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Feasibility Study of a New Surface Mining Method "Longwall Stripping"

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FEASIBILITY STUDY OF A NEW SURFACE MINING METHOD "LONGWALL STRIPPING"

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ABSTRACT

"Longwall stripping" is a new surface mining concept developed by the Environmental Protection Agency. Longwall stripping adapts existing underground longwall mining technology for use in recovering shallow cover coal without the total environmental disturbance often associated with surface mining. This study investigated the environmental, mining and economic feasibility of longwall stripping.

Longwall stripping was determined to be a feasible method for mining coal under shallow cover. A discussion of the criteria that is necessary to consider in selecting a site and developing the mining plan is included. Additionally, alternate methods of the longwall stripping concept are discussed.

This report was submitted in fulfillment of Contract 68-01-0763 under the sponsorship of the Office of Research and Development, Environmental Protection Agency.

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SECTION 1

CONCLUSIONS

1. Longwall stripping is a technically feasible method for extracting coal at shallow depths utilizing present technology for some known coal seams.

2. Longwall stripping utilizing present technology is feasible for either area or contour surface mining.

3. Longwall stripping for shallow cover coal will produce significantly less environmental disturbance than other known mining methods.

4. The economics of longwall stripping will be dependent on the rate at which coal can be produced. This rate will be influenced by the physical conditions of the site and the application of equipment and systems. Economic feasibility will also require either ample contiguous reserves or numerous, scattered reserves which will enable rapid placement and removal of the longwall system. However, it is concluded that where longwall stripping is applicable the cost per ton of coal at the mine will be less than produced from large deep mines but more than from most "conventional strip mines."

5. Longwall stripping and its variations, if developed, can be utilized in many coal reserves that are presently surface mined. It can also be used for recovering coal from many areas where either surface or underground mining is not permissable or practical.

SECTION 2

RECOMMENDATIONS

1. In order to establish meaningful environmental and operational data it is recommended that a demonstration mine be implemented.

2. The following mining conditions are recommended for the first demonstration of this method:

(a) The coal seam should be at least 48 inches thick with economics improving with increased thicknesses.

(b) A strong eight to ten foot thick sandstone or consolidated shale member immediately above the coal is preferred.

(c) The floor should be strong, preferrably shale, and reasonably impervious to water.

(d) A flat or slightly upward pitching coal seam with surface topography conducive to good drainage and drainage ditching is preferred. This will reduce the tendency of slush or mud to enter the mine through fissures caused by caving, thus avoiding or minimizing the need to install pumps and discharge lines.

(e) The coal seam should be of uniform thickness and be free of serious undulations or heavy pyritic intrusions.

(f) A readily marketable coal.

3. The following are the recommended factors to be considered in selecting equipment for the first demonstration mine:

(a) A drum shearer, mounted over and travelling on or along the conveyor pan, should be used. Consideration should be given to the use of a double drum ranging arm shearer because of its higher production capacity over a single drum shearer. However, the double drum shearer will require a thicker coal seam.

(b) Chocks and conveyors should have ample cross-sectional area between front and rear legs to permit installation of a 24 to 30 inch diameter ventilation tube between the hydraulic legs in order to provide at least 3,000 cubic feet of air per minute delivered to within 10 feet of the inby end of the face. Additionally, there should be room for the movement of men between the chocks and the conveyor.

(c) Chocks should be selected to quickly move under the newly exposed roof behind the advancing shearing machine in order to provide immediate roof support.

(d) Chock movement in groups by bank control could be used.

(e) Chock movement by remote control should also be considered.

(f) Heavy duty chocks, capable of being regulated as to yield pressures, with wide canopies to achieve maximum roof coverage and minimum psi at yield loads are recommended. The base area should be ample to minimize floor pressure at the yield rating of the chocks.

(g) Because of the critical nature of the outby area (highwall) it is recommended that buttress supports, packwalling, or stowing, special shielding, resen bolting or other highwall support methods be considered.

(h) A continuous and steady operation preferably three shifts per day, five days per week is recommended to reduce the possibility of stress build-up due to settling over long idle periods.

4. It is recommended that after the site has been selected, and prior to finalizing the mining plan consideration be given to the variations of longwall stripping in particular "shortwall stripping."

SECTION 3

INTRODUCTION

The long-term and more recent dramatic increases in the production of coal by surface mining methods has caused concern over environmental degradation in many areas. The recent dramatic increases in surface mine produced coal can easily be seen between the years 1969 and 1970 when production increased from 197,023,000 to 244,117,000 tons, a one year record unprecedented in the history of the coal industry of the United States.[1] More current records show a continued increase in strip mining activity to reach a new high of 259,000,000 tons for 1971, which accounted for 46.9 percent of the total U.S. coal production. During 1971 an additional 316,200 acres or 4,650 acres per week were disturbed by surface mining.[2,3]

The present alternative to surface mining for coal is underground mining. While this method for mining coal could possibly supply the coal requirements of the Nation, it to is beset with problems. However, the scope of this study is not to focus on the possibility of abolishing strip mining nor an investigation of one mining method versus another, but to determine the feasibility of a new surface mining method, often called "longwall stripping," that can substantially reduce environmental disturbance. Mining in this manner is visualized as allowing needed strippable reserves to be recovered with a minimum of disturbance to land and water resources.

The new mining method, longwall stripping, was developed by EPA as a possible answer to some of the problems caused by surface mining. (Refer to Appendix A). If a conventional longwall mining system could be advanced at right angles to a narrow trench or along a strip mine highwall, a number of benefits important to the environmental and energy crisis could be achieved. Strippable coal could be mined without destroying all the overlying vegetation. Such a mining system could also achieve complete coal extraction, total resource recovery. This greatly reduces the chance of long-term environmental problems such as uncontrolled subsidence and acid mine drainage. The resulting caved area should be more completely sealed, reducing or eliminating the channels which act as tributaries for the eventual release of acid mine drainage.

This study discusses the economic and technical feasibility of longwall stripping and presents the conditions that should be considered in demonstrating this new mining method.

SECTION 4

STATE OF THE ART

Literature Survey

Some information is available in the literature on the general subject of strata control relating to the stratigraphic action likely to develop in longwall stripping. Part of this information relates directly to shallow depth mining[3,4,5,6] while the remaining information involves situations such as extracting coal from destressed areas that have been previously under mined.[7,8,9] However, information on longwall mining systems running under extremely shallow cover or "open end faces" is minimal and no experiences of longwalling with "open-end faces" is recorded. A study of many technical articles and commercial brochures covering longwall roof control has been made, and a brief discussion of strata control follows.

Strata Considerations[9,10,11,12,13,14,15,16,17]

In longwall stripping the theories of strata control are somewhat similar to those employed in conventional longwall mining in underground mines; the immediate roof strata above the coal must be supported and allowed to cave in such a manner to allow controlled support and caving of the upper strata. As the longwall face advances, a desired sequence of events should take place generally as follows:

(a) The immediate roof sags away from the stronger higher strata.

(b) The immediate roof is relieved of the load of the upper overburden.

(c) As the chocks advance the roof span increases until caving of the immediate roof occurs creating a cantilevered shelf which extends out from and is maintained by the supports, and a breaker line is formed at or behind the chocks to shear and cave the overhanding immediate strata.

(d) The caved immediate roof material expands to fill the void in the mined area and the upper roof forms a span between the gob material and a line where the immediate roof has separated from the upper roof over and near the advancing wall face, conditioning the roof strata for caving and the coal for mining.

(e) Most of the roof pressure is distributed between the solid coal ahead of the advancing face and the gob. The supports merely maintain the relatively light load of the immediate roof.

However, longwall stripping, as opposed to conventional underground longwall mining, can be expected to be carried out under extremely shallow cover ranging from 30 or 40 feet to not more than 200 feet from outby to inby end of the face, while conventional longwall mining is generally done under 400 or more feet of overburden. A combination of (a) massive or too competent roof strata that had not been subject to the normal conditioning stresses imposed by heavier and deeper overburden, and (b) shallow cover, will generally require heavier duty chocks than deeper cover longwall mining conditions, and the need of heavy duty roof supports in longwall stripping can be anticipated.

On the assumption that sites selected for longwall stripping will have general roof, bottom, and gradient characteristics to warrent a demonstration application, we would expect fairly normal roof action along the face except on the outby or open end.

When the chocks are in place in the initial development entry the exposed roof will be supported on the solid coal to be mined, the chocks, and the solid coal behind the chocks. As the longwall face advances, the width of the strip of unsupported roof behind the chocks will increase and remain up, but with some deflection, as a uniformly loaded beam supported by the back canopy of the chocks and solid coal. Deflection will vary according to strata acting as the beam, and when the width of the opening is increased to the point that the strata will no longer support the uniform overburden load, the strata beam will fail, usually in shear, to form the shelfs at the back end of the chocks.

It is anticipated, with an open end face as in longwall stripping, that the deflection of the roof strata at the outby or open end of the face could cause horizontal movement of the unconfined strata resulting in a fall of overburden out into the faced up area where the longwall controls, pumps, and face conveyor discharge end are located. For this reason, it is anticipated that special "buttress" chocks and possible packwalling will be necessary at the outby end of the face.

Prior to the failure of the roof strata behind the chocks and when the unsupported width of the open area is at its maximum, a maximum load will be imposed on the back legs of the chocks. The ability of the roof strata to remain unsupported will vary from strata to strata and chock yield loads and structure strength should be sufficiently high to withstand what is commonly known as the "pressure wave."

After the initial failure of roof strata in shear behind the chocks, the roof will then be supported by the unmined coal face and the chocks. As the face advances and chocks are moved ahead, the strata left unsupported will hang back and act as a cantilevered beam supported on the chocks with the unsupported end extending back into the mined area or "gob." If the immediate roof strata is sufficiently strong so as to resist failure in shear and hangs back a long distance into the gob, the resultant total overburden load on the back of the chock could become very high until actual failure in shear behind the chocks occurs.

Sufficiently heavy duty chocks can overcome this load along the interior of the face, but again, special "buttress" chocks and a packwall at the open end of the face are anticipated as necessary to eliminate this high cantilever loading at the outby end of the face, with resultant horizontal movement and collapsing of the overburden along the highwall.

In planning longwall stripping along the outcrop of a coal seam it is important to recognize that weathering and surface seepage may have made the immediate roof strata and bottom strata less firm and solid than those same strata would normally be at greater depths. This, of course, will vary from seam to seam, but in general, must be taken into account when chock bearing areas, top and bottom, are selected so that proper variability of yield loads is provided. The chocks must support the roof, but must not allow the roof to be crushed or the bottom penetrated when the chocks are set or when loads approaching yield load are imposed on the chocks during the so called "pressure waves."

Since the possible necessity of packwalling the outby end of the longwall stripping face behind the chocks to prevent excess stresses that could cause horizontal movement of roof strata and consequent highwall collapse is recognized, a system, method, and means of doing this must be provided. There appears to be several options such as (a) building packs manually with timber, concrete blocks, rock, etc., (b) pushing dirt and rock into the mined area mechanically, (c) crushing and blowing mine waste material using pneumatic stowing systems currently in use in Europe, and (d) using a precrushed material such as power fly ash and pneumatic stowing equipment.

Considering all the apparently desired factors for the first demonstration mine it is suggested, due to the low cover, the open end face and mining an outcrop area, that successful longwall stripping could most likely be carried out in areas having the following general physical characteristics:

(a) A firm coal seam of fairly uniform thickness between 48 and 72 inches, relatively free from pyritic intrusions, and fairly level or slightly rising from the outcrop in the proposed mining direction.

(b) An immediate roof strata of a fair to medium sandstone or firm shale between 5 and 10 feet in total thickness.

(c) A firm strata of laminated shale, 8 to 10 feet thick above the immediate roof. This strata, along with the immediate roof in (b) should be firm enough to allow almost vertical walls when the outby bench is formed.

(d) A firm, fairly hard bottom, somewhat impervious to water, which parts freely from the coal.

While the above characteristics are desirable and are recommended as necessary for any demonstration site, it is quite likely that, as more experience is gained in the art of longwall stripping, methods and equipment revisions and innovations can be made to overcome most physical shortcomings of the seam and strata.

