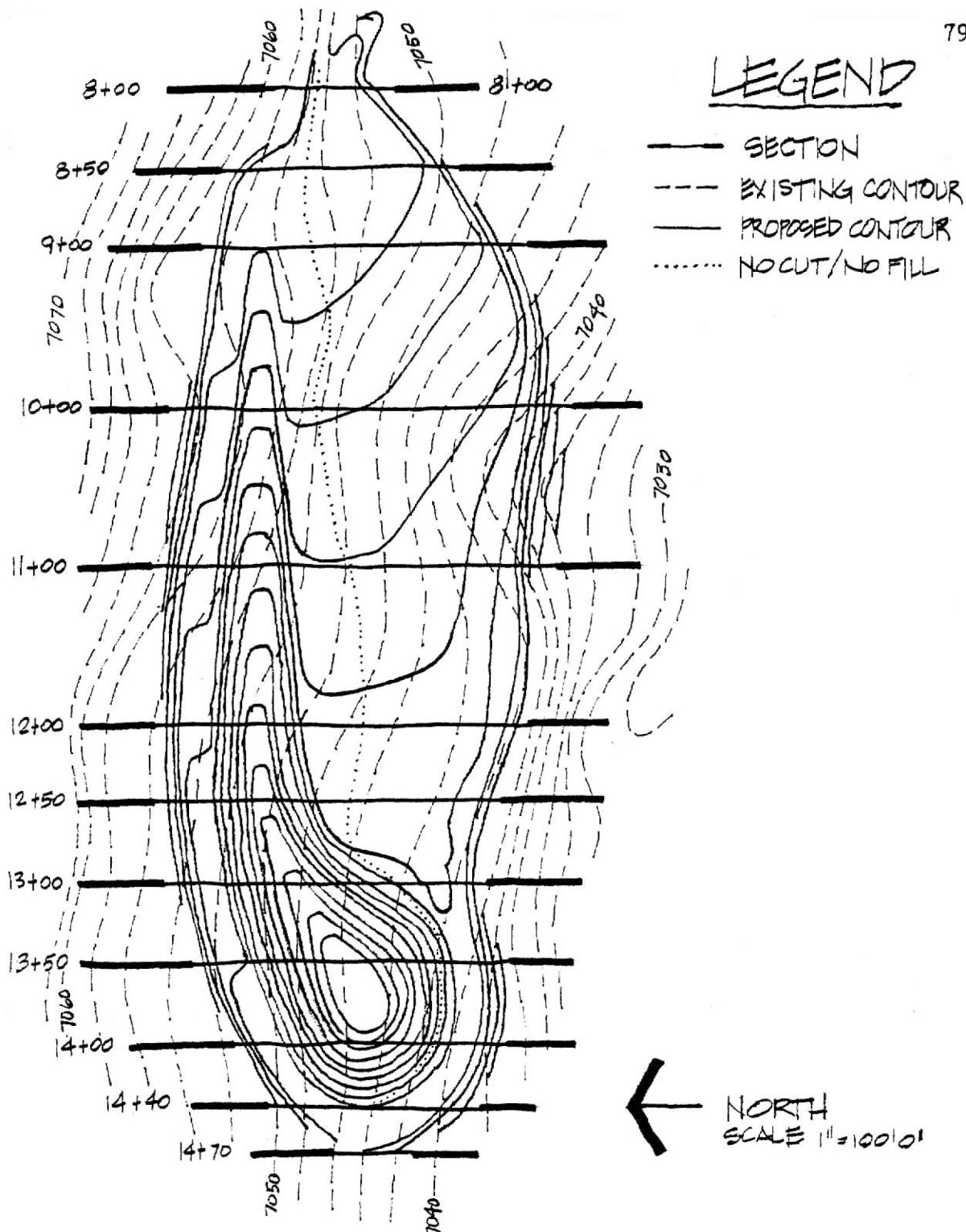
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SIDE SLOPE
PRODUCTION

