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Environmental Impact Assessment For Steeply Dipping Coal Beds

North Knobs Site

November 8, 1978

AC03-77ET13108

Review Draft

MASTER

Gulf Research and Development Company
Pittsburgh, Pennsylvania

TRW Energy Systems Planning Division
McLean, Virginia

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1.0 SUMMARY

The U.S. Department of Energy is funding an underground coal gasification (UCG) project in steeply dipping coal beds (SDB), at North Knobs, about 8 miles west of Rawlins, Carbon County, Wyoming. The project is being conducted by Gulf Research and Development Company and TRW Energy Systems, to determine the technical, economic and environmental viability of such a technology.

In essence, underground coal gasification consists of drilling boreholes into the coal seam much like producing natural gas or oil, igniting the coal, injecting a reactant such as compressed air down one borehole, passing the reacting gases through permeable paths in the coal seam, and producing a combustible gas from another borehole.

Recognizing the potential of UCG in meeting the Nation's energy requirement, the Department of Energy (DOE) has funded the development of UCG technology in several different geologic settings. The Morgantown Energy Research Center is charged with development of Underground Coal Gasification in thin horizontal seams of swelling Eastern bituminous coal. The Laramie Energy Research Center and Lawrence Livermore Laboratories are developing UCG technology in relatively thick horizontal seams of subbituminous Wyoming coal. This project is aimed at the gasification of steeply dipping subbituminous Western coals (i.e., those coals which lie at an angle to the surface of 35^{o} or greater).

The development of SDB is an interesting target for UCG since such beds contain coals not normally mineable by economically ordinary techniques.

Although the underground gasification of SDB has not been attempted in the U.S., Soviet experience and theoretical work done recently indicate that the gasification of SDB in place offers all the advantages of underground gasification of horizontal coal seams plus some unique characteristics. The steep angle of dip helps to channel the produced gases up dip to off take holes and permits the ash and rubble to fall away from the reaction zone helping to mitigate the blocking of the reaction zone in swelling coals. The intersection of SDB with the surface makes the seam accessible for drilling and other preparation.

The tests at the North Knobs site will consist of a series of three tests, lasting 20, 80 and 80 days, respectively. The first of these tests is expected to start around October 1, 1979. A total of 9,590 tons of coal is expected to be gasified, with surface facilities utilizing 15 acres of the total section of land.

The area is rural, semi-arid with gentle contours. The primary use of the land is for grazing. The nearest population center is the city of Rawlins, a community of 11,840 residents. No conflicts with local or regional activities are known.

1.1 SUMMARY OF ENVIRONMENTAL EFFECTS AND ENVIRONMENTAL IMPACTS

The environmental effects of the experiment are expected to be very small. The underground gasification of coal appears to be environmentally sound, the scale of the experiment is small, and the relative isolation of the North Knobs site precludes significant environmental damage. The experiment will provide data to evaluate the potential environmental consequences of larger-scaled future commercial operations.

The key environmental impact is potential groundwater contamination by reaction products from coal gasification. There is good evidence that the surrounding coal effectively blocks the migration of these contaminants.

Other potential areas for environmental damage such as surface cracking due to subsidence, and plant effluents, can be controlled or rectified by well-established techniques.

Since the experiment is being conducted under the water table, the possibility of a run-away, or uncontrolled fire is not likely.

Additional environmental impacts not considered in the above discussion are expected to be small, and in most cases temporary. On-site operation of vehicles, compressors, etc. will introduce small amounts of pollutants into the air. There will be increased traffic on local roads leading to the site - particularly during the gasification portion of the experiment. There should be no significant effect on local wildlife, and only a very localized and basically reversible effect on plant life. No archaeological or historical items or landmarks are known to exist on the site.

1.2 ALTERNATIVES TO THE PROPOSED PROJECT

DO NOT CONDUCT THE UCG-SDB PROJECT

The field test is necessary to develop the data, including environmental impact data, to determine if future use of underground coal gasification of steeply dipping coal beds is technically and economically feasible.

DELAY THE PROJECT

This delays the development of data relative to deciding upon the commercial expansion of underground coal gasification of steeply dipping beds, and delays the development of data that assesses feasibility and contribution of UCG-SDB to the energy supply.

CONDUCT A SMALLER-SCALE PROJECT

Given the nature of underground gasification, the field is the laboratory. The first burn to be conducted is the smallest practicable size which will provide significant information.

CONDUCT A LARGER-SCALE PROJECT

The technical undertainties and economic costs associated with an initial large-scale burn are not justified until a smaller-scale initial burn is conducted for valuable design data.

UTILIZE A DIFFERENT SITE(S) FOR THE TEST BURNS

Several sites were considered for the project. The Wyoming site was the site that best meets the technical requirements and objectives, while offering minimal potential for environmental damage.

PERFORM EXPERIMENTS ON HORIZONTAL COAL BEDS ONLY

Steeply dipping coal seams are a significant and unique resource which is not being developed in this country. Horizontal coal beds, on the other hand, are being developed through both mining and UCG. Prime SDB resources are close to markets, which expands resource development options for UCG.

USE ALTERNATIVE COAL TECHNOLOGIES TO ACHIEVE THE SAME END RESULT

Underground coal gasification extends the coal resource base in a potentially environmentally acceptable manner. It is not a direct competitor to conventional uses of coal, or surface coal gasification. Nor can such technologies effectively utilize steeply dipping coals.

USE ALTERNATIVE RESOURCES TO ACHIEVE THE SAME OBJECTIVE

The commercial applicability of underground coal gasification is dependent upon supply and cost of alternative sources of gas. Alternative resources such as unconventional gas, deep gas, gas from Mexico, and LNG all can contribute to the same end uses. The objective of this project is to determine the viability of UCG technology and economics, permitting the comparison with alternative resources.

2.0 INTRODUCTION

This document presents an assessment of the environmental impacts for the underground gasification of coal in steeply dipping coal beds at a selected site near Rawlins, Wyoming. The project is the first private industry project for underground coal gasification funded by the U.S. Department of Energy (DOE). Several underground coal gasification (UCG) projects have been initiated by DOE in horizontal coal beds, however, this project will be the first experiment in the United States for gasification of steeply dipping ($>35^0$) coal beds (SDB).

2.1 BACKGROUND

Underground coal gasification has the potential to contribute significantly to satisfying the overall energy demand projected for the nation within the next twenty years. It may provide a means for the development of national coal resources from coals technically or economically unmineable by conventional mining techniques. There are an estimated 5.8 trillion tonnes (6.4 trillion tons) of coal in the United States within 1,829 m (6,000 ft.) of the earth's surface and of low-volatile bituminous or lower rank. An estimated 1.6 trillion tonnes (1.8 trillion tons) may be recoverable for use as a UCG resource.

Those steeply dipping coal beds potentially suitable for UCG are defined to be at least three feet thick and dipping at angles greater than 35 degrees. Such coals are found in four major coal provinces: Appalachian, Rocky Mountain, Pacific Coast and Alaska. The total U.S. resource is estimated to be 90.7 billion tonnes (100 billion tons) of which 63.5 billion tonnes (70 billion tons) is in seven Western States: California, Colorado, Montana, New Mexico, Utah, Washington and Wyoming. (Figure 2-1).

Steeply dipping beds occur mainly along margins of large structural basins, on monoclinal folds and on limbs of anticlinal-synclinal folds. They occur mainly where land value is low and population sparse. Due to their steepness or irregularity, they have been difficult or uneconomical to mine.

Underground coal gasification is an emerging technology which utilizes coal resources in place, or in situ, to produce a low-Btu gas or, if oxygen is injected instead of air, a medium Btu gas. The gas produced can be used

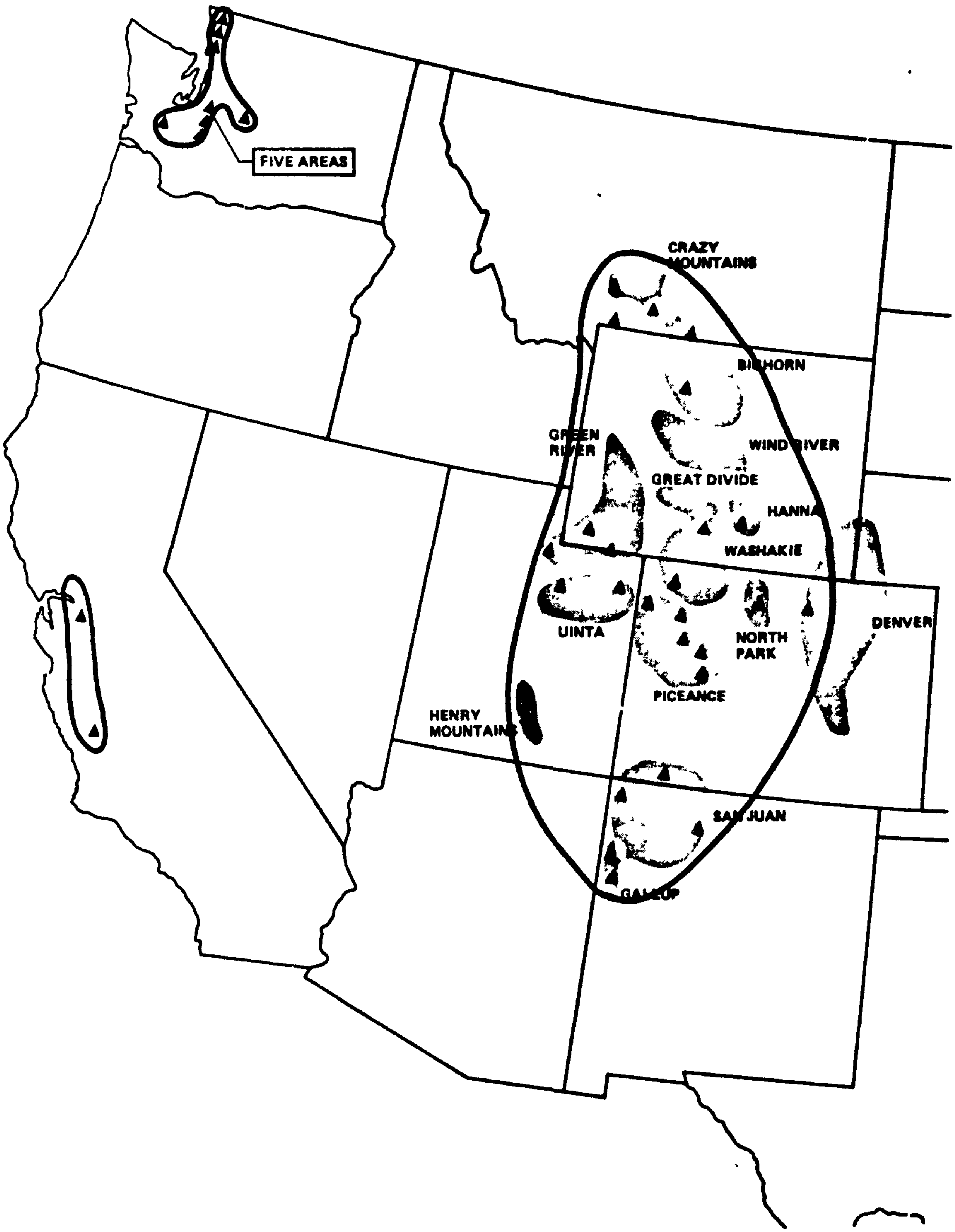


Figure 2-1
Coal Deposits of the Western U.S. Containing Steeply Dipping Beds

for various markets, including generation of electric power, substitute natural gas, and chemical feedstocks for other products such as methanol or ammonia.

Recognizing this potential the Department of Energy (DOE) has funded the development of UCG technology in several different geologic settings. The Morgantown Energy Research Center is charged with development of Underground Coal Gasification in thin horizontal seams of swelling Eastern bituminous coal. The Laramie Energy Research Center and Lawrence Livermore Laboratories are developing UCG technology in relatively thick horizontal seams of subbituminous Wyoming coal. This project is aimed at gasification of steeply dipping subbituminous Western coals.

Privately funded projects in UCG are also in horizontal beds. Texas Utilities Services is developing UCG in Texas lignites and ARCO is developing deep, thick subbituminous coal in the Powder River Basin of Wyoming.

Coal of low rank (lignite and subbituminous coal) are the easiest to gasify underground. These coals tend to shrink when heated, creating additional permeability for gas flow. In contrast, bituminous coals are the most difficult to gasify since they tend to swell when heated and produce viscous tars which tend to plug natural or induced permeability channels. The degree to which swelling coals expand ranges from very little to 1000 percent based upon ASTM free swelling index test.

Although the underground gasification of SDB has not been attempted in the U.S., Soviet experience and theoretical work done recently indicate that the gasification of SDB in place offers all the advantages of underground gasification of horizontal coal seams plus some unique characteristics. The steep angle of dip helps to channel the produced gasses up dip to off take holes and permits the ash and rubble to fall away from the reaction zone helping to mitigate the blocking of the reaction zone in swelling coals. The intersection of SDB with the surface makes the seam accessible for drilling and other preparation.

2.1.1 Process Description

Underground Coal Gasification (UCG) is an underground process which converts coal into a combustible gas. In order to understand the process to be used at the Rawlins site, the following detailed process description has been derived from the U.S. Department of Energy's (DOE) Underground Coal Gasification Program published in ERDA 77-51, March 1977, and from the GR&DC Phase I Report: Feasibility and Program Plan SAN 1472-5, March 1978.

In essence, underground coal gasification consists of drilling boreholes into the coal seam much like producing natural gas or oil, igniting the coal, injecting a reactant such as compressed air down one borehole, passing the reacting gases through permeable paths in the coal seam, and producing a combustible gas from another borehole.

There are several processes which have successfully been used to gasify coal underground, all of which involve two basic steps:

- Preparation of the coal seam
- Gasification of the coal

The first step, preparation of the coal seam, is necessary to increase the permeability of natural coal to permit sufficient volumes of reaction products to flow through the coal during the gasification phase. Four preparation techniques which have been tested in the past are directional drilling, reverse combustion, electrolinking, and hydrofracturing. All four methods form narrow, highly permeable channels which link the wells drilled into a coal seam. The reliability of electrolinking and hydrofracturing have not been adequately demonstrated for UCG. The use of directionally drilled holes offers much promise, especially for large-scale projects where positive control over the location of the link is necessary. In the case of steeply dipping seams, directional drilling techniques have been used by the Soviets to achieve controlability of the process.

The sequence of events in the underground gasification of steeply dipping coal beds is shown in Figure 2-2. If the production and injection wells do not intersect, reverse combustion will be used to complete the linking. The coal is ignited at the base of the production well (Figure 2-2, Event 1). Air is pumped into the production well only during coal ignition. After ignition, the linking process begins with high-pressure, low-volume air being pumped into the injection well and through the coal to the production well (reverse burn linking). During linking, the burn front advances from the base of the production well toward the source of air at the bottom of the injection well. This is shown in Figure 2-2, Event 2. The link is completed when the burn front reaches the bottom of the injection well and the pressure of the system suddenly drops. Due to the dipping coal seam, thermal override during the linking phase will probably not occur.

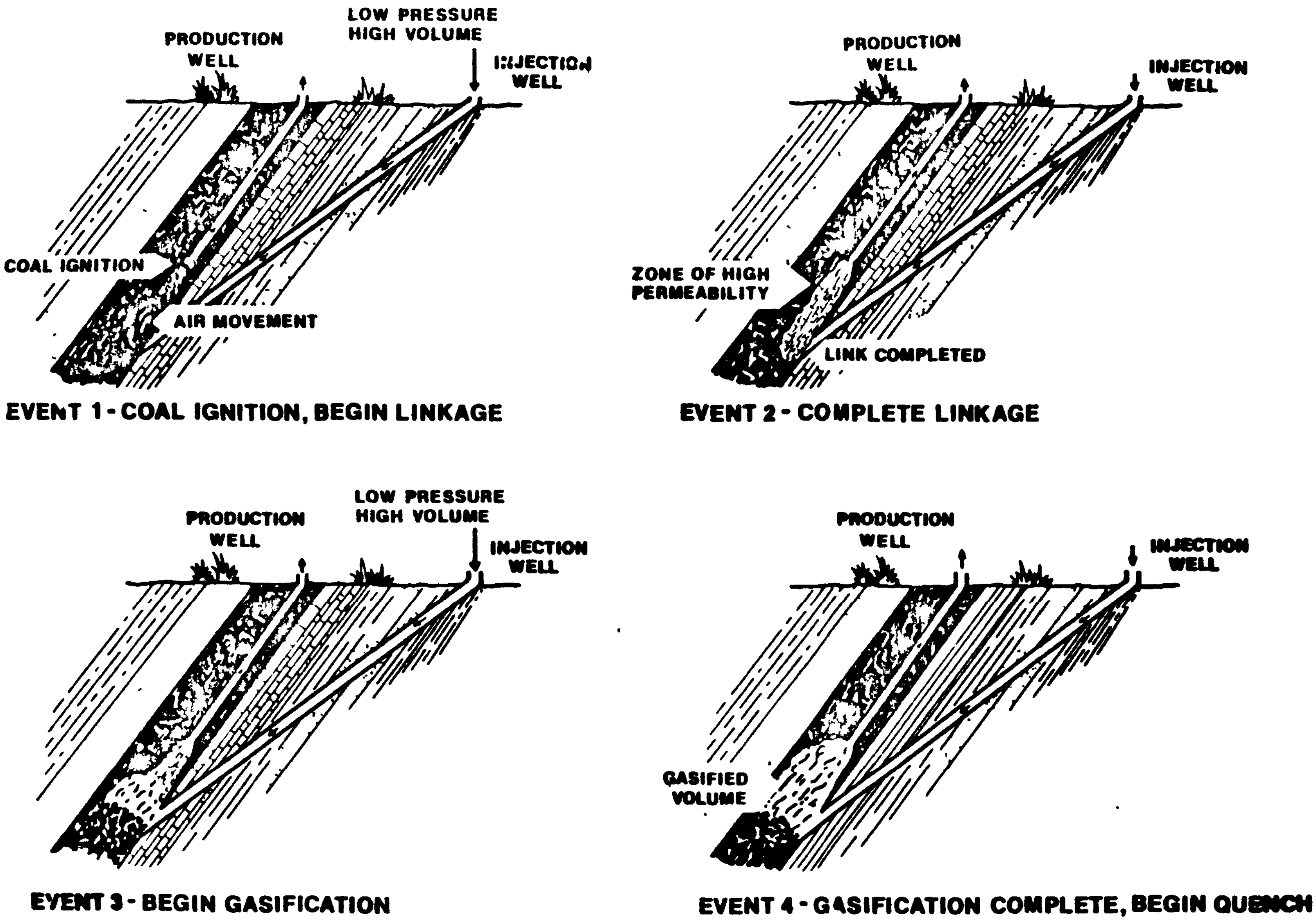


Figure 2-2. Sequence of Events in UCG/SDB

The seam is now ready for gasification which is accomplished using low-pressure, high-volume air with water injection if the formation water is inadequate for gasification. Gasification progresses from the base of the injection well to the base of the production well, as shown in Events 3 and 4, with the production gases flowing through the linkage channel to the production well. These gases react with fresh coal and with water (which enters the gasification zone from the coal or is injected as steam) to form combustible products - methane (CH_4), carbon monoxide (CO), and hydrogen (H_2). As gasification proceeds along the linkage path, coal falls into the gasified cavity and creates a highly-reactive rubble zone. The existence of a long, hot linkage channel ensures that the product gas is properly reduced and has a high heating value that remains uniform with time.

The reaction zones, shown in Figure 2-3 (an idealized conception of UCG in a horizontal bed), contain several chemical processes, starting with the drying of the coal, followed by pyrolysis, reduction, and oxidation. The same basic chemical reactions are involved in the more common surface coal gasification processes. However, in UCG, residence times and contact paths for the gaseous and solid reactants can be quite long compared to conventional surface gasification. In UCG, less control is possible over process variables like water influx rates, coal size, pressure, and temperature, than in surface processing. Successful development of commercial UCG processes, therefore, requires an understanding of the underground environment, remote instrumentation, and techniques for controlling the key process variables.

UCG is a complex physical and chemical process influenced by many different factors. The most important process variables which have been identified are air injection rates, water intrusion rate, and coal seam thickness. Tests so far indicate that gas compositions and heating values partly depend on the water-to-air ratio. For a given coal seam thickness, there is an optimum water-to-air ratio that gives the maximum heating value of the product gas. Figure 2-4 shows the effect of seam thickness on product gas heating value for several (sub-optimal) rates of water intrusion into the seam, based on a fixed gasification rate of 2-tonnes coal/hour. It can be seen that the product gas quality deteriorates rapidly for coal seams thinner than about 1.5 m (5.0 ft.). It is not possible to successfully gasify very thin, wet seams by currently known methods.

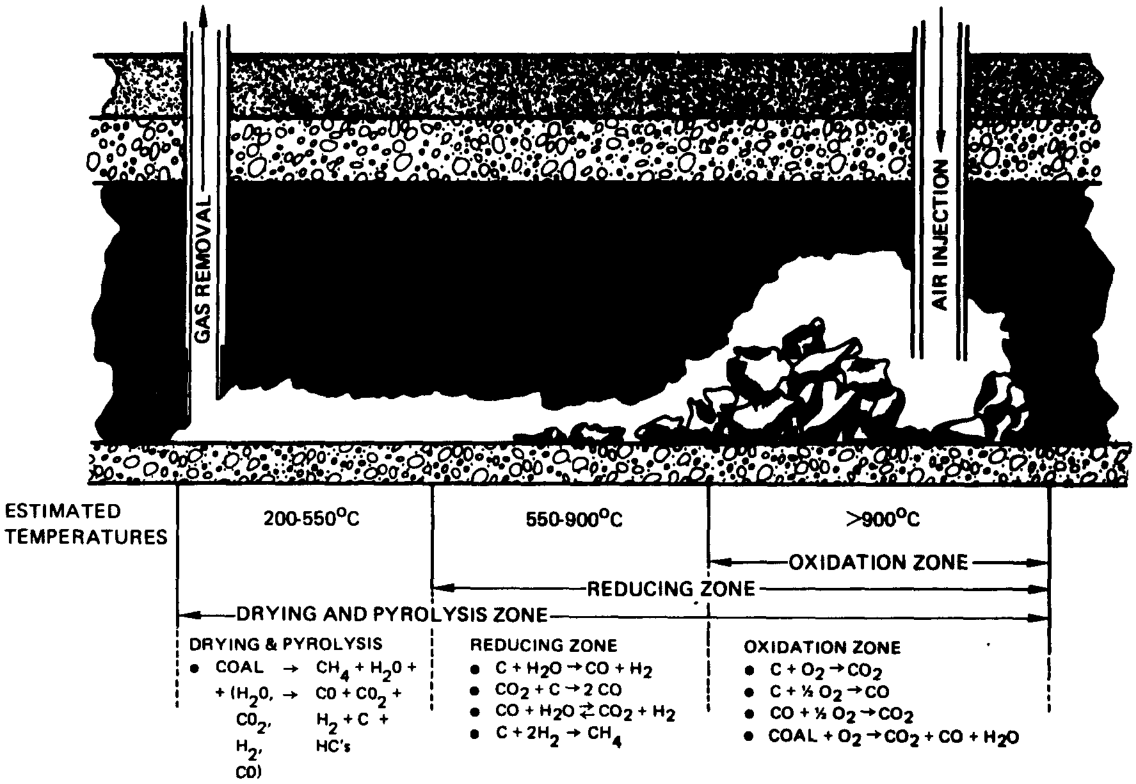


Figure 2-3. UCG Forward Combustion

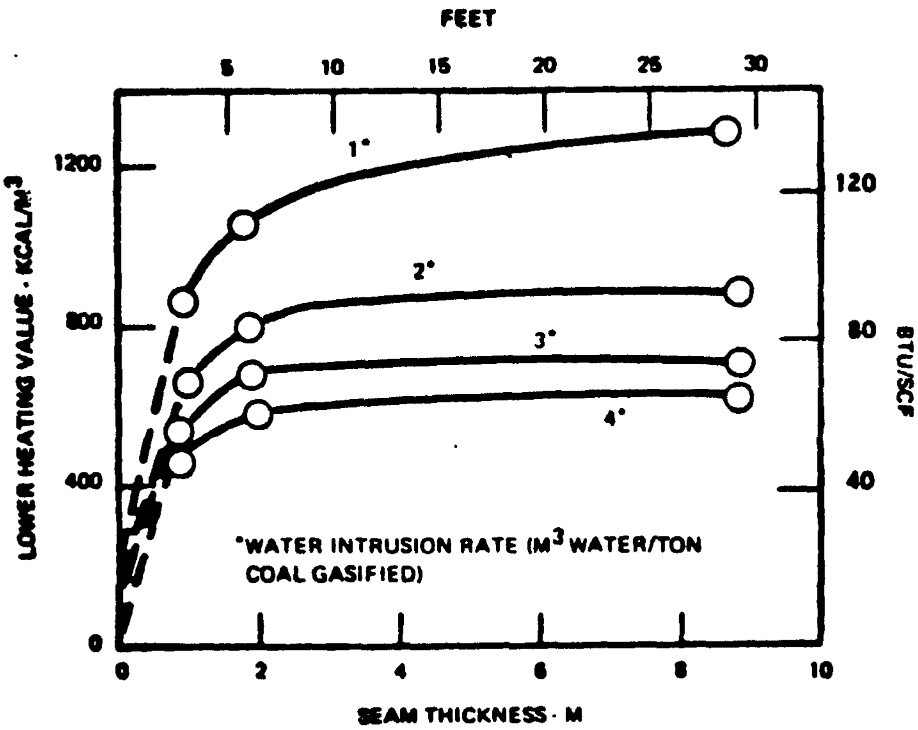


Figure 2-4. Effect of Seam Thickness of Heating Value

Other important process variables are oxygen enrichment, coal ash content, well spacing and configuration, and pressure. For example, in thin seams, gasification intensity can be increased, or oxygen-enriched air can be used, to raise the gas heating value somewhat. The degree to which coal swells as it is heated, and the coal chemical reactivity, are other process variables.

2.2 BRIEF PROJECT DESCRIPTION

The field test project being performed by Gulf Research and Development Company (GR&DC) with TRW Energy Systems as the prime subcontractor for the Department of Energy will evaluate the technical and economic feasibility of the underground gasification of steeply dipping coal beds. The project will be conducted in four phases over a five year period.

2.2.1 Location of the Project

A site for the GR&DC/TRW project has been selected in the North Knobs area of Wyoming. The selected site is approximately 11.5 km (8 miles) west of Rawlins, Wyoming in Carbon County, as shown in Figure 2-5. The site is located on Section 11, T21N, R89W, which contains three steeply dipping coal beds in the Fort Union Formation. It is along the southeastern edge of the gently rolling prairies terrain that characterizes the Great Divide basin, at an elevation of about 6,800 feet.

2.2.2 Resource Definition

Three (3) steeply dipping coal beds that have the potential for UCG underlie the North Knobs SDB/UCG site. They are the Wally Bed, ranging in thickness from 0-13 feet; the G Bed, ranging in thickness from 7-25 feet; and the I Bed, ranging in thickness from 5.5-16 feet. The test burn will be conducted in the G seam, which has an outcrop length of 4500 feet and a total estimated reserve, from 200 to 1000 feet down dip of 2.2 million tons on the North Knobs site. The total estimated SDB reserves for the North Knobs area and its extension to the North is 400 million tons. The coal is of subbituminous rank with a coal quality of about 9429 Btu/lb.; 20.8% moisture; 6.4% ash and .19% sulfur. The coal dips from 60° to 68°.

2.2.3 Process Definition

In order to develop the necessary technical and cost data for a pilot-scale UCG demonstration leading to eventual commercialization, this project

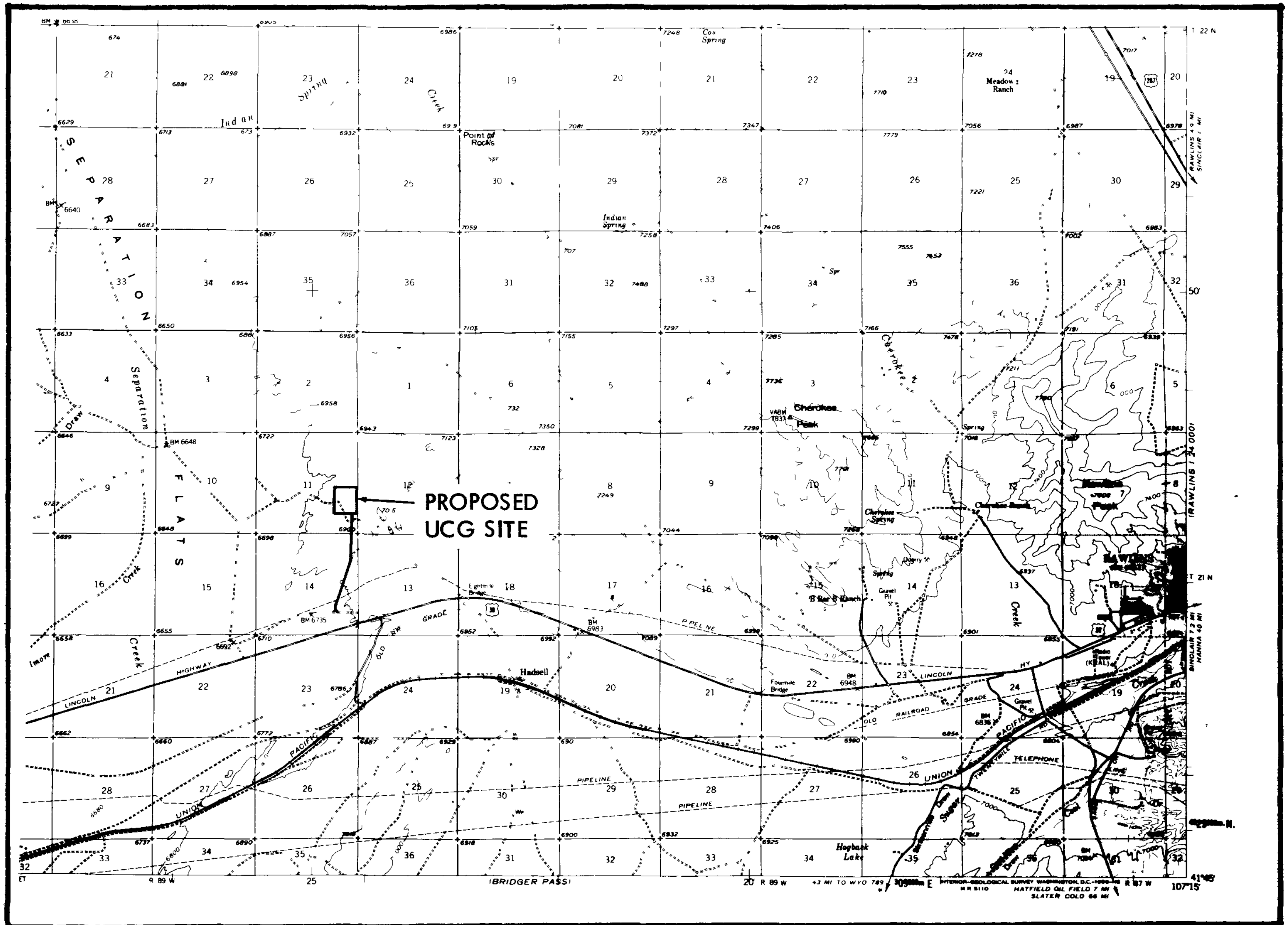


Figure 2-5. UCG Site

incorporates the execution of several tests. The first test, using the simplest module configuration, serves the purpose of developing the necessary skills and procedures for demonstrating linking and gasification. The sequence of events will be to ignite the module, burn for 20 days, and extinguish the module. The second test will be used to develop the relationship of the process gas quality to programmed changes in the process variables. The module will be operated for 80 days. Operating conditions will be maintained near those felt to be optimum for a commercial gasification process and then perturbed from this baseline to evaluate the effects of these changes on gas quality and estimated economics. The third test involves a repeat of the test two sequence over an 80 day period. Operations will be expanded to include two linked modules. The ability to successively link multiple modules is a requisite for eventual commercial operations. Prior to, during, and following the above tests, environmental data will be collected. The impact of gasification operations on air, subsurface water, vegetation, and the ground surface will be monitored and compared to baseline values. Collectively these operations will provide a technical, economic, and environmental data base which can be used to evaluate the impact of pilot-scale, and possibly full scale commercial UCG operation.