Equipment Survey

Longwall systems have advanced from the old heavily timbered longwall employing center packs to the manually placed mechanical jack and, most recently, to the modern self-advancing hydraulic roof support system.[17,18,19,20,21] Modern longwall offers many options and, when properly applied, is known to be capable of achieving outstanding production performance. This outstanding record is frequently achieved because companies tend to place longwall systems in reserves of the highest physical quality. This choice is especially timely when the installation represents a companys first application of a longwall system.

Builders of modern longwall systems offer many options to increase potential for successful application. (Refer to Appendix B). The optimal mating of these options to stratigraphic conditions is the key to a successful installation. Some currently available options and conditions that commonly lead to their selection follow:

Coal Getting Machines

Cutters and Plows - Where applicable, plows are the preferred method for cutting coal. Conventional plows find application with friable coal and/or with coal under deep cover, where advantage can be taken of the natural crushing action that takes place as a result of the high arch pressure along and behind the coal face. Plows are capable of operating in thin seams under 48 inches and they do not require an attendant while in progress at the face. Because plows generally merely shave or plane a coal seam, the resulting narrower web exposes a minimum of new roof with each pass. Hence, the self advancing hydraulic roof support system does not need to extend as far back toward the gob area and, therefore, requires less elaborate and robust construction than an equivalent shearer equipped section. Finally, plows do not tend to grind coal as do shearers and, therefore, in some applications they produce less gas and dust. However, plows need a tail entry or an offset opening, generally called a "stable hole" on the inby end of the face to cut into if unidirectional or to turn around if bi-directional, and this would be a handicap to the initial demonstration of longwall stripping. Several new type plows are in successful operation in the United States and Europe in mining conditions that have been traditionally considered unappropriate for plowing. This success could broaden the use of plows and result in additional options to increase the flexibility of longwall mining.

Shearers - Shearers were developed to facilitate longwall mining in the many physical conditions that could not be worked with plows. The shearer is the most popular coal winning machine used in longwall mining throughout the world. It can be used to mine either narrow 12" webs or up to about 30 inches as determined by conditions. Shearers are fairly compact machines, self-propelling, and with ranging arms, capable of readily adapting to changes in mining height or gradient. Recent experiences in this country indicate that these units generally require less total horsepower per ton/minute capacity than do our continuous miners, and shearer maintenance costs have been proven satisfactory. Actual productivity of the shearer is simply determined by the depth and height of the cut and the cutting speed along the face. Generally, it has been seen that transportation facilities outby the longwall faces are the limiting factors in achieving shearer productivity.

Self Advancing Hydraulic Roof Support Systems

Chocks and frame supports are currently used in America. Chocks are almost entirely used with shearers while either chocks or frames are used with plows. Frame supports are highly flexible but require skillful operations to maintain alignment as the face advances. Chocks are aligned with the conveyor and require less operational skills. Self advancing hydraulic roof supports can be obtained with various options including immediate roof support capability behind the advancing cutter, walkway between the conveyor and props, bank control for semi-automatic chock advancement, oversized bearing surfaces for the roof or floor, heavy duty hydraulic legs, choice of prop and bearing surface configurations, extendable front and rear supports, slush guards, etc. Where very friable or fractured roof conditions exist, roof strata breaking up and falling into the chocks can be quite a problem. To counteract this, new designs incorporating "flushing shields" have been marketed and used successfully.

Conveyors

Conveyors account for only a very small percentage of the total downtime in longwall installations. Longwall conveyors generally consist of a heavy single or triple strand drag chain with center mounted and evenly spaced flights positioned within a rectangular trough extending the full length of the longwall face. One important consideration is the "snaking" length of the conveyor. A short snaking length has advantages in that, with some hydraulic support systems, more rapid roof coverage can be achieved. This advantage, however, may be offset by the tendency toward greater conveyor wear.

Current Practice

Longwall mining with self-advancing hydraulic chocks had its first U.S. application in West Virginia in 1960. European miners had little choice but to utilize longwall mining, but in this country longwall had to compete economically with high production room and pillar systems. The productive potential of this mining method is now recognized throughout the industry and a little over 4 percent of our total tonnage now comes from longwall faces.

European mines generally have conditions which are extremely difficult to hold pre-driven entries open and consequently employ advance longwalling wherein travel and haulways are created by supporting areas in the gob behind the advancing face. However, in this country, with better conditions and high production entry driving equipment, travel and haulways are pre-driven and the longwall face "retreated" between sets of entries.

The advent of more comprehensive regulations regarding personnel protection from roof and dust along with more rigid required ventilation practices have increased the interest and incentive for U.S. mines to adopt longwall mining. Today there are over 50 longwall faces in operation with shearer faces outnumbering plow faces, and extreme interest indicates a rapid increase in the number of faces in the near future.

All longwall faces are in underground operations with face lengths varying from 300 to 600 feet in length and under cover of from 200 to 2500 feet or so in isolated cases. As stated previously, no experience has been gained in operating an open end face as contemplated in longwall stripping.

In almost every instance, operating companies indicate that their lowest cost underground production is from longwall faces. Additionally, much higher coal recovery is possible from the longwall system of mining than from conventional room and pillar methods.

SECTION 5

SITE CONSIDERATIONS

Site Selection Guidelines

With the first attempt at longwall stripping, a site in a flat area or in a mountainous area with long, straight valleys where the coal is located close to the surface or valley floor should be considered. A long and straight strip mine highwall also offers a potentially attractive site for the first demonstration mine. While longwall stripping could probably be used to run a contour where the face would necessarily turn to follow the outcrop, it is suggested, that because of the many mining and environmental problems that will require sound engineering solutions, this first mine only consider a straight run operation. This of course is not meant to imply that production rates would not decrease when turning. However, since ample evidence exists that longwall faces are being turned this problem should not be one of the more critical. Longwall mining equipment systems offer enough options that mining should be technically feasible under most conditions. Additional considerations for this first demonstration mine are as follows:

1. Reserves should be ample to insure that equipment can be profitably depreciated.

2. The site should be accessible and means should be available to transport the coal to previously established markets.

3. Physical features associated with the site that are considered to be desirable are a coal seam between 48 inches and 72 inches thick. A strong sandstone or shale member, perhaps 8 to 10 feet thick, should be located over the coal. Additionally, a strong 15 foot thick shale located above the sandstone, especially on the outby side, is desirable. The floor should be strong. A flat or slightly upward pitched seam can facilitate drainage and reduce or eliminate the need to install face pumps. Surrounding surface topography should be conducive to good water runoff to lessen the possibility of mud and slush from entering the mine through fissures caused by the shallow caving action. Also, the coal seam should be of uniform thickness and free of undulations and intrusions.

Areas For Possible Application

It is not possible to produce authoritative estimates of areas of the United States where a successful longwall stripping system could be employed, since the full range of conditions under which this system or variation can operate is not yet known. Methods used to report strip and deep mineable reserves are based on certain present and presumed mining equipment systems and economics. Strippable coal occurs in 28 of the 50 states. The state with the most strippable reserves of coal, regardless of type, is Wyoming (13.971 billion tons) followed by Montana (6.897 billion tons), Alaska (4.411 billion tons), Illinois (3.247 billion tons), New Mexico (2.474 billion tons), West Virginia (2.118 billion tons), North Dakota (2.075 billion tons), Kentucky (1.758 billion tons), Texas (1.390 billion tons), Missouri (1.160 billion tons), Indiana (1.096 billion tons) and Ohio (1.033 billion tons). Reserves of approximately 3.451 billion tons are located in the remaining 16 states.[22]

A most likely location for the application of a successful longwall strip mining operation would be in a rural area containing the combination of shallow, presently strippable coal reserves coupled with rich agricultural or forested lands. Such an area should also be located near population centers, rail heads, river or power plant, where the coal would most likely be used. Coal in these locations should be of suitable thickness (between 4 to 6 ft.), and a well developed system for distribution of the coal to surrounding markets should be in operation. Coal reserves that most appropriately fit the preceding description occur in greatest abundance in Illinois, West Virginia, Kentucky, Missouri, Indiana and Ohio.

SECTION 6

THE MINING SYSTEM

The objective of this feasibility study was to determine how longwall stripping could be utilized in recovering shallow cover coal with minimal environmental damages. Several constraints were placed on the study of which the most important from the mining consideration was the use of existing equipment. Additionally, if the concept was determined feasible, a mining system was to be suggested that could be utilized in a demonstration mine proving the concept. While the suggested mining system may not demonstrate the answers to every question, it is believed that a successful demonstration of this concept will provide the answers to the major questions posed in a mining-environment balance.

It is proposed to open a long, straight and narrow trench into a coal seam in a flat area or slightly above the floor of a valley, and longwall strip at a right angle to the side of the trench. This should allow extraction of coal with minimal disturbance to the environment and be economically feasible. Figures 1 through 4 are included to illustrate arrangements that might be used in a demonstration of longwall stripping. Because this concept involves a number of mining considerations, each consideration is discussed separately in the following sections.

Health and Safety

Whether the seam is opened and the longwall equipment set up in an open trench or in an entry driven in from the highwall, the ventilation of the longwall face seems quite simple. The installation of a suitable portable exhaust fan outby the entrance to the face with suitable tubing extending through the chock line to the tail end of the face should assure a minimum of 3000 cfm of fresh air continually flowing inby along the face and into the tube at the tail end.

Since all personnel would normally be outby the shearing machine during mining, any dust produced should be carried toward the tail with the fine dust being picked up by the ventilation tubing and discharged into a dust collector located outside. The fan location would be such as to avoid the possibility of recirculation.

All personnel required to be underground during mining or for any reason would be continually under the steel chock canopies and not exposed to unsupported roof.

Suitable emergency controls, lights, paging or communication systems etc. would be installed even though the end of the face would be only about 250 feet from the surface opening.

Suitable personnel protection from any highwall material would be furnished by self advancing steel canopies of proper area and design.