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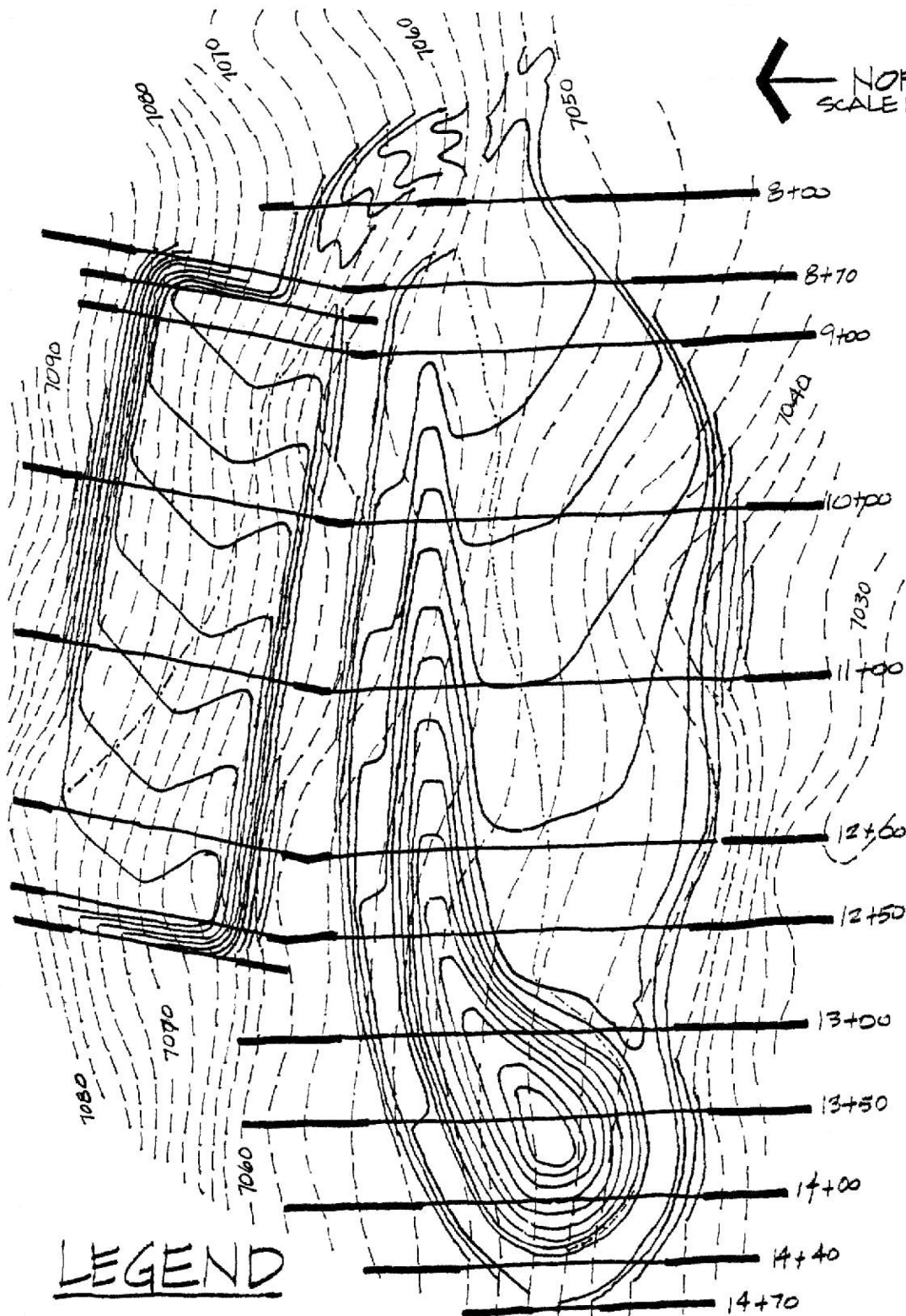