2.3.4 Time Frame

Implementation of the above activities has been divided into four sequential phases covering five years. The content of each of these phases is described below.

Phase I - (5 months) - The critical elements of program planning were contained in this phase. Among these were site selection, evaluation of potential environmental and permit acquisition problems, development of a plan for execution of the three tests, definition of the facilities and instrumentation requirements, and evaluation of any special problems (such as quench methods or slant well drilling) which might be associated with project activities. Phase I was completed February 28, 1978.

Phase II - (19 months) - Phase II has been initiated and is underway. A detailed geological and hydrologic characterization of the test site is performed. The facility and instrumentation system are being designed, and items requiring a long lead time are being ordered. Baseline environmental monitoring has been initiated, and appropriate permits are being secured. The process holes associated with the first test have been drilled and the air permeability between them will be measured. Equipment footings, roads, and other appurtenances necessary to support the later installation of the facility are being designed and emplaced. Plans and procedures for operation of the site and execution of the tests are being produced. Phase II is scheduled for completion September 30, 1979.

Phase III - (30 months) - The facility and instrumentation are installed and the test site is staffed. In this phase all necessary systems are checked out and calibrated. Test No. 1 is initiated. The modules for burns 2 and 3 are installed, tested, and ignited. Collected data are analyzed and interpreted in terms of experiment objectives. Environmental monitoring continues. After completion of test No. 3, the site is restored to its original condition. Phase III is scheduled for completion March 30, 1982.

Phase IV - (6 months) - Using the data collected in Phases I through III, the cost of constructing and operating a pilot UCG unit is estimated. The project will be completed September 30, 1982.

2.3 PROJECT OBJECTIVES

The primary objectives of the project are: (1) to demonstrate process feasibility; and (2) to provide data on the economics of the system. Information from the project's gasification experiments will be used to produce a design concept and cost estimate for the design, construction, and operation of a pilot plant as the next step toward commercial development of the underground coal gasification process for steeply dipping beds.

There are several secondary objectives of the project, which include:

- To determine optimum values for injection gas flow rate, reactor pressure, and amount of water in the reactor.
- To determine resource utilization and recovery potential.
- To determine effects of simultaneously operating two modules in communication with one another.
- To estimate effects of subsurface subsidence on the process in steeply dipping beds.
- To evaluate environmental impacts associated with the process.

The GR&DC/TRW project represents a major step toward commercialization of underground coal gasification. The sequence of steps of which it is a part is shown below.

- Develop and demonstrate in situ gasification technology in horizontal beds. This is being done by DOE via projects at Lawrence Livermore Laboratory and Laramie Energy Technology Center.
- Develop and demonstrate in situ gasification technology in steeply dipping beds (the GR&DC/TRW project).
- Transfer UCG technology to industry and demonstrate the technology in a coal environment which is representative of a significant national resource.
- Develop reliable economic data for estimation of operating costs for a scaled-up facility.
- Demonstrate large (multi-module) burns.
- Demonstrate pilot plant scale usage of UCG process gas from a multi-module burn, determining the economic viability of full-scale commercialization.
- Construct and demonstrate a full-scale (commercial) plant.

2.4 ENVIRONMENTAL CONSIDERATIONS

In situ coal gasification is expected to have a less severe environmental impact than a combination of conventional mining plus surface gasification.

- The mineral solids, otherwise appearing as wastes, remain underground.
- The cost of surface reclamation will be lower for underground coal gasification than for surface mining.
- Reduced quantity and lower quality of water is used in the process.
- Manpower requirements will be less than required for conventional mining techniques.
- Health and safety problems will be less severe than those due to conventional mining processes.

There are, however, some key environmental impacts or potential impacts associated with the process, although most will only be significant in large-scale operations.

- Aquifer disruption and contamination will occur and surface water disruption could occur.
- Chemical and particulate emissions will be released to the air and require cleanup.
- Unpredictable subsidence is a potential land problem with large-scale activities.

One of the reasons for proceeding with small scale field experiments is to develop data for verification of the potential environmental benefits of the technology along with the development and analysis of the economic and technological considerations.

3.0 DESCRIPTION OF THE PROJECT

The experiments to be conducted for the Department of Energy at the North Knobs site near Rawlins, Wyoming are small-scale tests of the technical and economic feasibility of gasifying steeply dipping coal seams in place. These tests will provide the technical, economic and environmental data bases to be used in the planning and evaluation of a pilot-scale activity. The activities involved in the development of the data base have been divided into four sequential phases occurring over a five year period.

During Phase I a site was selected, a preliminary evaluation of environmental impacts was made, a review of permit acquisition requirements was initiated, a test plan was developed, an definition of facilities and instrumentation requirements was completed and an evaluation of slant-well drilling and quenching methods was made. Phase I was initiated October 1, 1977 and completed February 28, 1978.

Phase II is currently underway an is expected to take 19 months. A detailed geologic and hydrologic characterization of the test site is being done. Site facilities and field instrumentation are being designed. Baseline environmental monitoring for air and groundwater quality and permit acquisition have been initiated. Detailed plans and procedures for test operation are being developed.

Phase III, which consists of the actual gasification tests will begin about October 1, 1979. Three separate tests are planned during this phase. At the completion of the third burn, the site will be restored, environmental monitoring will continue beyond this phase into Phase IV.

The actual field trials will consist of three separate in situ gasification tests, with each succeeding test based on results obtained from the prior test. Because of the experimental nature of the projects, only the first planned test can be described in detail. Plans for the other tests should be considered preliminary.

Phase IV will last about six months and will result in the design for the construction and operation of a pilot-scale UCG plant.

A milestone schedule for major events is included as Figure 3-1.

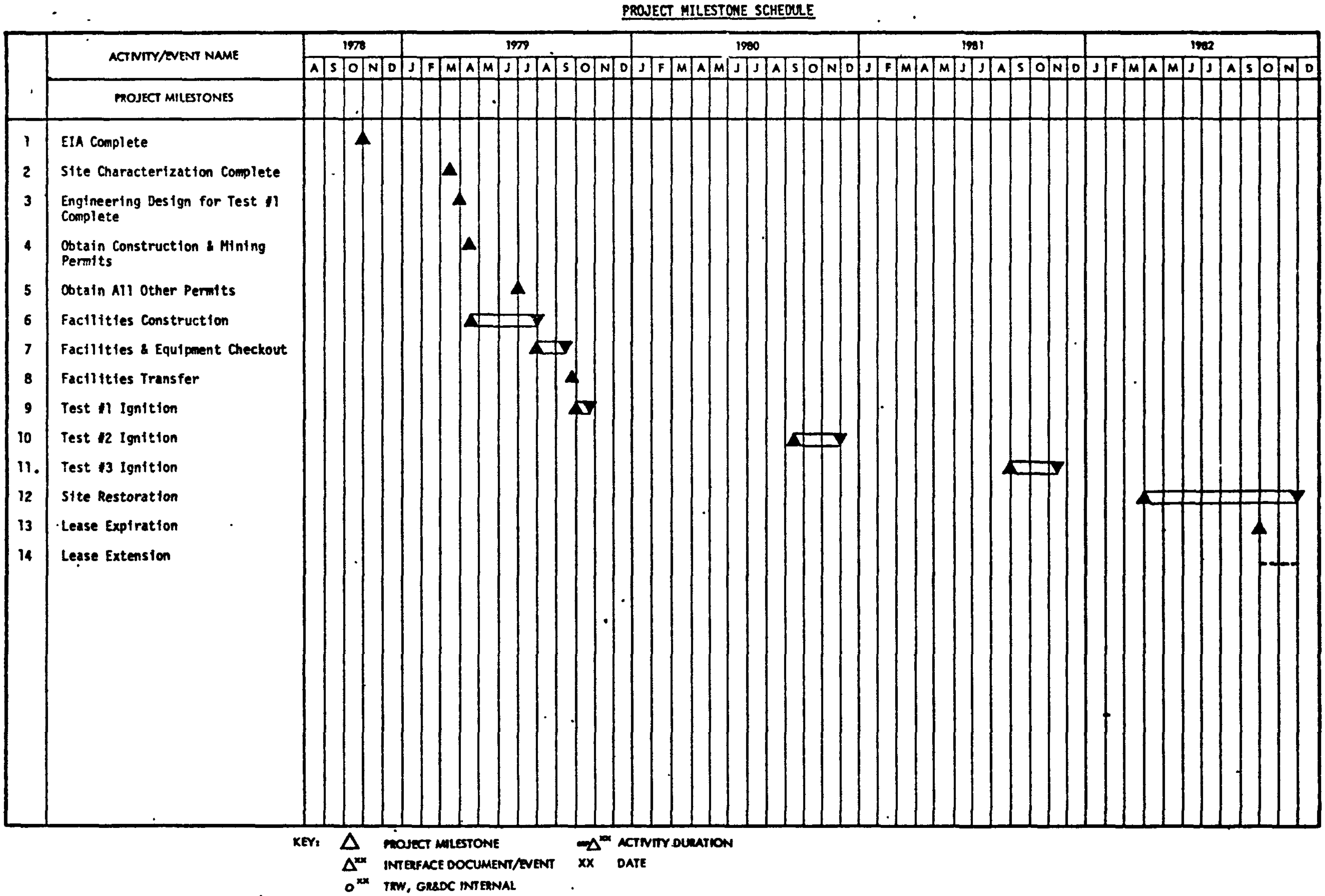


Figure 3-1
Project Milestone Schedule

3.1 PROJECT LOCATION

The North Knobs area is located approximately eight miles west of the town of Rawlins, Wyoming (Figure 3-2). Rawlins, the county seat for Carbon County, has a population of over 11,840. Interstate Highway 80 passes east-west through the southern edge of the area, and the Union Pacific Railroad passes within one half mile of the area. Rocky Mountain Energy Company (RME) has defined the North Knobs area and this study uses their property boundary (see Table 3-1).

TABLE 3-1

DESCRIPTION OF NORTH KNOBS AREA

Description	Acres
T 21 N, R 89 W	
Sec. 1: All	640
Sec. 2: All	640
Sec. 11: All	640
Sec. 12: All	640
Sec. 13: All	640
T 22 N, R 89 W	
Sec. 27: All	640
Sec. 34: All	640
Sec. 35: All	640
Total Acres	5120

The site selected from this area (Section 11, T21N, R89W) is shown on the geological map (Figure 3-3).

Access within the study area is by unimproved dirt roads. Traversing ground where no roads exist is relatively easy, and no serious access problems are foreseen. The terrain is generally flat with outcrops of sandstone beds that overlie individual coal seams.

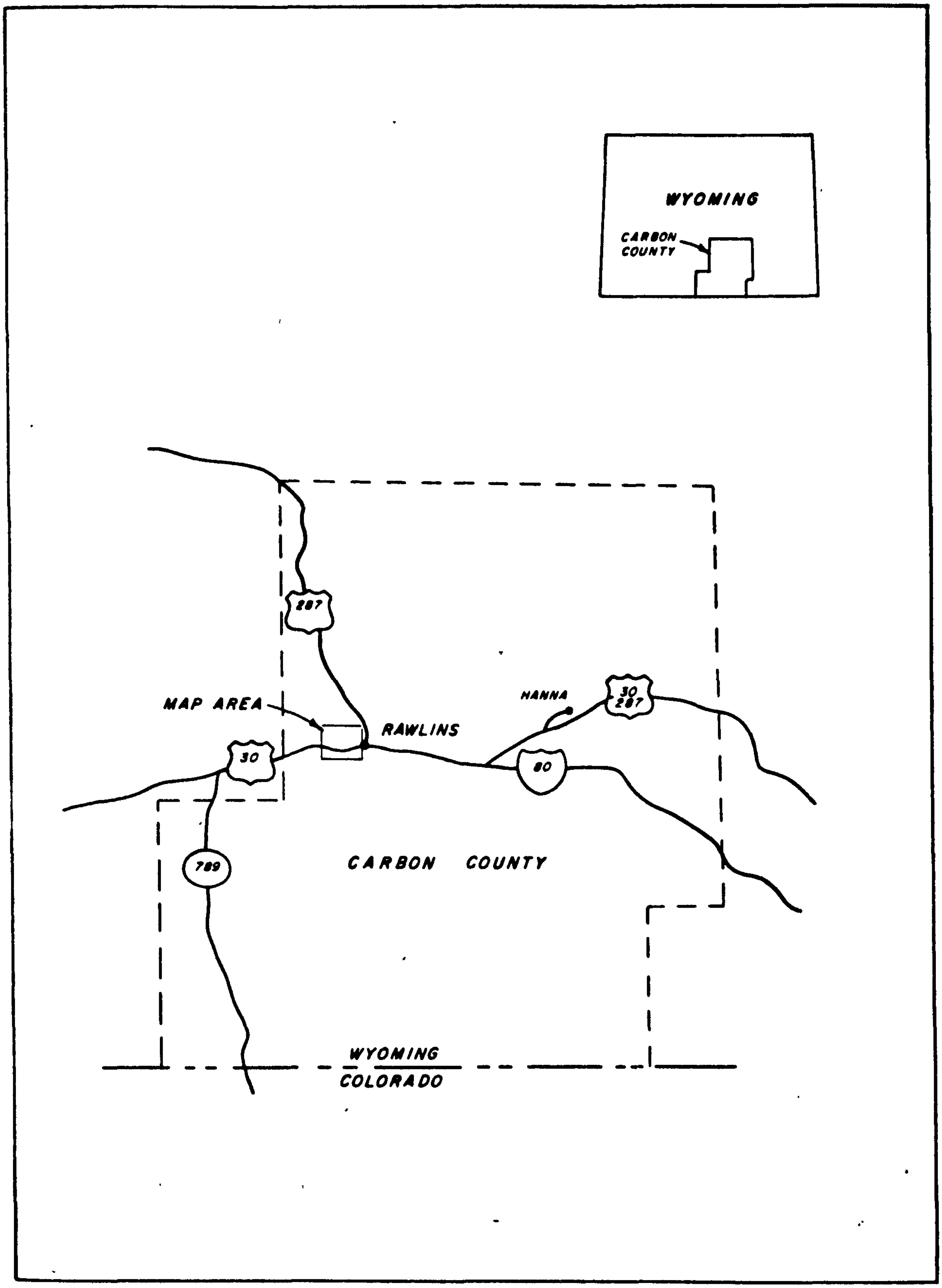


Figure 3-2
Index Map of North Knobs Area, Carbon County, Wyoming

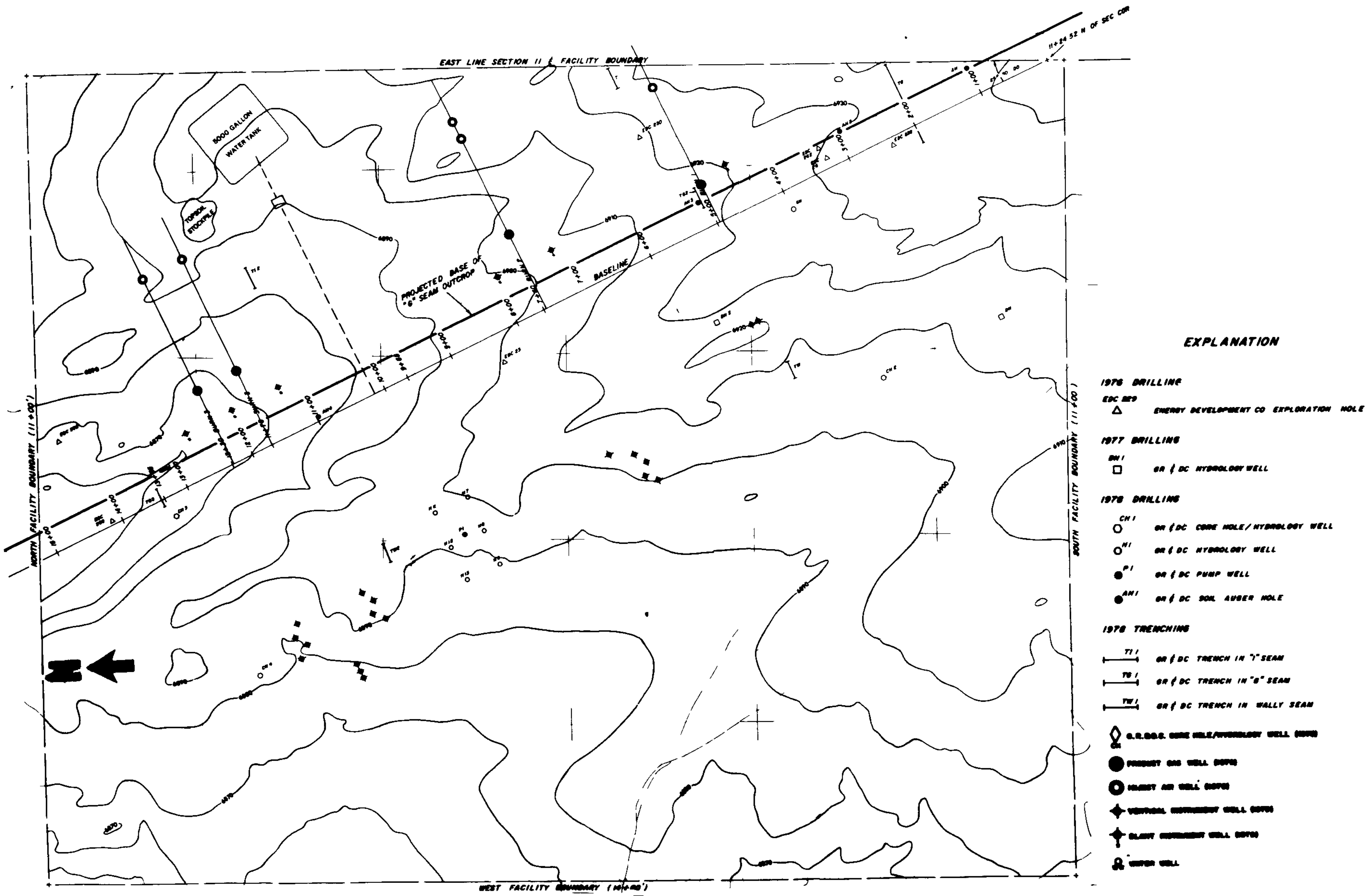


Figure 3-3
Site Map

Permission to use the North Knobs site to conduct in situ coal gasification experiments on all coal lying below 250 feet has been granted to GR&DC by Rock Springs Royalty Company. Rock Springs Royalty Company, a subsidiary of Rocky Mountain Energy Company, controls all the coal on the site, subject to a strip mine lease. Mining on the site will not begin until after 1982.

3.2 SITE SELECTION

The criteria used to select the site were as follows:

- The dip angle of the coal seam shall be between 45^0 and 75^0
- The gasification of the coal shall occur below the water table
- The coal shall be subbituminous
- The coal seam thickness shall be between 10 and 30 feet
- The geology shall be relatively simple
- A lease for performing UCG tests on the site shall be obtainable

The resources defined by DOE in the RFP included bituminous as well as subbituminous coals contained in seams with dip angles with respect to the horizontal plane of 45^0 or greater and with thicknesses normal to the angle of dip of at least five feet. However, coal resources in the U.S. potentially suitable for in situ gasification by the SDB concept have broader limits than the 45^0 dip and five-foot thickness required for the initial test sites. In a study included as part of the original Gulf/TRW proposal, the probable limits for minimum coal-bed dip and thickness values were determined to be 35^0 and three feet, respectively. The SDB deposits identified and the resource estimates made are based on the 35^0 dip and three-foot thickness values.

The national coal resource was reviewed to identify the magnitude and geographic extent of the SDB resource which met the criteria. The U.S. SDB resource contains approximately 100 billion tons of coal in four large geographic areas: 50 billion tons in the Rocky Mountain states, 20 billion tons in the Pacific Coast states, and 15 billion tons each in the Appalachian states and Alaska. A detailed geotechnical literature and on-site review was conducted to locate representative SDB-UCG sites in the three (3) geographic regions within the continental U.S. From these activities, the following seven areas were selected: North Knobs, Wyoming, and the Johnny Moore Syncline and Grand Hogback, Colorado (the Rocky Mountain region), Green

River, Roslyn, Wilkeson, and Carbonado Fields, Washington (Pacific Coast region), and Burton Ford, Virginia (Appalachian region). Preliminary on-site geotechnical investigations were conducted and the possibility of obtaining leases for SDB-UCG field sites within the seven areas was investigated. Leases were obtained within the North Knobs, Wyoming, and Johnny Moore Syncline, Colorado, areas.

After the DOE-ERDA SDB-UCG contract was awarded to GR&DC and TRW on October 1, 1977, detailed geotechnical review of the two leased sites was conducted. This review consisted of an intensive program to collect and analyze all available site specific geologic and hydrologic data for the leased sites; to examine the data from the ongoing exploratory drilling program being conducted by the lessor in the Johnny Moore Syncline; and to conduct a preliminary geologic and hydrology exploratory drilling program at North Knobs, Wyoming, site. As a result of these activities, the North Knobs, Wyoming site was selected by Gulf and TRW as the prime site for their SDB-UCG experiments.

More detail as to criteria used in evaluating potential SDB-UCG sites is included in Section 10, Alternatives to the Project.

3.3 MODULE CONFIGURATIONS

A number of different module configurations are possible with the SDB process. Due to the dipping bed, the coal seam can be entered through the roof, down the seam at the outcrop, and through the floor of the seam. Options considered for the SDB field test are listed in Table 3-2. The α (Figure 3-4) configuration is the linked vertical well design utilized in most U.S. horizontal bed UCG field tests. The β, π, and γ configurations have appeared in the Russian literature (Figures 3-5, 3-7 and 3-8). The τ option (Figure 3-6) is a modification of the β configuration that moves the injection well away from the subsidence zone. The γ configuration (Figure 3-8) combines the advantages of footwall entry with the ability to continue production as the burn front advances up the coal seam. Only the α configuration utilizes conventional vertical drilling methods like those employed at Hanna and Hoe Creek. The other four require slant drilling at varying angles. Some of the advantages of slant well module configurations and drilling techniques are listed below.

TABLE 3-2

MODULE CONFIGURATION OPTIONS

MODULE CONFIGURATION OPTIONS

Configuration	Drilling Requirements	Angle from Horizontal	Linking	Subsidence	Leakage	Surface Facilities
α	Conventional vertical	(90°) (90°)	Backward burn linking (BBL)	Interference with injection and production well	Same as horizontal beds	Same as horizontal
β	Down seam and vertical	(65°) (90°)	BBL or drilled borehole	Injection well	leakage up the production well	Large run of piping
γ	Down seam foot wall	(65°) (45°)	BBL or drilled borehole	Minimal possible physical blockage of injection well	Leakage up the production well	More compact no facilities over subsidence area
π	2-foot wall wells	(50°) (50°)	BBL	Possible blockage of injection well by rubble	Minimal	Most compact facilities located away from subsidence area
τ	Slant drilling down seam	(65°) (65°)	BBL or borehole	Some pinching of injection well, but less than α or β	Leakage up the production well	Covers greatest area longest runs

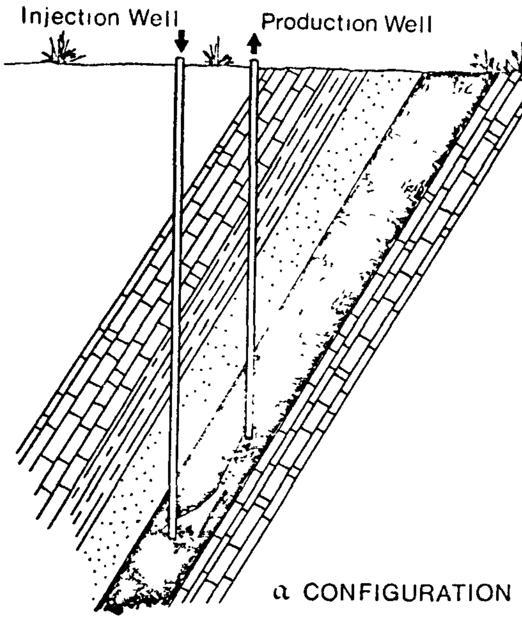


Figure 3-4

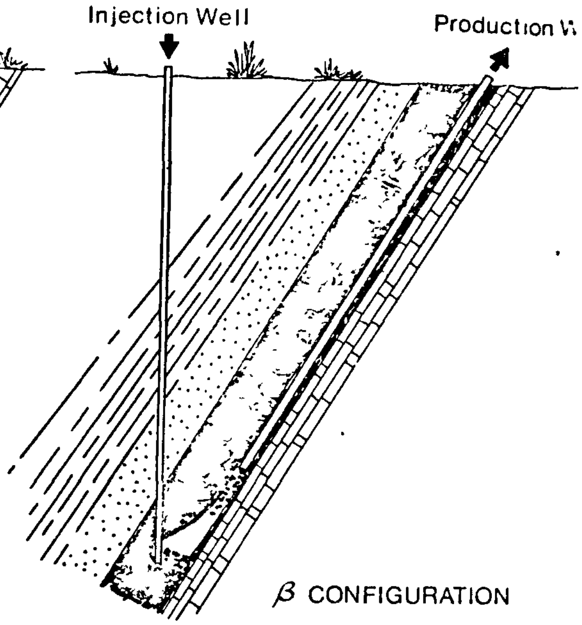


Figure 3-5

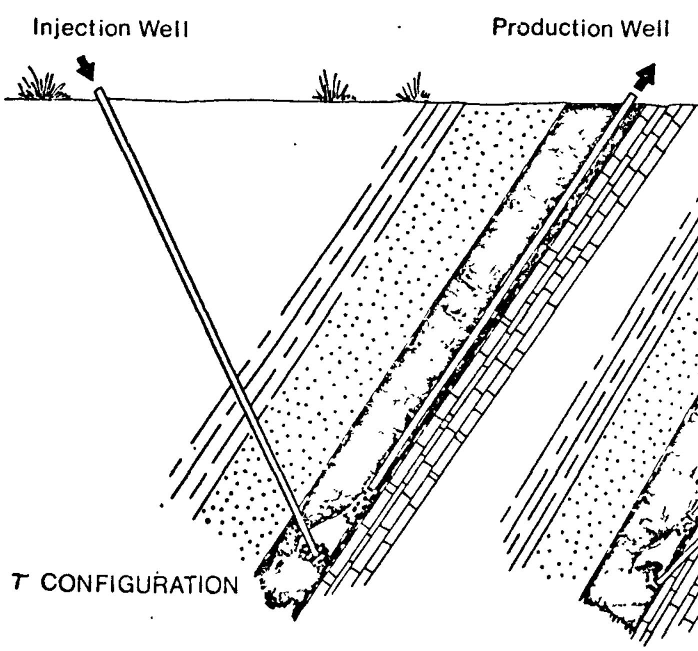


Figure 3-6

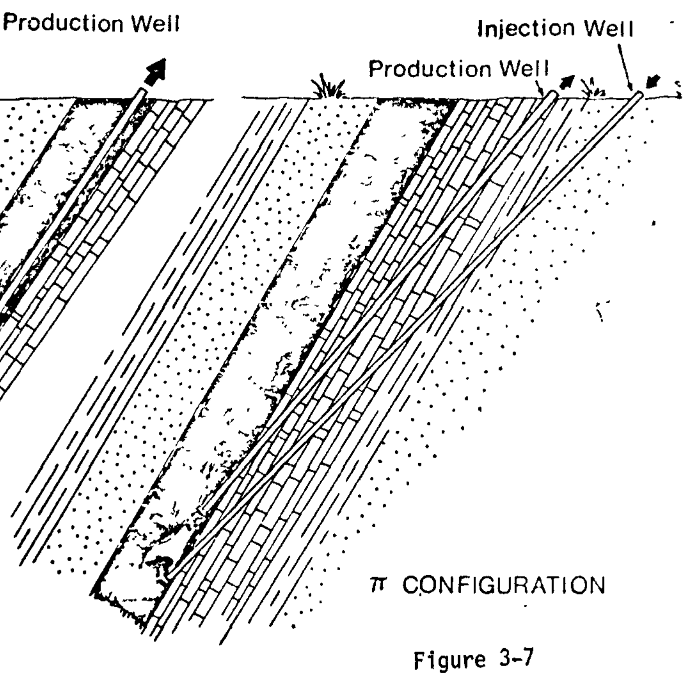


Figure 3-7

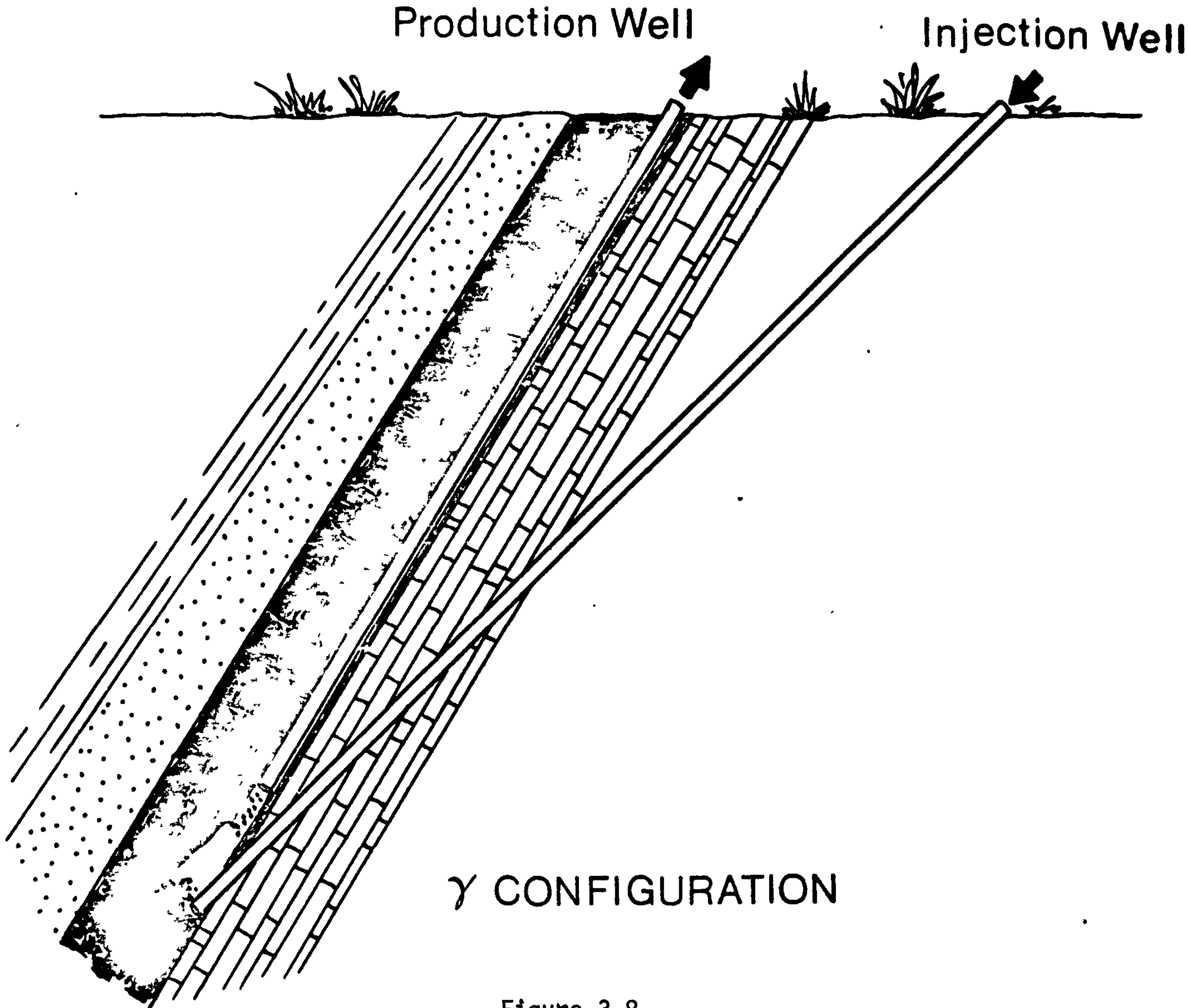


Figure 3-8

- Freedom from subsurface subsidence effects. Russian work in SDB has shown that roof fall can result in variation in flow rates or reactor pressure and in extreme cases can pinch-off vertical wells resulting in process termination.