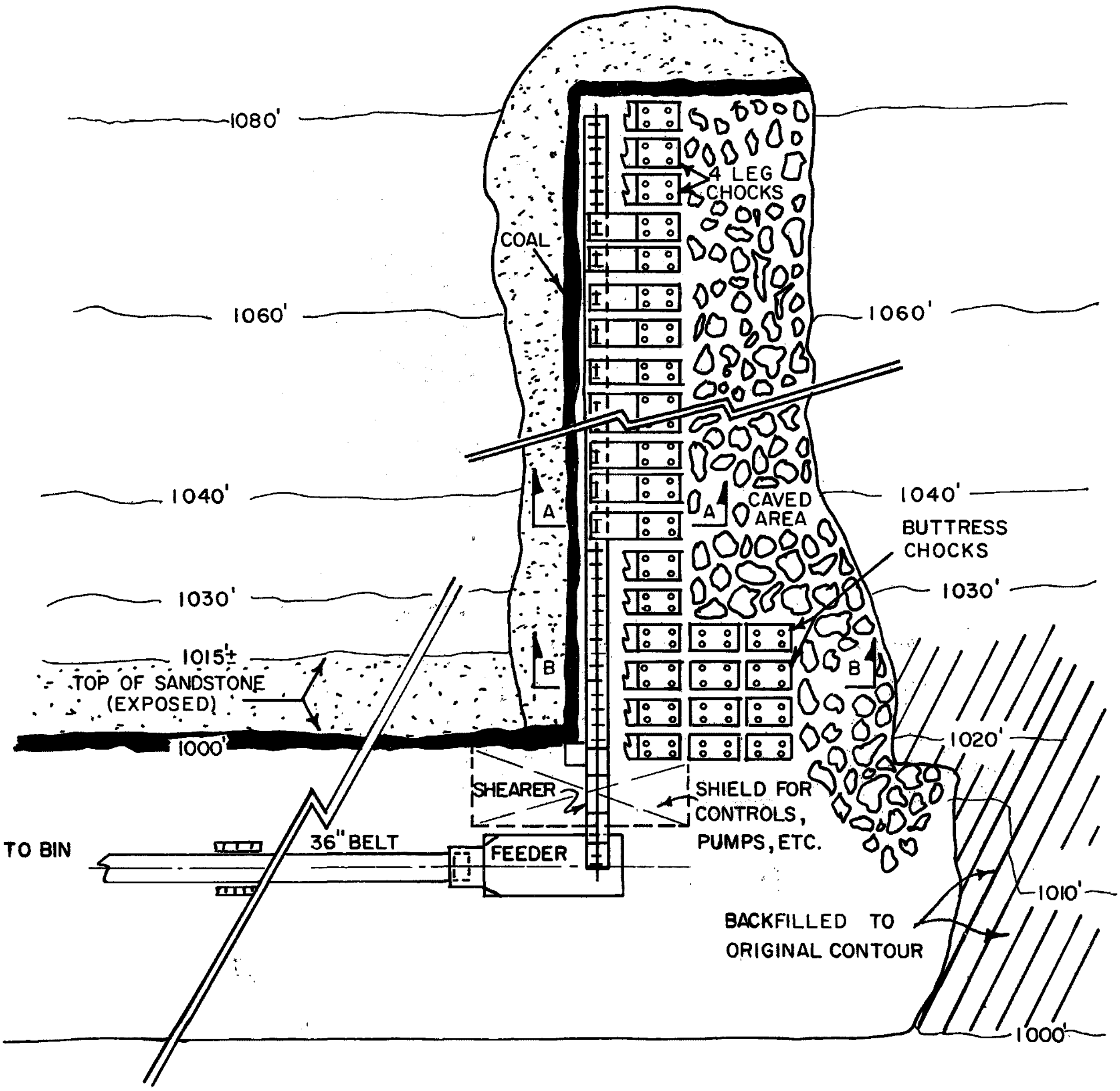
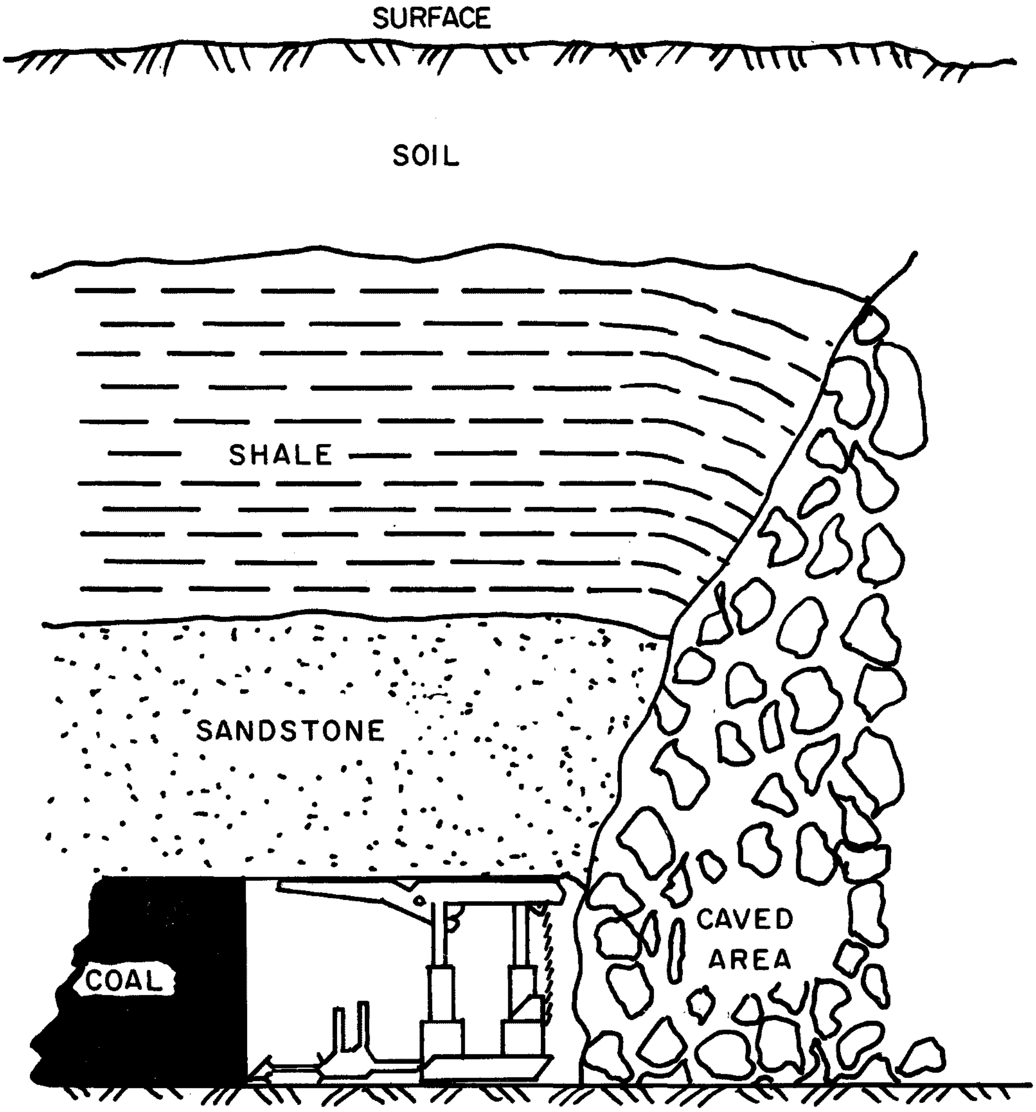


Figure 1 - PLAN VIEW OF LONGWALL STRIPPING SYSTEM



SECTION A—A

Figure 2- TYPICAL CROSS-SECTION VIEW OF LONGWALL STRIPPING SYSTEM

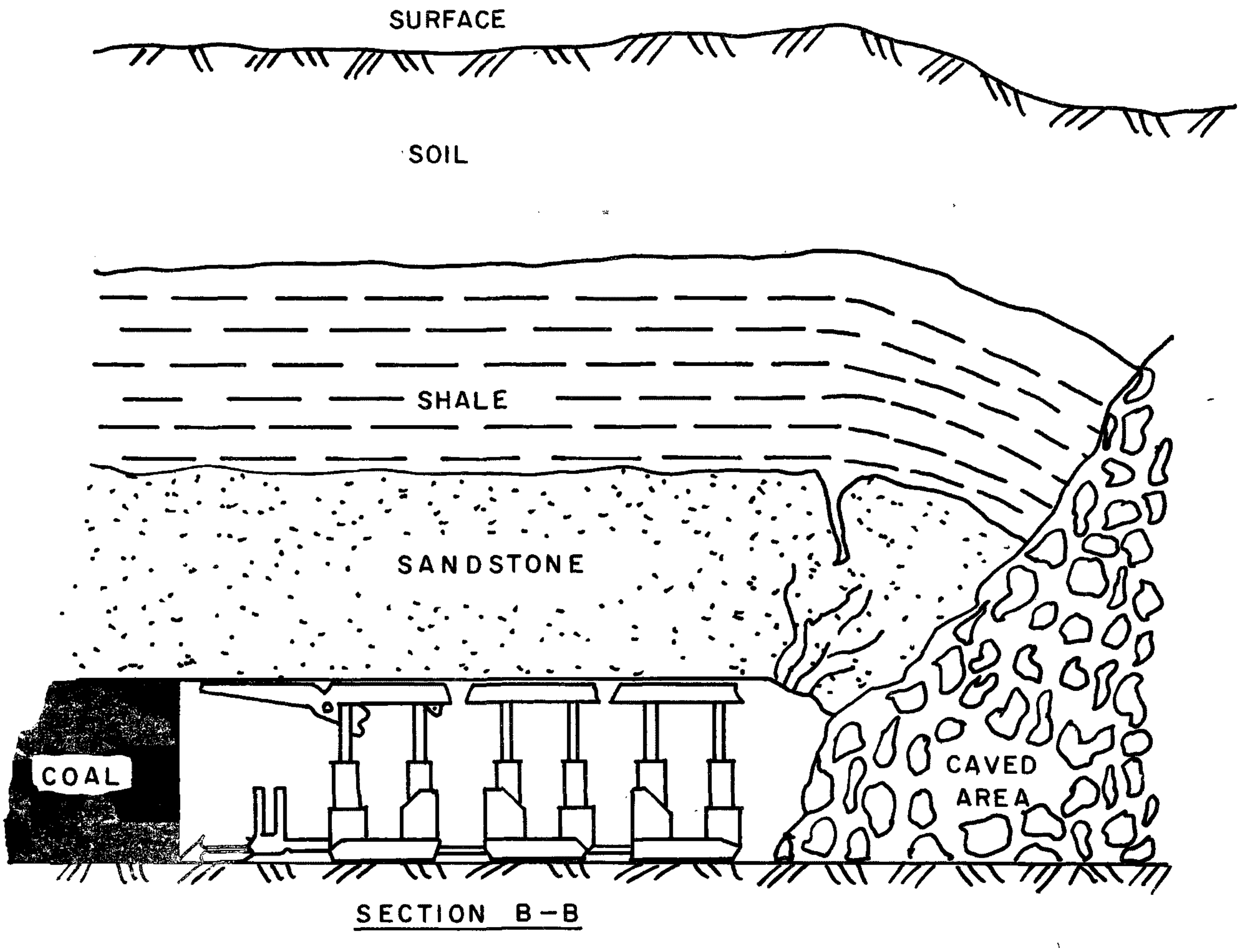


Figure 3- CROSS-SECTION VIEW OF LONGWALL STRIPPING SYSTEM ALONG HIGHWALL.