NOTE: WELLHEAD IS
LOCATED ON SECTION
STATION 10+00

VALLEY
ALTERNATIVE 2
© V.F. POOL 1982

← NORTH
SCALE 1"=100' 0"



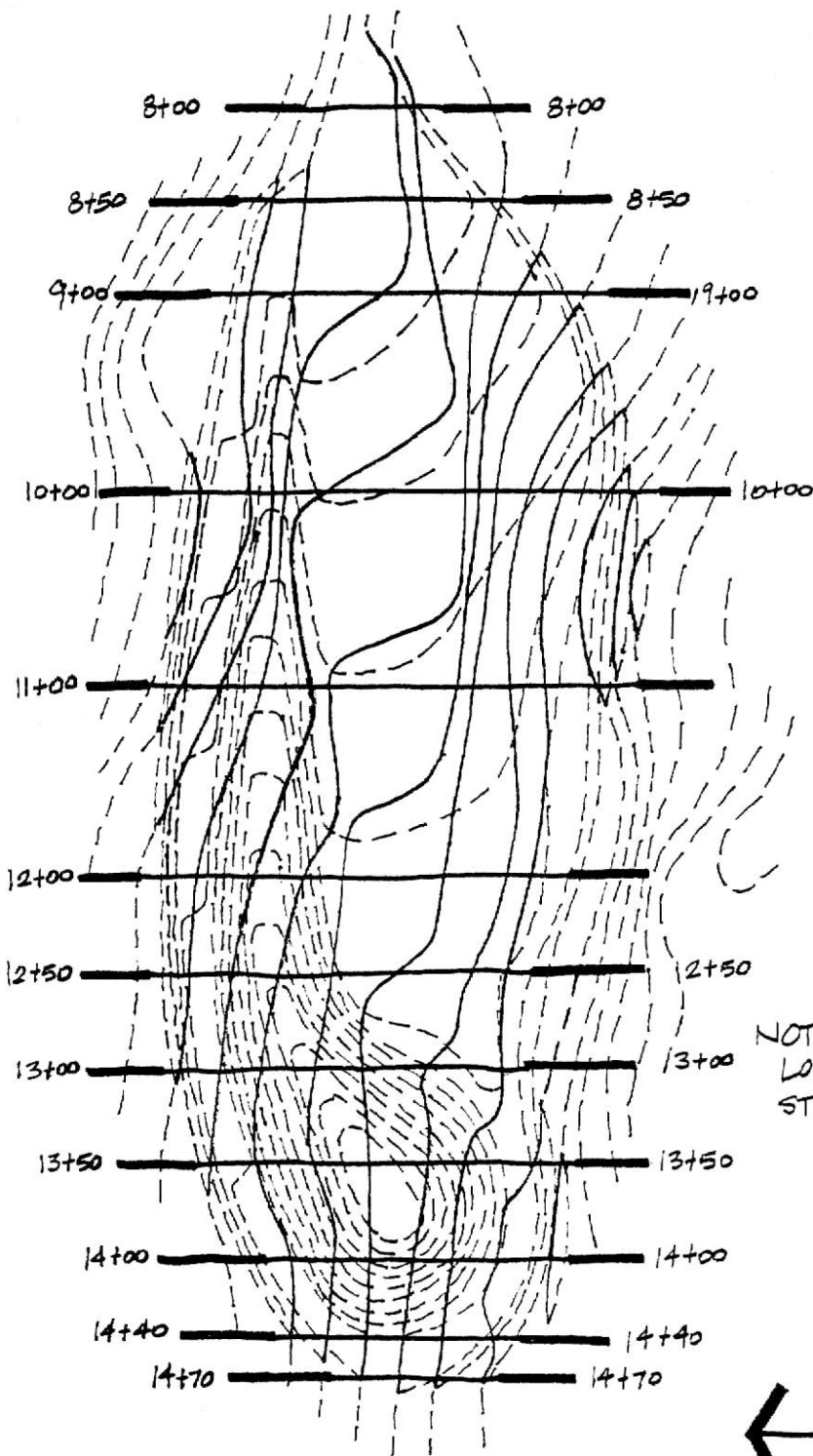
LEGEND

- SECTION
- EXISTING CONTOUR
- PROPOSED CONTOUR
- NO CUT/NO FILL

NOTE: WELLHEAD IS LOCATED ON
SECTION STATION 10+00

VALLEY
ALTERNATIVE 3

© V. F. POOL 1982



LEGEND

- SECTION
- - - EXISTING CONTOUR
- PROPOSED CONTOUR

**VALLEY
PRODUCTION**

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Conceptual studies of alternative pad design layouts were prepared which addressed the issues and problems identified during the field work. Conceptually, a linear pad on the contour seemed to be more compatible with the rugged environment and it seemed capable of meeting the necessary operational and safety standards. This concept was applied to ten existing wells and comparisons between the two were made. The results show that, in fact, a significant reduction can be made in the area of disturbance and earthwork quantities without sacrificing the space needed for safe and efficient operation of the drill rig or production facilities. The potential savings to both the industry and the environment are very significant when applying these concepts to the large number of wells expected to be drilled in the future.

15. "3109-Surface Management Requirements for Oil and Gas Operations," 35 FR 9688, June 13, 1970, Supplement September 2, 1976.
16. White, Douglas L., Drilling Engineer, "Practical Insights in Drilling and Exploratory Oil and/or Gas Well in the Overthrust Belt," Institute on the Overthrust Belt Oil and Gas Legal and Land Issues, Rocky Mountain Mineral Law Foundation, Salt Lake City, Utah, November 20, and 21, 1980.

COST EFFECTIVE PAD DESIGN FOR
OIL AND GAS DEVELOPMENT

by

VAN F. POOL

B.S.L.A., Texas A&M University, 1973

AN ABSTRACT OF A MASTER'S THESIS
submitted in partial fulfillment of the
requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

ABSTRACT

Since the oil and gas embargo of the early 1970s, it has become increasingly apparent to our petroleum-oriented society that more domestic petroleum reserves are needed to maintain the current standards of living. This need along with the decontrol of oil prices has made it desirable and possible for the petroleum industry to explore in the more remote locations of the Rocky Mountains.