- Alternate linking options. Backward burn linking is presently considered to be the preferred method for establishing communication between injection and production wells. Downseam drilling poses another linking possibility.

- Footwall entry of air. The location of the rubble bed at the bottom of the reactor makes footwall entry desirable.

- Simplicity of surface facilities. The injection and production wells are located away from the reactor zone areas and areas of potential subsidence.

- Control of the spacing between the injection and production well heads.

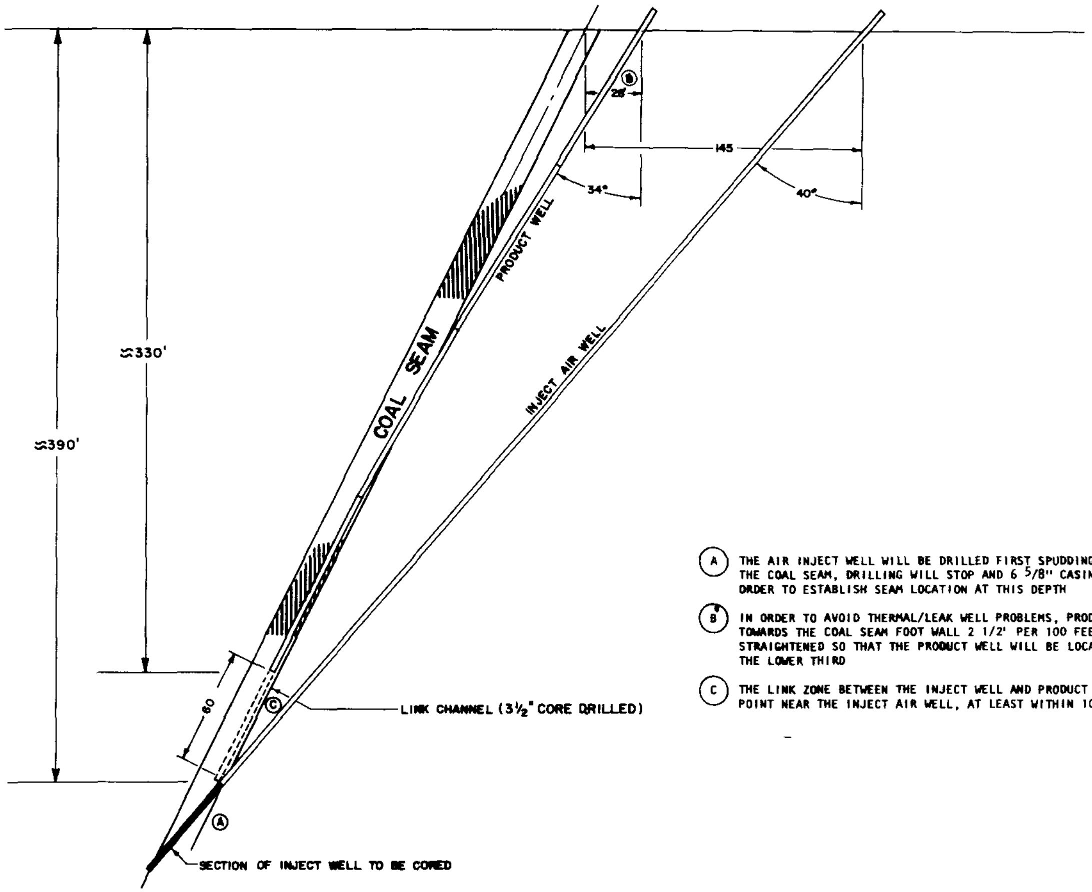
Slant hole module configurations also pose potential disadvantages. Among these are difficulty in precisely drilling the holes, added difficulty in installing the well casing and cementing it in place, and the possibility of leakage paths for gas being created by shrinkage of the coal away from a hot production gas pipe running through the coal seam.

A modification of the γ configuration is being contemplated for Test #1, (Figure 3-9). This configuration is expected to reduce the chances for leakage of gases around the product well, from shrinkage of the coal around the hot pipe.

3.4 TESTS

3.4.1 Test #1

Using a module configuration similar to the one shown in Table 3-2, a short-duration (approximately 20 day) test of the underground gasification of steeply dipping beds is planned. This test will establish the ability to ignite, control and estinguish the process. Process instrumentation and equipment will be checked out. Variations in the independent process parameters such as rate of air and water injection and injection processes will be attempted to obtain optimum values for these variables.



(A) THE AIR INJECT WELL WILL BE DRILLED FIRST SPUDDING IN AT 40° AND AT THE POINT WHERE THE BIT ENTERS THE COAL SEAM, DRILLING WILL STOP AND 6 5/8" CASING SET, AT THIS POINT THE SEAM WILL BE CORED IN ORDER TO ESTABLISH SEAM LOCATION AT THIS DEPTH

(B) IN ORDER TO AVOID THERMAL/LEAK WELL PROBLEMS, PRODUCT WELL WILL BE SPUDDED IN AT ~ 34° AND DEFLECTED TOWARDS THE COAL SEAM FOOT WALL 2 1/2' PER 100 FEET, ONCE INSIDE THE SEAM, THE BORE HOLE WILL BE STRAIGHTENED SO THAT THE PRODUCT WELL WILL BE LOCATED PARALLEL TO THE SEAM FOOT WALL AND WITHIN THE LOWER THIRD

(C) THE LINK ZONE BETWEEN THE INJECT WELL AND PRODUCT WELL WILL BE CORED WITH A SMALL SIZE BIT TO A POINT NEAR THE INJECT AIR WELL, AT LEAST WITHIN 10-15'

Figure 3-9

Cross Section View
Module 1
Well Directional Geometry

ENGINEERING SKETCH		TRW SYSTEMS AND ENERGY ENERGY SYSTEMS PLANNING DIVISION		
ORIGINATOR N. MCGINNIS	DATE 8/31/78	CROSS SECTION VIEW MODULE I WELL DIRECTIONAL GEOMETRY		
DRAWN M BUINICKAS	9/11/78	SIZE C	CODE IDENT NO	SK-UCG-2
CHECKED L. FELTS	9/11/78	SCALE 1/4" = 10'		SHEET OF
MJO				

The following minimum data will be collected during the gasification process to establish the optimum values for the process variables.

- Injection air flow rate, temperature, and pressure
- Water content of the injection air
- Pressure drop between the injection and production wells
- Production gas flow rate, temperature, and pressure
- Production gas composition
- Particulate concentration in product gas

These field data will be used to evaluate the major process performance parameters: coal resource utilization, production gas heating value, water influx rate, gas leakage rate, and percent energy recovered. Additionally, the quantities below will be computed.

- Time required for linking
- Amount of coal affected during the linking process
- Amount of air injected per linear foot of linkage
- Configuration and rate of movement of the burn front during linking and gasification
- Effects of variation in injection air flow rate, pressure, and water content on product quantity and quality
- Variation in gas production rate and product gas composition as a function of time
- Variation in the gross heating value and temperature of the product gas and the total gas production per day
- Extent of roof falls
- Extent of surface subsidence
- Useful life of each module

Due to the short gasification period, the first test will principally give trends, rather than hard process data. A maximum of 550 tons of moisture-ash free (MAF) coal are expected to be consumed during this burn with approximately 100 million standard cubic feet of gas produced.

The expected distance between the single injection well and the product gas well is expected to be about 60 feet. The depth of the gasification zone to the surface is from about 389 feet to 335 feet (Figure 3-10).

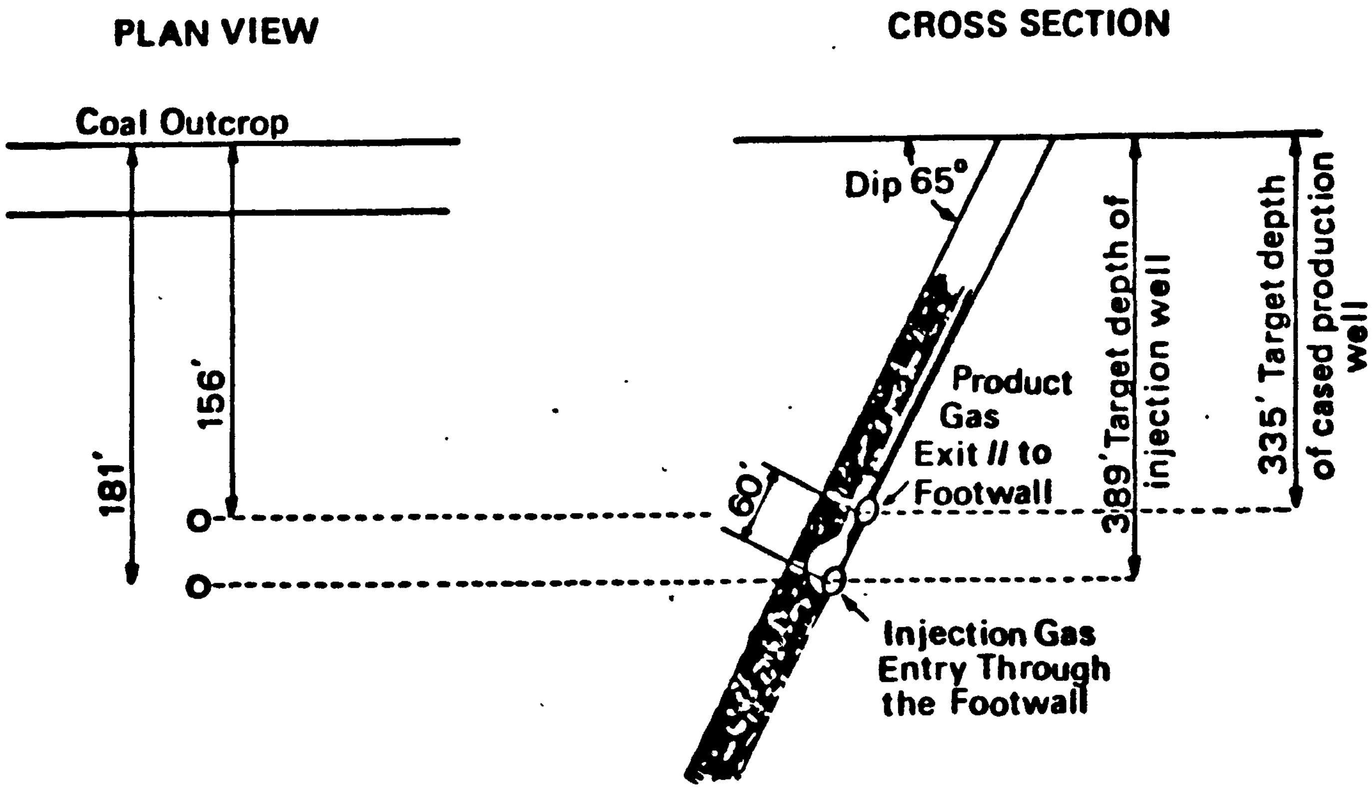


Figure 3-10
Process Wells for Test No. 1

3.4.2 Test #2

The second test is expected to have two injection wells and one process well, with the experiment lasting from 60 to 80 days, (Figure 3-11). The test will utilize reactor definition instrumentation to monitor the burn zone growth. The upper injection well eliminates the problem of the reaction zone being blocked by rubble and ash. The initial injection well will be shut in after the reactor zone reaches the second well. A systematic study will be made relating the performance of the reactor with controllable variables.

A maximum of 2,950 tons of (MAF) coal are expected to be consumed in this experiment producing 650 million standard cubic feet of product gas. The final length of coal gasified along the dip of the coal seam should be about 160 feet. The process will be quenched by shutting in the wells.

3.4.3 Test #3

Test #3 involves a two-module parallel configuration (two injection, two production wells) which will operate for 60-80 days using data obtained from the second test. Linkage between the injection wells across the strike will be accomplished with a reverse burn. The modules will then be operated simultaneously with a sweep of the combined area while maintaining a high-quality production gas. The sweep will be controlled by choking or closing the various wells to provide maximum air flow past the desired burn front. The test will utilize both reactor definition instrumentation to monitor the process and the required process instrumentation. Helium gas tracer studies will be used to estimate the degree of communication between the wells.

Figure 3-12 pictures the wells, anticipated for Test #3.

A maximum of 5,160 tons of (MAF) coal will be utilized in this experiment, producing 952 million standard cubic feet of product gas. The final length of coal gasified should be 60 feet.

Table 3-3 shows the significant values for test parameters for all three tests.

3.5 FACILITIES DESIGN

A design effort has been performed to arrive at a preliminary configuration for the on-site facility which will support the three tests. The purpose of this conceptual design was to define the facility components in sufficient detail to permit preparation of detailed construction plans as

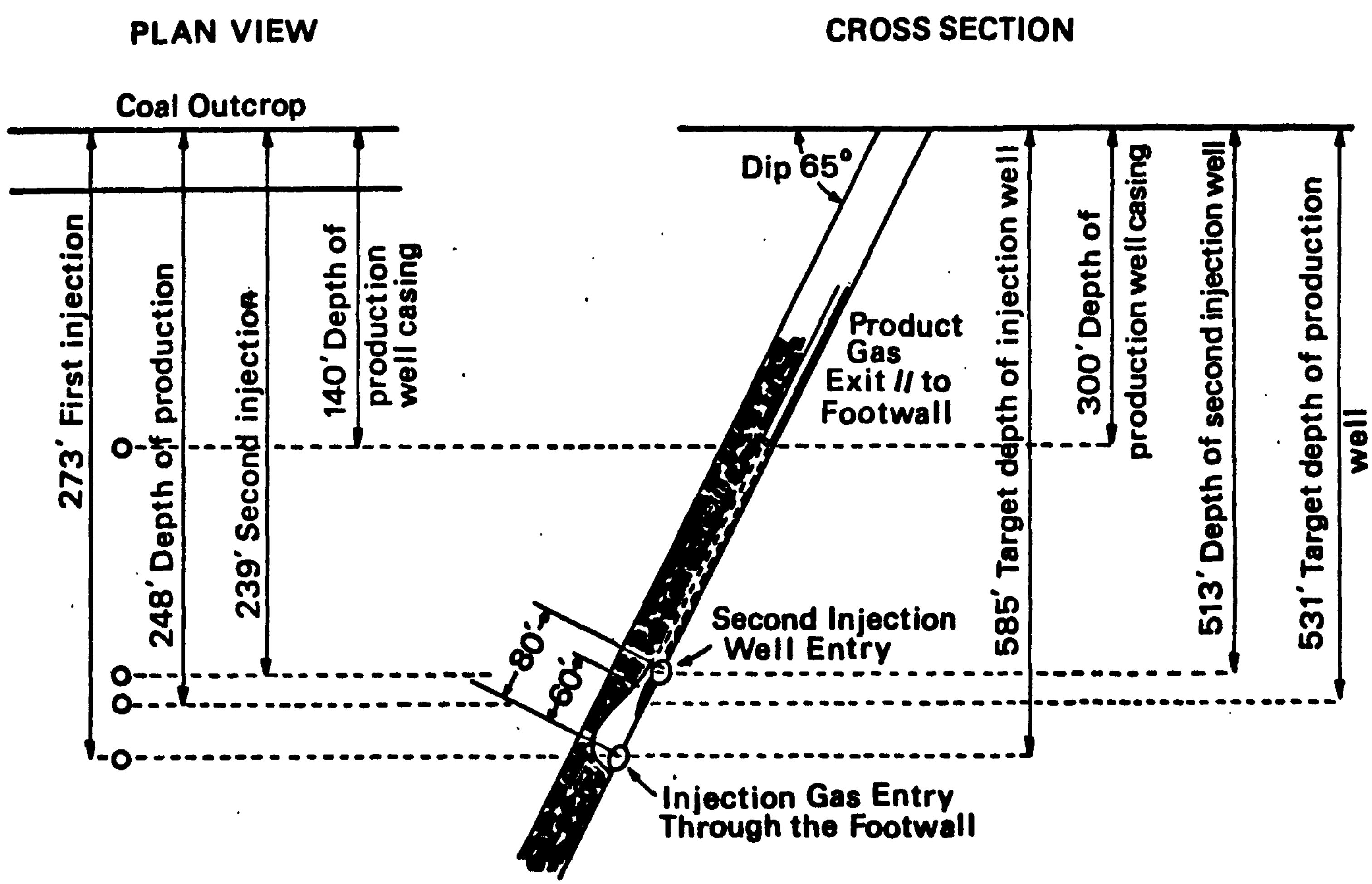


Figure 3-11

Process Wells for Test No. 2

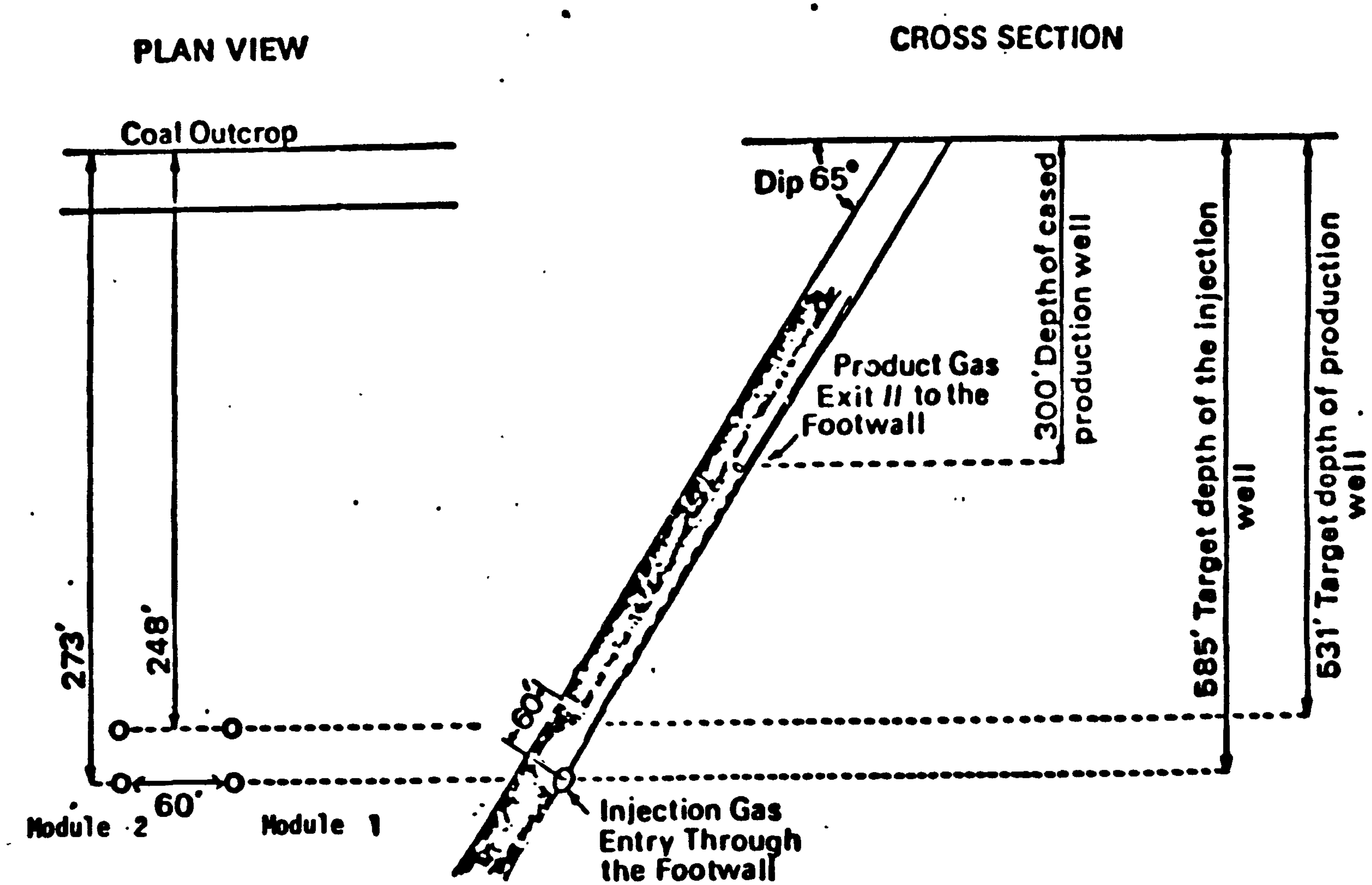


Figure 3-12
Process Wells for Test No. 3

TABLE 3-3
SIGNIFICANT TEST PARAMETER VALUES

	BURN NUMBER		
	1	2.	3
Duration (Days)	≤ 20	≤ 80	≤ 80
No. Injection Wells	1	2	2
No. Production Wells	1	1	2
Tentative Injection Well Depth (Ft)	350	450	500
Link Distance (Ft)	60	60	60
Estimated Link Time (Days)	14	14	35
Link Pressure (psi)	350	350	350
Air Injection (MMscfd)	0.25-2.0	0.5-5.0	0.5-9.0
Injection Pressure (psig)	125	125	125
Water Injection (gpm)	0-2	0-4	0-8

well as specifications and procurement documentation. In addition this effort provided sufficient design detail to develop realistic construction and procurement schedules and cost estimates compatible with the program milestones. The test site facility consists of production and instrumentation wells, manifolds and gas piping systems, injection gas systems including linking and process air compressors, buildings, access roads, a fuel oil system, a water supply, and an electrical network.

3.5.1 <u>Site Layout</u>

A preliminary site layout is shown in Figure 3-13. Only a portion of the facility shown in Figure 3-13 will be constructed for Test #1. The exact location of the facility with respect to the three coal outcrops and the section lines has not yet been determined. The positioning of the three test chambers along the coal bed will be determined by the results of the geotechnical site characterization program presently underway. The entire test site, including four well modules (three tests), instrumentation wells, linking and injection compressors, water supply, support buildings, access and interconnecting roads, will be located in an area approximately 1,000 feet by 1,000 feet.

The site layout is determined by the well depths, well configurations and drilling angle for the injection wells. The wells for Test #1 dictate location of the compressors, flare stack and pipe racks. The support buildings, instrument vans, fuel oil tanks, and vehicle parking, as well as the compressors, are grouped around this module. Subsequent construction and extension of piping and racks for Tests #2 and #3 can be accomplished without interfering with Test #1 operation. The injection gas system, which consists of the linking gas compressor and up to six production compressors, is located to keep the high cost piping runs as short as possible. A minimum 100-foot separation between the heavy compressors and the product wells keeps any subsidence from affecting the compressors, piping or structures.

Supporting systems, such as the diesel generator, electrical substation, diesel oil storage, water supply and buildings, are located on the periphery of the gas systems since their interface is with the gas systems and roadways. The maintenance building and related shelters are located "upwind" or "crosswind" from the gas flare and the compressor.

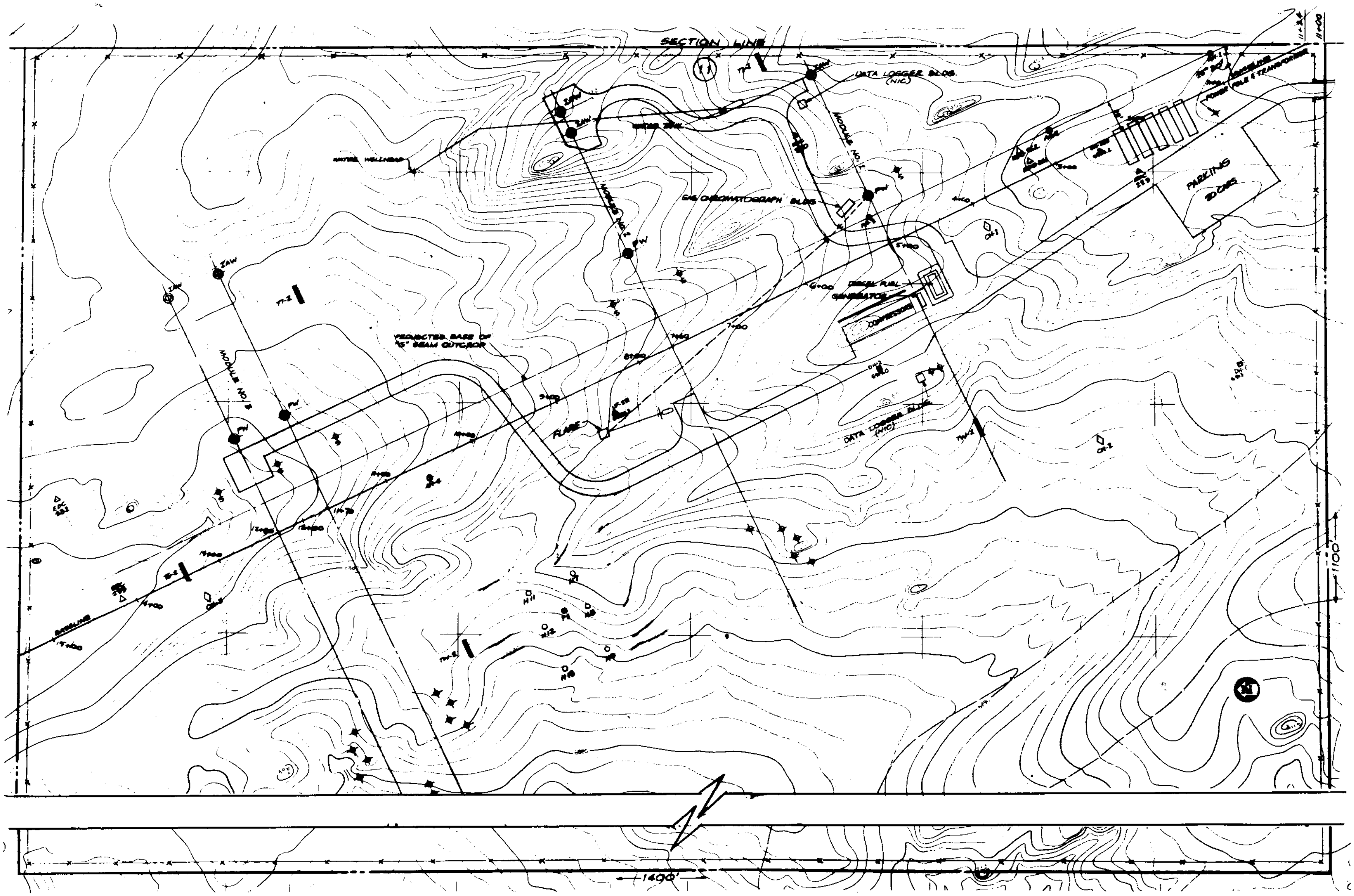


Figure 3-13
Preliminary Site Layout

A 15,000 gallon storage tank provides fuel for operation of the diesel engines. The water supply provides process water, water for domestic plumbing, and fire control protection.

A tradeoff analysis is being performed to determine the economics of installing electrical service at the site to provide power for the compressors versus providing diesel-engine driven compressors. The linking gas injection system consists of a low flow high pressure compressed air system. The compressed air supply for the gasification production process is provided by four production compressors capable of producing 5.5 MM scfd to service Tests #1 and #2. Two additional compressors each capable of producing at least 2 MM scfd will be installed prior to Test #3. Water will be added into the injection air stream, if necessary, to assist in controlling the temperature and therefore the reaction rates and the heating value of the production gas. The water also serves as a reactant in the gasification process. However, there may be sufficient water in the coal for process purposes.

3.5.2 Instrumentation

Instrumentation planned for inclusion in this project falls into the broad categories listed below:

1. Process Instrumentation - used to measure process gas flow rates, temperatures and pressures

2. Product Analysis Instrumentation - measures the composition and heating value of the process gas

3. Reactor Definition Instrumentation - monitors physical properties produced by the subsurface gasification to infer the reactor cavity shape and location as a function of time

4. Safety and Environmental Monitoring Instrumentation - determines wind speed and direction, aquifer levels and composition, the presence of hazardous gases and toxic byproducts

5. Computer Analysis and Display Instrumentation - captures, interprets and formats the data in order to control and understand the dynamics of the gasification process.

3.6 PROJECT INPUTS AND OUTPUTS

Inputs to the planned project can be divided into two categories: process inputs and other resource requirements. Process inputs include items such as the amount of coal, air and water used in the burn, the duration of the gasification process and the composition of the coal. Resource requirements include physical resource needs such as land, electricity (for operation of equipment), water (for sanitary and drinking purposes) and diesel fuel (for operation of motors and generators). Figure 3-14 shows a simplified process diagram.

Process outputs are comprised of the effluent gases produced from the gasification process, the average heating value of the gas produced and the thermal efficiency. The effluent gases produced include H_2, N_2, O, CO, CH_4 and CO_2.

Because the North Knobs field test is the first attempt at underground gasification of SDB coal, there are little data available to indicate the exact nature of the project inputs and outputs. Rather, it is part of the experiment to develop this data for use in future UCG experiments. Therefore, to approximate the inputs and outputs of the North Knobs test, data regarding project inputs and outputs for two other gasification projects have been used for comparison. These other two projects were field experiments utilizing the UCG technology in western subbituminous coal, and are known as Hanna III conducted by Laramie Energy Technology Center and Hoe Creek II conducted by Lawrence Livermore Laboratory. The project inputs and outputs for all three projects, North Knobs, Hanna III and Hoe Creek II are shown in Table 3-4.

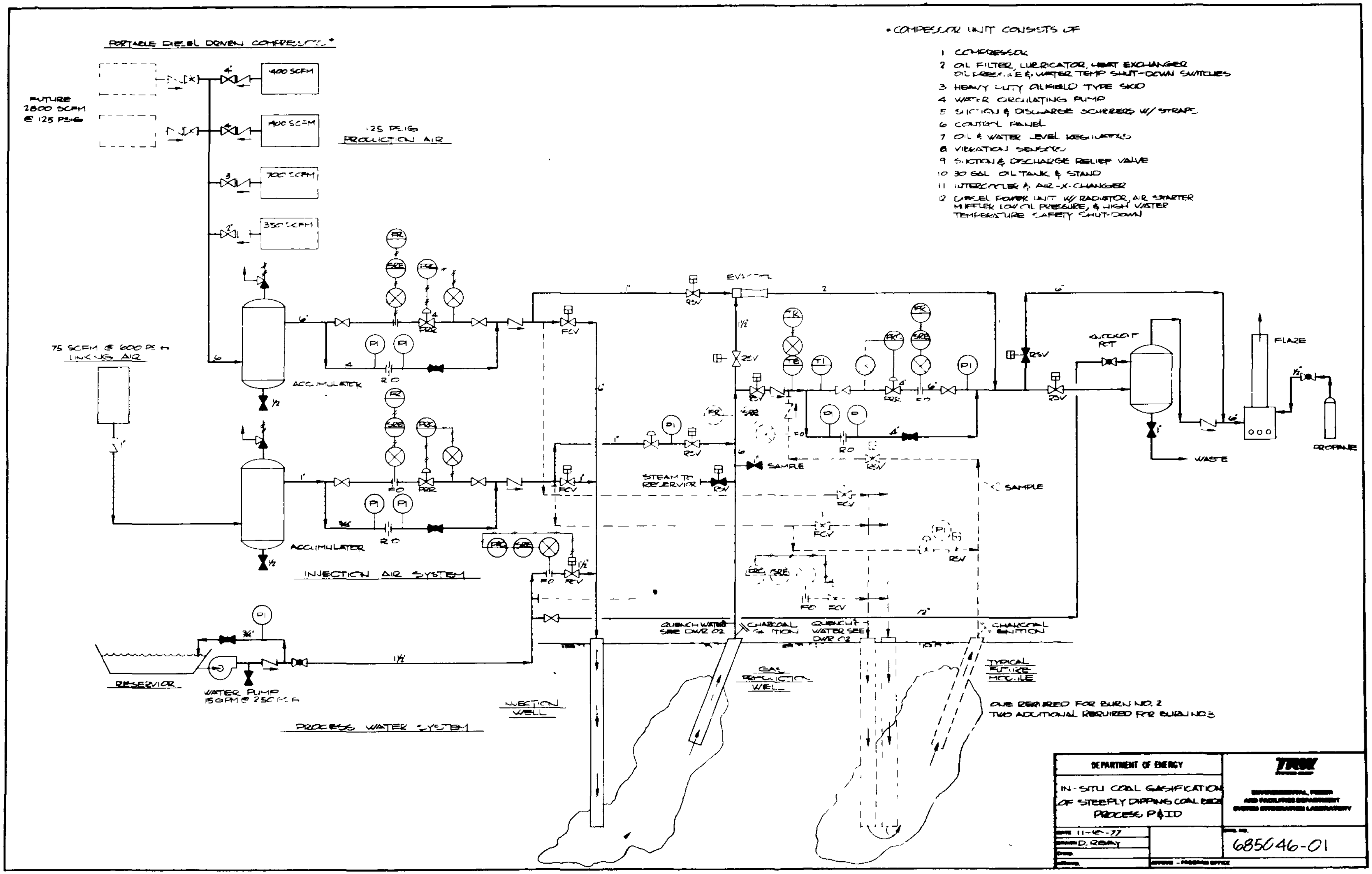


Figure 3-14. Process P&ID

TABLE 3-4

COMPARISON OF PROCESS INPUTS/OUTPUTS BETWEEN NORTH KNOBS TEST #1, HANNA III AND HOE CREEK II

	NORTH KNOBS WYOMING (Estimated)	HANNA III WYOMING	HOE CREEK II WYOMING
PROCESS OUTPUT			
Process Gases Produced (Mole Percent)[a]			
H_2	18.0	13.47	11.9
N_2	48.4[b]	52.94	38.1
O_2	---	0.01	0.0
CO	18.0	15.16	6.1
CH_4	5.0	3.51	1.1
CO_2	10.0	13.79	11.0
H_2S	0.1	---	<0.1
Incinerated Gases Produced[c]			
CO_2	---	---	---
N_2	---	---	---
O_2	---	---	---
SO_2	---	---	---
Average Heating Value (Btu/scf)	176	138	108
Thermal Efficiency (%)	100	78	73
PROCESS INPUTS			
Amount of Coal Used (tons)	470	2,867	1,952
Coal Composition			
Sulfur Content (%)	0.19	0.5	0.9
Ash Content (%)	6.4	13.0	4.5- 8.0
Moisture Content (%)	20.8	11.0	28.0-30.0
Heating Value (Btu/lb)	9,429	9,830	8,050
Duration of Gasification (days)	20	38	58
Air Injection Rate			
Linking Phase (scf/min)	20-173	Not Available	Not Available
Gasification Phase (scf/min)	500-2800	2,000-4,500	2,000-4,000

[a]Based on Phase I Reports, Parametric Costs, Appendix; 8000 Btu/lb, 100 percent efficient UCG with 176 Btu/lb product.