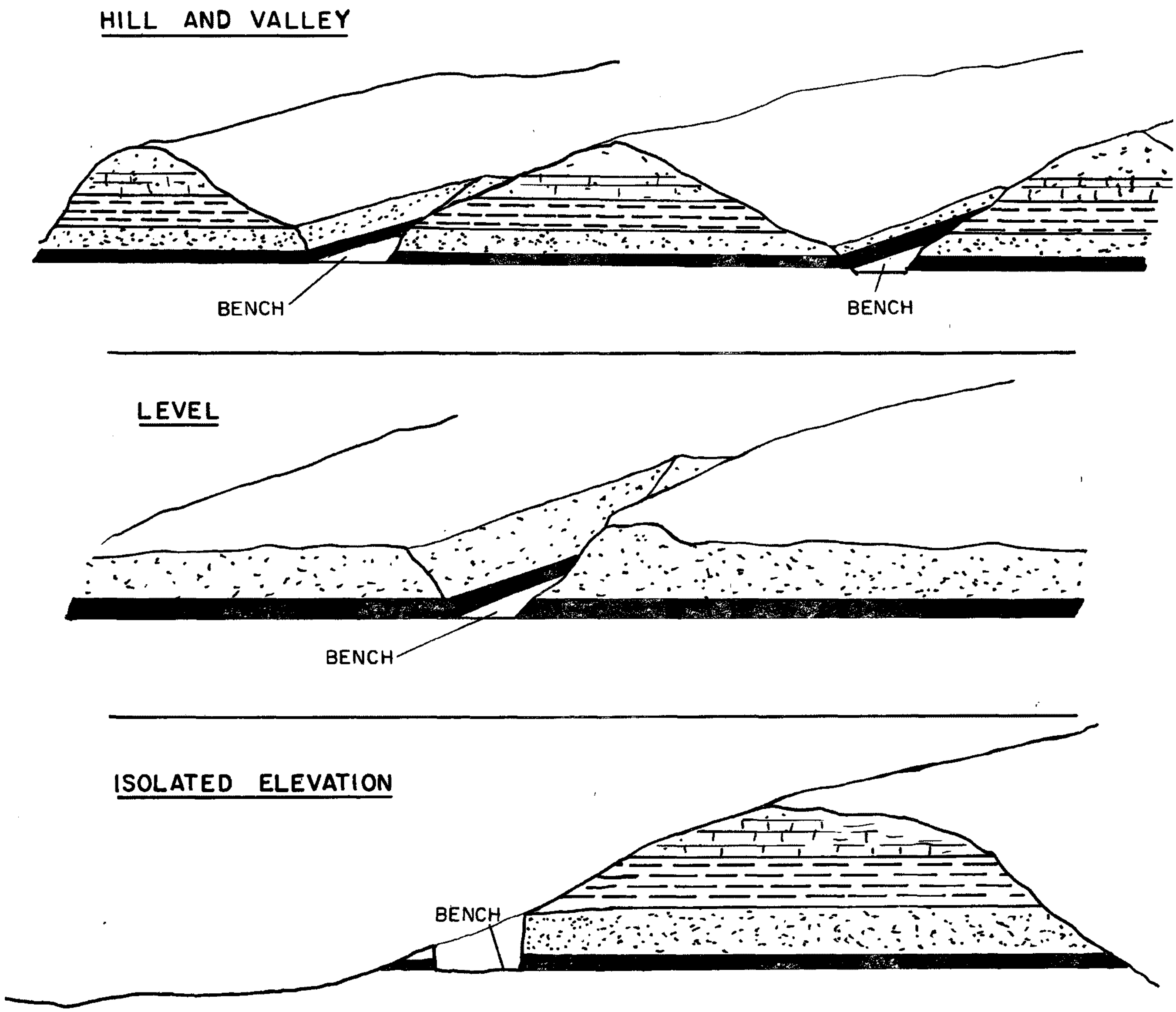


Figure 4- VARIOUS TYPES OF TERRAIN APPLICABLE TO LONGWALL STRIPPING SYSTEM

Self Advancing Hydraulic Roof Support

Since production from longwall faces depends on the successful operation of three interlocked systems involving hydraulic roof support, cutters and conveyors, the failure of any one system will cause production stoppages. Of the three systems, the hydraulic roof support is undoubtedly the most critical. Chocks or frames are used for hydraulic roof support. Chocks, which are most applicable to this project, should have sufficient area between the front and back legs to permit extending a 30 inch diameter ventilation tube to within 10 feet of the inby or solid end of the longwall. The size and bearing capacity of supports used in shallow mines are always constructed for the heaviest duty, and similar applications in longwall stripping would be no exception. It is very important that when a chock is lowered, the roof remains in place long enough to permit the chock to be placed back to its original elevation. If the roof is punctured and settles around the chock or if the roof converges, the chock will be repositioned at lower and lower elevations and eventually be unable to advance. Therefore, large roof and floor bearing surfaces should be used. Additionally, to minimize the load on the chocks, the chocks should be selected to minimize the length to which they extend back away from the face and into the gob. However, this extended length should not be restricted so as to interfere with the movement of men or with the placement of the ventilation tubing.

Since the most critical area for the mine is at the outby end, or entrance, three or four chocks should be equipped with cantilevered, buttress supports extending back into the gob to help control roof breakage and facilitate orderly roof failure along this critical highwall area. Frame type or self advancing canopies may be useful for protecting men from rock falls along the highwall adjacent to the entrance to the longwall. Additionally, consideration should be given to a combination chock "highwall canopy" for additional safety.

In order to maximize the roof control, a system that will permit the advance of chocks immediately behind the shearer as it passes should be considered. This feature is particularly desirable where bad or friable roof is involved. Some designers believe that the potential answer to close in roof support should be sought through the use of a shorter snaking conveyor.

Although complete automation of the operation of the chocks from the trench is possible, such a feature may not, at this time, be needed. Instead a bank controlled method of automation for moving the chocks should be considered. With this method only one man is used to advance six to ten chocks from a single position. With bank control, all of the chocks along the longwall face could be moved by a single miner from different positions resulting in a less expensive, automated chock system. Another factor in the decision to automate the chocks, is that underground visibility is considered to be limited to 10 meters, about 30 feet, and this distance is equivalent to the length of 6 to 10 chocks. Hence, the bank control of 6 to 10 chocks would result in a form of "on-sight" automation.

Shielded chocks, although more costly, may find application when longwall stripping in areas containing unconsolidated strata above the coal seam. Roof strata of this type would be ideal from the standpoint of ease and economy in uncovering the trench, however, problems are envisioned if an entry is driven for the initial set up of the longwall. It is entirely possible that future developments could favor longwall stripping of shallow seams with extremely loose overburden using shielded chocks.

Although hydraulic roof supports seldom fail, when they do fail it is usually due to one of two causes:

(a) They become "solid" where the hydraulic prop is either gradually or suddenly compressed to its lower limit and is therefore incapable of being moved. This condition requires that the roof above the prop be shot-out to permit removal, a very time consuming procedure.

(b) Hoses and fittings may rupture if excessive pressure is sudden and/or if hydraulic releasing mechanisms are not fast acting.

<u>Cutting</u>

Unless both ends of a longwall stripping mine are open to the fresh air the use of a plow for longwall stripping should not be considered. Moreover, plows work best with friable coal under deep cover where the weight of the strata above tends to crush the coal making the face more amendable to plowing. Therefore, shearers are considered as the best choice for cutting coal in the first demonstration mine.

The use of a double drum shearer which would cut coal in one direction and flit back to repeat the cycle should yield the highest rate of production. However, a single drum ranging arm shearer with the drum on the inby end should be given serious consideration. Sumping features for the double drum were not considered desirable, since it can take as long to sump the double drum into the solid coal at the back end of the wall as it would to flit the double drum back. The use of a single drum shearer cutting the top of the seam and then brought back along the bottom may not have the production potential attainable with a unidirectionally operated double drum.

The automation of shearers has long been handicapped because of consistent failure to develop a probe capable of sensing where the coal ends and where the roof or floor begins. In the absence of such a proven sensing device, it appears that existing technology and economic constraints will require the shearer to pass three manned chock stations. If these men are removed, then an additional research effort will be needed to find methods to automate coal cutting with shearers. While there is not presently a proven probe, current work in this area may have advanced to a level for consideration during the demonstration mining operation.

Conveyors

Since the longwall stripping concept calls for a face conveyor 300 feet or less in length with the discharge end outside, it is likely that a single strand conveyor, running at the proper speed, and with one or two motors at the discharge end would be advisable for the demonstration project.

SECTION 7

ECONOMIC EVALUATION

A 250 foot longwall strip mine located in a 48 inch thick coal seam should be capable of producing about 100 tons of coal per pass of the shearing machine, assuming a 30 inch web cut. It should be possible to make 4 to 5 passes to produce from 400 to 500 tons per shift for an average shift production of 450 tons.

Although it is believed that as few as two men underground per shift could operate the mine with automated chocks, under favorable conditions, it is also possible that as many as six men might be needed, under less favorable circumstances. If only two men were needed underground, one man would be used to operate the shearing machine while the other man would operate the automated chocks. If six men were needed underground, two men would operate the chocks, one man would operate the shearer, one man would assist with shearer operation as a mechanic, one man would be stationed near the tail end and one man would be stationed in or around the outside entry.

In addition to the underground employees, an outside force is envisioned which could range from as few as two to as many as six men. If only two men were needed outside, as a result of an existing exposed highwall, one man could be a general mechanic while the other man could be stationed at the outside end of the longwall. If as many as six men were needed outside, to excavate a trench or highwall, one man would be a dozer operator, one man a small shovel operator, one man a grader operator, one man a rubber-tired loader operator, and two men would be needed for stabilization of the highwall and for operation and maintenance of outside coal conveyence and removal equipment. Other combinations of manpower are possible, depending upon conditions, but the range of manpower needs is believed to include most foreseeable situations. The role of foreman could be combined with one of the previously mentioned jobs.

In addition to the preceding manpower needs, most of all of the following equipment would be required. Equipment is listed together with approximate cost.

<u>Underground Equipment</u>

A. Chocks

56 - 4 leg 500 ton units @	$ 9,000 each
4 - 4 leg 500 ton pack chocks @	$ 12,000 each
4 - 4 leg buttress chocks @	$ 12,000 each
1 - Power pack, pumps, tanks, etc.	$ 18,500 each
1 - Set of line hoses and fittings	$ 7,000
Remote control system	$155,000
Stowing machine and compressor	$ 50,000
Canopy at highwall	$ 10,000

B. Shearers

Single drum unit	$160,000
Double drum unit	$190,000

C. Face Conveyor

Basic price (250 foot long)	$ 40,000
Accessories including ramp plates, tube guides, spill plates, etc.	$ 40,000

D. Power Center and Controls $ 50,000

Surface Equipment

Shovel (2 1/2-4 yd)	$120,000
Dozer with ripping attachment	$143,000
Highlift	$160,000
Grader	$ 80,000
Drill	$120,000

In consideration of two separate mining operations one being the underground longwall face, and the second being the construction of the trench, an effort was made to arrive at an average cost for the combination of production from both operations.

It is projected that the longwall face will progress approximately 33 feet per day. To accommodate this advance rate the construction of the trench will also advance at approximately the same rate. The trench width would be approximately 30 feet wide, progressing 33 feet per day in a coal seam of at least 4 feet in thickness would produce about 150 tons per day or approximately 36,000 tons per year. The tonnage of the trenching operation, being at the outcrop, would be blended with longwall mined coal or maintained separately depending on available markets. In the following table of costs we have inserted a cost of $10.00 per ton or $360,000 per year for all outside construction which includes site maintenance and final restoration.

Tons/shift	450	longwall face
Tons/day	3x450 = 1350	longwall face
Tons/year	200x1350 = 270,000	longwall face
Tons/day	150	trench excavation
Tons/year	240x150 = 36,000	trench excavation

Total tons/year produced 306,000

Longwall labor	$0.875/ton
Longwall supplies	0.400/ton
Longwall power	0.200/ton

Longwall labor, supplies, power $1.475/ton

Depreciation	$0.750	
Royalty (UMWA)	0.800	
Taxes, Ins., etc.	0.400	
Royalty (coal)	0.500	
Longwall royalties, depreciation, taxes, ins., etc.		$2.450/ton
Total Longwall cost	$1,059,750/yr	$3.925/ton
Total Outside cost	$ 360,000/yr	
Total production cost at site	$1,419,750/yr	
Trucking ($.80/ton)	$ 244,800/yr	
Tippling or processing ($.25/ton)	76,500/yr	
Highwall stabilization (if necessary)	153,000/yr	
Administrative & engineering	92,000/yr	
Total cost of 306,000 tons	$1,986,050	or $6.49/ton

NOTE: Estimates are based on 7-year equipment write-off period using straight line depreciation. Labor is estimated at $55 per man per shift. Costs are for coal delivered to the mine loading bin and prepared for delivery.

Costs might range substantially depending upon the mining conditions encountered. These costs are comparable to some strip mining costs and fall below most deep mining costs. If poor mining conditions are encountered, even with well proven and long established mining systems, mining ventures can be unenconomical. Hence, the success of a longwall strip mine installation will depend as much or more on site selection as with any other, less experimental, mining venture.

SECTION 8

ALTERNATIVES TO THE SYSTEM

In the study of the concept of mining coal under shallow cover utilizing underground longwall mining technology, several alternates or modifications become readily apparent. The most significant development for making this new mining method feasible was the recent advances in self-advancing remote control roof support systems. With the ability to control the strata above the coal now technically possible, several alternatives to the original concept of longwall stripping appear viable and possibly more attractive. These are:

1. A shortwall mining system which is a continuous mining machine and a continuous haulage conveyor used to cut inward along the face and at right angles to the highwall. The roof support system would be similar to those previously discussed and are similar to those specially built chocks that are presently being used with underground shortwall installations. The shortwall has all of the advantages of the longwall except that supporting the ends would need further consideration.

2. By driving two shallow and parallel slopes, spaced 300 to 600 feet apart, into a surface mineable coal seam the longwall mining between and behind the advancing slopes, would also appear to be advantageous. The advantages are that it would not differ too greatly from conventional longwall underground mining and, except for the shallow location of the strata control techniques that need proven, should be deemed less experimental. Very little vegetation would be destroyed, since an open cut trench would not be needed. Additionally, since ventilation would follow routine procedures, the limitations to longwall stripping that may be caused by some local mining laws would be eliminated. The disadvantage is that additional men and one or two continuous mining units would be needed underground.

3. The use of a continuous mining machine coupled with the longwall roof support system would have certain advantages and disadvantages. The advantages are that the continuous mining units could be used to develop a single line of support pillars along the highwall to eliminate the need for stowing while the longwall could be used inby the support pillars to mine the solid coal. With the exception of the extremely shallow mining, this approach comes close to the type of mining which is presently practiced in the deep mining industry and, therefore, is of a less experimental nature. The disadvantages would be that more men would be required underground, and some acid mine drainage may be released from the uncollapsed, pillar supported, edge of the highwall with possible long term environmental consequences.