Recent observations of the energy development activity in the mountainous Overthrust Region of western Wyoming reveal that the traditional drilling rig pad layouts are being used as if the drilling operations were taking place in the flatter Plain States. The rectangular patterns of traditional pad design covered approximately four acres, caused little visual impact, and were easy to reclaim in the flat areas of Wyoming, Kansas, Oklahoma, and Texas. However, placing these pads in the steeper terrain of the Overthrust Belt is disturbing large areas of the environment resulting in increased environmental damage and higher development cost associated with construction and reclamation of the pad.

There is a better, more cost efficient, environmentally sound method of designing pads for the exploration and production of petroleum resources in the western U.S. than is currently being used.

Six months of field study was devoted to investigating the current drilling and production activities in the Overthrust Region. The purpose of the investigation was to learn the construction and operation problems associated with present procedures and to identify the spatial safety and regulatory requirements which affect drill pad design.

Conceptual studies of alternative pad design layouts were prepared which addressed the issues and problems identified during the field work. Conceptually, a linear pad on the contour seemed to be more compatible with the rugged environment and it seemed capable of meeting the necessary operational and safety standards. This concept was applied to ten existing wells and comparisons between the two were made. The results show that, in fact, a significant reduction can be made in the area of disturbance and earthwork quantities without sacrificing the space needed for safe and efficient operation of the drill rig or production facilities. The potential savings to both the industry and the environment are very significant when applying these concepts to the large number of wells expected to be drilled in the future.