[b]Estimate includes argon.

[c]All produced gas will be burned in a flare with excess air.

4.0 DESCRIPTION OF THE EXISTING PROJECT SITE ENVIRONMENT

The site to be used for the experiment is located approximately 8 miles west of Rawlins, Wyoming in Carbon County. The site is 18 miles east of the continental divide along the southeastern edge of the gently rolling prairie terrain that characterizes the Great Divide basin. The site is roughly bisected by a dry creek bed running to the northeast. The site is approximately 6800 feet above sea level, with relief about 180 feet and slopes generally less than 3.5 percent grade.

The area is sparsely populated, with the local population concentrated in Rawlins (1976 population estimated at 11,840 of Carbon County total of 20,886).

The land use in the immediate area is ranching, with the primary livestock being sheep and cattle. Other land uses in the general area are mineral exploration and minimal dry land farming, since the average annual precipitation is 7-9 inches.

This chapter has been divided into sections describing the physical environment, the biotic environment and the human environment.

4.1 PHYSICAL ENVIRONMENT

This section contains information on geology, hydrology, water quality, climatology, air quality and noise quality.

4.1.1 Geology

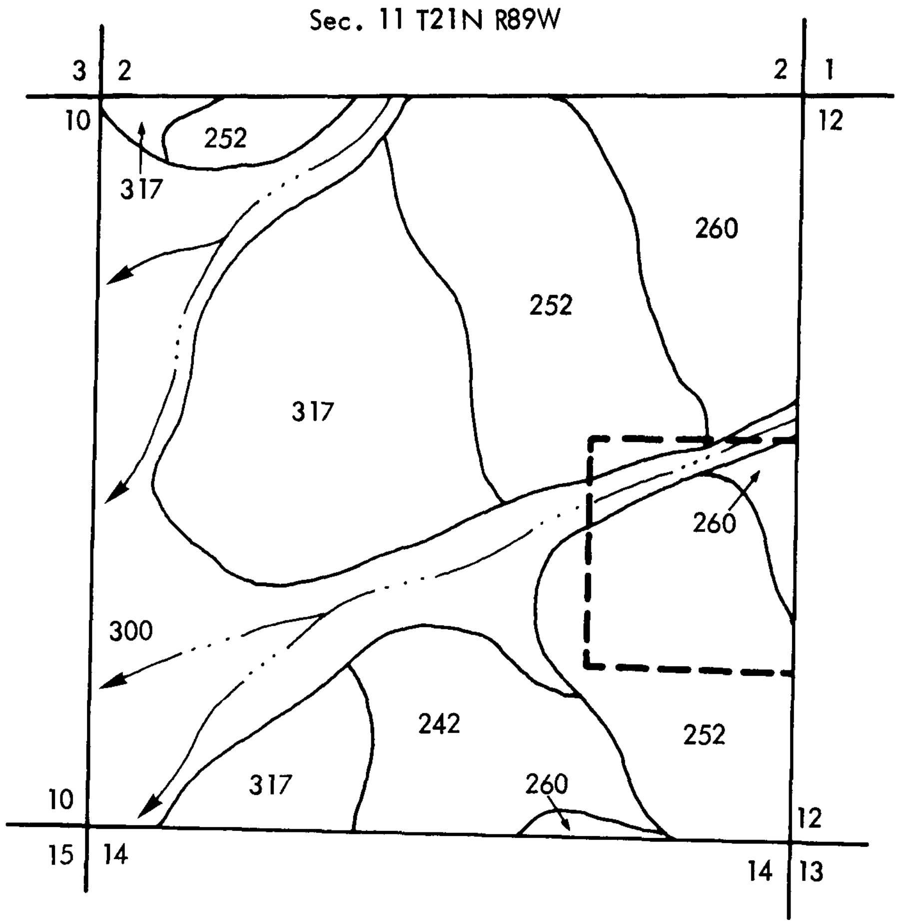
Information on soils and topography of the area is provided in detail in the surface geology section. The subsurface geology section provides data on the stratigraphy and lithology.

4.1.1.1 Surface Geology

Soils

General soils information for Section 11, and specific soils information for the site were obtained from the U.S. Department of Agriculture, Wyoming Soils Conservation Service and is described below.

A soils association map of Section 11 was prepared and is shown as Figure 4-1. The two soils associations found on the site are the Shinbara-Blazon-Rock outcrop Complex (Soils Mapping Unit 252) and the Ryan Park-Rock River Association (Soils Mapping Unit 260).



UNIT NO.

242	Blackhall-Blazon Complex
252	Shinbara-Blazon-Rock Outcrop Complex
260	Ryan Park-Rock River Association
300	Monte-Clowers Complex
317	Littsan, Deep Variant-Sage Creek, Coarse Variant Complex

Figure 4-1. Soil Associations in Section 11, T21N, R89W

The Shinbara-Blazon-Rock outcrop Complex are found on sloping to steep slopes (10-40%) at elevations between 6,500 and 7,300 feet. The Shinbara soil makes up 35 percent of the complex, with the Blazon soil about 30 percent and Rock outcrops about 25 percent.

The Shinbara series is a very shallow, excessively drained soil. It formed in very shallow loamy deposits weathered from shale interbedded with sandstone. Permeability is moderate to slow. The effective rooting depth is 3 to 10 inches and the available water capacity is very low. Surface runoff is medium to rapid and erosion hazard is moderate to severe.

The Blazon series is a shallow, well drained soil. It formed in shallow loamy deposits weathered from interbedded sandstone and shale. Typically the surface layer is brown, moderately alkaline clay loam about 5 inches thick. The substratum is pale brown, moderately alkaline clay loam about 11 inches thick. Interbedded sandstone and shale deposits occur at 16 inches. Permeability is moderate. The effective rooting depth is 10 to 20 inches and the available water capacity is very low. Surface runoff is medium to rapid and erosion hazard is moderate to severe.

The Shinbara-Blazon-Rock outcrop complex soils are used for rangeland and wildlife habitat.

The Ryan Park-Rock River Association is found on gently sloping to moderately sloping (2-20%) topography at elevations between 6,500 to 7,800 feet. The Ryan Park sandy loam makes up 45% of the Association, and Rock River makes up 30% with areas of Grieves and Blackhall soils making up the remaining 25% of the soil mapping unit.

The Ryan Park soil is a deep, well drained, soil forming in alluvium. Typically, the surface layer is brown sandy loam about 1 inch thick. The subsoil is yellowish brown sandy loam about 16 inches thick. The upper part of the substratum is pale brown sandy loam about 25 inches thick. The lower part of the substratum is yellowish brown sandy loam to a depth of 60 inches. Permeability is moderate. The available water capacity is moderate. Effective rooting depth is 60 inches or more. Surface runoff is medium, and erosion hazard is moderate.

The Rock River soil is a deep, well drained, soil forming in alluvium. Typically, the surface layer is brown sandy loam about 2 inches thick. The subsoil is brown sandy clay loam about 10 inches thick. The substratum is calcareous, yellowish brown sandy loam to a depth of 60 inches. Permeability is moderate. The available water capacity is moderate. Effective rooting depth is 60 inches or more. Surface runoff is medium and erosion hazard is moderate.

These soils provide some food and cover for antelope, deer and sage grouse.

Topography

The UCG site is located approximately 1¼ miles north of Interstate 80 at the Knobs exit. The area is then accessible by dirt road. The area is part of the eastern edge of the Great Divide Basin.

The topography in the eastern part of Section 11 is gentle, sloping moderately from 5-10% southwestward. Maximum and minimum elevations within the project area are 6960 feet and 6800 feet, respectively. The landscape contains sandstone outcrops up to 15 feet high, and shallow gullies infilled with alluvium covered with sagebrush.

The sparse vegetation and minimal talus exposures allow detailed observation of the strata, which consists of alternating sandstone, shale, siltstone, and coal.

4.1.1.2 Subsurface Geology

The rocks of the UCG site belong to the Tertiary (Paleocene) Fort Union Formation, which is a deposit of fluvial origin. As such, individual units may thicken or thin or disappear over short distances. Within the site area, the thicker sandstones and coal beds generally form the most continuous stratigraphic units, although the characteristics may change along the strike.

The rock units at the UCG site strike about N25W and dip SW from 60-70^{o}, averaging 65^{o} in most places. Observations at the UCG site indicate that dips become more shallow westward.

There is no indication of faulting at the UCG site. The disappearance of certain units across the draws is probably attributable to a decrease in rock (erosion) resistance. This feature is related to the location of local drainage basins.

Cross Sections

Coal beds of interest in the North Knobs and surrounding area are contained in the Cretaceous Lance and Tertiary Fort Union Formations. The thicknesses of these units are estimated from outcrop width and dip of beds to represent the following general stratigraphic column for North Knobs and the surrounding area:

System	Formation	Thickness (ft)
Tertiary	Fort Union	7,250
Cretaceous	Lance	4,800

A cross-section sketch is shown in Figure 4-2.

Lance Formation

The Lance Formation contains the Nebraska bed which lies about 700 feet stratigraphically above the base of the formation. Outcrops of the bed in the North Knobs area are limited to Sections 1, 2 and 12, T21N, R89W, i.e., they do not outcrop on Section 11.

Drilling indicates that the bed thins from about 11 feet at the southern end of Section 1 to 7 feet at the northern end. The bed appears to be clean and devoid of shale partings, with the roof and floor interpreted (from geophysical logs) to be shale or mudstone. Detailed geophysical logs have been prepared for a drilling program located along the coal outcrop in Section 1 and adjacent sections.

Fort Union Formation

Three coal beds of interest (the Wally, G, and I beds) occur in the Fort Union Formation. Typical ranges in coal bed and interval taken from geophysical logs are:

Seam	Range (ft)
Wally Bed	0.0 - 13.0
Interval	155.0 - 250.0
G Bed	7.0 - 25.0
Interval	140.0 - 210.0
I Bed	5.5 - 16.0

The base of the I Bed occurs about 1,200 to 1,300 feet above the base of the Fort Union Formation.

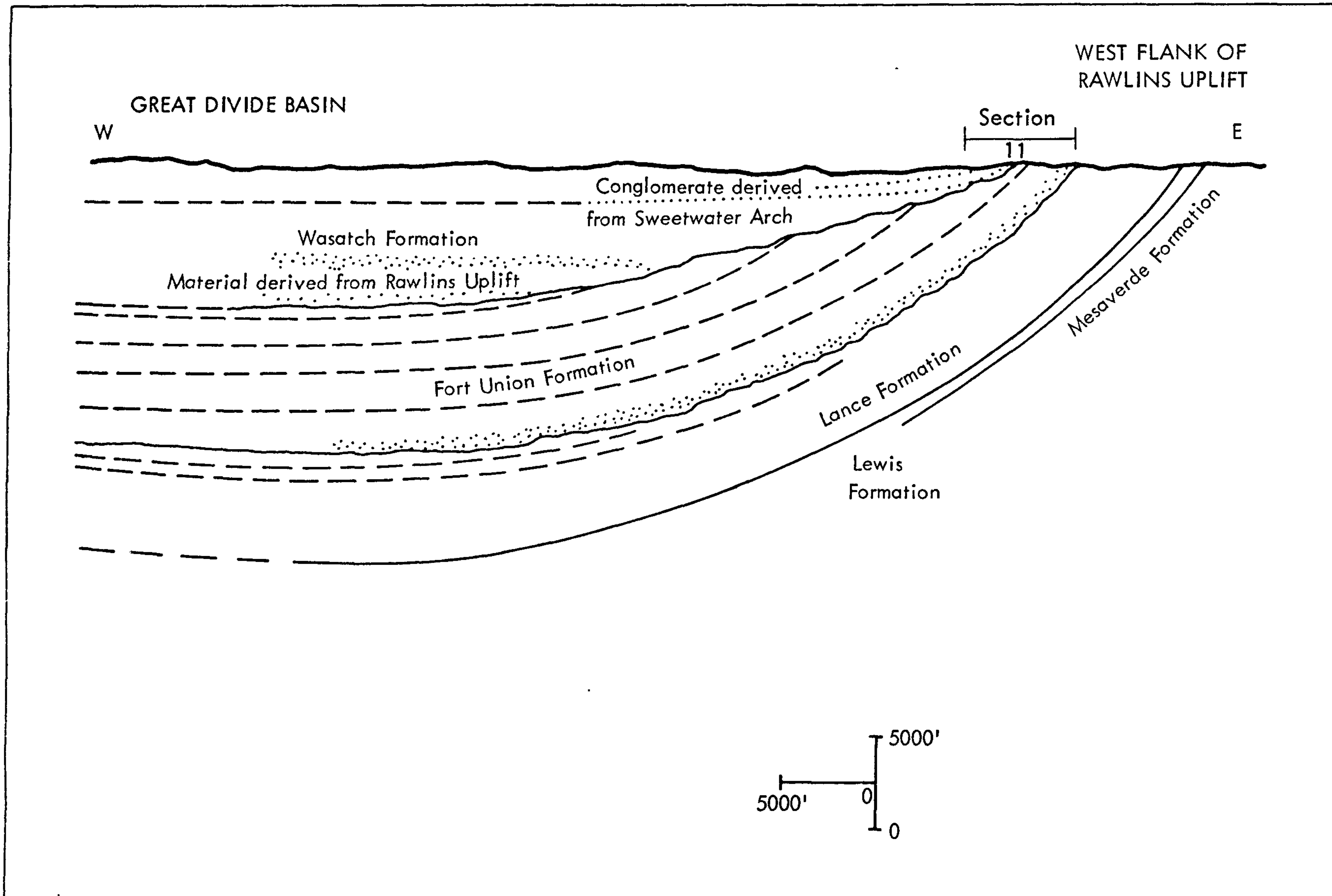


Figure 4-2. East-West Cross Section at Northwest Flank of Rawlins Uplift and Great Divide Basin Showing Structural and Stratigraphic Interpretation of Upper Cretaceous and Early Tertiary Formations (For Cross-Section Location, See Figure 4-5)

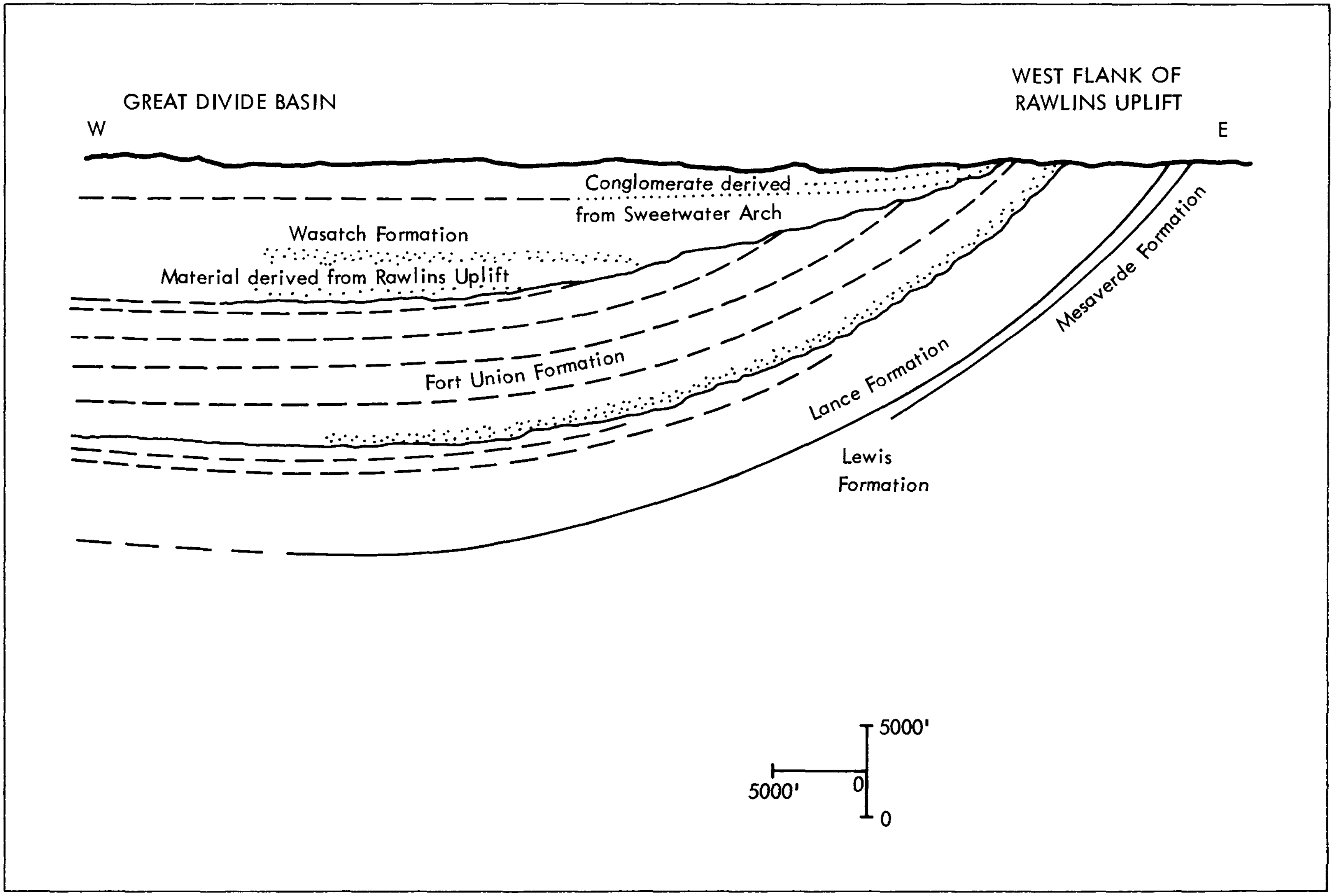


Figure 4-2. East-West Cross Section at Northwest Flank of Rawlins Uplift and Great Divide Basin Showing Structural and Stratigraphic Interpretation of Upper Cretaceous and Early Tertiary Formations

Wally Bed

This bed appears to be less than 6.0 feet thick. Drill hole data indicates that the bed thickens from about 5.0 feet near the center of Section 11 to approximately 8.0 feet at the northern line of that section. The Wally Bed appears to maintain a true thickness of about 10.0 feet in Section 35, T22N, R89W if the 64° dip is assumed.

G Bed

Thirty-nine holes were drilled in several sections to define the G Bed; the holes are distributed as follows:

Location	No. Holes
Section 13, T21N, R89W	14
Section 11, T21N, R89W	17
Section 35, T22N, R89W	8

I Bed

Eighteen holes have been drilled through the I Bed. The holes are distributed as follows:

Location	No. Holes
Section 13, T21N, R89W	8
Section 11, T21N, R89W	6
Section 35, T22N, R89W	4

The I Bed is split into three distinct benches at the southern edge of the study area; about 1,500 feet north of the south line of Section 13, the middle and lower branches merge, but are still separated by a thin shale parting. The upper bench remains as a rider northward into the center of Section 11, T21N, R89W, where it apparently pinches out. A typical geologic cross-section of Section 11 is shown in Figures 4-3 and 4-4. Figure 3-3 presents the geology of the outcrops on Section 11; Figure 4-4 shows a cross-section of sandstone, shale and coal found in Section 11. The location of the cross-section, in relation to the coal seams and Section 11 is shown in Figure 4-5.

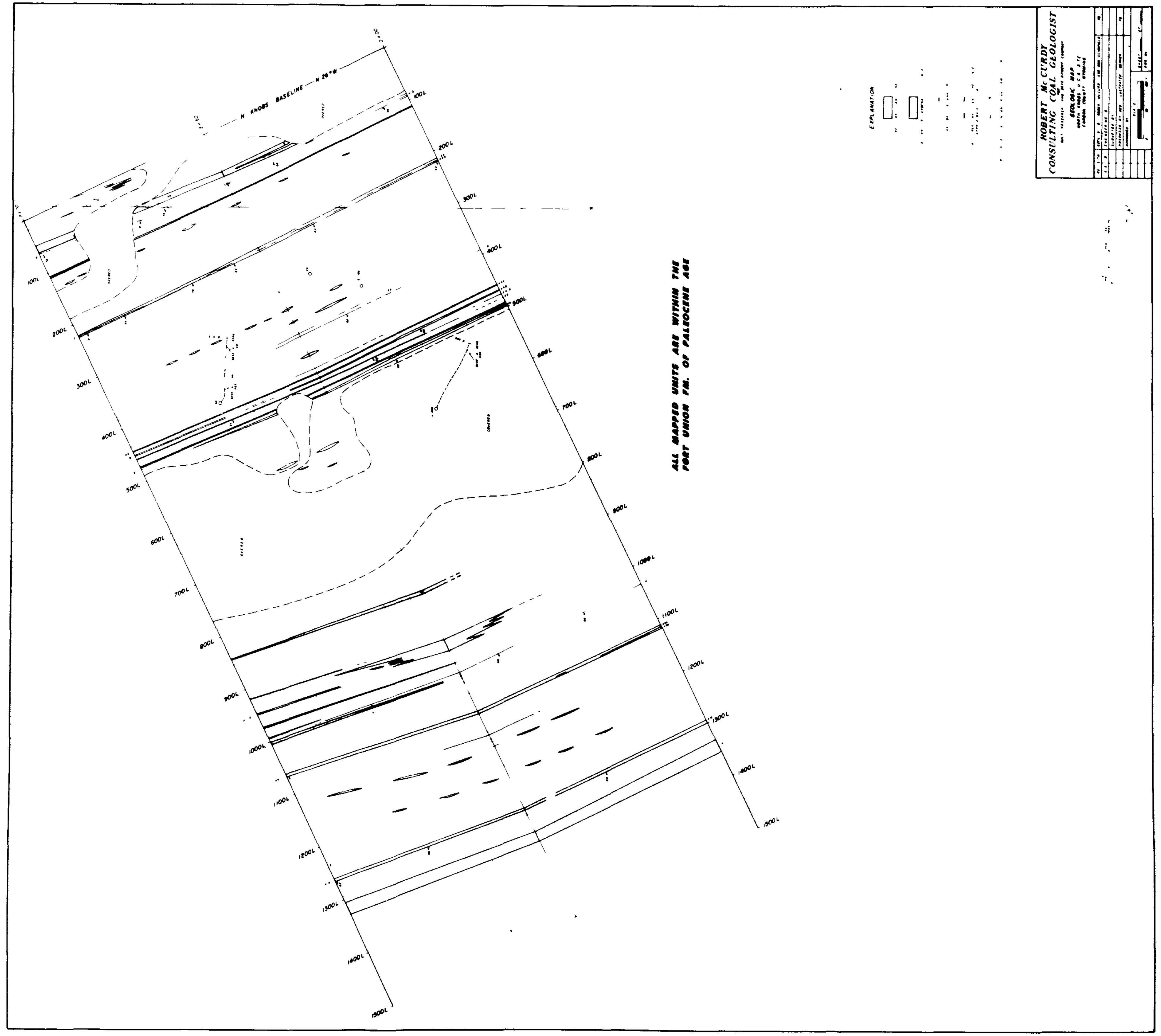


Figure 4-3. GEOLOGIC MAP

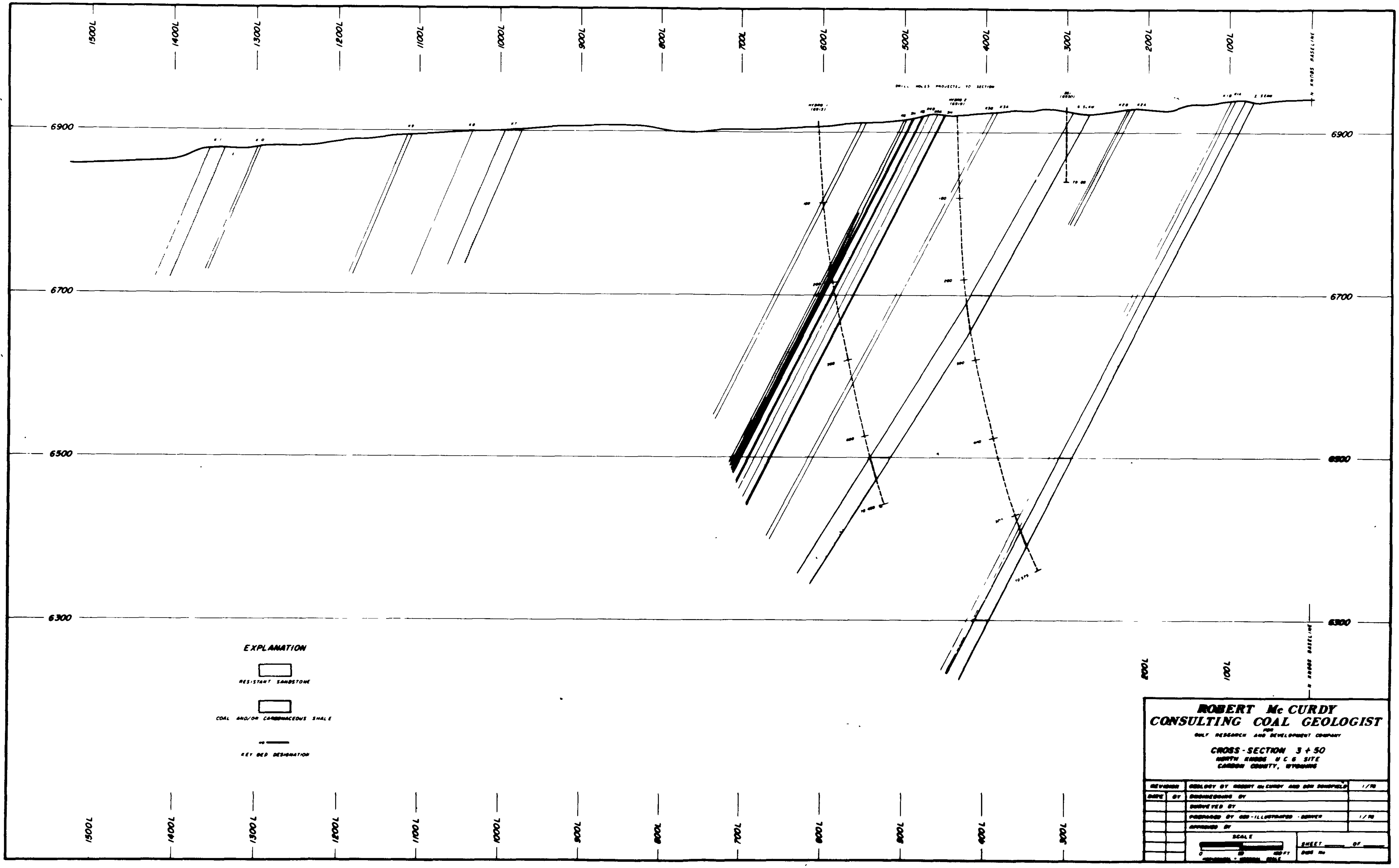


Figure 4-4. GEOLOGIC CROSS-SECTION

4-9

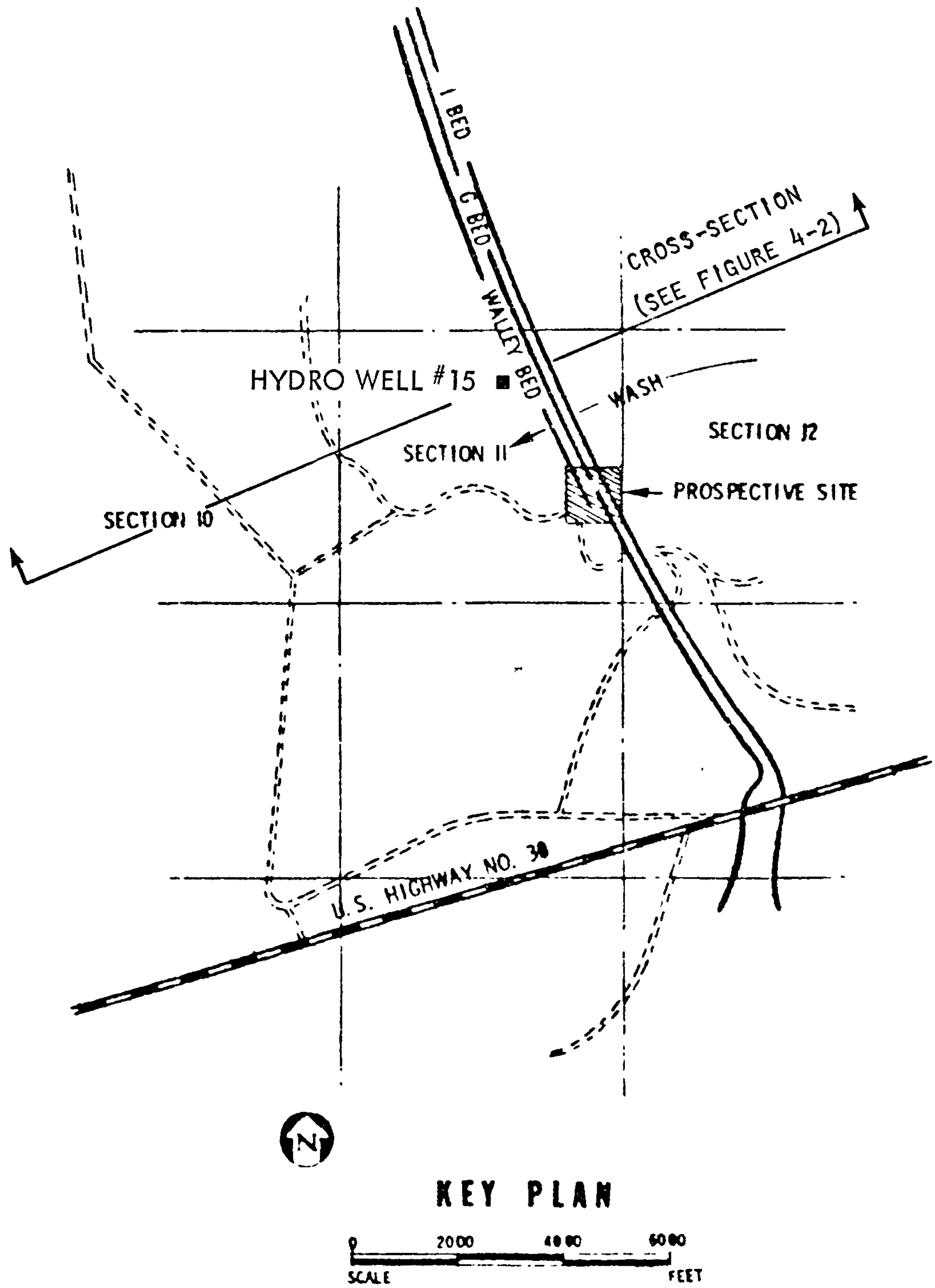


FIGURE 4-5. LOCATION OF HYDRO WELL #15 AND GEOLOGIC CROSS-SECTION

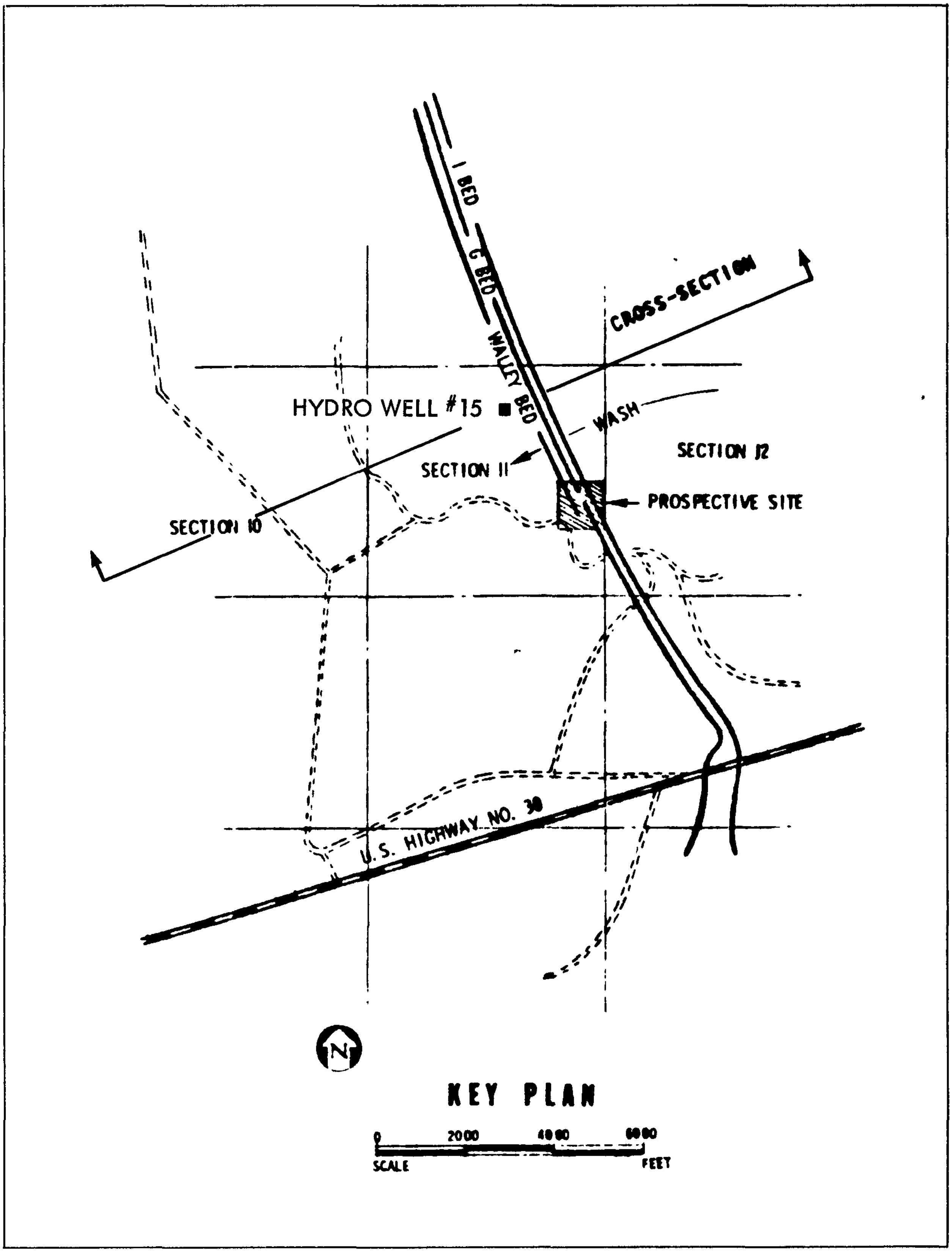


FIGURE 4-5. LOCATION OF HYDRO WELL #15 AND GEOLOGIC CROSS-SECTION

The I, G and Wally Beds, as well as minor coal stringers, occur within the UCG site boundary. However, only the I and the Wally Beds crop out at the surface. The G seam is covered by a minimum of 16 feet of soil and overburden as determined by auger data. The nearest location where it may be seen to crop out is in Section 2, T21N, R89W.