4. The "stowing" of rock, fly ash, etc. behind the roof support system instead of "caving." This would provide obvious environmental benefits by replacing the void left by the mining operation with waste material and preventing any subsidence of the surface.

SECTION 9

RESEARCH NEEDS

1. The need for a demonstration mine to develop information which could be useful for determining the optimal application of existing equipment and to aid in the design of new equipment for longwall stripping and its alternatives is obvious. Some of this needed information is as follows:

(a) determine the overall environmental effects of this new mining method

(b) the distribution of stress and ground movement both before and after collapse of the main roof

(c) determine the effect of various rates of face advance on strata behavior both with and without stowing

(d) determine the effect of periods of inactivity on strata behavior

(e) determine the capability of sustaining high levels of production

(f) analysis of each job to determine optimal allocation of work functions as a means to minimize underground exposure

(g) analysis of the effects of caving on the surface vegetation with and without stowing

(h) analysis of the quantity and quality of any water that might be released from the caved areas with and without stowing

(i) determine modifications and improve knowledge about the selection of existing equipment

2. An important and seemingly attainable objective of longwall stripping is to reduce or eliminate the exposure of men to underground hazards. An examination of the potential of major design changes for longwall systems in these applications should be considered. These design changes should be directed at developing a less elaborate, lower cost, highly productive system with the ultimate objective of not requiring any full time employees underground with only occasional entry to the mine for maintenance. To achieve this objective more information is needed on:

(a) a compact and flexible roof support system which is closely integrated with conveyor and cutter

(b) a system that can be inserted or removed from the highwall and readily lengthened or shortened

(c) a system more easily turned from a straight line of advancement to maintain higher production.

(d) specialty equipment capable of preparing a trench while minimizing surface degradation.

3. Longwall stripping of multiple coal seams.

SECTION 10

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SECTION 11

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Appendix A is a concept paper written by John J. Mulhern, Mining Engineer, Environmental Protection Agency, Washington, D.C. This concept paper was the initial study of longwall stripping and was part of the RFP bidders package dated March 23, 1972. It is included by the authors as the initial reference and work on longwall stripping.

Longwall Stripping

Introduction

In the early 1800's miners on Mauch Chunk Mountain in eastern Pennsylvania started a mining practice that has been used to extract millions of tons of coal from the earth - surface mining. The practice of surface mining in the United States goes back to this early beginning where miners with dynamite, picks and shovels removed the covering earth to expose a seam of anthracite coal. While the art of surface mining has been practiced for many years, it is only (relatively) recently that technology has developed new hugh machines that are capable of chewing deeply into the earth. These giant earth movers can literally peel the earth to uncover coal as much as 150 feet below the surface.

The extraction of coal by surface mining methods seems to be a simple process. The overlying vegetation, dirt and rock are scraped, dug and blasted to expose the coal seams. The coal seam is then brushed to remove loose dirt and the coal broken or "ripped" for loading into trucks. When the cover overlying the coal, called overburden, becomes too deep for the earth moving equipment to economically move, giant augers are sometimes used to mine further into the earth. These augers (large coal drills as much as seven feet in diameter) penetrate many hundreds of feet into the exposed edge of the coal seam. Hence, surface mining simply uncovers coal seams for easy coal removal.

Environmental Degradation

Sheer cliffs, barren land, overturned and fractured rocks, pooled water that is blue-green with alage or brownish red with acid - iron, a few deformed or mishappen trees, and patches of the more hardy weeds, are the stark monuments of many surface mines. The monsters that chew rock and earth to uncover the black mineral fuel, coal, have left their mark on the countryside. Far reaching draglines, slicing bulldozers and giant drills slowly chew their way into the earth. The earth that covered and protected this coal now lies broken, heaped and scattered. The trees, forests, farms and pastures have all yielded to the rape of the mechanical monsters.

This devastation of land is not completely confined to that portion of earth covering the coal but often extends past the coal to nearby areas. The harmful effects on water spread downstream like tentacles carrying the strip miners legacy, siltation and acid waters.

The vegetative cover, scraped off by the slicing bulldozers, once bound the soils they grew upon, to the earth. With this protective cover removed, even the gentlest rainfall may carry soil particles into the streams and heavy rains or major storm events dramatically increase the amount of sediment carried into the streams. The sediment load washed from strip mined lands can be 20,000 to 40,000 times greater than from natural forest lands.

The mechanisms through which sediment can impair the water quality and reduce the quantity of available water supplies are well known. It is enough here to remember that sediment reduces the food producing capability of a water body and its productivity, makes water less desirable for water supplies, recreation and scenic values, and fills up impoundments and lakes, destroying their usefullness to man and nature.

While "acid mine drainage" may also result from other mining activities, it is readily apparent that surface mining contributes a substantial amount of pollution to the Nation's waters. Acid water, and the associated metal compounds, can kill the desirable aquatic life in streams and ponds. Most aquatic life in placid lakes and running streams cannot survive in the hostile environment of acid waters and these waters are often lost to other uses such as boating and swimming. Additionally, as is so obvious, the downstream municipalities and other water users must increase their water treatment facilities (and costs) to make the water useable for their residents.

Thus, the overturned earth and rock create problems to surrounding areas many miles removed from the coal. As rains wash these stripped lands, sediments and acid waters are carried into surrounding streams and rivers. These water pollutants pass out of the immediate coal lands to affect those who are unfortuantely, "just downstream." It is estimated that 25% of the mine drainage pollution in U.S. streams is caused by abandoned surface mines. Additionally, 4800 miles of streams and 29,000 surface acres of impoundments and reservoirs have been estimated to be seriously affected by surface coal mine operations.

Severe degradation of the environment is the heritage often left by miners in many parts of Appalachia, and throughout the Nation. The barren desolation of unproductive land that was poorly reclaimed, if reclaimed at all, stands as a monument to their efforts. It is said that in time nature can heal all its wounds, but one must wonder, when looking at this utter devastation that has been wrought, if man has that much time.

Energy

Energy is the capacity to do work. It can be provided by man and animals or fossil fuels, falling water or nuclear power. Man by himself can provide the energy to do work but a ton of coal today, properly converted, can produce more work in one hour than 1,000 men in the same time period.

The Nation's demand for energy in all forms is increasing at rates that have exceeded most predictions. A three to four percent yearly increase ("historic rate of growth") has been erroneously used to predict energy demands even in recently published "Energy Crisis" articles. Yet in the past five years the annual growth rate in energy demand has been at least 5%, and since 1968, it has risen to 5.6%. This underestimating of the Nation's energy growth rate is in large measure the real cause of the energy crisis. The investment in new fuel and power production and distributuion facilities was geared to the historic rate of growth and, consequently, the energy crisis is present.

Energy consumption can be divided into four major categories - industrial, transportation, household and commerical and electric utility. Of these categories, electric generation has been increasing the most rapidly. In 1955 electric generation was 547 million megawatt hours (1 megawatt hour equals 1,000 kilowatt hours and is abbreviated kwh) and in 1970 it was 1,530 million mwh almost a threefold increase.

The Federal Power Commission (FPC) is the regulatory agency charged by Congress to oversee the Nation's electrical energy needs. The FPC projected an average annual growth rate of about 7% in the demand for electricity in the 1960's. The FPC predicts that coal consumed by electric utilities will increase about 4 to 5% per year reaching 472 million tons by 1980 and 615 million tons by 1990. If this projection proves correct the utility industry alone will use more coal in 1990 than the entire coal industry produced in 1970.

As previously mentioned, an average annual growth rate of about 7% was projected in the demand for electricity in the 1960's. Instead, since 1968, this growth has been around 9% per year. A 2% increase in demand may not seem to amount to very much, but since it takes considerable time, about 5 years, to build a power plant from conception to first generation of electric power, electric production is more than 10% behind demand.

The Office of Emergency Preparedness in mid-May 1971, released data estimating net dependable generating capacity as of May 31, at 342,279 mw with an estimated peak demand of 296,791 mw, and a reserve of 15.3% (this reserve capacity compares with a 15.9% reserve capacity reported the previous year). However, these figures do not completely agree with those of the FPC which reports the net dependable capacity as 326,677 mw with an estimated peak demand of 257,419 mw. The reserve within the 15 to 20% range that FPC generally considers normal to guard against unexpected failures and higher peak loads than predicted.

The FPC reported 43 power outages in official statisitics prior to June 1970, and only 15 in the last half of 1970. However, prior to June, all power system failures over 25 mw (equivalent to the electric power used by a community of about 40,000) were reported. However, on June 21, 1970, FPC Order Number 331-1 became effective. This order redefines power interruptions to be reported in order to increase the minimum reporting level to the lesser of (1) 100,000 kilowatts or (2) half of the annual system peak load. With this revision to the reporting system, official power outage statistics may not be easily correlated to past performance or be readily related to the present "Energy Crisis".

The energy requirements within the conterminous United States have been estimated for 1990 by the FPC. The energy production requirements for 1990 are 5,828,000 mwh (5,828,000 mwh equals 5,828 gigawatt hours or 5,828 gwh) which is substantively higher than the 1,530,000 mwh produced in 1970. While these figures show the demand for electrical production is definitely increasing, the past prediction rates indicate that these figures may very well be conservative. The energy used to supply this power in 1970, was falling water (hydro-electric), coal, oil, natural, gas and nuclear energy. To produce this power for 1990 it will be necessary to utilize the same energy supply that produced our electrical power in 1970.

Nuclear energy, beset with many problems, has been decreasing in popularity with the electric utility companies. Higher construction cost, public concern over the potential hazard of a nuclear power plant, and the failure to develop technological improvements (such as the breeder reactor) are all given as causes for this decrease in popularity. At the end of 1969, the FPC reports only 4 million kilowatts of nuclear generation were in commerical operation and 69 million kilowatts were under construction or on order. To meet the future load growth, the breeder reactors that would use 80% of the potential energy in uranuim fuel instead of the present 1% used by today's reactors, will be needed. However, the research on breeder reactors has not progressed as originally anticipated and they may not be available for use until at least sometime in the 1990's if they in fact become a reality.

The use of natural gas and oil for electric generation is only one of the many uses found for these fossil fuels. Natural gas and oil provide approximately 75% of the total energy used by this Nation. Because of the National dependence on these energy sources, we must be concerned with their total impact on energy and not just electrical power generation (although 35% of the Nation's electrical production was supplied by oil and natural gas). The cause of this concern is the low level of estimated reserves of natural gas and oil. In the 1970 FPC annual report the Nation's nautral gas reserves/production (R/P) ratio is reported as 13.3 for 1969, a decline of 10.1% from the 1968 ratio of 14.8. This National ratio is the measure of the gas industries annual working inventory of natural gas divided by the annual consumption rate. This ratio has been steadily declining from 26.9 for 1950 to its present 13.3 for 1969. Additionally, it is predicted that the R/P ratio in 1973 will be 10.2.

Unfortunately, the Nation's crude oil recoverable reserves, assuming maximum recovery and present growth rates, indicate similar concern. Present estimates for the complete depletion of the Nation's crude oil reserves ranges from about the year 1990 to 2000. Fortunately, this energy source can be augmented by oil shale and foreign reserves (which should extend this energy source beyond the year 2000).

The remaining source, other than coal, is falling water (hydroelectric). Additional hydroelectric power in many areas of the United States is unavailable simply because there aren't many rivers left that can be developed. Hydroelectric power accounts for only some 4% of the Nation's total energy.

Electricity produced by coal in 1970, was 709.1 billion kwh or almost half of the electricity produced in the Nation. To produce this electricity 322 million tons of coal were burned. (Total coal mined in 1970 was about 590 million tons). Unlike, other energy sources, the technology needed to produce electricity from coal is available and the remaining coal reserves represent about two thirds of the total energy reserves. Present proven U. S. coal reserves, mineable at near present cost, are estimated to last nearly 800 years at todays consumption rates.

Environment or Energy

As now practiced, surface mining causes severe environmental degradation. Where surface mining is practiced with total disregard to the environment, utter and total devastation generally occurs to the land and surrounding waters. Unfortunately, even when environmental safeguards are considered the effects of surface mining on the environment are substantial.

With the present surface mining and reclamation technology the prospects are for only slight improvement in environmental quality. Much research is needed into surface mining methods and procedures before any substantive improvement can be expected. Additionally, technology is needed in applying reclamation techniques that will allow the land to be returned to its original condition. Present methods of reclamation at best are only implemented to comply with such minimum standards that exist.

The Nation's ever increasing need for energy is well documented and this need for energy will in turn increase the demand for coal. Coal is the only proven energy source that can supply the Nation's electrical power demands now and into the far distant future as the known supply of coal is substantially greater than all other useable energy sources.

Surface mined coal, much of which is "steam coal" quality, rather than "metallurgical" quality, fills about 50% of the Nation's coal requirement. Therefore, most of this steam coal is being used to produce electricity; about 25% of the Nation's electrical power is produced from surface mined coal. Banning or even severely restricting surface mining of coal could have serious and drastic consequences on the Nation's capabilities to generate electricity.

The capability to generate enough electricity to meet the Nation's increasing demands has so far been possible. Occassionally, however, an increased peak demand, such as caused by thousands of overloaded air conditioners on a hot summer day, coupled with an equipment failure can cause unbelieveable chaotic conditions. The New York City "black-out" in mid - 1967, is a classic example of what can happen when a city and her people, dependent on electricity, have it suddenly and completely turned off.

The day of this black-out was a warm late spring day. The weather was clear and very warm. More and more windowless office buildings, apartments, homes and factories increased their demand for electricity. As the New York City demand increased, electrical power was brought in from generating stations far away, over an elaborate grid system's transmission lines. Suddenly a switching unit failed and no electric power was available in New York City. Air conditioners, factory machines, gas station pumps, traffic lights, elevators, lights, trains, and many other electrically powered devices stopped. The City of New York literally ground to a halt. Railroads, buses, cars and subways could not move into, out of, or within the City. Most people were only inconvenienced, unfortunately however, some suffered severely. The time of day and the time of year this black-out occurred probably prevented much more serious consequences to the City and its people.

The chaotic conditions that occurred in New York City are will remembered by those who were there. This situation could be repeated if surfaced mined coal was unavailable and already overloaded systems would strain to produce demanded electricity as a sudden peak load. Without surfaced mined coal to help supply the Nation's electric energy these black-outs could become reoccurring realities.

Continued surface mining of the coal necessary to produce the electrical energies demanded by the Nation will continue to degrade the environment. Since other forms of energy are immediately exhaustable or at present, limited by technology, the coal produced by surface mining is vital to the Nation's supply of electricity. Therefore, the unavoidable environmental degradation must be carefully balanced against the Nation's economic welfare and, in fact, its very existence.

The existing practices of surface mining coal seriously affect our environment. However, it is also recognized that we need the energy that this surface mined coal can produce for the Nation. It is evident a new alternative for extracting those coals presently surface mined is needed.

Alternatives to Conventional Surface Mining

Much of the coal mined in the United States today is extracted from the earth using underground mining methods. Tunneling into the earth to remove the coal can be done by several methods. Todays modern underground coal mine no longer uses horse drawn carts and men with picks and shovels to extract the coal but rather employs modern mining equipment, such as continuous miners that literally chew the coal from the earth and automatically load it into shuttle cars. Today seven men produce as much coal as one hundred men with picks and shovels could only a generation ago. Another method, recently adopted from European practice, is called longwall mining. This mining system is further increasing the underground coal production rates. These mining methods are able to extract the coal from the earth with less obvious environmental impacts than surface mining.

While underground mining methods may cause less obvious environmental degradation than surface mining, other more favorable considerations influence the decision to surface mine. For example, the costs of developing a deep underground coal mine are often quite high and may require 3 to 5 years to reach full production. It is not uncommon for an underground mine and its necessary support facilities (i.e. preparation plant, offices, portals, etc.) to cost well over 20 million dollars exclusive of coal and land costs. The necessary capital outlay for surface mining, however, can usually be accomplished for considerably less money. Many active strip mines are in operation at less than one tenth of the initial capital outlay required for a comparable deep underground coal mine.

While there are definite economic incentives for surface mining over underground mining, there are also technological problems that prohibit deep mining methods from extracting much of the surface mined coal. Shallow cover coal, where the overburden is relatively thin, provides a very poor "roof" for a coal mine. This poor roof is detrimental to the safety of men and equipment. In a recent issue of "Mining Engineering", the publication of the Society of Mining Engineers, roof failures in underground coal mines are given as the greatest causes of accidents in coal mining. Poor roof in a mine increases the probability of dangerously severe and often fatal accidents. The very plastic and fluid type roofs normally found over shallow cover coals place severe limitation on the safe recovery of coal. This is a most important reason for not using conventional underground mining methods.

Additonally, much of the coal presently surface mined lies in relatively thin seams. Seam thickness of twenty-eight inches or less are not uncommon. With thin seam coal and the inherent poor roof a very difficult underground operation results. The poor roof requires that more supporting coal pillars be left and the mineable coal, or the coal actually recovered, could be well below fifty percent. Therefore, to mine small pockets of thin seam coal with poor roof would not be technically or economically feasible using conventional underground methods.

Estimates vary between 45 to 130 billion tons of coal mineable using present surface mining practices. West Virginia alone has an estimated 58 billion tons of coal reserves with approximately one-fifth recoverable only by surface mining. If surface mining was banned, or severely restricted, it is probable that much of this coal could not be recovered utilizing present conventional underground mining operations.

Since it would be difficult for present underground mining methods to recover this large reserve of coal, consideration should be given to the alternative of full restoration of surfaced mined areas. Careful removal of the existing top soil and each layer of earth strata will insure that minimal pollution will result, provided of course, it is carefully returned in the same manner and position it was removed. Obviously, this restoration would be completed within days of the coal removal. By careful revegetation of a substantial ground cover the land can then be returned to almost the original contour and vegetation it held before the coal was removed. Thus full and complete restoration would allow the coal to be removed, returning the land to almost the same state it existed in before the coal was taken. The most significant change taking place being only a slight lowering of the land and its contours a depth equal to the coal seam thickness.

Minimal environmental destruction will occur when full and complete restoration of the surface mined land immediately after the mineral has been removed, is practiced. The actual mining operations of course being planned to distrub only small land areas at any one time. Additionally, the size of equipment and method of operation will be reduced to be compatable with minimum surface disturbance. Surface mining practiced in this manner should eliminate much of the harmful effects of present surface mining practices.

Full and complete restoration of the surface mined land will create minimal environmental degradation. The scarred land with its long term water polution from sediment and acid mine drainage would not be left behind after the coal is mined to cause problems that the Nation now is faced with. However, the full restoration that would be necessary to remove this coal without these harmful effects would be very expensive, if indeed always possible. While definitely minimizing and possibly eliminating the long term effects of environmental degradation that surface mining practices generally cause, the cost would be exceedingly high. These practices would prevent much of the present environmental degradation but at a very substantial increase in the cost of energy.

Although possible alternatives exist for recovering this coal without the present total environmental destruction, new technology needs to be developed and demonstrated that more effectively and efficiently supplies the coal necessary to satisfy the Nation's energy needs. Another alternative that is now suggested may satisfy the environmental criteria and also supply the Nation with needed coal energy. It would utilize an underground mining method recently adopted in this country while exposing only a relatively small area of the earth. It would protect the environment and supply the coal needed for the Nation.

A Proposed New Surface Mining Method - "Longwall Stripping"

The mining of shallow cover coal is necessary and vital to the Nation. Air, water and land - the environment - is also necessary and vital to the Nation. To provide the Nation the means to extract shallow cover coal while protecting the environment, a new surface mining system is proposed - "Longwall Stripping".

Longwall Stripping is a method employing the underground mining system successfully used in European countries for many years. In the early 1960's this method was successfully adapted for underground coal mines in the United States. In 1970, there were 30 longwall mining systems operating or available for operation in the United States. One of these systems in Pennsylvania mined 7,280 tons of coal in a 24 hour period, a very high production rate. The continued future of this mining method in U.S. coal mines appears certain.

A longwall mining system consists of a series of basic components that are used in combination to mine coal. The coal is severed from the coal seam by a cutter, usually called a "plow" or a "shearer", passing over the coal "face". The severed coal falls onto an "armored chain conveyor" and is moved from the working face for transport out of the mine. Roof supports or "jacks" are used along the full length of the working face to support the roof while mining is in progress. These jacks can be equipped with conveyor shifting rams that will move the armored chain conveyor forward as the plow or shearer passes and also move the jacks forward as the coal is removed.

The actual severing of the coal in a longwall mining system is by one of two devices. The coal plow is a sort of wedge shaped shoe that is pulled along the coal face literally plowing the coal down. A shearer is a drum shaped device with hardened metal bits that revolves and chews into the coal. Both devices cause the coal to fall on to a conveyor parallel to the working face to be transported to the end of the working face or panel for further transportation out of the mine.

The roof support system of jacks is able to support tremendous depths of overburden. These jacks are able to support areas that have a very weak roof allowing otherwise hazardous areas to be mined safely. These jacks can be self-advancing to move forward as the plow or shearer passes. Additionally, they can also push forward the face conveyor that transports the mined coal from the face. These supporting jacks, as they move forward, allow the roof to collapse behind the jacks (in the "gob area") eliminating many of the voids and openings normally found in a mined out area. These already developed and proven roof supporting jacks could readily be applied to mining shallow cover coal and are possibly the most significant component of the system.

Longwall Stripping would utilize existing longwall equipment inserted into the coal seam. The opening of the earth's surface need only be large enough to allow the equipment to be inserted, then quickly covered and completely restored. The only other surface land that would be disturbed would be a small traveling opening to remove the mined coal that would also be quickly covered and completely restored as the miner passed. Thus when the mine was operating at full production only a small surface land area (about 100 feet), would be disturbed at any one time.

Longwall Stripping is actually a very simple concept. First a small trench is opened. This trench would not be much bigger than trenches that are presently used for large sewer lines. The coal is then removed and the longwall mining equipment inserted into the coal seam. Prependicular to and at the "outby" end of this trench, a second opening is started. This opening allows the mined coal to be removed and also acts as a dike to prevent water from draining out of the mining area. As the mining proceeds, and the face advances, this outby opening also advances. Once the face has advanced sufficiently, the original trench, opened for the inserting of the longwall mining equipment, can now be backfilled and completely restored. The outby opening advancing with the longwall mining system is also back-filled as the system advances. Because of the very small land surface disturbed, this opening can have nearly immediate and total restoration.

The recovery of shallow cover coal by Longwall Stripping offers many advantages to both the environment and the mining industry. Since little surface land need be disturbed and full seam mining can be practiced, virtually all the coal can be recovered. This benefits both the environment and the operator. The free-flowing property of the plastic roof should cause the roof to simply flow behind the jacks preventing many of the voids and openings, normally found in underground mines. Eliminating under ground voids and openings prevents the formation of water drainage channels that allow acid waters to flow long after mining has ceased. Additionally, this immediate and complete joining of the roof and floor will eliminate most of the subsidence of surface land that commonly occurs from underground mines as pillers and timber supports deteriorate due to age and surface activities. Longwall Stripping simply lowers the elevation of the land by the thickness of the coal seam.

The economics of Longwall Stripping also appear to offer advantages over present surface mining methods. Obviously, the virtually 100% coal recovery from the coal seam is an economic incentive. The capital cost of the surface equipment (2 or 3 small sized piees for the minor amount of earth moving involved) would be relatively inexpensive. The longwall mining system itself consisting of standard "off-the-shelf" equipment with little, if any, modification required should far exceed present surface mining production rates at equivalent capital investment. Additionally, several ancillary benefits that are part of the overall system could add a considerable economic edge to this new mining method.

The ability of the longwall mining system to operate remotely offers an ancillary benefit that would substantially increase the safety of the underground coal miner. While mining the coal using the Longwall Stripping method no men are needed underground. The miner operates the system from a totally enclosed cab located outside the mine. When maintenance and adjustments are necessary, the system is completely shutdown. The miner can then safely go in to observe or maintain and repair as necessary. While in the mine he would work safely under the jacks supporting the roof. These jacks are presently supporting many hundreds of feet of earth and rock in underground mines and are considered by the mining industry as the safest known roof support.