Along line 13+00, the midline in the site paralleling the exposed seam, thicknesses are given below:

Seam	Thickness (Ft)
Wally	4.5
Interval	176.7
G (main body)	19
Interval	183
I	12.8

(Interpretations were made from outcrop and drill hole data assuming a 65° dip).

A description of the I and G Beds along line 13+00 follows:

I Bed Lithology		G Bed Lithology	
Coal	.6	Coal Rider	2.1
Carbonaceous Shale & Coal	1.7	Sandstone	2.5
Coal	5.9	Coal	19.0
Shale and Coal	2.1	Sandstone	2.5
Coal	.6	Carbonaceous Shale	2.5
Coal and Shale	.2	Coal	2.7
Coal	2.3	Shale and Coal	1.9
	12.8	Coal	.8
			34.0

The I Bed coal is generally crumbly, mixed with shale, and contains little bright coal. By contrast, the G Bed coal is quite clean and its main section contains up to 40 percent bright coal, and is much more tight, sometimes forming consolidated drill cores two feet in length.

4.1.2 Hydrology

A general discussion of the hydrology of the area can be given, based on site activities to date and a review of the available literature. Site specific hydrologic testing is still underway, with completion planned by November 15, 1978. Specific information relative to the site hydraulic characteristics, in addition to data interpretation, will be submitted with the hydrologic testing data.

4.1.2.1 Surface Waters

There are no permanent or intermittant surface drainage streams in the area.

4.1.2.2 Subsurface Waters

The coal aquifer characteristics presented were in large part, obtained through observation and sampling at Hydro No. 15 (see Figure 4-5). This hydrologic observation is well located outside the northwestern corner of the UCG/SDB site and was completed in the "G" coal seam to monitor its hydrologic characteristics. The coal is approximately 650 feet deep at this point. The water level in this well stabilized at 85-90 feet (based on piezometric readings) indicating a hydrostatic pressure in the coal of approximately 240-280 psig. A better description of the hydrologic properties will be supplied after the hydrologic testing is complete (November 15, 1978).

The coal aquifer has a very low yield. The preliminary pumpdown tests to date show an approximate 0.8 gal/hr recharge rate at a water head of 395 feet and a 2-4 gallon/hr recharge rate at an approximate 10 foot head.

From a review of the available literature, surface geologic observations, preliminary drilling data, and a general knowledge of the area as a result of mineral exploration investigations, some generalizations can be made about the geologic setting of the "G" seam. At present, the only identifiable potential aquifers are the G and I coal seams and sandstones K4A and K6. The K4A sandstone and the K6 sandstones are 145 feet and 171 feet above the top of the G seam, respectively. These potential aquifers are confined and are very poor, i.e., yields are very low (in the range of 1 gal/min or lower). There should be no natural hydraulic communication between these sandstones and either the G and I seams. The G seam is bounded at the roof by a 39 foot sandstone and below by a 41 foot sandstone (see Figure 4-4). The hydrological characteristics of these sands are not known with certainty nor is the degree of communication between them but, based on current information, the bottom strata contains a very limited amount of water which is not in communication with the G seam. The lower stratum (41 foot thick) is a clay-like sandstone which probably has a permeability comparable or below that of the G seam. The upper major stratum (39.8 foot thick) is a soft, poorly cemented sandstone which contains 5-10 percent feldspar with permeability characteristics probably equal to that of the lower sandstone.

While completing the observation wells, the bottom and the top of the coal seam will be sealed from the neighboring formations by careful cement grouting extending at least 30 inches into the coal seam and at the same length into the bordering formation. The material used for cementing provides a water-tight seal eliminating completely any water movement from the formation into the coal or vice versa.

It is extremely important not to disturb the hydraulic system as it exists today during the construction phase of the proposed holes. From reports describing the piezometric surface south of the site and also from our own observation of the three initial hydro wells, it is known that the water table has an initial slope toward the north implying a recharge to the formations and a possible discharge somewhere to the north. Since a sloping piezometric surface has a different hydraulic geometry from a static one, the accurate determination of the pretest conditions and the careful elimination of any interference with these conditions during the drilling program is of extreme importance.

4.1.3 Water Quality

4.1.3.1 Surface Water Quality

There are no permanent or intermittant drainage streams in the area.

4.1.3.2 Groundwater Quality

Drilling of the water monitoring wells to be sampled during the field test has not yet begun. These wells can be properly located only after the directional characteristics of the groundwater flow are known which, in turn, depends on the hydrologic testing program to be completed in late fall in 1978. Baseline water samples were obtained, however, from a hydrologic observation well (completed in coal seam) drilled northwest of the UCG site location, coordinates, north - 416805.128, east - 477877.286.

The top and bottom of the G coal seam are at 609 and 652 feet, respectively, and the seam extends between 634 and 640 feet. (The true thickness of the seam at this point is 18 feet). The well is cased with a nominal 3-inch steel casing.

Due to this small diameter casing, an initial water sample was obtained by lowering a copper dip tube to a depth of 638 feet and pressurizing the sealed well to force water up the dip tube, and followed with another sample taken after pumping out one well volume. The pumping of two well volumes (as recommended) prior to sampling, may be a problem since the well recharge rate is so slow (approximately 0.8 gal/hr). The long time involved in waiting for the well to recharge may make it difficult to obtain a representative or consistent sample since stratification or other time related phenomena may occur.

The September 19, 1978 sample is, at present, probably the most representative of the G seam water. It was taken over two weeks after the well completion, and after five gallons were pumped from the well. Even with the incomplete analyses obtained to date, it appears this water may be Class III or IV (suitable for domestic use or irrigation), according to the newly proposed DEQ Water Quality Rules and Regulations (Chapter VIII). More analyses will be made before any confirmed classification of the site groundwater is made. Additional analysis will be performed and provided to DEQ by November 15, 1978. The complete listing of water quality parameters and preliminary groundwater data is shown in Table 4-1.

Samples will be taken from a sufficient number of monitoring wells to demonstrate the variations in concentration of selected parameters that occur in the vicinity of the SDB-UCG experiments. A minimum of four monitoring wells will be drilled for determining the variation in water quality occurring in the SDB-UCG testing area. Adjacent underlying and overlying aquifers (if present) will also be sampled to serve as baselines on checks for contamination as a result of SDB-UCG.

TABLE 4-1

PROPOSED STANDARDS FOR CLASSIFICATION OF WYOMING GROUND WATER QUALITY

CLASS / CONSTITUENT OR PARAMETER	I	II	III	IV	V	VI	VII	NORTH KNOBS DATA
	Concentration or Range in mg/l							
Al				5.0				
As	0.05			0.1	0.2			0.127
Ba	1.0							0.10
Be				0.1				0.002
B	1.0				5.0			<1.0
Cd	0.01				0.05			<0.002
Cl	250	500	750		2000			645
Co				0.1	1.0			
Cr	0.05			0.1				<0.02
Cu	1.0			0.2	0.5			<0.02
F	1.4-2.4			1.0	1.0			1.30
Fe	0.3			5.0				<0.03
Pb	0.05			5.0	0.1			<0.05
Li				2.5				
Mn	0.05			0.2				<0.01
Na				0.01				460
Ni				0.2				<0.02
Hg	0.002				0.00005			<.001
NO_3 as N	10.0				100.0			8
NO_2 as N	1.0				10.0			.37
Phenols	0.001							
Se	0.01			0.02	0.05			<.002
Ag	0.05							
SO_4	250	500	750		3000			316
V				0.1	0.1			.10
Zn	5.0			2.0	25.0			<0.01
TDS	500	1000	1500 (4000**)	<2000	<5000	>5000	>5000	1800
pH	5.0-9.0 Std. Unit	4.5-9.0		4.5-9.0	7-9 Std. Unit			9.9 Std. Unit
+RSC				2.50 meq/l				0.43 meq/l
*SAR				15 meq/l				1.84 meq/l

Classes I, II, III - Suitable for Domestic Use

Class IV - Suitable for Irrigation
V - Suitable for Livestock
VI - May Have Some Beneficial Use
VII - No Beneficial Use

+Residual Sodium Carbonate

*Sodium Adsorption Ratio

**4000 ppm is upper limit if no better water available.

Because of low rates of groundwater flow and the plume migration characteristics of pollutants in groundwater, each of the three test sites will have to be monitored individually. One strategically placed monitoring well on the down gradient side of each test site should adequately indicate rates of pollutant migration, and will indicate the extent of pollutant resorption by the coal seam. Two test sites will be monitored from a single well, and one site will be monitored from two wells.

The location of the monitoring wells is a critical factor for determining contaminant plume direction, extent, duration, and quality, during test and post-test monitoring. Adequate baseline data can be obtained from wells located to serve the requirements of test and post-test monitoring. The specific location will be chosen after the rate and direction of groundwater flow are known.

Table 4-2 summarizes the parameters to be measured before, during and after the tests. The samples will be analyzed and preserved in accordance with recommendations in the "Methods for the Chemical Analyses of Water and Wastes," Environmental Protection Agency (EPA).

At least two replicate samples will be collected quarterly from each monitoring well in the coal seam during baseline monitoring to insure that a sample representative of that aquifer is being obtained. These samples will be collected shortly after the monitoring wells have been constructed. The baseline sampling program will commence in the fall of 1978. This will allow sufficient time for sample analysis, data assessment, and possible resampling before the field test begins.

Groundwater quality test pumpdown will be accomplished using a positive displacement type pump with a capacity of 0.5 to 1.7 gal/min. The water levels in the inner wells (i.e., closest to the pumpdown well) will be monitored by downhole transducers connected to a data acquisition system to allow almost continuous monitoring of water level.

If water is removed from a geologic formation, the pressure reduction at that point will initiate a water flow toward the point of withdrawal. Depending upon the structure of the formation, the water will either move through the formation as a porous media, or, if there are discontinuities in the formation, it is likely that water will follow the network of these

TABLE 4-2

SELECTED PARAMETERS FOR BASELINE GROUNDWATER QUALITY MONITORING

PARAMETER	OBTAINED 9/19/78	TO BE OBTAINED
Alkalinity	1485 ppm	
Bicarbonate (HCO_3)	495 ppm	
Carbonate (CO_3)	990 ppm	
Calcium (Ca^{++})	3.4 ppm	
Chloride (Cl^-)	645 ppm	
Magnesium (Mg)	.8 ppm	
Nitrate (NO_3)	8 ppm	
Nitrite (NO_2)	376 ppb	
Sodium (Na)	460 ppm	
Sulfate (SO_4)	316 ppm	
pH (field)	9.9	
Hardness		x
Potassium (K)	55 ppm	
Total Dissolved Solids	1800 ppm	
Total Suspended Solids	696 ppm	
Barium (Ba)	0.10 ppm	
Beryllium (Be)	0.002 ppm	
Cadmium (Cd)	<2 ppb	
Zinc (Zn)	<10 ppb	
Cobalt (Co)		x
Lithium (Li)		x
Chromium (Cr)	<2 ppb	
Copper	<20 ppb	
Silver (Ag)		x
Iron (Fe)	<30 ppb	
Manganese (Mn)	<10 ppb	
Molybdenum (Mo)	10 ppb	
Nickel (Ni)	<2 ppb	
Sulfide ($S^=$)	300 ppb	
Lead (Pb)	<5 ppb	
Selenium (Se)	< 2 ppb	
Fluorine (F^-)	1300 ppb	
Temperature (field)		x
Arsenic (As)	12.7 ppb	
Boron	<1.5 ppm	
Uranium	< 50 ppb	
Ammonia (NH_3)	1.3 ppm	
Cyanide (CN)		x
Organic Nitrogen		x
Total Sulfur		x
Gross Alpha & Beta Activity of Filtrate		x
Aluminum (Al)		x
Mercury (Hg)	<1 ppb	
Vanadium (V)	100 ppb	
Characterization of Specific Organic Groups		x
Chemical Oxygen Demand (COD)		x
Phenols		x
Total Organic Carbon (TOC)	0	

structural conduits. Discontinuities in deep-lying formations may be primary, originating at the time of the deposition of the formation, or secondary, originating from later structural failure of the material while subjected to stresses originating from tectonic forces.

With the lowering of the hydrostatic pressure in the formation, water will move from the storage toward the pumped well along the route of least resistance. The pressure reduction will expand in the formation and will reach the formation boundaries both above and below. Depending upon the boundary itself and the hydraulic characteristic of the bounding formation, water may or may not enter the formation through the boundary. If no water enters the formation, it is a truly confined system. If, on the other hand, water enters from one or both of the bounding formations, then the system is characterized as a leaky system with a leaky roof or leaky bottom referencing the appropriate formation. Both of these systems are described in the literature of the groundwater hydraulics but one must definitely determine which one is the case at any hydraulic testing. For this reason, it is important that the piezometric surfaces in the overlying and the underlying formations are monitored with the same accuracy as are in the coal seam itself.

While pumping the well, it is important that the piezometric surface not be lowered to a degree that would allow water to enter the coal seam during the test, but at the same time sufficient responses be observed in all of the observation wells. On the basis of permeability data obtained from other tests, the pump discharge most likely to satisfy the above criterion would be about 0.5 gal/min. A short duration exploratory pump test program may be necessary prior to the test to confirm the validity of this estimate. The duration of the pumping test is currently estimated as about two weeks, not including the subsequent recovery test.

4.1.4 Climatology

No climatic data have been systematically collected at the UCG site. The nearest data recording center is in Rawlins, eight miles west of the UCG site.

The climatic data for Rawlins are characterized by a low annual rainfall, high daily evaporation rates, and wide diurnal and seasonal temperature variations. The wide range in temperature between summer and winter and between daily maximums and minimums is due predominantly to the high elevation and dry air which permits rapid incoming and outgoing radiation and the passage of both warm and cold air masses.

The summer days are usually dry and mild, and summer nights are relatively cool due to the low relative humidity and almost constantly blowing winds. The winters are also relatively dry; however, they are also very cold due to the high winds.

As shown in Table 4-3, the normal annual precipitation in Rawlins is 7.74 inches. The wettest season of the year is generally the spring with the highest rainfall occurring in May (1.05 inches). The highest observed annual precipitation was 17.00 inches in 1912, and the lowest was 3.80 inches in 1907.

The mean annual temperature is 42.6°F, also shown in Table 4-3. Mean monthly minimum temperatures are generally below freezing (32°F) from October to April; therefore, the effective length of the growing season is usually only about four months. However, below freezing nightly temperatures have been recorded in all months of the year.

Winds at Rawlins are predominantly from the west; however, the presence of the mountains to the north and west of town (the Rawlins uplift) modify the westerly pattern. Mean seasonal wind speeds are also shown in Table 4-3. As this table indicates, the mean range in seasonal wind speed is from 8 to 14 miles per hour, although daily winds commonly exceed 50 miles per hour throughout the year.

The Rawlins area receives abundant snowfall, sometimes from September until the following June. Snowfall and sleet historical means and extremes are shown in Table 4-4. As this table shows, the annual mean for snowfall in this area is over 40 inches, and can be as high as 28 inches in one month.

Thus, based on the recorded climatic data for Rawlins, the site would be classified as a BSh climate in the Köppen Climatic Classification System.

An integration of the seasonal climatic data for Rawlins is discussed below, as developed by NOAA.

TABLE 4-3

SUMMARY OF CLIMATOLOGIC DATA FOR RAWLINS, WYOMING

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL
TEMPERATURE (^{o}F)													
MEAN MAXIMUM	31.6	32.8	38.7	52.2	64.1	75.7	83.6	80.9	71.9	57.7	40.2	33.7	55.3
MEAN MINIMUM	13.5	14.0	17.6	26.8	36.2	44.4	50.8	49.9	40.4	30.6	18.5	15.1	29.8
MEAN	22.6	23.4	28.2	39.5	50.2	60.1	67.2	65.4	56.2	44.2	29.4	24.4	42.6
PRECIPITATION (INCHES)													
TOTAL	0.46	0.63	0.75	0.79	1.05	0.73	0.57	0.58	0.47	0.77	0.51	0.43	7.74
MEAN SEASONAL WIND SPEED (MPH)	13.9			12.4			8.9			11.1			

TABLE 4-4

MEANS AND EXTREMES FOR SLEET AND SNOW FOR
1927-1931 AND 1937-1960 AT THE RAWLINS STATION
(All Values in Inches per Year)

MONTH	MEAN	MAXIMUM (MONTHLY)	YEAR	GREATEST (DAILY)	YEAR
JANUARY	7.3	23.9	1937	15.0	1951
FEBRUARY	7.0	27.9	1959	11.0	1948
MARCH	7.7	22.8	1940	15.0	1940
APRIL	5.4	22.7	1931	12.0	1931
MAY	2.3	19.5	1950	10.0	1950
JUNE	0.1	2.0	1947	2.0	1947
JULY	0.0	0.0	----	0.0	----
AUGUST	0.0	0.0	----	0.0	----
SEPTEMBER	0.4	3.0	1927	3.0	1929
OCTOBER	2.7	12.5	1928	8.0	1942
NOVEMBER	5.5	18.4	1938	6.0	1930
DECEMBER	5.8	22.5	1948	10.0	1956
YEAR	41.5	27.9	FEB 1959	15.0	JAN 1951

Source: U.S. NOAA, Climatography of the United States No. 30-48, Climatological Summary.

Winter

The winter season has the coldest temperatures, the lowest amount of precipitation, the highest average wind speed, and the least amount of total suspended solids (TSS). The mean daily temperatures are generally below freezing; therefore, the daily evaporation rates are low and the ground surface normally is frozen. In addition, the precipitation occurring at this time of the year is snow. Thus, large amounts of TSS are not generated despite the presence of strong winds due to the passage of winter weather systems during this season.

Spring

The spring season has mean monthly temperatures which begin to rise above freezing early in the season and continue to rise throughout the season, the highest amount of precipitation which changes its form from snow to rain as the temperatures change, lower wind speeds, and significantly higher amounts of TSS. Since the temperatures are rising to above freezing at this time of the year, the ground is thawing and individual soil particles are exposed to the winds. In addition, the soil evaporation rates increase, thereby drying out the soil. As a result of these factors, the winds during this season are able to substantially increase the amounts of TSS which cause the spring to have the second highest TSS concentration for the year.

Summer

The summer season has the highest mean monthly temperatures, lower amounts of precipitation, the lowest seasonal wind speeds, and the highest amounts of TSS. Both the mean monthly temperature and evaporation rates continue to rise during the summer. In addition, large differences in wind speeds occur due to the differential heating and cooling of the land surface during the diurnal cycle. These factors contribute to the soils being their driest in this season and most accessible to eolian erosion during the daylight hours and especially in the early to midafternoon hours.

Fall

The fall season has steadily decreasing mean monthly temperatures and evaporation rates, decreasing amounts of precipitation, and increasing wind speeds. As a result, the TSS content of the air remains relatively high during the early fall; however, the precipitation increases slightly and temperatures begin to fall below freezing by mid-fall, and TSS concentrations begin to decline.

4.1.5 Air Quality

The Rawlins UCG site is within the Wyoming Intrastate (#243) Air Quality Control Region (AQCR). This AQCR encompasses Carbon County, as well as 12 other counties in the west and northwestern part of the state.

Authority for air quality control in Wyoming is vested with the Department of Environmental Quality, Division of Air Quality. To aid in air pollution implementation plan development and evaluation, the Environmental Protection Agency (EPA) in conjunction with the Division, has divided each AQCR into priority classifications, (Priority I, II or III) according to the complexity of the air pollution problem. Concentrations of the pollutants are highest if categorized as Priority I and lowest as Priority III. The priority classification for the Wyoming Intrastate AQCR is shown below:

	PARTICULATE MATTER	SO_2	CO	NO_x	O_x	HC
REGIONAL PRIORITY	III	III	III	III	III	III

An ambient air monitoring program is being conducted at the UCG test site for the purpose of establishing baseline air quality prior to the start of the gasification tests. Air quality data is being collected for each of the six ambient air quality criteria pollutants, trace elements, and selected meteorological parameters. The criteria pollutants are total suspended particulates, sulfur dioxide, nitrogen dioxide, photochemical oxidants, carbon monoxide, and non-methane hydrocarbons. The federal and Wyoming air quality standards are presented in Table 4-5, along with the air quality data gathered from the UCG site since June. In addition, the Wyoming DEQ operated a particulate monitoring station in Rawlins. Both seasonal and monthly particulate geometric means are presented in Table 4-6 for the Rawlins DEQ sampling station.

The data indicates that, because of the rural setting of the area, the ambient air quality is generally good and free of chemical pollutants. Total suspended particulates, sulfur dioxide and nitrogen oxides are generally products of stationary fuel combustion sources and industrial

TABLE 4-5

UCG AIR QUALITY DATA SUMMARY

	AMBIENT AIR QUALITY STANDARDS ($\mu g/m^3$)			AIR QUALITY DATA ($\mu g/m^3$)			
	FEDERAL		WYOMING				
	PRIMARY	SECONDARY	PRIMARY & SECONDARY	JUNE	JULY	AUG.	SEPT
Sulfur Oxides							
Annual Arithmetic Mean	80	--	60	--	--	--	--
3-Hour Concentration*	--	1,300	1,300	52	35	26	22
24-Hour Concentration*	365	--	260	25	4	4	5
Suspended Particulate Matter							
Annual Geometric Mean	75	60	60				
24-Hour Concentration*	260	150	150	37	39	33	89
Carbon Monoxide							
8-Hour Concentration (mg)	10	10	10	--	--	--	--
1-Hour Concentration (mg)	40	40	40	2.9	4.6	1.5	0.1
Photochemical Oxidants (Ozone)							
1-Hour Concentration*	160	160	160	196	160	160	137
Nitrogen Oxides							
Annual Arithmetic Mean	100	100	100	--	8.7	11.3	9.6
Non-Methane Hydrocarbons							
3-Hour Concentration* (6-9 a.m.)	160	160	160	(<500	<500	<500	<500)**

* Not to be exceeded more than once a year, 2nd high reading.

**Instrumentation does not accurately measure low levels, therefore, results inconclusive. No currently approved EPA methods are available.

TABLE 4-6

SEASONAL AND MONTHLY PARTICULATE LEVELS
FOR RAWLINS, WYOMING

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Particulate Geometric Mean ($\mu g/m^3$ seasonal)	7.6			17.3			24.2			14.1			
Particulate Geometric Mean ($\mu g/m^3$ monthly)	7.9	5.8	12.8	17.8	22.6	28.2	18.4	26.6	19.3	15.0	9.6	9.5	14.7

processes. Neither Rawlins nor the UCG site support such activity. Carbon monoxide levels in the area will probably remain low since it is related to motor vehicles and is very source specific.

Photochemical oxidant levels (as ozone) are expected to remain near the standard during the daylight hours of intense sunlight because of the elevation of the test site. In this area, the high readings are probably due to stratospheric concentrations of ozone, and long range transport from other areas.

The EPA regional office in Denver was contacted to determine if high ozone levels are unusual in rural areas such as Rawlins. Although ozone data for these areas are limited, high levels have been recorded in other rural areas in the region and EPA also feels that long range transport may be a significant factor. The EPA Office of Air Quality Planning and Standards in North Carolina is presently conducting several research programs to resolve the questions of ozone transport.

There is no immediate explanation for the high levels of non-methane hydrocarbons at the test site. Discussions with Wyoming DEQ personnel indicate that high hydrocarbon levels have been found in other areas of the state also, due to hydrocarbons released from coal, oil, and gas production, as well as natural vegetation. The current state-of-the-art of non-methane hydrocarbon monitoring instrumentation is such that it does not allow accurate measurement of certain levels of this pollutant. There is no EPA approved instrumentation for monitoring this pollutant at the present time, therefore confirmation of the levels recorded is difficult and no accurate conclusions can be drawn from the data.

As shown in Table 4-7, trace elements sampled at the site also are at low levels. This is due mostly to the fact that particulate levels for the area are low, since the analysis for the elements is based on the hi-vol sample filters. There are no ambient standards for trace elements although a standard has been proposed for lead for an ambient concentration of 1.5 $\mu g/m^3$ for 24-hour sample. The lead level at the site was recorded at 0.015 $\mu g.m^3$.

TABLE 4-7

TRACE ELEMENT ANALYSIS

	CONCENTRATION ($\mu g/m^3$)
ALUMINUM	0.049
ANTIMONY	0.026
ARSENIC	<0.0006
BERYLLIUM	0.0018
BISMUTH	0.003
BORON	0.116
CADMIUM	0.0006
CALCIUM	12.54
CHROMIUM	0.0037
COPPER	0.1
GERMANIUM	<.092
IRON	0.95
LEAD	0.015
MAGNESIUM	3.33
MERCURY	<0.0006
MOLYBDENUM	<0.0006
NICKEL	0.009
SELENIUM	<0.001
SILICON	---
TIN	0.008
TITANIUM	<0.06
VANADIUM	<0.0006
ZINC	0.172

Data collected during week of
June 19, 1978.

4.1.6 Noise Quality

The UCG site is located approximately two miles from one of the major east-west transportation corridors, the Union Pacific Railroad and Interstate 80. Since the terrain is gently rolling with minimal vegetation to serve as a natural noise baffle, the ambient noise levels may be expected to range between 45 and 50 dB.

4.2 BIOTIC ENVIRONMENT

This section presents information on terrestrial and aquatic ecology.

4.2.1 Terrestrial Ecology

The discussion on terrestrial ecology includes both flora and fauna.

4.2.1.1 Flora

The GR&DC UCG site is mostly upland sagebrush, rock outcrops, washes and some lowland grassy areas. The majority of the groundcover species are prairie grasses and shrubs. The specific grasses found on the site include indian ricegrass, bluebunch wheatgrass, thickspike wheatgrass and canby bluegrass. The shrub species found on the site include low rabbitbrush, bottlebrush squirreltail, Gardners saltbrush and birdsfoot sagebrush. A map illustrating the species distribution is presented as Figure 4-6.

The rangelands primarily support low groundcover such as grazing species, as a function of soil types and precipitation. Since the climate is generally described as semi-arid with slightly over seven inches of precipitation annually, the site cannot support deciduous species.