The environmental benefits of this mining method are substantive. First, the complete and total recovery of the coal with its subsequent lowering of the overlain strata eliminates most if not all the voids and openings for water drainage. Second, only a small land area need be disturbed for mining the coal. Full restoration of the disturbed land area can then be easily accomplished. Third, the trench used for coal removal, when mining "up slope", would also prevent acid water from draining into nearby streams. Any water in the mine would be promptly removed, and treated if necessary, prior to releasing it to nearby streams.

This type or method of mining can be used in almost all areas that are presently being surfaced mined. For example, on a typical contour mining situation where surface mining normally removes the coal along the edge of a ridge, Longwall Stripping could be utilized efficiently and economically. As another example, this new mining method would be applicable on the "plains" ("area mining") where the land surface is reasonably flat. Here, however, the procedure used is slightly different. Two longwall mining systems extending outward (at right angles) from a center (advancing) trench are used. They mine in a direction parallel to the initial (starting) trench perpendicular to the center trench. The center advancing trench is the operating trench and is where the coal is removed.

The use of Longwall Stripping in area mining can have a significant impact on coal production and surface mining. Additionally, it is quite probable that new equipment will be developed for use in a Longwall Stripping system for shallow cover coal. Second and subsequent generations of equipment could substantially increase production, efficiency and economics while continuing to protect the environment from destruction.

Proposed Demonstration Project

Longwall Stripping offers the Nation the opportunity to recover much needed energy, coal, while protecting the environment-air, water and land. No other surface mining method, presently practiced or proposed, can offer the balance between energy and the environment. To demonstrate that Longwall Stripping can in fact provide this balance, it is proposed that a small project be undertaken that will document the advantages - both environmental and economic.

The demonstration project proposed would be a modest one, requiring less than 100 acres of a 3 to 4 ft. coal seam. This small project would be conducted within the constraints of present mining laws, existing equipment design and obviously, the geographical and topographical conditions of the selected site.

In any initial installation of new technology, existing constraints and site conditions will dictate certain methods and procedures to be followed. For this discussion of the proposed demonstration project, those constraints that are known will be used, all others will be assumed. In either case these constraints will be identified.

The initial application of this new mining concept could be most anywhere that a sufficient coal reserve existed. Since only a modest demonstration project is proposed, about 100 acres of a 4 ft. coal seam will be assumed. Additionally, it will also be assumed that this coal reserve will be in a continous strip about 200 ft. wide, such as often found in "contour strip mining".

The site selection, coal reserve and seam thickness, are the basic assumption. With these assumptions made the development of the proposed mine can now be discussed. The first step is to determine the most advantageous place to start mining that allows for maximum travel advance. For example, the strip of coal on this assumed site, approximately 200 ft. wide, could have the starting point at either end, with the longwall mining system advancing as a continuous 200 ft. face towards the opposite end.

The placing of the longwall system would be relatively simple. A trench is cut at the starting end of the strip, wide enough to allow the coal to be removed and the longwall mining system inserted. The earth removed for this trench would be carefully segregated (i.e. topsoil, rock, clay, etc.) to allow easy return for complete restoration. Once the longwall system has advanced into the coal seam this trench is then backfilled and vegetation completely restored.

Perpendicular to this starting trench an advancing trench is cut. This opening to the longwall mining system will advance with the face and will be the entry to servicing the equipment and for removing the mined coal. The trench is excavated in such a manner to allow the complete restoration of the land immediately after the longwall system has passed. Additionally, this trench also acts to prevent acid water from draining from the mine into nearby streams. Should there be harmful drainage this trench could be used to treat this water prior to its release to a receiving stream.

The longwall mining system used for this demonstration will have the same components used in today's underground coal mines. All components making up this longwall system are standard designed equipment available from several U. S. mining equipment suppliers. Although some of this equipment could be modified and redesigned for Longwall Stripping, for this first demonstration project only equipment already proven in U. S. coal mines will be used. While the actual site and coal seam will determine the exact specifications required for the longwall mining system equipment, the basic components can be selected based on the previous criteria established for the proposed demonstration project.

The mining of coal in a longwall mining system is done with a "shearer" or a "plow". The shearer cuts the coal with a moveable powered arm. This arm has a head with spaced bits, like small picks, that rotates into the coal causing the coal to be severed from the seam. The plow is pulled back and forth across the face of the coal shearing the coal from the seam with its many pointed edge. Because of the shearer's moveable powered arm it should be more versatile than the plow for trimming and cleaning the inside ("inby") and outside ("outby") ends of the face. Additionally, it can be used more easily for full seam mining where slate and rock would have to be removed. Since the plow would not be as versatile as the shearer in the initial mine without special redesign, the shearer is the obvious choice as the "coal cutter" for this first mine.

The remainder of the longwall mining system for this first Longwall Stripping mine is also available as off-the-shelf equipment. Additional basic components of the longwall system - the remote control, self - advancing jacks for the roof support that, while over-designed for shallow cover coal, will provide maximum safety for the equipment and maintenance men; the armored chain conveyor that moves the coal mined by the shearer to the outside for loading on surface transportation; and the dozer plate ("rabbit") for pushing the mined coal onto the armored chain conveyor - will also be utilized in this demonstration mine. Other components required such as cable handler, tube guides, spill plates, etc. that make the total engineered "package" of a longwall mining system is presently available from several mining equipment suppliers in the United States.

The next consideration in this demonstration mine is the operating face. Because of the present underground ventilation requirements this face will be limited to an initial 200 feet. This ventilation requirement constraint is why the approximate width of the site selected is 200 feet. However, this 200 foot face should adequately prove the concept. It is rather obvious that future mining utilizing this system can mine considerably longer faces.

Because of the short 200 ft face, the periodic inspection and maintenance required can utilize a simple industrial type exhaust system for ventilation. This ventilation system is similiar to those installed in many industries.

By using a flexible ducting and a modest hood design, the mine air could be rapidly evacuated when it was necessary for personnel to go inside. However, while the actual mining is in progress no one is underground and all inspection, maintence and repair is performed only when the shearer is not in operation. Additionally, this ventilation system could be so designed to allow observation during the actual mining operation using a closed circuit television system and the necessary lighting. This would be accomplished by fixing the ventilating system to provided continuous ventilation to the working face, exhausting the dust to a dust collector located outside the mine.

The operation of the above system, located completly underground, will be from an instrumented, climate controlled, operator's cab. This cab, located in the advancing trench at the outby end of the working face, travels along the cut guiding the mining operation. This control cab provides a "total environment" for the miner while he operates the underground longwall system from the safety of the operator's cab.

As the coal is mined and conveyed out of the mine, the operator from his cab can control its flow onto a belt conveyor for transfer to the surface loading point. Both the load-out point and transfer point can be observed by the operator and are so designed to be moved as the mining progresses.

Also included in the traveling area of the advancing trench and necessarily coupled to the operators control center, is the power center required for the longwall system. The power center supplies electrical power to operate the system. Electrical power is the only utility required since all equipment for this mine are electrically driven.

Advancing ahead of the working face, on land, is the earth moving equipment required to excavated the advancing trench. Because the trench is small the earth moving equipment is minimal. The equipment needed would be a three to five cubic yard dragline, or shovel, a bulldozer, coal transfer belt, coal storage bin and a means for coal haulage such as a belt conveyor or trucks. Because of these few pieces of earth moving equipment, the longwall mining system and the few support items required, this proposed demonstration projects inital capital cost are modest.

The advancing trench that moves with the operating face is relatively small and is not at any great depth. This small trench, and the correspondingly small amount of material disturbed, allows the efficient and effective restoration of the disturbed area. Additionally, this trench is refilled, recontoured and revegetated as quickly as the face has passed.

The relatively small amount of vegetative cover removed when the trench was opened requires a minimum of time and expense to replace. Because of this small area disturbed and the restoration quickly practiced, the environmental degradation usually caused by present surface mining operations should not occur.

The obvious benefits resulting from this new surface mining method are substantive. The ability to mine shallow cover coal without degrading and destroying the environment will provide the Nation much needed energy at a reasonable cost. The surface land disturbed has full and complete restoration within days after the earth is opened and exposed to the elements. This precludes the environmental distruction that often occurs with many surface mines. Coupled with this minimum surface land disturbance, the use of full seam mining will eliminate much of the future land subsidence, voids that provide water drainage channels and the sulfuritic and other material that produces harmful drainage. This new mining method will protect the environment yet permit the economic recovery of the coal.

Longwall Stripping offers an answer to the Nation's need to balance energy and the environment. This is the purpose of this new mining method. However, an ancillary benefit to the health and safety of the Nation's miners is worth considering. This system requires no men underground while mining. The coal is mined with the miner outside the mine away from the dust, explosions and fire hazards that make coal mining one of the most dangerous industries in the United States. Additionally, the miner need only go "inside" when the shearer is not running and he would be protected by the roof support system that is considered to be the safest available in the mining industry. When it is considered that the present underground coal miner has about one chance in ten of being involved in a serious or fatal accident this ancillary benefit becomes very significant.

In summary the mining system proposed is simply one of a marriage of underground technology with surface mining techniques that provides a peaceful coexistence, or balance, between energy, coal mining, and the environment, air, water and land. The recovery of coal, the natural resource so vitally needed for our Nation's energy requirements, can be accomplished economically, if not in fact, more econcomically than present surface mining practices.

The Nation needs energy to grow and prosper. Coal can provide this energy. The Nation also needs the environment - air, water and land - to exist. Longwall Stripping can provide the Nation energy without destroying the environment. The trade of a mineral resource, coal, for other natural resources, land, water and air, can become a practice of the past.

Appendix B is the report of visits to European mines and mining equipment manufacturers to learn their advanced technology on long-wall mining systems.

May 21, 1973

A Report on a Visit of Three U.S. Mining Engineers to England, France & Germany

by John J. Mulhern, Environmental Protection Agency
Henry F. Moomau, Potomac Engineering & Surveying Co.
Joseph W. Leonard, West Virginia University

This report covers a visit to mining equipment manufacturers and mines in England, France and Germany to obtain the information necessary to complete work on a contract entitled "Feasibility Study for a New Surface Mining Method," often called "longwall stripping."

"Longwall stripping" is a surface mining method that minimizes the environmental disturbance often caused by conventional surface mining. Utilizing longwall stripping the surface need not be completely overturned, such as in conventional strip mining, nor wasting of coal or drainage tunnels, as in auger mining. This new surface mining method simply utilizes a longwall mining system, as currently practiced in some U.S. deep mines and extensively practiced in European coal mines, that is adapted for shallow cover conditions normally surface mined.

To illustrate how longwall stripping works, assume a steep slope hill area where the coal outcrops along the edge of the hill. Inside this coal outcrop a narrow "bench" is cut from the surface down to the bottom of the coal seam. A 15 or 20 foot strip of coal along the outcrop is allowed to remain that will act as a barrier for any water drainage and allow a continuous contour line to be established thereby preventing sediment and landslide problems. Assume the 15 to 20 ft. strip of outcrop is lying to the west with the coal and hillside to the east. From this narrow "bench" which is called the "outby" or "fresh air side" a narrow entry is driven for insertion of the longwall mining system. This is perpendicular to the bench and in a direct easterly lie. This coal "face," for the demonstration mine approximately 250 feet in length, will travel perpendicularly to the bench in a northerly direction. The coal cutter, called a "shearer" will cut the coal allowing the coal to fall onto an armored conveyor which is pushed forward by the roof supporting system called "chocks." As the entire coal seam is removed one of two mining methods behind the chocks will be used. One is called "caving" which simply allows the earth strata to fall behind the chock as the chocks advance. This will cause immediate subsidence of approximately 50 to 70% the height of the coal seam. Within about a year the consolidation of the material caved should be such that normal surface activities could be carried out with little if any chance of further subsidence. The other method would be "stowing" which utilizes a material such as fly ash to be pneumatically placed behind the chocks causing the strata to be supported so no subsidence should occur. An additional feature of stowing, with such material as an alkaline fly ash, is the barrier affect preventing any future acid mine drainage problem from the area.