4.2.1.2 Fauna

Mammals, birds, reptiles, and amphibians which could occur on the Gulf Research and Development site are presented in the Appendix, Tables A-1 to A-3. Sixty-three species of mammals have ranges that include the site area. Fifteen species are expected to occur on the site and the status of 11 other species is undetermined. Other species occurring on this list are not expected because habitat requirements are not met on the site or because the site is near the periphery of the species range. About 332 species of birds are known to occur in Wyoming. About 75 species of birds are associated with habitats which occur on the Gulf R&D site and would

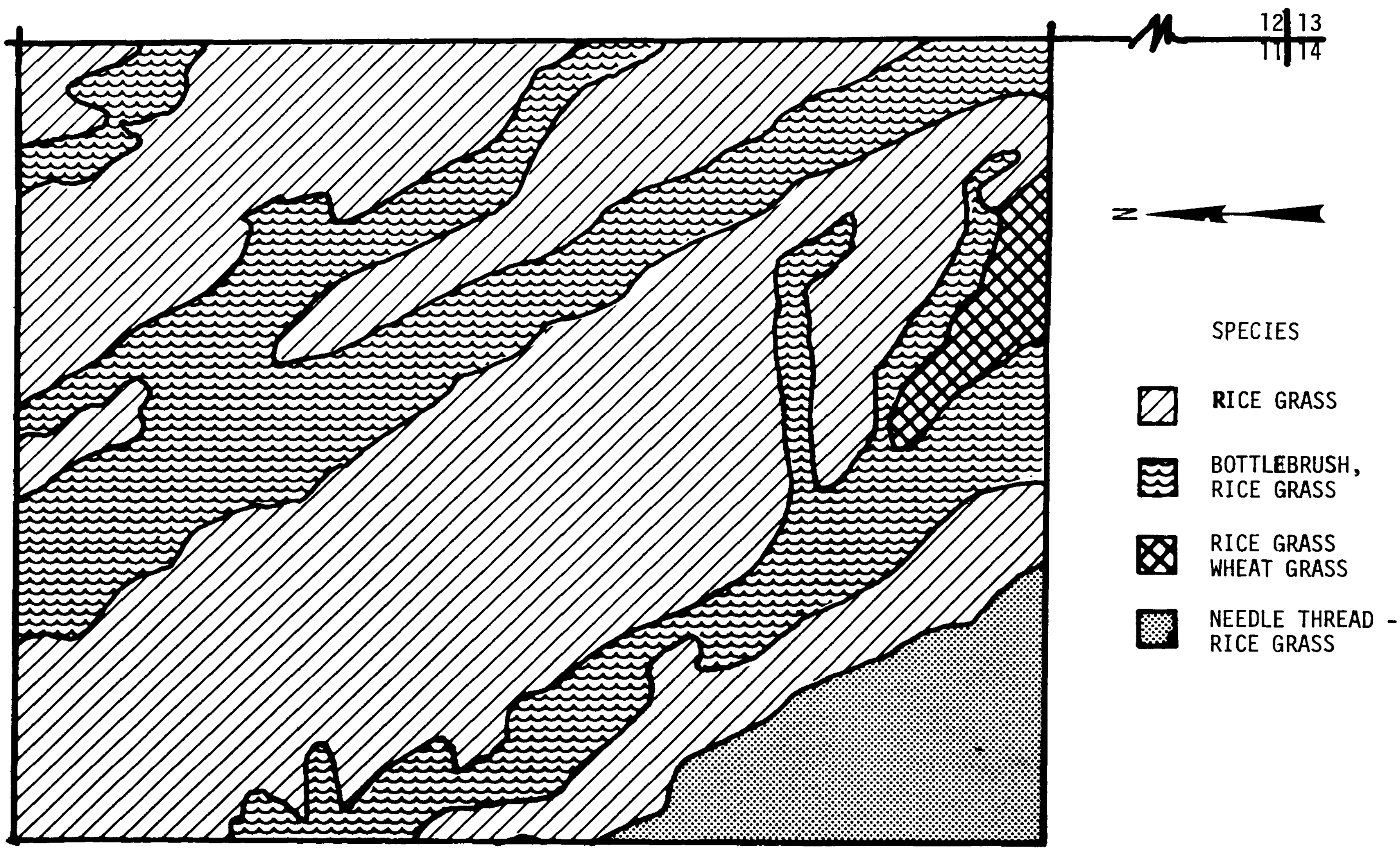


Figure 4-6

Species Distribution on UCG Site

occur on the site as breeders, permanent residents, winter residents, etc. About 50 species could be expected on the Gulf R&D site. Nine species of reptiles and four species of amphibians have ranges that include the site. Few species are expected to occur on the site.

Twelve species of mammals were recorded on the site during surveys on August 14 and 25, 1978 (Table 4-8). Elk, wild horses, and Ord's kangaroo rat were expected, but occurrence was not definitely confirmed. Striped skunk and porcupine were observed within five miles of the site. Prairie dogs occur in the region and may occur near the site. Desert cottontails and deer mice were the most common mammals observed. An average of 12 cottontails per mile was recorded during early morning surveys on and near the site. Cottontails were abundant in all habitats with suitable cover. Deer mice were the most common small mammal trapped during surveys on August 25 (Table 4-9). They were common in all habitats sampled. Pronghorn were also common on the site. Nineteen individual pronghorn were observed. Nineteen species of birds were observed (Table 4-10). The most abundant species were Brewer's sparrows, sage thrashers, horned larks, and sage sparrows. These species are associated with dry shrub-steppe-grassland communities and are expected to be the dominant breeding avifauna on the site. Marsh hawk, American kestrel, Swainson's hawk, and burrowing owls were recorded during these surveys. Several old, inactive raptor nests were found. No raptors were expected to have bred on the site in 1978. Sage grouse and mourning dove were the only game birds recorded. Populations are not expected to be high. Two species of reptiles were recorded in Table 4-11; the sagebrush lizard and gopher snake are the only other species expected. Amphibians are not expected because of lack of permanent water on the site.

The GR&DC R&D site is mostly upland sagebrush, rock outcrops, washes, and some lowland grassy areas. Most animal species are directly dependent on sagebrush and outcrop areas for food and cover. Small mammals occur in all habitats, but are most common near rock outcrops and sagebrush areas with dense herbaceous vegetation. Desert cottontails also prefer these habitats. White-tailed jack rabbits prefer more open areas. Pronghorn were seen throughout the site, but seemed to prefer lowland sagebrush areas, with scattered areas of pure grass.

TABLE 4-8

MAMMALS OR THEIR SIGN OBSERVED ON THE GR&DC SITE
AUGUST 24-25, 1978

Species	Comments
Desert Cottontail	Abundant-sighting-sign
Pronghorn	Common, 19 individuals on site
Badger	Sign-dens, fresh digging
Bushy-tailed Woodrat	Uncommon-sign
Coyote	Uncommon-reported
White-tailed Jackrabbit	Common-sighting
Deer Mouse	Abundant-trapped
Northern Pocket Gopher	Common-sign
Least Chipmunk	Common-sighting
Richardson's Ground Squirrel	Sign-burrows, scat
Olive-backed Pocket Mouse	Common-trapped
Skunk	Sign-dens
Species recorded of undetermined status -	
Horse	Sign-droppings
Elk	Sign-droppings
Ord's Kangaroo Rat	Sign
Species recorded within 5 miles of the site -	
Striped Skunk	Road Kill
Porcupine	Road Kill

TABLE 4-9

RESULTS OF THE SMALL MAMMAL SURVEY ON THE GR&DC SITE, AUGUST 25, 1978

Species	Rock Outcrop (8)[a]	Resid-ential (4)	Dense Sage, Grass (8)	Upland, Mixed Sage, Grass (8)	Prickly-pear Grass (4)	Wash (4)	Grass (4)	Total
Peromyscus Maniculatus Deer Mouse	7[b]	4	8	5		1	2	27
Perognathus Fasciatus Olive-backed Pocket Mouse				1	2		2	5
TOTAL	7	4	8	6	2	1	4	32

Total Trap Success = 80%
Relative Abundance - Deer Mouse = 84.3%
Olive-backed Rocket Mouse = 15.7%

[a]Total number of traps in each habitat.
[b]Total captures of each species in each habitat.

Source:

TABLE 4-10

BIRDS OBSERVED ON THE GR&DC SITE,
AUGUST 24-25, 1978

Species	Number Observed	Comments
MacGillivray's Warbler	1	
Loggerhead Shrike	3	
Black-billed Magpie	14	
Horned Lark	26	
Brewer's Sparrow	55	
Sage Thrasher	41	
Common Nighthawk	1	
Sage Sparrow	24	
Sage Grouse	15	Reported
Marsh Hawk	1	
Rock Wren	2	
Say's Phoebe	1	
Blue-gray Gnatcatcher	1	
Burrowing Owl		Pellets
Swainson's Hawk	2	
Lark Bunting	1	
American Kestrel	1	
Vesper Sparrow	1	
Mourning Dove	1	
TOTAL	191	

Golden Eagle - 2 inactive nests.

TABLE 4-11

REPTILES AND AMPHIBIANS SIGHTED OR EXPECTED TO OCCUR ON THE GR&DC SITE

Species	Comments
Short-horned Lizard	Reported to be common. One observed on site.
Western Rattlesnake	Reported only.

Birds are commonly associated with shrub-type communities. Most birds were observed in areas with dense sagebrush, near rock outcrops. Brewer's sparrows, sage sparrows, sage thrashers, and horned larks prefer to nest in or near these sagebrush habitats. Rock wrens and Say's phoebes will nest in rock outcrops. Rock outcrops are preferred nest and perch sites for some raptors.

Short-horned lizards were found in open, rocky areas with scattered sagebrush. Habitat affinities of other reptiles or amphibians were not determined.

Endangered Species

No endangered species are expected to occur on the site (Table 4-12). The black-footed ferret is considered endangered by the U.S.D.I., and considered rare by the State of Wyoming. Ferrets are dependent on fairly large concentrations of prairie dogs. Since few or no prairie dogs occur on the site, it is unlikely that ferrets would occur. However, ferrets have been reported near the site (approximately 10 miles west of Rawlins near Interstate 80). The Peregrine falcon, also a federally endangered species, is not expected to breed in this region. The species may, however, migrate through the state. The burrowing owl has been reported on the site and is on Wyoming's rare species list. Breeding on the site is unlikely. Burrowing owls reported on the site during surveys in August could have been late summer migrants. The smooth green snake is on Wyoming's rare species list, but is not expected to occur on the site because of lack of suitable habitat.

No fishing occurs in the Gulf R&D site. Hunting access on the one-mile section will probably be restricted. Pronghorn, desert cottontail, mule deer, and sage grouse are the only game species with huntable populations occurring on the site (Table 4-13). Hunting is expected to be somewhat restricted because of the small size of the site and close proximity of hunters to work crews. Road access into the area is not expected to be affected.

4.2.2 Aquatic Ecology

There are no waterbodies on the site, even on an intermittant basis. Therefore, there are no aquatic flora or fauna.

TABLE 4-12

RARE OR ENDANGERED BIRDS, REPTILES AND MAMMALS WHICH COULD OCCUR ON THE GULF RESEARCH AND DEVELOPMENT SITE

Species	Status
Black-footed Ferret[a]	U.S.D.I. Endangered List, Wyoming Rare List
Burrowing Owl[b]	Wyoming Rare List
Peregrine Falcon[c]	U.S.D.I. Endangered List, Wyoming Rare List
Smooth Green Snake[d]	Wyoming Rare List

[a]This species is expected to occur near fairly large prairie dog towns. There are no prairie dog towns on the site capable of supporting a Ferret population. However, a Black-footed Ferret has been reported within five miles of the site.

[b]Pellets of this species were found on the site. Breeding is not expected.

[c]The Peregrine Falcon may migrate near the study area. Nesting is not known or expected in this area.

[d]The smooth green snake prefers damp, grassy or forest environments. The species is not expected on the study area because of lack of suitable habitat.

TABLE 4-13

GAME BIRDS AND MAMMALS WHICH OCCUR ON THE GULF RESEARCH AND DEVELOPMENT SITE

SPECIES	STATUS
Mourning Dove Sage Grouse[a]	Fairly Common
Elk[b]	Rare
Mule Deer[c]	Uncommon
Pronghorn[d]	Common
Desert Cottontail[e]	Abundant

a. Fifteen reported on site in late summer. Significant resident population not expected.

b. Elk may occasionally move through the area during the winter. No significant population expected.

c. Mule deer are probably more common on the site in winter.

d. Occur on site all year. Probably more common in winter when antelope are in large herds. Reported more common on site in winter by site personnel.

e. Most abundant game species on site.

4.3 HUMAN ENVIRONMENT

This section contains information on demographics, land use, transportation, aesthetics and cultural interests, and socioeconomics. These data point out the sparsely settled nature of the area.

4.3.1 Demography

The population of Carbon County and its major center and county seat, Rawlins, grew steadily during the period of 1920 to 1950, then declined during the period of 1950 to 1970. This decline was largely related to decreased coal mining employment. Population by decades is shown in Table 4-14 for Carbon County and Rawlins. By year-end 1976, Carbon County will have 20,886 residents with 62 percent of this total or 11,840 residents, in the city of Rawlins. The 1970 Census provided a thorough demographic profile of the Carbon County population. Current demographic characteristics of Rawlins are available from a recent resident survey.

4.3.2 Land Use

4.3.2.1 Existing Land Uses

Ranching, consisting of cattle and sheep grazing is the primary form of current land use within the region. Crop cultivation is very limited. BLM regulates grazing by dividing the range into grazing allotments. Ranching stock ponds and reservoirs occur throughout the region. They are fed by impoundment or diversion of surface runoff or by groundwater.

Since access into the project areas is limited, and there is abundant wildlife, the principal recreational use of the land is hunting. Big game permits include deer, antelope and elk, while a very limited number of black bear and big horm sheep permits are issued for the Medicine Bow National Forest. Depending on the availability of game, some hunting areas are closed in certain years. Hunting season generally runs from September through November with some special seasons at other times in the year. Small game hunted in Carbon and Sweetwater Counties includes ducks, geese, chuker, blue grouse, ruffled grouse, sage grouse, mourning doves, cottontail rabbits, snowshoe hares and squirrels. Sage grouse is the only upland game bird of significance in the project areas.

TABLE 4-14

POPULATION OF CARBON COUNTY AND RAWLINS

	POPULATION	
YEAR	CARBON COUNTY	RAWLINS
1920	9,525	3,969
1930	11,391	4,868
1940	12,644	5,531
1950	15,742	7,415
1960	14,937	8,968
1970	13,354	7,855
1976	20,886	11,840
1985	41,987	24,897

Source: Rawlins-Carbon County Planning Office.

In addition to hunting, there are other recreational land uses. Some residents drive along the Overland Trail, a stagecoach and covered wagon route that runs east-west through the region roughly paralleling I-80 and the Union Pacific Railfoad, 20 miles north. Other people search for fossils, chalcedony, petrified wood, jade and gold in various parts of this area.

4.3.2.2 Future Land Uses

Land use in the Rawlins area will gradually shift to energy development as coal and uranium reserves are extracted. Carbon County has an estimated 4.9 billion tons of coal reserves and about half of the state's uranium reserves are believed to be in the Crooks Gap, Gas Hills or Shirley Basin areas. The extent to which these reserves are recoverable will relate to a variety of factors including yellowcake and coal prices, technological developments, and national energy policies. In any event, these resources combined with increasing energy demands suggest considerable development possibilities, and subsequent economic and population effects in the Rawlins area.

4.3.3 Transportation

There are two main highways that cross the region. The principal east-west highway is Interstate 80 (I-80)-U.S. 30 which follows the general course of the Union Pacific Railroad. I-80 serves as a major route for east-west traffic across Wyoming and the Nation and has an average daily traffic (ADT) flow of approximately 5,300 vehicles at Rawlins, half of which are out-of-state vehicles. The principal north-south route in this region is Wyoming 789. It runs coterminous with U.S. 287 from Rawlins northward. Traffic flow averages 1,460 vehicles along this section. Wyoming 789 also heads south from Rawlins, leaves I-80 at Creston Junction and leads to Baggs, carrying 450 vehicles per day. Numerous other light duty roads that criss-cross the region are used mainly by local residents as access roads to ranches, recreation areas or hunting areas. Most of these unpaved earth roads are impassable in winter when they become blocked by snow drifts. They also can be difficult to negotiate at other times due to creek crossings and rainstorms.

4.3.4 Aesthetic/Cultural/Historic Interests

The Wyoming Recreation Commission has conducted an archeological survey of the site and the site access road and determined that the project will not disturb nor disrupt any prehistoric archeological or historic sites.

The earliest inhabitants of the area include several tribes of Indians. These nomadic tribes included Shoshoni, Arapahoe, Comanche, and Cheyenne. They were primitive people who subsisted by hunting, fishing, and gathering. None of the tribes practiced any kind of cultivation or agriculture. After 1750 A.D., when horses were introduced from the south and guns were brought in from the northeast, major changes in several facets of life occurred to Indians of this area in Wyoming. The Comanche left entirely. The Shoshoni migrated west. The tribes of this region of Eastern Wyoming came to depend upon the buffalo. Eventually, in the middle of the 19th century, Sioux tribes came into the region. After 1880, Indians were moved to reservations.

As the tracks of the Union Pacific Railroad approached the Wyoming area from Nebraska and the east in the spring of 1867, the region began to get its first permanent settlers with a European heritage. During the next ten years, population in the southern portion of Carbon County grew, largely with the railroad. This was a settling down period when the basic business was running a railroad, maintaining it by mining coal, and performing other services necessary to make a success of the nation's first transcontinental line. Other fundamental activities included government at several levels and increased livestock grazing. By 1880, Carbon County ranked fourth in the state in terms of population. The largest percentage of the population was clustered around the Union Pacific railway. The population of Rawlins, the nearest town, was 2,235. In the decade preceding 1900, the population growth rate declined. The 1900 census showed 2,317 people living in Rawlins. More rural areas to the north were being settled mainly due to more advanced means of transportation. By 1950, the population of Wyoming lived largely in the urban center. The population of Rawlins had risen to 7,415. At present, farm and ranch population continue to decline, and the most significant growth is in urban areas.

4.3.5 Socioeconomics

4.3.5.1 Employment

Carbon County has a diverse economic base, with mineral resources, government and trade comprising the major sectors of the economy. Other important sectors include agriculture, services, transportation (mainly the Union Pacific Railroad), communication and public utilities. Annual average employment for various sectors for 1970 and 1975 in Carbon County are shown in Table 4-15. Mining has become the largest employer and income producer in Carbon County with much of the increase due to the coal mining activity in the Hanna Basin in the eastern part of the county. The percentage of total county employment in mining is expected to continue to increase. The mining contribution to Carbon County employment is presented in Table 4-16.

4.3.5.2 Education and Income

Rawlins is the trade and services center for the county with three-quarters of the total retail sales of Carbon County being generated in Rawlins. Agriculture has traditionally been a stable sector in the economy. Since 1940, agricultural employment has decreased in percent of total labor force while tts absolute employment level has remained constant.

Evidence of recent economic and population growth in Rawlins and Carbon County is found in selected economic indicators as shown in Tables 4-17 and 4-18. With anticipated long-term interest in nearby coal and uranium resources, both Carbon County and Rawlins are expected to have a period of further economic growth.

Growth has created changes in the basic demographic data over a six year period. Some examples of change are median income and median age. In 1969, median income for Carbon County families was slightly below that of Rawlins, $8,614 and $8,750, respectively. In 1975, the median income for the county was believed to be below that of Rawlins which has increased to $14,960. Median age was 29.2 years in Rawlins in 1970 compared with 26.5 years in 1976, a lowering of the median age.

School District 1 serves the western part of Carbon County, including Rawlins. The district has six elementary schools, one junior high school and two senior high schools (located in Rawlins and Baggs). Five of the

TABLE 4-15

ANNUAL AVERAGE EMPLOYMENT BY SECTOR FOR CARBON COUNTY

1970 and 1975

Industry	1970 Number Persons	1970 Percent	1975 Number Persons	1975 Percent
Manufacturing	340	6.2	380	5.2
Agriculture	680	12.4	680	9.4
Mining	620	11.3	1,270	17.5
Construction	130	2.4	360	5.0
Transportation, communication and public utilities	650	11.8	630	8.7
Trade	870	15.8	1,150	15.8
Finance, insurance and real estate	90	1.6	140	1.9
Services	470	8.6	640	8.8
Government	970	17.6	1,210	16.7
Other	680	12.4	800	11.0
TOTAL	5,500	100.1	7,260	100.0

TABLE 4-16

MINING IN CARBON COUNTY

	CARBON COUNTY
ANNUAL AVERAGE LABOR FORCE	
1972	5,904
1973	6,141
1974	6,468
1975	6,913
1976	7,278
Percent change (1972-1976)	23 %
MINING AS A PERCENT OF TOTAL COVERED EMPLOYMENT	
1972	24.9%
1973	25.9
1974	28.1
1975	30.1
1976	29.8
CONSTRUCTION AS PERCENT OF TOTAL COVERED EMPLOYMENT	
1972	7.8%
1973	6.6
1974	8.2
1975	7.1
1976	8.9
COVERED EMPLOYMENT CHANGES (1972-1976)	
Mining	56 %
Construction	50
Total	30

Source: Wyoming Employment Security Commission

TABLE 4-17

ECONOMIC INDICATORS FOR RAWLINS AND CARBON COUNTY FOR 1970, 1973 and 1976

ECONOMIC INDICATOR	1970	1973	1976
Commercial Bank Deposits-Rawlins Banks (Millions-June 30)	$26.2	$46.6	$ 63.9
Savings and Loan Assets-Rawlins (Millions - June 30)	$ 8.2	$10.4	$ 15.9
Assessed Valuation (Millions)			
Carbon County	$58.5	$86.0	$162.7
City of Rawlins	$ 9.7	$10.1	$ 13.8
Coal Production - Carbon County (Tons-Millions)	1.6	6.7	10.6 (1975)

TABLE 4-18

ECONOMIC INDICATORS FOR
RAWLINS AND CARBON COUNTY

COMMUNITY BANK DEPOSITS (MILLIONS)*	
December 1970	$ 31.4
December 1976	77.8
Percent Change	148 %
TELEPHONE LINES**	
1970	2,733
1976	4,436
Percent Change	62 %
ASSESSED VALUATION (MILLIONS)***	
City	
1970	9.7
1976	13.8
Percent Change	42 %
County	
1970	58.5
1976	162.7
Percent Change	178 %
City as a Percent of County	
1970	16.6%
1976	8.5
Percent of 1976 County Valuation Attributable to:	
Oil and Gas Production	6.6%
Coal Production	46.3
Public Utilities	2.0
COUNTY FISCAL YEAR SALES AND USE TAX COLLECTIONS (THOUSANDS)***	
Sales Tax Collections	
1970	973
1976	2,702
Percent Change	178 %
Use Tax Collections	
1970	99
1976	755
Percent Change	664 %
COUNTY SCHOOL ENROLLMENT (ADM)****	
1969-1970	3,233
1976-1977	3,868
Percent Change	20 %

Source: *American Bank Directory; BBC Casper-Star Tribune Article.
**Mountain Bell Telephone
***Wyoming Department of Revenue and Taxation
****Wyoming Department of Education

nine schools are located in Rawlins. Combined enrollment as compared with design capacity junior high level is at capacity. Expansion of the district's facilities is underway. For example, the Sunnyside Elementary School in Rawlins is adding six classrooms which will increase the capacity by 180 students. In the fall of 1978, it is planned that a new 6-8 junior high will open in Rawlins with a capacity of 800.

4.3.5.3 Housing and Services

Growth in Carbon County has accelerated since 1970. Persons-per-household in Rawlins increased from 3.03 in 1970 to 3.21 in 1976. Housing patterns have changed in Carbon County over recent years. For example, single-family housing units have increased substantially, from 3,956 in 1970 to 4,410 in 1976, and multi-family units have increased from 651 in 1970 to 758 in 1976. The greatest growth, however, has been in the mobile home category, from 459 in 1970 to 992 in 1976.

In the summer of 1976 residents of Carbon County were polled for their perception of the adequacy of selected community services. Housing was rated the least adequate, followed by water, airport facilities, health care, shopping facilities and recreation. The highest adequacy ratings were given to fire protection, schools and utility services (telephone, gas, electric).

Carbon County is operated by a three member commission (elected for four-year terms) and provides services to a large area with many geographically dispersed small communities. The City of Rawlins, as the major urban area in the region, provides a wide variety of services and facilities. However, the size of the city combined with a relatively stable population base, until recent years, has not provided an environment in which substantial capital or operating improvements could be made. Certain inadequacies, such as a limited amount of administrative space and others, discussed below, are apparent.

In terms of housing, the chief problem is the construction of adequate, yet reasonably priced homes. Utilities are not a limitation on construction because hook-ups are readily available. Many of the new single-family homes in Rawlins are of the modular variety. An increase is also readily apparent in the number of mobile homes. To date, adequate capital has been available in the area to finance residential developments. Housing supply has purportedly been catching up to demand in the last few years in Rawlins though the housing situation still remains tight.

Water and sewer facilities in the City of Rawlins are in need of improvement. Although a number of wells and one reservoir supply some water to Rawlins, an old, deteriorating wooden stave transmission line is used to bring additional water 33 miles from Sage Creek. During the summer months, water consumption in Rawlins usually must be tempered through rationing programs. Water meters have recently been installed in a number of homes to further reduce consumption. Generally, the present water supply and distribution system is inadequate for both present and future demands. To bring this water system up to an adequate level, even for the present population, an estimated $8.4 million is required.

Currently, 40 percent of Rawlins' sewage receives primary treatment, but the other 60 percent is discharged directly into Sugar Creek. Nearly two-thirds of Rawlins' sewer lines were installed in or before 1923 and overloading problems are present in parts of the system. Rawlins has received an EPA grant and has authorized $975,000 in sewer bonds to upgrade the system. The estimated cost of bringing this system to an adequate level is $4.6 million.

Outside of Rawlins, the cities of Baggs in Carbon County and Wamsutter in Sweetwater County have water and sewer systems. Both Baggs and Wamsutter have received State Farm Loan Board grants to upgrade water or sewer systems. For the Wamsutter water system, $86,000 has been allocated to upgrade the system. Water and sewer improvement grants for Baggs amount to $75,000 to upgrade the system to a 1,000 inhabitant maximum.

Health care in Carbon County is limited to one hospital with various private medical services that complement the hospital services. Memorial Hospital of Carbon County, constructed in 1972, is the only overnight facility in the county. There are 134 employees at the hospital, including 10 active physicians, that man the emergency room facility and provide other needed services. The hospital has two ambulances and five other ambulances are assigned to rural communities. Memorial Hospital, at present, operates well under design capacity and thus, physical facilities are available to handle a greater number of people.

Law enforcement is provided in the City of Rawlins by 16 full-time officers plus six persons in support roles and additional manpower is desired. The city jail and the police station are in the basement of City Hall. The county sheriff's department is located in the County Courthouse in Rawlins. Seven full-time deputies are supported by volunteer personnel and six vehicles. Additional full-time deputies and patrol cars are needed to make the county law enforcement services adequate.

The City of Rawlins is served by a one-station volunteer fire department. Equipment and service is viewed as adequate at the present time; however, rapid growth would probably strain these fire protection departments. Five fire protection zones, each with a separate fire station, have been established. In addition to the fire station in Rawlins, others are located in Shirley Basin, Medicine Bow, Encampment and Baggs. Sixty-five volunteer firemen make up the combined force. Growth in the Hanna area has made fire protection inadequate for that community. Adequate fire ratings are given to Rawlins and Sinclair. Ratings indicating the lack of an organized department, or improper or inadequate equipment, or facilities are given to Elmo, Elk Mountain, Riverside, Dixon and Baggs.

In Rawlins, three city parks offer 40 acres of recreational space. The largest city park has horseshoe pits, volleyball and basketball courts. Two pools, of which one is a municipal facility, are open to the public and four municipal tennis courts are available. Additional youth-oriented facilities are desired. Considerable recreational opportunities are available in the county. Two reservoirs, 16 parks, 33 camping or picnicking areas and a number of private recreational areas are available. Medicine Bow National Forest represents an important recreational asset.

The Rawlins Municipal Airport is located two miles east of Rawlins. Trans Mountain Air offers charter flights into the area and hanger space is available for private aircraft. The paved runway is 5,500 feet long.

Eight branch libraries are maintained in Carbon County. The main branch, with 4,500 square feet of space, 40,000 volumes and four full-time employees is in Rawlins. Present facilities are adequate although growth in Hanna and Rawlins will probably require expansion in the near future.

5.0 POTENTIAL ENVIRONMENTAL IMPACTS

5.1 EFFECTS ON THE PHYSICAL ENVIRONMENT

A temporary impact on the land will be caused by construction of shelters for office space, for storage, and to house instrumentation and air compressors and for drilling and operating the wells. These shelters will be primarily trailers or vans requiring no foundations or footers except for the air compressor which will require a temporary concrete pad and/or foundation.

5.1.1 Geology

About one mile of road has been upgraded. This road upgrading has consisted of scraping, leveling and graveling a previously rough and unimproved trail.

Three wells were drilled to obtain information on the subsurface geology, aquifers, and coal thickness and character. Geophysical logs were also obtained in these wells. Four production/injection wells and 15 additional wells for use in the combustion experiment and for monitoring studies will be completed before project end. Core wells may be drilled after burn completion. Although these activities interfere with the land surface, the disturbances for the most part will be temporary in nature, lasting only through the duration of the experiment (Fall, 1982) or shortly thereafter. Upon completion of the project, the land surface will be restored as near as possible to its original condition.

Another aspect of the project that could have an adverse effect on the land surface as well as on the water quality, vegetation, air quality and health, is the potential of fractures and faults, both existing and produced by the experiment, providing conduits for escape of combustion products to the surface, however, the depth of the coal seam reduces this hazard.

The coal will be removed from three areas of the coal seam. The estimated sizes of these gasified areas for Test Nos. 1, 2 and 3 are 40 feet x 15 feet x 20 feet, 100 feet x 40 feet x 20 feet, and 100 feet x 100 feet x 20 feet, respectively. The respective minimum depths for the burns will be 350'; 425' and 425'.

Another potential impact of the experiment could be ground subsidence. This is due to the possible creation of subsurface voids caused by combustion of coal, where the goal is to utilize the total resource in the area being processed. When this is done there is no coal left to support the overlying material, and this roof material must, of necessity, subside into the void below.

The phenoma of subsidence has been discussed by Gregg and Olness. Typical underground coal gasification systems are constructed by first forming a pattern of highly permeable channels along the bottom of the coal seam and intersecting them periodically with pipes leading to the surface, which are used for air injection and product gas removal. When gasification takes place, the coal is removed by carrying out partial combustion in the channels that grow in diameter and extend up into the coal seam until they eventually merge. Initially, when the channels are small, they can form stable, open channels supporting an arched roof. However, as they grow wider and approach merging, subsidence is unavoidable. The size to which the channel grows before the beginning of subsidence depends critically on the physical properties of the formation layers above the coal. For example, soft clay roofs will sag into the void while the channels are relatively small.

Bending subsidence is most frequently associated with steeply dipping beds. Bending subsidence (trough subsidence) results when the overburden simply bends or sags into the underground cavern. One of the most significant features of this type of subsidence is that there is very little bulking, with the result that -- above a critical cavern size -- a large fraction of the underground displacement is observed at the surface, regardless of cavern depth. This type of subsidence is most likely to occur when the roof material is a soft clay.

The most catastrophic, uncontrollable, and unpredictable subsidence characteristics that have been observed when gasifying thick seams (7 meters in thickness) have been due to general growth and widening of the coal channels above the gasification zone.

Russian experience with steeply dipping seams and subsidence is best represented by the Uzhno-Abinsk Station (seam 0.8-9.0 meters thick, 55°-70° slope) where severe subsidence occurred with abrupt formation of deep craters, resulting in a dramatic increase in gas leakage from the system until the craters were filled with mud by bulldozers.

Subsidence in gasification of thin seams (1 to 3 meters) is dominated by bending subsidence for steeply dipping beds. There is no measurable time delay between gasification of the coal and observation of the surface subsidence. Thick seams present more severe subsidence problems, as expected, with steeply dipping beds being the most hazardous for any given thickness. This is due to the formation of steeply dipping shafts which can cause major catastrophic subsidence, forming craters and resulting in massive gas leakage from the system.

5.1.2 Hydrology

Among the significant environmental concerns associated with in situ coal gasification are possible effects on groundwater. The reactions that take place underground during in situ gasification yield a variety of organic and inorganic compounds. Some of these reaction products, in the form of ash and tars, remain underground as potential groundwater contaminants.

During the course of the gasification process, organic condensible and coal ash will be formed and a fraction of them will remain in the gasification cavity. After the gasification process is terminated, i.e., stopping air injection and closing in the wells, water from the G seam will slowly permeate into the cavity. Contact of this water with the coal ash and organics will undoubtedly introduce some coal ash and organic components into the G seam water.

Following the gasification process, groundwater reenters the gasification zone and will, ultimately, resume its natural flow through the coal. Reaction products that are soluble in the resulting solution will be leached out and carried downstream by the flowing groundwater. The hydrodynamic transport, dispersion, and sorption of the dissolved reaction products will determine the future distribution and concentrations of the potential contaminants.

There have been numerous studies and patents that utilize coal as an absorptive material to remove organics from water. As related to coal gasification, LLL and the Hoe Creek experiment and studies by Mead, Campbell and Stephens have revealed that coal seams are very absorptive toward phenolic and other organic components leached from coal.

Included in these organics are polynuclear aromatics (PNA's) which are also thought to be formed in the gasification process. Many PNA's are carcinogenic and mutagenic but should remain on the unaffected coal immediately surrounding the burn cavity rather than migrate appreciable distances.

These studies have also suggested a mechanism for the migration of products from the burn area. As groundwater moves through the area, soluble UCG by-products can be leached out of the reaction zone creating a plume (Figure 5-1). The shape and rate of movement of this plume represents excursion of the process by-products.

Plume behavior will be a complex function of the size of the cavity, coal characteristics, groundwater quality, and flow rate.

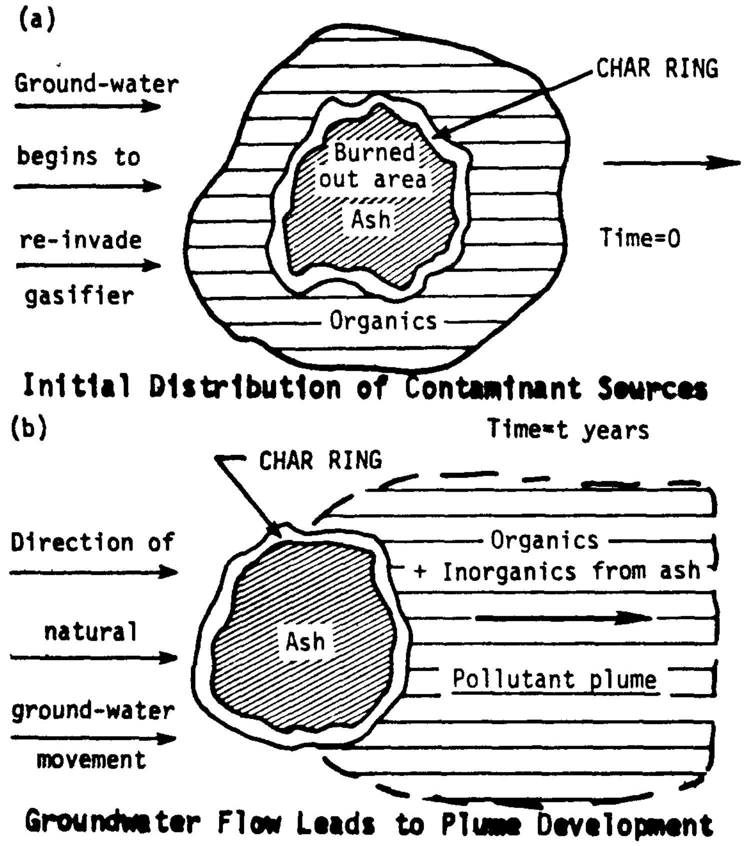
To a large extent, therefore, the G seam coal appears to be a self restoring aquifer due to the adsorptive characteristics of the coal itself. Furthermore the geology of the area is such that essentially all of the UCG affected water will remain in the coal seam long enough to allow the cleansing action to occur.

Table 5-1 lists the parameters which will be measured in water samples from the coal seam aquifer. The parameters which were found to increase as a result of UCG operations (Mead et al., 1977) will be monitored more frequently than the others and be used to indicate plume movement into the coal.

5.1.3 Air Quality

The product gases produced during the gasification operation will consist primarily of H_2O, H_2, N_2, CO and CO_2, together with a variety of organic compounds resulting from pyrolysis. Small amounts of particulate matter and H_2S are also expected to be present.

The gas produced at the site will be burned in an incinerator producing mainly carbon dioxide and water vapor. Nitrogen in the product gas will pass through the burner to the atmosphere. Some NO_x may be produced but this quantity is expected to be small.



Source: Mead, Campbell and Stephens, 1977.

Figure 5-1
Suggested Mechanism for Migration of Organic and Inorganic Materials from UCG Burn Area

TABLE 5-1

PARAMETERS TO BE MONITORED DURING TESTS

Al	Na
As	Ni
Ba	Hg
Be	NO_3 as N
B	NO_2 as N
Cd	Phenols
Cl	Se
Co	Ag
Cr	SO_4
Cu	V
F	Zn
Fe	TDS
Pb	Mg
Li	pH
Mn	Na
HCO_3	Ca
Conductivity	CO_3
Temperature	CN
TOC	

The (gas) product mix expected from the process is shown below.

	N_2	Ar	CO_2	CO	H_2	H_2O	H_2S	CH_4	C_2H_4	C_2H_6	C_3H_6	C_3H_8	Tars
Volume %	45.9	0.5	10.9	15.4	14.4	7.3	.02	4.6	0.1	0.5	0.1	0.1	0.2
Weight %	50.8	0.8	19	17.1	1.1	5.2	.03	2.9	0.11	0.6	0.16	.165	2.0

In order to minimize emissions of criteria pollutants, the entire product stream will be burned in a flare/incinerator. In time of low Btu gas production, incineration will be propane assisted. This incinerator will be equipped for remote reignition in case of blowout since the health impact of an unlit incinerator is significant. If, for any reason the incinerator cannot perform its function, operations will be terminated until proper repairs are made.

The following tables contain total emissions per year, for the three testing years. Table 5-2 presents the total of all emissions discharged from all sources, i.e., construction, unpaved roads, vehicles, operating equipment, and the test site flare. Table 5-3 presents the emissions from the flare for the three test years, disaggregated into linking and gasification modes of operation.

Based upon the flare emissions, the air quality impacts were projected using air quality dispersion models. Two models were used. The first, PTMAX produced an analysis of maximum concentration as the function of wind speed and stability. Projections were made of impacts from the smallest and largest tests (Test 1 and 3 respectively), and are shown in Table 5-4. Assumptions employed in PTMAX are attached in Appendix B.

The second air quality model used is called the Valley Air Quality Dispersion Model. The Valley Model projects concentrations based upon complex terrain, and changes in elevation. Assumptions employed in the Valley Model are attached in Appendix B. The following tables (Table 5-5 through 5-8) contain computer model predictions for ground concentrations of SO_2, NO_x, CO and PM as a result of projected emissions from the UCG flare/incinerator. They are ground concentrations from the UCG facility only. The tables represent extremes in flow rates, 30 scfm up to 8,500 scfm, with intermediate 2,500 and 7,200 scfm also included, with the ranges occurring during linking and gasification, respectively.

TABLE 5-2

TOTAL AIR CONTAMINANTS EMITTED
(Tons/Year)

COMPONENT	1979	1980	1981
Carbon Monoxide (CO)	67.9	255	260
Hydrocarbons (HC)	2.50	8.61	8.76
Nitrogen Oxides (NO_x)	11.3	39.5	45.7
Aldehydes (RCHO)	0.13	0.05	0.05
Sulfur Oxides (SO_2)	12.2	70.7	79.7
Particulate Matter (PM)	4.14	9.67	10.9

TABLE 5-3

FLARE EMISSIONS
(Tons/Year)

COMPONENT	1979 LINK	1979 GASIF.	1980 LINK	1980 GASIF.	1981 LINK	1981 GASIF.
Carbon Monoxide	.003	.18	.003	1.1	.006	1.2
Non-Methane Hydrocarbons	∿0	∿0	∿0	∿0	∿0	∿0
Nitrogen Oxides	0.095	5.3	.095	31.8	.19	37.8
Sulfur Oxides	.23	11.6	.23	70.1	.46	78.8
Particulate Matter	.021	1.17	.021	7.1	.042	8.0

TABLE 5-4

GROUND CONCENTRATIONS FROM UCG FLARE USING PTMAX

POLLUTANT	TEST 1 MAXIMUM DAYTIME CONCENTRATION $\mu g/m^3$	TEST 1 MAXIMUM NIGHTIME CONCENTRATION $\mu g/m^3$	TEST 3 MAXIMUM DAYTIME CONCENTRATION $\mu g/m^3$
SO_2	185	164	227
Particulates	19	16	18

TABLE 5-5

GROUND CONCENTRATIONS OF POLLUTANTS FROM UCG FLARE [a]

LOW VELOCITY, LOW WIND SPEED

RECEPTOR (Meters)	SO_2 [b] ($\mu g/m^3$)	NO_x [b] ($\mu g/m^3$)	CO [c] (mg/m^3)	PM [b] ($\mu g/m^3$)
75.2	4.18 (10^{-8})	1.67 (10^{-8})	0.0	1.05 (10^{-8})
100	2.01 (10^{-4})	8.04 (10^{-5})	0.0	5.03 (10^{-5})
200	3.73	1.49	7.35 (10^{-5})	0.93
300	8.68	3.47	1.59 (10^{-4})	2.17
400	17.6	7.04	3.18 (10^{-4})	4.40
500	8.26	3.30	1.47 (10^{-4})	2.06

(a) The analysis using the Valley Model was for a stack radius = 1.5 feet, stack exit velocity = 1.7 ft/sec., flow rate = 30 scfm, and wind speed = 1 m/sec, F stability.

(b) SO_2, NO_x and PM concentrations are for a 24-hour averaging period.

(c) CO ground concentrations are in mg/m^3 and are for a 8-hour averaging period.

TABLE 5-6

GROUND CONCENTRATIONS OF POLLUTANTS FROM UCG FLARE (a)

LOW VELOCITY, MODERATE WIND SPEED

RECEPTOR (Contours in Ft)	X (Meters)	SO_2 [b] (μg/m3)	NO_x [b] (μg/m3)	CO [c] (mg/m^3)	PM [b] (μg/m3)
6900	75.2	0.00	0.00	0.00	0.00
6923.3	89.5	0.00	0.00	0.00	0.00
6939	161.9	0.00	0.00	0.00	0.00
6940	167.6	0.00	0.00	0.00	0.00
6959.7	253.4	5.3 (10^{-15})	2.1 (10^{-15})	0.00	1.3 (10^{-15})
7015	503.0	0.41	0.17	1.22(10^{-5})	0.10
7000	905.0	5.86	2.37	1.10(10^{-4})	1.45
7200	2,815.7	21.90	8.84	3.92(10^{-4})	5.40
7328	2,916.0	20.76	8.40	3.67(10^{-4})	5.14
7350	3,519.7	15.60	6.30	2.82(10^{-4})	3.86
7400	5,832.6	7.51	3.03	1.35(10^{-4})	1.86

(a) This analysis, using the Valley Model was for a stack radius = 1.5 ft., stack exit velocity = 95 ft/sec., a flow rate = 2,500 scfm, and a wind speed = 2 m/sec, E stability.

(b) SO_2, NO_x, and PM concentrations are for a 24-hour averaging period.

(c) CO ground concentrations are in mg/m^3 and are for a 8-hour averaging period.

TABLE 5-7

GROUND CONCENTRATIONS OF POLLUTANTS FROM UCG FLARE [(a)]

MODERATE VELOCITY, MODERATE WIND SPEED

RECEPTOR (contours in feet)	X (meters)	SO_2^b ($\mu g/m^3$)	NO_x^b ($\mu g/m^3$)	CO^c (mg/m^3)	PM^b ($\mu g/m^3$)
6900	75.2	0.0	0.0	0.0	0.0
6923.3	89.5	0.0	0.0	0.0	0.0
6939	161.9	0.0	0.0	0.0	0.0
6940	167.6	0.0	0.0	0.0	0.0
6959	253.4	0.0	0.0	0.0	0.0
7015	503.0	$2.6\ (10^{-17})$	$1.03(10^{-17})$	0.0	$6.3\ (10^{-17})$
7000	905.0	$2.13(10^{-6})$	$8.62(10^{-7})$	0.0	$5.29(10^{-7})$
7200	2,815.7	24.85	10.03	$4.41\ (10^{-4})$	6.16
7328	2,916.0	52.7	21.3	$9.44\ (10^{-4})$	13.06
7350	3,519.7	42.9	17.31	$7.72\ (10^{-4})$	10.62
7400	5,832.6	21.62	8.73	$3.92\ (10^{-4})$	5.36

(a) This analysis, using the Valley Model was for a stack radius = 1.5 feet, stack exit velocity - 275 feet/sec., flow rate = 7,200 scfm, and a wind speed = 2m/sec, E stability.

(b) SO_2, NO_x, and PM concentrations are for a 24-hour averaging period.

(c) CO ground concentrations are in mg/m^3 and are for a 8-hour averaging period.

TABLE 5-8

GROUND CONCENTRATIONS OF POLLUTANTS FROM UCG FLARE [a]

HIGH VELOCITY, MODERATE WIND SPEED

RECEPTOR (contours in feet)	X (meters)	SO_2[b] ($\mu g/m^3$)	NO_x[b] ($\mu g/m^3$)	CO[c] (mg/m^3)	PM[b] ($\mu g/m^3$)
6900	75.2	0.0	0.0	0.0	0.0
6923.3	89.5	0.0	0.0	0.0	0.0
6939	161.9	0.0	0.0	0.0	0.0
6940	167.6	0.0	0.0	0.0	0.0
6959.7	253.4	0.0	0.0	0.0	0.0
7015	503.0	$7.43(10^{-23})$	$3.0\ (10^{-23})$	0.0	$1.8(10^{-23})$
7000	905.0	$1.2\ (10^{-8})$	$5.0\ (10^{-9})$	0.0	$3.1(10^{-9})$
7200	2,815.7	14.7	5.93	$2.65\ (10^{-4})$	3.64
7328	2,916.0	41.65	16.81	$7.48\ (10^{-4})$	10.32
7350	3,519.7	36.72	14.82	$6.61\ (10^{-4})$	9.09
7400	5,832.6	20.90	8.44	$3.79\ (10^{-4})$	5.18

(a) This analysis using the Valley Model was for a stack radius = 1.5 feet, stack exit velocity = 325 feet/sec., flow rate = 8,500 scfm, and a wind speed = 2 m/sec, E stability.

(b) SO_2, NO_x, and PM concentrations are for a 24-hour averaging period.

(c) CO ground concentrations are in mg/m^3 and are for a 8-hour averaging period.

An unexpected but possible source of air pollution would result if subsidence were to cause open cracks extending from the underground gasification zone to the surface. To guard against this potential danger to operating personnel, surface monitoring of H_2S and CO will be a necessity during the entire gasification procedure. These monitors will also serve to monitor for ambient air quality. Significant surface leaks would require at least a temporary interruption in the gasification procedure.

Other sources of air quality impact will result from operation of internal combustion engines on site. Dust will also arise from normal operations of vehicles and heavy equipment.

5.1.4 Noise Quality

The background level of noise in the area was estimated to range between 45-50 dB.

The operation of drilling equipment, pumps, compressors, and trucks at times results in high noise levels. The use of standard noise suppression devices on all internal combustion engines and, more importantly, the relatively remote location of the experimental site should reduce the noise impact on the surrounding populace to low levels.

5.2 EFFECTS ON THE BIOTIC ENVIRONMENT

5.2.1 Terrestrial Ecology

The most significant impact on vegetation will probably result from road construction and site preparation and development. Most of the vegetation at the drilling locations, and building and equipment locations will be destroyed. The total land area affected will probably only be up to 15 acres.

Restoration and revegetation of the damaged areas will be accomplished within a year of the completion of the project.

There are several species of wildlife in the site area. Game animals such as pronghorn, mule deer, desert cottontail rabbits and sage grouse are present. The wildlife will probably be displaced from portions of the site for the period of the experiment but should return after the work is completed. Therefore, no long term impacts on wildlife are anticipated.

Drilling, construction and testing operations may generate loud and perhaps continuous noise. However, because the surrounding region is relatively undeveloped, wildlife can avoid the area, thereby minimizing contact with the test activities.

5.3 EFFECTS ON THE HUMAN ENVIRONMENT

The underground coal gasification experiment will result in minimal impacts to the socioeconomic environment of the region. The total duration of the test burn activities will last four years, with intense on-site activity for short increments of time for each burn:

Test No.	Initiation of Linking Phase	Initiation of Gasification Phase	Length of Gasification Phase
1.	Sept 15, 1979	Oct. 1, 1979	20 days
2.	June 15, 1980	July 1, 1980	60-80 days
3.	Aug. 1, 1981	Sept 1, 1981	60-80 days

5.3.1 Demographic Characteristics

The labor force requirements for the project are not expected to have any significant effect on the Rawlins or Carbon County area. Construction and testing will have the greatest on-site labor force requirements associated with the program, however, no significant effects on the local labor force is expected. During the construction phase, activities will require some temporary local labor for facility construction, but most of these activities will be temporary with a duration of only a few months. On-site personnel during testing operations will probably not exceed 20 persons. Approximately half of these on-site personnel will be local hires. Only five or six persons will be on-site for the duration of the testing operations. Project evaluation will require minimal on-site personnel since the primary on-site activity will be environmental monitoring.

5.3.2 Land Use

The site for underground coal gasification of steeply dipping beds has been used for livestock grazing and recreational hunting for the past 20 years and continues to be used as such at the present time. Since there will be a minimum of surface area disturbance during this gasification activity, it is assumed that the land will be used for the same purpose following restoration.

The original mineral rights leaseholder, Rocky Mountain Energy Company, plans to develop the site as a coal stripmine when the UCG lease expires in 1982. The stripmine will extract coal from the upper 250' of the exposed coal outcrops as the mine is developed in the mid-1980's.

5.3.3 Transportation

A 1¼ mile graded and gravelled road has already been upgraded to provide access to the test site. This road will be restored upon completion of the test burn. Because of the small number of personnel and the short duration of the tests, minimal impacts are expected to the existing transportation system within the area. Existing roads are adequate to handle the small increase in traffic.

5.3.4 Aesthetic/Cultural/Historic Interests

The Wyoming Recreational Commission, offices of the state historian and archaeologist, visited the site and determined the project would not disrupt any sites of interest. The appropriate clearances were given for project construction.

5.3.5 Socioeconomics

The UCG project is expected to have minimal impact on the local economics of either Rawlins or Carbon County. The project's limited duration and its experimental (non-commercial) nature are not expected to cause any significant effects on major economic indicators or cause potential economic impact associated with commercial coal development activities. Some positive economic benefits may be gained by use of local construction firms for construction and testing activities, but these effects will not be of the same magnitude as experienced for commercial facilities.

The number of on-site personnel will vary significantly during the program phases, primarily as a function of the program activities. At most, five or six personnel are likely to relocate to the Rawlins area for the duration of construction. For the most part, personnel will be on-site only periodically during construction and testing and will require only temporary living accomodations such as motels/hotels. Minimal impact on housing and services is expected to result from the program at the Rawlins area site and those that may result will be temporary in duration, occurring primarily during operation of the field test program.

5.3.6 Health and Safety Impacts

5.3.6.1 Occupational Health

Field experiments involving underground coal gasification (UCG) are designed to obtain process data in order to define engineering specifications for larger scale operations. Process testing occurs under less than optimal conditions. Even with careful planning and the use of best engineering practices, the exploration of new technologies is accompanied by unforeseen problems and failures. This is a primary reason for performing small-scale field tests. Leaks, emergencies, equipment dismantling for maintenance, repair or modification are all likely occurrences with UCG. In addition are the uncertainties with dealing with the geological environment as the reactor vessel adds additional uncertainties.

The worker at a UCG site may be exposed to toxic materials by inhalation of gases or airborne particles, skin deposition of airborne material, contact with contaminated surfaces, and accidental ingesting. During maintenance and routine operations, liquid and solid residues may be encountered that would not ordinarily constitute normal operational hazards in a commercial plant. The equipment is designed to prevent continuous handling of coal by personnel. More than 95 percent of all tars/water produced will be directly burned in the incinerator.

Appropriate protective measures for workers will be taken including the use of protective clothing, and carbon monoxide monitors. Health and safety procedures will be developed and strictly adhered to.

5.3.6.2 Public Health Effects

The short duration of the experiment and the smallness of scale preclude any significant public health effects from this experiment.

5.3.6.3 Catastrophic Events

The question of whether underground coal gasification will result in an uncontrolled coal fire underground that will propagate through the coal seam for many miles needs to be addressed. The experiment is being conducted under the water table, and with air being piped in from the surface. Shutting in all the wells to the surface at the completion of the experiment and allowing water to reenter the reaction zone should prevent any uncontrolled fire after completion of the experiment. It is possible to flood the gasified cavity with water, if there is evidence that the fire has not gone out but that option may present more adverse effects.

Experience from past field experiments has not provided any evidence for the continuous advance of the flame front after the termination of UCG tests. In a number of cases, it has actually been found to be difficult to maintain the coal combustion process during the test period. However, the history of outcrop fires which manage to maintain a source of oxygen over great periods of time is well documented. Fire fighting efforts have often been unsuccessful.

A more likely accident would be failure of the flare or incinerator. The incinerator will be propane assisted and will have dual torches and is designed to convert and dispose the product gases to produce a minimal environmental effect. In the event of failure, accidental release of the product gases, including carbon monoxide and hydrogen sulfide could pose a danger to operating personnel. In the event of a significant release, emergency procedures will be enacted.

Additional potential emergencies are ground surface rupture and rupture in pipes and other gas handling equipment. It is unlikely that surface cracks will occur; however, bulldozing of the surface or the use of cement could be used to fill the cracks. Ruptures in pipes will be handled the same as a flare or incinerator flame-out.

6.0 POTENTIAL CUMULATIVE OR LONG-TERM EFFECTS

The principal benefits of the Steeply Dipping Beds UCG experiment are of a long-term nature. The experiment is designed to yield meaningful technical, economic and environmental data. Although this data will be site specific, it will be directly applicable to evaluate the feasibility of using underground gasification as an environmentally superior means of recovering energy from now unavailable resources. The method of coal utilization to which this experiment may ultimately lead will require a decade of research prior to commercial development. However, at that time, the environmental advantages and the increase in available energy could assume enormous importance on a national scale.

Successful completion of the Steeply Dipping Beds UCG experiment could have far reaching beneficial effects in the future production of energy in an environmentally acceptable manner. The cumulative or long-term environmental effect of this project will remove this site from future coal development. (With the present energy supply-demand situation, the possible loss of this small site area from future use is not considered sufficiently detrimental to preclude operation of the experiment).

Short-term benefits will include a considerable increase in knowledge concerning the underground gasification of western subbituminous coal with regard to other general aspects of the gasification process and the environmental impacts of the process. Such knowledge is an essential prerequisite to the more advanced stages in the evaluation of this method of coal utilization.

7.0 UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

The small scale of the experiment and the relative isolation of the site are outstanding environmental advantages. These factors virtually preclude serious environmental consequences, even when precise prediction of environmental results is not possible. Although some of the potential environmental effects call for careful attention and appropriate preparation, they are effects that can be fully controlled using standard techniques.

Plant effluents will be monitored and limited to acceptable levels. Abrupt surface subsidence may occur; however, it can be rectified.

The principal environmental concern is the protection of the groundwater quality against possible contamination by gasification reaction products. There is good evidence that contaminants introduced into the unburned coal region after gasification is completed will be restricted to the immediate area, by the cleansing action of the coal itself.

It is apparent that some of the environmental control measures to be applied will depend upon measurements made during and after the experiment. Since the magnitude and nature of the environmental effect is not now known, the uncertainty limits the extent to which control techniques or mitigating measures may be specified.

Other unavoidable adverse impacts will be temporary in nature. These will result from construction and operation of the site. Additional traffic, dust, noise will be on a small scale and last only the duration of the experiment.

8.0 IRREVERSIBLE OR IRRETRIEVABLE COMMITMENT OF RESOURCES

The principal irretrievable commitment associated with the proposed test burn is the complete utilization of approximately 8,660 tons of moisture-ash free, (MAF) coal. Test #1 will consume 550 tons, Test #2, 2,950 tons and Test #3 will consume 5,160 tons of MAF coal. It is possible that although only a small fraction of the coal in place will be burned, that the coal under the test area may become unrecoverable, due to the activities associated with the test burn.

Commitment of manpower, money and some equipment will also be irretrievable. This category includes any gasoline, diesel oil, propane or other energy source utilized in equipment operation.

The Steeply Dipping Bed UCG experiment will also involve some relatively minor irreversible alterations to the environment. These will only impact a localized region surrounding the in situ gasification site at Rawlins. Some reaction-product contaminants may occur at the site impacting water quality and soil. There is a possibility that long term groundwater quality could be degraded due to dissolution of organic compounds produced by gasification, and inorganic compounds from the ash. Soil sterilization, if it occurs, would be due to spillage of any produced organic compounds carried to the surface in the product gas stream. Studies of potential problems will be continued during and after the experiment.

After completion of the experiment, the land will be restored to its pre-gasification condition and former land uses may be resumed.

9.0 COORDINATION WITH FEDERAL, STATE, REGIONAL OR LOCAL PLANS

There are no known state, regional, or local plans or programs in this area with which the proposed experimental activities would conflict.

Energy Development Company (EDC) have outlined plans to strip mine the Wally, G and I Coal seams in Section 11 (Figure 9-1), and the adjoining sections along the coal outcrop. These plans will be implemented by EDC if they are awarded the coal leases for the even numbered sections which are held by the Bureau of Land Management (BLM). These development plans do not interfere with the proposed project.

There are no active or inactive coal mines located on Section 11, T21N, R89W; and, there is only one inactive mine on the adjacent section. This mine is located in the southwest quarter of Section 12, T21N, R89W (Figure 9-2). This mine was a strip mine that operated in the I coal seam. On-site inspection of the location has indicated that the upper 20 to 50 feet of coal has been removed for a few hundred feet along the coal outcrop. No data was located as to when this mine was operational. This project is not expected to have any impact on this mine.

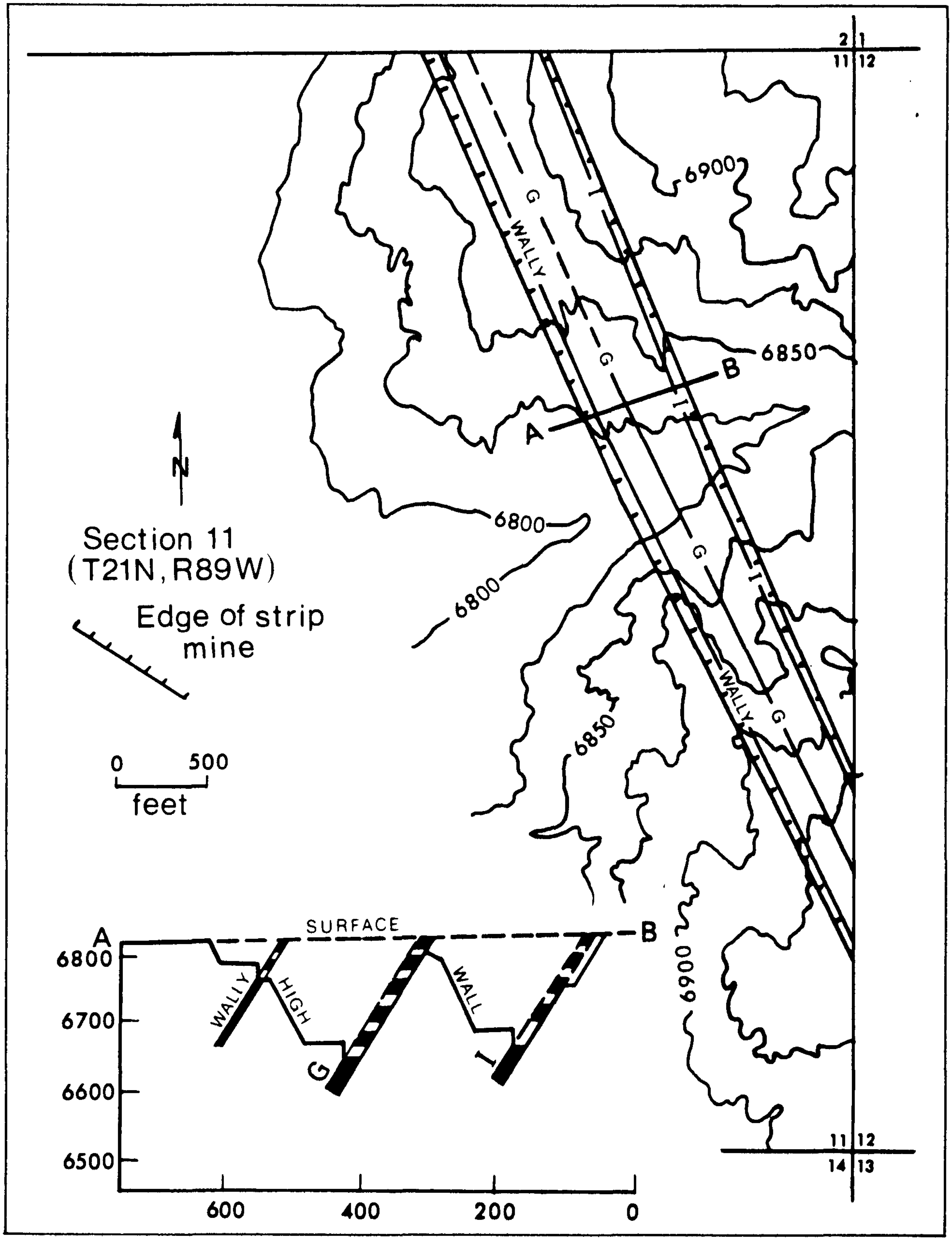


Figure 9-1

Energy Development Company's Projected Mine Plan for Section 11

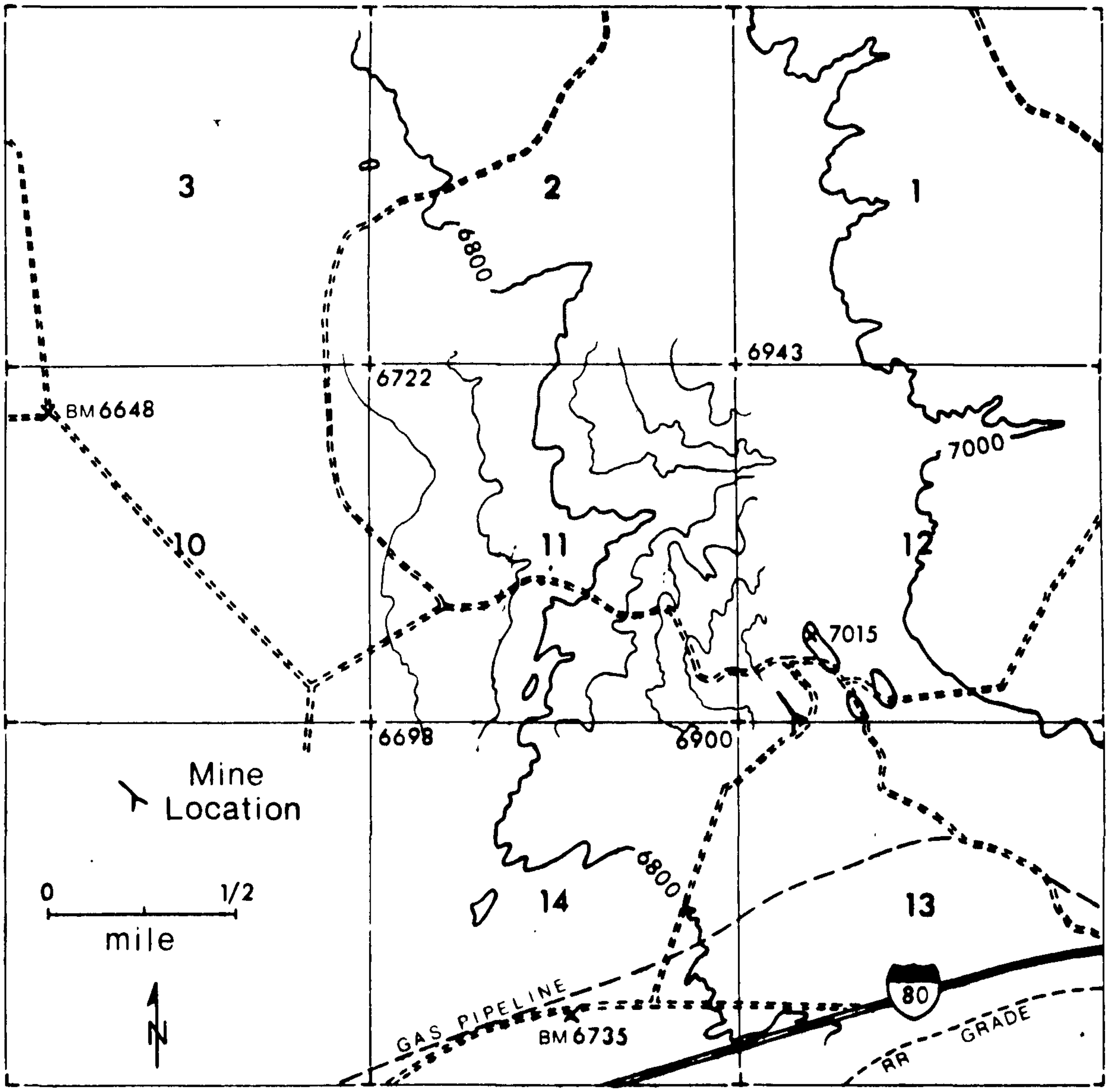


Figure 9-2
Inactive Coal Mines on Sections Adjacent to Section 11

10.0 ALTERNATIVES TO THE PROPOSED PROJECT

The National Environmental Policy Act (NEPA) requires consideration of "alternatives to the proposed action." Given the various possible combinations of alternatives, the number of potential alternatives which might be considered is limited only by the imagination. However, a meaningful analysis of alternatives requires a careful balancing of the need to consider a comprehensive set of alternatives with the need to focus the discussion of each meaningfully in the context of the proposed Underground Coal Gasification experiment.

The definition of the alternatives considered proceeds from the consideration of the objectives stated in Section 2.3.

The primary objectives of the project are: (1) to demonstrate process feasibility; and (2) to provide data on the economics of the system. Information from the project's gasification experiments will be used to produce a design concept and cost estimate for the design, construction, and operation of a pilot plant as the next step toward commercial development of the underground coal gasification process for steeply dipping beds.

There are several secondary objectives of the project, which include:

- To determine optimum values for injection gas flow rate, reactor pressure, and amount of water in the reactor
- To determine resource utilization and recovery potential
- To determine effects of simultaneously operating two modules in communication with one another
- To determine effects of subsurface subsidence on the process in steeply dipping beds
- To determine environmental impacts associated with the process

Additionally the SDB project represents a major step toward commercialization of underground coal gasification. The sequence of steps of which it is a part is shown below.

- Develop and demonstrate in situ gasification technology in horizontal beds. This is also being done by DOE via projects at Lawrence Livermore Laboratory and Laramie Energy Technology Center

- Develop and demonstrate in situ gasification technology in steeply dipping beds

- Transfer this technology to industry and demonstrate the above technology in a coal environment which is representative of a significant national resource

- Develop reliable economic data for estimation of operating costs for a scaled-up facility

- Demonstrate large (multi-module) burns

- Demonstrate pilot plant scale usage of UCG process gas from a multi-module burn, determining the economic viability of full-scale commercialization

- Construct and demonstrate a full-scale (commercial) plant

Alternatives deriving from consideration of the objectives include:

- Do not conduct the UCG-SDB project
- Delay the project
- Conduct a smaller scale project
- Conduct a larger scale project
- Utilize a different site(s) for the test burns
- Perform experiments on horizontal coal beds only
- Use alternative coal technologies to achieve the same end results
- Use alternative resources to achieve the same results

Do Not Conduct the UCG-SDB Project

Not conducting the project would preclude information needed to determine if future use of underground coal gasification of steeply dipping coal beds can help to meet our national energy requirements is technically, economically and environmentally feasible and desirable. Underground coal gasification (UCG) is an emerging technology which may provide a means for utilizing coal resource considered technologically or economically unmineable by conventional mining techniques. Therefore, all data obtained from the test burns, including data indicating potential environmental impacts resulting from UCG, will be essential to the development of the UCG technology. Thus, if the tests are not conducted, vital research for National energy supply resource utilization may suffer.

Delay the Project

By proceeding with the current schedule of development, the gasification of steeply dipping coal can be expected to become a commercial reality by the year 1990. The need for alternate means of producing electricity and providing a feedstock for chemicals and natural gas is expected to become critical. Delaying the research postpones the decision whether or not underground gasification of these coals can contribute to the energy supply and the start date when this process can contribute.

Conduct a Smaller-Scale Project

The magnitude of scale of UCG field projects leads one to believe that the technology may be further along in its development than it is in actuality. The significant factor in underground coal gasification is the use of the ground as a reactor vessel. A fairly complicated chemical process is carried out with few adjustable parameters. With a surface plant, the dimensions as well as other operating parameters of the reaction can be varied. The underground portion of the system must be engineered to operate in a predictable and controllable manner. No laboratory experiments can adequately predict and model what happens in the field. In essence, the field is the laboratory. The first burn to be conducted is the smallest practicable size which will provide significant information.

Conduct a Larger-Scale Project

The small scale of the first test is of sufficient scale to obtain many of the criteria and parameters necessary to evaluate the potential of the UCG technique. A larger scale experiment for the first test at the current state of development of the technique, would provide additional necessary data, although would probably not add knowledge commensurate with the additional economic cost. In addition, the technical uncertainties associated with underground gasification warrant the smallest-scale field experiment possible for the first test with scale-up to follow as technical problems are solved.

Utilize a Different Site for the Test

Steeply dipping coal beds are restricted mainly to coal provinces within, or marginal to, the great tectonic belts comprising the north-south-trending, major mountain chains of the United States:

1) The Rocky Mountain Province, including the Rocky Mountain Foreland, Cordilleran Foldbelt, and Colorado Plateau structural complex,

2) The Pacific Coast Province, including the Cascade Range of Washington and the Coast Ranges of California,

3) The Eastern Province, consisting of portions of the Appalachian Mountains, and

4) The Alaska Province, specifically deposits on the southern flank of the Alaska Range, adjacent to Cook Inlet

Steeply dipping coal beds are essentially absent from provinces lacking major deformational folding, such as the Northern Great Plains, Gulf, and Interior provinces.

Western coal fields and areas are of the most immediate interest because they tend to occur in thick, readily combustible beds and present minimal environmental problems. Many occur near major markets or gas pipelines.

Though eastern deposits are a potentially valuable resource, they are generally of higher rank than most western coals and therefore difficult to burn in situ.

Alaskan coal is too far from major markets for its development by any gasification process to be economically feasible in the near future.

At least 40 coal fields or areas, distributed through seven Western States, contain steeply dipping coal beds.

A total of approximately 100 billion tons of coal is estimated to occur within the United States in beds dipping greater than 35 degrees, at depths less than 3,000 feet. This resource comprises 70 billion tons in the western United States, including 50 billion tons in the Rocky Mountain Province and 20 billion tons in the Pacific Coast Province, as well as approximately 15 billion tons each in the Eastern Province and Alaska.

After selecting the seven possible test sites shown on Figure 10-1, a substantial effort was made by GR&DC and TRW to evaluate each site before selecting and acquiring the final site. For final site selection, GR&DC:

- Retained three groups of consulting coal geologists, each group of which specializes on one of the areas containing Steeply Dipping Bed deposits -- the Rocky Mountain Region, the State of Washington, and Appalachia;
- Performed on-site geological evaluation, reconnaissance mapping, and land-coal-right ownership searches for the North Knobs, North Park, and Grand Hogback sites
- Prepared formal reports on the above three Wyoming and Colorado sites
- Performed electrical resistivity surveys for determination of water-table levels at the prime sites at North Knobs and North Park
- Performed on-site evaluations of the Roslyn, Wilkeson-Carbonado, and Green River sites in the State of Washington

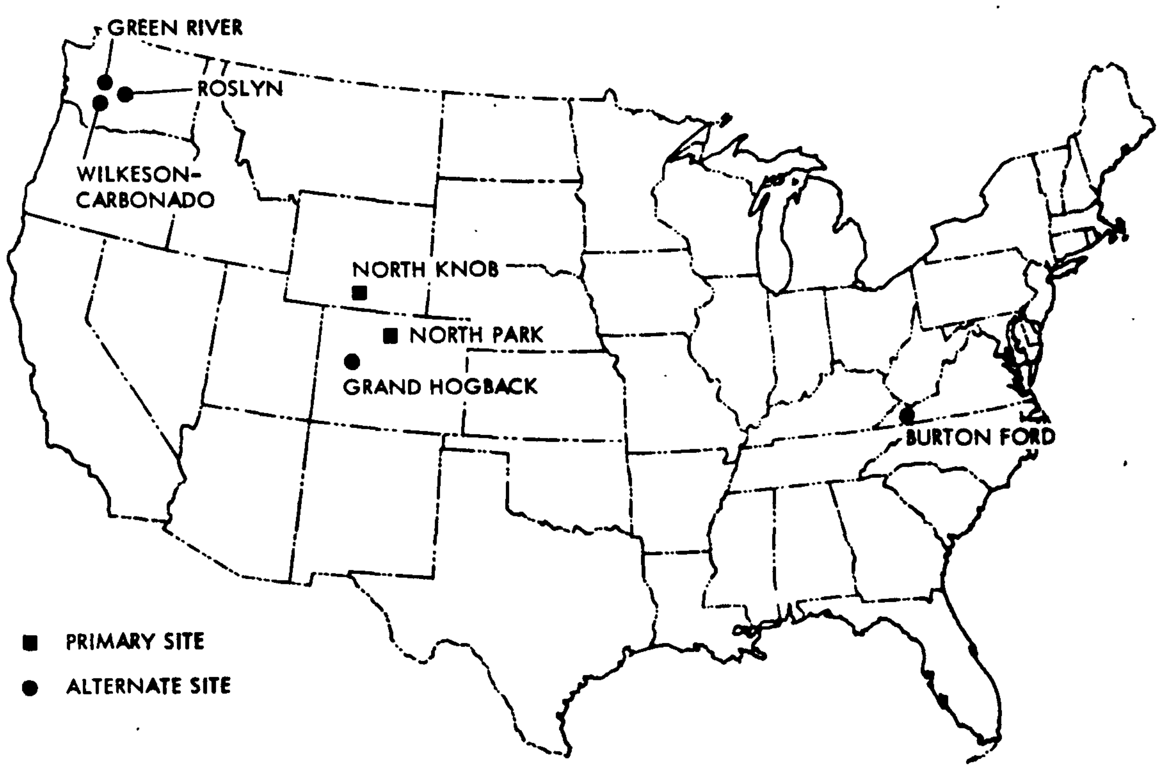


Figure 10-1
Index Map of Primary and Alternate Test Sites

- Prepared summary reports on the applicability of Roslyn and Wilkeson-Carbonado SDB deposits for in situ gasification
- Performed on-site evaluation of the Burtons Ford site
- Inspected all of the Rocky Mountain Region sites and prioritized them

Detailed information on all the sites appears in Appendix C of the proposal submitted to DOE by Gulf/TRW.

All of the seven sites were analyzed according to the following criteria and all but the North Knobs site were eliminated from consideration:

- The coal seam shall have a dip angle between 45° and 75°
- The coal gasification shall be below the water table
- The coal shall be subbituminous (shrinking upon heating)
- The bed thickness shall be between 10 feet and 30 feet
- The geology shall be relatively simple
- Site construction, access and restoration should be relatively simple
- GR&DC shall be able to obtain a lease for doing UCG tests on the site

Table 10-1 lists the site selection considerations for UCG of steeply dipping coal beds.

Perform Experiments on Horizontal Coal Beds Only

Since the argument could be used that the potential resource for horizontal coal beds is so much greater than steeply dipping coals, the question may be asked as to why this particular technology should be pursued? The prime steeply dipping coal bed targets are Eastern and Northwest coals because of their proximity to markets. The Wyoming site was chosen because of its accessibility and ease of operation. Since this is an experimental program, a site that offers the best chances for technical success and ease of problem solving was chosen for the first application of SDB technology in the United States. Steeply dipping coals may also be the key for transferring UCG technology to lutuminous eastern coals.

Use Alternative Coal Technologies to Achieve the Same End Result

Low Btu gas for electrical power generation and process heat, and medium Btu gas for use as a synthesis gas may also be achieved by surface gasification

TABLE 10-1

SITE SELECTION CONSIDERATIONS FOR IN SITU
GASIFICATION OF STEEPLY DIPPING COAL BEDS

Geological Characteristics of the Coal Bed

	*Stages Effected				**Others
	D	I&L	G	P.B.	
Structural Considerations					
-Dip & Consistency of Dip w/ Depth	x	-	x	x	x
-Folding	x	x	-	-	-
-Faulting	x	x	x	-	x
-Cleating,Other Minidislocations	-	x	-	-	-
-Tectonic Thickness	x	x	x	-	-
Stratigraphic Considerations					
-Detailed Lithologic Column	x	x	x	-	-
-Thickness	x	x	x	x	-
-Lenticularity, Fecies, & Continuity	x	x	x	-	-
Outcrop and/or Subcrop					
Coal Reserves	-	-	-	-	x
Groundwater	-	x	x	x	-
Physical Properties					
-Expansion Characteristics	-	x	x	-	x
-Agglomerating Characteristics	-	-	x	-	-
Chemical Properties					
-Volatile Matter	-	-	x	-	x
-Ash Content	-	-	x	-	-
-Moisture Content	-	-	x	-	-
-Heat Content	-	x	-	-	-
-Oxygen, Carbon & Hydrogen Content	-	x	x	-	-

Geological Considerations External to the Coal Bed

	*Stages Effected				**Others
	D	I&L	G	P.B.	
Physical Geology					
-Topography	x	-	-	-	-
-Surface Water	-	-	-	x	-
Aquifers					
Roof & Floor Characteristics					
-"Container" Tightness	-	x	x	x .	-
-Roof Fall	-	-	x	-	-
Surficial Deposits & Burn	x	-	-	-	-
Overburden Characteristics	x	-	-	x	-

*Operating Stages Affected Where:

D = Development Drilling Stage
I&L = Ignition & Linking Stage
G = Gasification Stage
P.B. = Post Burn Stage

**Other = Other Considerations

X = Indicates Effect
- = Indicates No Effect

of coal. Both environmental and economic considerations seem to favor underground coal gasification, although UCG is not a direct competitor to surface processing. One disadvantage of UCG is the requirement to have the coal resource near the power plant. Electric power may also be generated by direct burning of coal. UCG is not a competitor to this technology where the power plant is located away from the resource.

Use Alternative Resources to Achieve the Same Objectives

Electric power generation from hydroelectric sources, geothermal energy, oil, natural gas, and nuclear energy are all expected to be supplemented by gas from coal. Unconventional gas, deep gas, gas from Mexico, and LNG all can contribute to the same end uses. The pricing of natural gas will affect all of the above sources. The actual contribution in terms of quantities of gas from coal will depend in part on the quantities of all of the above sources. Gas from coal uses a vast though depletable resource, and UCG is a promising means of extending that resource base. Thus, this technology is more likely a supplementary rather than competive user of resources.

APPENDIX A

WILDLIFE THAT MAY BE FOUND ON SITE

TABLE A-1

MAMMALS WHOSE GEOGRAPHIC RANGES INCLUDE THE GULF RESEARCH AND DEVELOPMENT SITE

Common Name	Scientific Name	Comments[a]
INSECTIVORES		
Masked Shrew	Sorex cinerus	Range
Vagrant Shrew	Sorex vagrans	Habitat
Dusky Shrew	Sorex obscurus	Habitat
Dwarf Shrew	Sorex nanus	
Water Shrew	Sorex palustris	Habitat
Merriam's Shrew	Sorex merriami	Expected
BATS		
Little Brown Myotis	Myotis lucifugus	Habitat
Long-eared Myotis	Myotis evotis	Habitat
Long-legged Myotis	Myotis volans	
Small-footed Myotis	Myotis leibii	Habitat
Silver-haired Bat	Lasionycteris noctivagans	Habitat
Big Brown Bat	Eptesicus fuscus	Habitat
Hoary Bat	Lasiurus cinerus	Habitat
Townsend's Big-eared Bat	Plecotus townsendii	Habitat
LAGOMORPHS		
Pika	Ochotona princeps	Habitat
Nuttalls's Cottontail	Sylvilagus nuttalli	
Desert Cottontail	Sylvilagus audubonii	Expected
Snowshoe Hare	Lepus americanus	Habitat
White-tailed Jack Rabbit	Lepus townsendii	Expected
RODENTS		
Least Chipmunk	Eutamias minimus	Expected
Yellow-bellied Marmot	Marmota flaviventris	Range
Richardson's Ground Squirrel	Spermophilus richardsonii	Expected
Thirteen-lined Ground Squirrel	Spermophilus tridecemlineatus	Habitat, Range
Golden-mantled Ground Squirrel	Spermophilus lateralis	Habitat
White-tailed Prairie Dog	Cynomys leucurus	
Red Squirrel	Tamiasciurus hudsonicus	Habitat
Northern Pocket Gopher	Thomomys talpoides	Expected
Olive-backed Pocket Mouse	Perognathus fasciatus	Expected
Ord's Kangaroo Rat	Dipodomys ordii	Expected
Beaver	Castor canadensis	Habitat
Western Harvest Mouse	Reithrodontomys megalotis	Habitat, Range
Deer Mouse	Peromyscus maniculatus	Expected
Northern Grasshopper Mouse	Onychomys leucogaster	Expected

TABLE A-1

(Continued)

Common Name	Scientific Name	Comments
Bushy-tailed Woodrat	*Neotoma cinerea*	Expected
Southern Red-backed Vole	*Clethrionomys gapperi*	Habitat
Montane Vole	*Microtus montanus*	Habitat
Long-tailed Vole	*Microtus longicaudus*	Habitat
Prairie Vole	*Microtus ochrogaster*	Habitat
Sagebrush Vole	*Lagurus curtatus*	
Muskrat	*Ondatra zibethicus*	Habitat
Norway Rat	*Rattus norvegicus*	Habitat
House Mouse	*Mus musculus*	
Western Jumping Mouse	*Zapus princeps*	Habitat
Porcupine	*Erethizon dorsatum*	Habitat
CARNIVORES		
Coyote	*Canis latrans*	Expected
Red Fox	*Vulpes vulpes*	Range
Swift Fox	*Vulpes velox*	
Black Bear	*Ursus americanus*	Habitat, Range
Marten	*Martes americana*	Habitat, Range
Ermine	*Mustela erminea*	Habitat
Long-tailed Weasel	*Mustela frenata*	Habitat
Black-footed Ferret	*Mustela nigripes*	
Badger	*Taxidea taxus*	Expected
Western Spotted Skunk	*Spilogale gracilis*	
Striped Skunk	*Mephitis mephitis*	
River Otter	*Lutra canadensis*	Habitat
Mountain Lion	*Felis concolor*	Habitat, Range
Bobcat	*Felis rufus*	
EVEN-TOED UNGULATES		
Wapiti or Elk	*Cervus elaphus*	
Mule Deer	*Odocoileus hemionus*	Expected
White-tailed Deer	*Odocoileus virginianus*	Habitat
Pronghorn	*Antilocapra americana*	Expected
Mountain Sheep	*Ovis canadensis*	Habitat

a. Range = species not expected because site is on periphery of species known range.

b. Habitat = species not expected because suitable habitat not available on site.

c. Expected = species expected to occur on site.

TABLE A-2

BIRD SPECIES WHICH MAY OCCUR ON THE GULF RESEARCH AND DEVELOPMENT SITE

Species[a]	Status
Red-tailed Hawk	Summer Visitor, Winter
Swainson's Hawk	Summer Visitor
Rough-legged Hawk	Winter
Ferruginous Hawk	Summer Visitor
Golden Eagle	Summer Visitor (Possible Breeder)
Marsh Hawk	Summer Visitor, Winter
Prairie Falcon	Summer Visitor, Winter
Merlin	Summer Visitor, Migrant
American Kestrel	Summer Visitor
Sage Grouse	Breeder, Winter
Killdeer	Summer Visitor
Mourning Dove	Breeder
Great Horned Owl	Summer Visitor, Winter
Burrowing Owl	Possible Summer Visitor or Breeder
Short-eared Owl	Summer Visitor, Migrant
Common Nighthawk	Summer Visitor (Possible Breeder)
Common Flicker	Summer Visitor, Winter
Say's Phoebe	Possible Breeder
Horned Lark	Breeder, Winter
Violet-green Swallow	Summer Visitor
Tree Swallow	Possible Visitor
Barn Swallow	Possible Visitor
Cliff Swallow	Summer Visitor
Black-billed Magpie	Summer Visitor, Winter
Rock Wren	Breeder
Sage Thrasher	Breeder
American Robin	Summer Visitor
Swainson's Thrush	Migrant
Mountain Bluebird	Possible Breeder
Blue-gray Gnatcatcher	Visitor
Cedar Waxwing	Summer Visitor, Winter
Northern Shrike	Winter
Loggerhead Shrike	Summer Visitor, Winter
Starling	Possible Visitor
Yellow-rumped Warbler	Summer Visitor
MacGillivrays Warbler	Migrant
House Sparrow	Possible Visitor
Western Meadowlark	Possible Breeder, Winter
Brewer's Blackbird	Summer Visitor
House Finch	Possible Visitor
Gray-crowned Rosy Finch	Winter
Black Rosy Finch	Possible Winter

TABLE A-2
(Continued)

Species[a]	Status
Common Redpoll	Winter
Lark Bunting	Breeder
Vesper Sparrow	Breeder
Lark Sparrow	Summer Visitor (Possible Breeder)
Sage Sparrow	Breeder, Winter
Dark-eyed Junco	Winter
Brewer's Sparrow	Breeder

[a]This species list compiled from on-site observations, evaluation of habitat, results of winter and summer bird censuses by "American Birds", and results of bird surveys conducted by NUS in other parts of Wyoming. The "Current Status and Inventory of Wildlife in Wyoming 1977", was also used.

TABLE A-3

REPTILES AND AMPHIBIANS WHOSE RANGES INCLUDE THE GULF RESEARCH AND DEVELOPMENT SITE

Common Name	Scientific Name	Comments[a,b]
Tiger Salamander	*Ambystoma tigrinum*	Habitat
Western Toad	*Bufo boreas*	Habitat
Striped Chorus Frog	*Pseudacris triseriata*	Habitat
Northern Leopard Frog	*Rana pipiens*	Habitat
Short-horned Lizard	*Phrynosoma douglassi*	Expected
Sagebrush Lizard	*Sceloporus graciosus*	Expected
Eastern Fence Lizard	*Sceloporus undulatus*	Not Expected
Racer	*Coluber constrictor*	
Western Rattlesnake	*Crotalus viridis*	Expected
Smooth Green Snake	*Opheodrys vernalis*	Not Expected
Gopher Snake	*Pituophis melanoleucus*	Expected
Western Terrestrial Garter Snake	*Thamnophis elegans*	
Common Garter Snake	*Thamnophis elegans*	Habitat

[a]Habitat - species not expected on site because of lack of proper habitat.

[b]Thirty-three species of reptiles and amphibians may occur in Wyoming. "Current Status and Inventory of Wildlife In Wyoming, 1977."

1. The four species of amphibians are considered to be "common" in Wyoming.
2. All reptiles are also considered "common" in Wyoming, except the Eastern Fence Lizard, which has a "peripheral" status, and the Smooth Green Snake, which is considered "rare" in Wyoming.

APPENDIX B

AIR QUALITY MODELING ASSUMPTIONS

PTMAX MODEL ASSUMPTIONS

PTMAX produces an analysis of maximum concentration as the function of wind speed and stability. A separate analysis is made for each individual stack. Input to the program consists of ambient air temperature, and characteristics of the source, such as emission rate, physical stack height, and stack gas temperature. Either the stack gas volume flow or both the stack gas velocity and inside diameter at the top are also required. Outputs of the program consist of effective height of emission, maximum ground level concentration, and distance of maximum concentration for each condition of stability and wind speed.

This program determines for each wind speed and stability the final plume rise using methods suggested by Briggs. This plume rise is added to the physical stack height to determine the effective height of emission. The effective height is used to determine both the maximum concentration and the distance to maximum concentration.

The following assumptions are made: a steady-state Gaussian plume model is applicable to determine ground level concentrations. Computations can be performed according to the "Workbook of Atmospheric Dispersion Estimates." The dispersion parameter values used for the horizontal dispersion coefficient, sigma y, and the vertical dispersion coefficient, sigma z, are those given in Figures 3-2 and 3-3 of the workbook. The stated wind speed occurs at the stack top for dilution of the plume and through the layer that the plume rise occurs. The stated stability occurs from ground level to well above the top of the plume. If there is a limit to vertical mixing, it occurs far enough above the top of the plume so that it has no influence upon the maximum concentration. There are no topographic obstructions in the vicinity of the source. The source exists in either flat or gently rolling terrain.

Use of this program is applicable where single sources exist in relatively uniform terrain. It is not applicable if aerodynamic downwash around buildings in the vicinity of the source effects the plume emitted from the stack. The calculated concentrations are for the single source considered. Where multiple stacks exist for a given single plant this program can be applied to each individual stack. It cannot give the maximum concentrations of the combination of the stacks however. This program is useful in determining what combinations of wind speed and stability produce maximum concentrations. For a given stability the critical wind velocity, that is, the wind speed that causes the maximum concentration, can be determined. This can be done by seeing which wind speed produces the highest concentration for that stability.

Calculations to Determine Volumerric Flow for Flare

To calculate volume burned (CFM) of individual components:

$$\% \times V_T \times \frac{T\ std}{Ts} \times \frac{Ps}{Pstd} = CFM$$

Where % = mole % (vol)

V_T = volumetric flow rate at stack temperature (ft ^{3}/min)

Ts & Ps = temperature and pressure of stack

Tstd & Pstd = standard temperature and pressure

To calculate heat released (Btu/min) for individual component:

CFM x Low Heat Value - Heat released

To calculate Net Heat Release (Q):

$$\Sigma \text{ heat release} \times \% \text{ effective} \times \frac{252}{60} = \text{Net Heat Release}$$

Where Σ heat release = sum of inidividual heat releases

% effective - portion of heat of combustion used to heat products of combustion

$\frac{252}{60}$ = convert Btu/min to cal/sec

To calculate Equivalent Volumetric flow rate (V_F) for a flare:

$$V_F = \frac{Q}{C_{Pp}\ T} \left[\frac{Ts}{Ts - T}\right]$$

Where V_C = equivalent volumetric flow of stack gas at standard conditions (m ^{3}/sec)

Q = net heat release - low heat value (calories/sec)

C_P = specific heat of air (0.24 calories/g ^oK)

p = density of air (1205 g/m^3)

T_x = temperature of stack gas (^oK)

T = temperature of ambient air (293^oK)

SOURCE DATA

UNDERGROUND COAL GASIFICATION PROJECT

Volumetric flow rate (unlit flare)	0.833 m^3/sec
Volumetric flow rate (lit flare)	6.68 m^3/sec
Stack height	9.14 m
Stack Temperature (unlit flare)	588°K
Stack Temperature (lit flare)	1000°K
CO emission[a] (unlit flare)	143.1 g/sec
H_2S emission[b] (unlit flare)	1.15 g/sec
SO_2 emission[b] (lit flare)	33.25 g/sec

[a]Calculated from 15% CO in exit gas.

[b]Calculated from 0.1% H_2S in exit gas.

FLUE GAS COMPOSITION AND NET HEAT RELEASE CALCULATION

UNDERGROUND COAL GASIFICATION PROJECT

Composition (Mole % Vol)	Volume Burned[1] (ft^3/min)	Low Heat Value[2] (Btu/ft^3)	Heat Released (Btu/min)
17.3	152	275	41,800
51.0	448	---	---
14.7	129	316	40,764
12.4	123	---	---
3.3	29	896	25,984
0.6	5.3	---	---
0.1	0.88	560	493
0.6	5.3	1938 (est)	10,271
	Total Heat Release		119,000 Btu/min
	Net Heat Release[3] (Q)		400,000 Cal/sec

[1]Calculation in preceeding assumptions.

[2]Value from Lang Handbook.

[3]20% of the heat of combustion is used to heat products of combustion to convert from Btu/min to cal/sec. (252/60).

VALLEY MODEL ASSUMPTIONS

- Stack aerodynamic effects depends on the ratio of the efflux velocity, V_s, to the crosswind velocity, V.

- There is no downwash due to building effects if the following criteria are met:

  $h^1 \geq h_b + 1.5\ l_b$, and/or the point of emission is $3\ l_b$ downwind from the source causing the turbulence.

- For the gas chromatograph building (the nearest building to the flare that might have any influence on the plume) the wind is assumed to blow directly from it towards the flare.

- The stability category is designated as the most stable class which can exist at the critical wind speed.

- In analyzing for downwash, plume rise due to the momentum flux is taken into account.

- The dependence of ground level concentration with averaging time is approximated by the relation defined by:(2)

  $$\chi \propto t^{-0.185}$$

- When there is stack aerodynamic effects, the effective height of the plume is set equal to the height of the stack.

- For plume downwash due to building effects, the plume downwashes to the ground at a distance of $3.5\ l_b$ from the point of emission.

METHODOLOGY AND RESULTS

- The criteria used to determine if and when the plume downwashes was taken from Briggs', "Diffusion Estimation For Small Sources."(1)

- There are no effects due to any buildings, because there are no buildings within $3\ l_b$ of the flare. The closest building is approximately 140 feet away which is much greater than the $3\ l_b$ (30 feet) criteria.

- An analysis using the data in Table B-1 was conducted. It was found that there would be stack aerodynamic effects at the efflux velocity equal to 1.7 ft/sec. Therefore, there was no plume rise assumed when calculating the ground concentrations from the flare at this exit velocity.

TABLE B-1

STACK PARAMETERS USED FOR CALCULATING GROUND CONCENTRATIONS FROM FLARE

	Gas Exit Velocities (ft/sec)			
	1.7	95	275	325
Gas Temperature (°F)	1450	1450	1450	1450
Gas Pressure (psia)	11.3	11.3	11.3	11.3
Gas Flow Rate (scfm)	30	2500	7200	8500
Emission Rates (gm/sec)				
Particulate Matter	0.1125	0.9375	2.7	2.7
SO_2	0.45	3.785	10.9	10.9
CO	0.00067	0.0556	0.16	0.16
NO_x	0.018	1.528	4.4	4.4

INTERCEPTION ANALYSIS USING THE "VALLEY MODEL" (Reference 4)

DISPERSION EQUATION USED IN VALLEY MODEL (Reference 4, page 2-4)

$$\chi\ (x, y, o; h, L) = 2.03 \cdot 10^6\ QK\ ((c-y)/c)\ ((401-D)/400)\ C$$

$$\cdot \sum_{N=-J}^{+J} \exp\{-.5\ [(H + 2NL)/\ \sigma_z]^2\}$$

$$\cdot \{\exp\ [-(0.693\ Xp)/(3600\ UI)]\}/(\sigma_z\ UX)$$

ASSUMPTIONS

- Concentration is to be calculated at the plume center line, i.e., y = o.
- There is partial plume rise, using Briggs (1971, 1972, reference 3) equation for partial plume rise.
- χ is in $\mu g/m^3$, therefore, C = 1.
- Half-Life (I) of PSD is assumed to be infinite, i.e., $I = \infty$.
- χ is not converted to standard conditions, i.e., K = 1.
- Calculation is for a point source, i.e., Xp = X.
- The mixing height is assumed to be 100 meters above the receptor, i.e., L = H + 100.
- The center line of the plume is always 10 meters above the receptor, i.e., H = 10m.
- Using E stability (stable conditions), and a wind speed of 2.0 m/sec, a persistence of meteorological conditions for 6 hours was assumed. For these conditions, D = receptor elevation - plume height for the interval $1 \leq D \leq 401m$. For direct impaction D = 1m.
- The dependence of ground level concentration with averaging time is approximated by the relation defined by: (Reference 2, page 38).

$$\chi \propto t^{-0.185}$$

METHODOLOGY AND RESULTS

- The following equation recommended by Briggs (1971, 1972) was used to determine partial plume rise. (Reference 3)

$$\Delta h = 1.6\ F^{1/3}\ U^{-1}\ X^{2/3}$$

where:

$$X^* = 14\ F^{5/8} \text{ when } F < 55$$

$$X^* = 34\ F^{2/5} \text{ when } F \geq 55$$

$$F = \frac{g\ Z_f}{\pi} \left[1 - \frac{T_a}{T_s} \right]$$

$$X \leq 3.5\ X^*$$

- Total plume rise is when X = 3.5 X*.

- The dispersion equation used to calculate ground level concentrations after applying the above assumptions for E stability was:

$$\chi\ (x,\ o,\ o;\ h,\ L) = 2.03 \cdot 10^6 Q(401-D)/400) \cdot \sum_{N=-5}^{+5} \exp\ \{-.5[H+2NL)/\sigma_z]^2\}$$

$$\cdot \frac{1}{\sigma_z UX}$$

- The vertical dispersion coefficient was calculated using the equation below. (Reference 4, page 2-8) This equation accounts for surface effects when stacks are less than 50 m high and SIGI is within the limits of 0 ≤ SIGI ≤ 30m, during unstable and neutral conditions.

$$\sigma_z' = (\sigma_z^2 + SIGI^2)^{1/2}$$

where:

$$\sigma_z = a\ Xp^b + d$$

SIGI = (50 - stack height)

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APPENDIX C

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