Although much of this concept is being practiced in Europe the fresh air or outby side makes this concept unique in the world. This is because U.S. coal measures are decidely different than those remaining in Europe.

It is estimated that 1,000 tons of coal per shift per 250 ft. face can be mined from a seam of about 52 inches. Although the potential is there to mine this coal without miners at the coal face while the shearer is cutting coal, the first mine will probably have three men inside but under massive shield-type chocks with remote control panels allowing them to operate the shearer, conveyor and chocks from the protection of these shields. Unfortunately the technology that exists in automating longwall mining systems is not available in the U.S.

The following is the day to day account of the visit to England, France and Germany.

<u>February 28, 1973 - Visit to England</u>

Discussions were held at Lancashire, England, with William Higgins, Export Sales Executive; Les Aarnot, Sales Manager; and Alan Purdy, Managing Director-Export, Gullick-Dobson Company Limited (Represented in the U.S. by Joy Manufacturing Co.). Three films produced by the National Coal Board and one film produced by the Gullick-Dobson Company were presented concerning automated longwall strata control and longwalling support systems. Following the films, a general discussion on longwall mining, longwall support systems (chocks), and the general concept of longwall stripping was held.

From these discussions, we gathered much information on the state-of-the-art of roof control and roof support practice throughout the world. It was generally agreed that the major problem with the longwall stripping concept was the outby side.

After a lengthy discussion with an exchange of ideas on mine roof control and coal cutting, the meeting was adjourned until the next day.

<u>March 1, 1973</u>

We returned to the Gullick plant to meet with Mr. James Anderson, Consultant to Gullick, who was formally the Chairman of the Northwestern Region of the National Coal Board and the inventor of the coal shearer used in longwall mining. Also present were Messrs. Purdy, Aarnot and Higgins.

The discussion focused on problems encountered in longwall mining of coal under shallow cover. It was suggested that there were several ways to manage the outby problem, a few of which follow: 1) packwalling behind the chocks closest to the outby side using material taken from the excavation; 2) cribbing with concrete blocks; 3) a specially designed chock on the outby side that would also act as a shield; 4) bolting with resin bolts and wire mesh or with resin bolts and metal plate strips to bind the overburden in place.

Additionally, other points discussed were: 1) consolidation from subsidence would be approximately 50% of the seam thickness; 2) after twelve months, material would be completely consolidated so that normal surface activities could occur without further subsidence; 3) the mined out area would probably be completely sealed eliminating drainage after mining; 4) a shearer offers the only practical means of off-the-shelf equipment for "coal getting;" 5) the entire system could (at considerable expense) be remotely controlled so that men would not be needed underground during operation.

At the conclusion of the visit, new developments were observed in an area of the Gullick plant used for applied research, development and special testing. They demonstrated their remotely controlled chocks, which they were in the process of final testing, for application in longwall mining.

Mr. Jim Francis, Chairman of the Gullick-Dobson Mining Group, was also interviewed. Mr. Francis discussed problems encountered in American mining operations. He stated that Gullick is interested in the concept of longwall strip mining and would provide engineering and roof control expertise wherever possible.

The following conclusions were reached after visiting Gullick: 1) roof control, particularly on the outby side, is the major critical point in longwall stripping. It is considered that the roof control inby will not be a particular problem with thick sandstones. Shales would be the next ideal roof; 2) the outby side can be supported with a specially designed chock which would be guaranteed by Gullick; 3) Mr. Alan Purdy, a Mining Engineer and Managing Director of Export, has experience and considerable knowledge about longwall mining of coal under shallow cover; 4) using the "caving" system of longwalling, recovery of coal under shallow cover is possible and only in rare instance would it be impractical; 5) American longwall mining technology seriously lags behind British and European technology. However, this is probably because of the different mining conditions and their exhaustion of the easy to mine coals in Europe; 6) our application of longwall stripping in a demonstration mine would be the first ever attempted.

<u>March 2, 1973 - Visit to the National Coal Board</u>

We visited with Mr. A. M. Clark, Deputy Chief Geologist of the National Coal Board. Discussions concerned the limitations of the "pressure arch theory", which is advanced by many theorists. Although some serious exceptions to the theory have been noted in recent years, it is still considered reliable.

Subsidence problems associated with longwall mining or caving of the material behind the face were also discussed. In certain mining situations, the British have special expertise and understandably lead American technology.

Mr. Clark was helpful in pointing out differences between British and American coal mines. As a geologist, his discussion was concerned with strata control at the great depths typical of British mines. Since British mines are much deeper than American mines, strata control frequently is achieved with techniques not commonly in use in America. Hence, in trying to adopt European technology directly to American mining conditions we must be careful in our understanding of these conditions.

To Mr. Clark's knowledge, longwall mining with the outby side in "fresh air" had not been tried before. He believed that the system is feasible. Moreover, he believed this system would prove practical and result in a significant advancement in mining technology.

Mr. Clark made several other points of interest: 1) surface mining ("open cast") of coal in England amounts to about 10% of total coal production; 2) it is about one-third as expensive to open cast mine in England than deep mining; 3) deep mining production averages about four tons per man; 4) reclamation costs were estimated to be about 25% of the cost of surface mining.

Mr. Clark recommended a visit to the Royal School of Mines. However, he did not think they could add much to what was already known since they specialized in "hardrock mining." He also suggested a return visit Monday morning to talk to Mr. Phillip Weekes the Director-General of Mining of the National Coal Board. Prior to leaving for the day, arrangements were made for a return visit with Mr. Weekes.

<u>March 3, 1973</u>

A visit was made to the Royal School of Mines, as suggested by Mr. Clark. Unfortunately, no one was available for discussion and this proved to be a meaningless trip.

<u>March 5, 1973</u>

We met with Mr. Phillip G. Weekes, Director-General of Mining, National Coal Board. A lengthy discussion was held with Mr. Weekes concerning the longwall stripping concept. Mr. Weekes advised that, to his knowledge, the system would be unique because of the fresh air outby side. It was his opinion that the system should be "quite successful." We also discussed at length with Mr. Weekes the use of automated longwall faces for extracting coal. It was apparent that automated longwall coal mining technology is much further advanced in Great Britain.

Mr. Weekes is attempting to develop an extensive library or source of material dealing with coal mining problems throughout the world. Therefore, the past and present work of the Environmental Protection Agency was discussed. Mr. Weekes was provided with a copy of the EPA project book together with the promise that final reports would be provided to him of projects he might find of interest.

March 6, 1973 - Visit to French Coal Mine

We met with Messr. Benno Niedzielski, who is the Public Relations Officer for the French Coal Mining Industry. Messr. Niedzielski acted as interpreter throughout the visit.

Two coal pits were visited in France; one at Mellebach, and the other at La Houve. The Mellebach mine will be closed by 1980 and is presently being pillared out.

The La Houve mine is the largest mine in Europe and is presently producing 8,000 tons of coal per day using longwall mining with powered chocks and drum-type shearers. Roof control problems were evident at the face but good team work by the miners and good engineering made it possible to keep the section operating. The coal face was over 100 meters long and was about 3100 meters below the surface.

As a general rule the mining conditions were more difficult than those encountered in American mines, and it is a tribute to the French industry, their engineers and miners that coal is provided so consistently.

Surface facilities were also visited and control panels for monitoring performance were examined. These panels indicate the percentage of methane, water problems, electrical problems, maintenance problems, and production problems at all working faces. Additionally, they observe the process of the tunnel driving crews to determine what, if any, problems are being encountered. Should it be necessary, the engineer monitoring on the surface can communicate with anyone underground.

A discussion was held with Messr. Cariven, the Chief Engineer of the La Houve mine and his engineers Messr. Bonnet and Messr. Sauder. Problems common to coal mining were discussed. The

French appear to be ten to twenty years ahead of our mining technology. Additionally, a meeting was held with Mr. Grison, Director, Houilleres du Basin de Lorraine who discussed, through Messr. Niedzielski, longwall mining and subsidence under shallow cover.

March 7, 1973 - Visit to German Mining Equipment Manufactures

We visited the Westfaila lunen Company of Lunen, Germany, one of the major suppliers of longwall mining systems to the United States. They are represented in the United States by Mining Progress Inc. The visit to the Westfaila Lunen Company was previously arranged by Mining Progress.

Meetings were held with Dr. Karl-Martin Zentgraf, New Products Director and Mr. Johannes E. Laabs, Chief Engineer, Technical Sales and Production of Westfaila Lunen. Discussions with these gentlemen lasted for several days, and included a visit to German mines.

The discussion the first day was on our concept, longwall stripping. Additionally, arrangements were made for our itinerary in Germany. It was decided that March 7th would be spent at Westfaila Lunen; March 8th with Eickhoff (manufacturers of shearers); March 9th with Westfaila (visiting pits) and March 11th reviewing with Westfaila their proposed equipment design for a longwall strip mine. Also, a tour of the Westfaila manufacturing facilities was scheduled.

March 8, 1973

We met with Mr. Heinrick Stock, Salesman, and Mr. Otto Renzing, Chief Design Engineer, Eickhoff. Application of Eickhoff equipment was the subject of much discussion and much information on coal cutting was obtained.

An evening meeting was held with Dr. Zentgraf to discuss Westfaila Lunen's Bischoff Company they recently acquired as a means to enter into the air and water pollution control market. Dr. Zentgraf was interested in the knowledge that was made available to him during the discussion.

March 9, 1973

We again met with Mr. Laabs from Westfaila and with him visited the West German pits, in particular the Westfailan Mine. The surface control room, where all underground activity is monitored, recorded work stoppages, the percentage of methane and any potential electrical malfunctions. In the event of a mining accident, the West German Inspectorate had access to all of these records and could pinpoint the cause with a high degree of accuracy. The Westfaila "shields" that afford maximum protection underground from falling roof were also examined at this mine. These chocks, first conceived by the Russians, appear to be an excellent roof support system for poor roof conditions. They are not yet used in the U.S.

March 11, 1973

A detailed discussion was held with Mr. Laabs on Westfaila's equipment proposal for application in our demonstration mine. Mr. Laabs felt that this condition was unlike anything in Europe, because of the fresh air or daylight entry. He believed if roof control could be achieved at the outby side, a most significant contribution to coal mining would result.

The system that he proposed appears to be viable. He believed the proposed system would be economically sound. He felt that plows might have some application for producing coal at the longwall face, but it would be necessary to have two outby areas, which could create difficulties for the first mine.

Mr. Laabs' initial suggestion included the new Westfaila shields. Mr. Laabs' cost estimate for these shields was about 25% more than the standard Westfaila chocks. His longwall system included a longwall face that would be about 80 meters long, (approximately 264 feet) with a 25 foot outside extension. His system also included a coal cutting device, such as a shearer, and an automated system that could remotely move chocks and advance the shear with only three men at the face. These men would remain in position at specially designed chocks (shields). A fourth man would be on the fresh air side at the end of the system. Mr. Laabs had, for budget purposes, included lighting, ventilation, etc. He estimated that a face of about 264 feet could cost approximately $4,000 a foot, including the 25 foot outside delivery system.

March 12, 1973

We met with the Becorit Company, Messrs. Walter Lubogatzky, Director, Technical, Peter Beckmann, Director, Commercial and Theodor Kolk, Engineer.

The discussion started with an explanation of longwall stripping. After the discussion, when the concept was understood, Becorit produced a film that was made in a German pit about five years ago, utilizing Becorit chocks, an Eickhoff shearer and a Westfaila panzer conveyer. This was an automated longwall system considerably advanced beyond any seen or discussed during our European visit. After discussing the film and how it related to our application, the proposed longwall stripping system was seen as being practical, economical, and safe.

Although Becorit does not have a sales agency or any export to the United States, the Gullick-Dobson Company which owns 51% of Becorit does (through Joy Manufacturing Company.) The Becorit Company requested the privilege of preparing a proposal for budget purposes and for the design of the outby supporting system. Based on their previous experience, they did not understand why coal, mined at shallow depths, should be a problem. Becorit chocks are different from the Gullick chocks and they may be more adaptable to American coal measures. The Becorit Company will send a copy of their film on the automated longwall mining system.

March 14, 1973 - Visit to the Rheinische Braunkohlenwerke AG

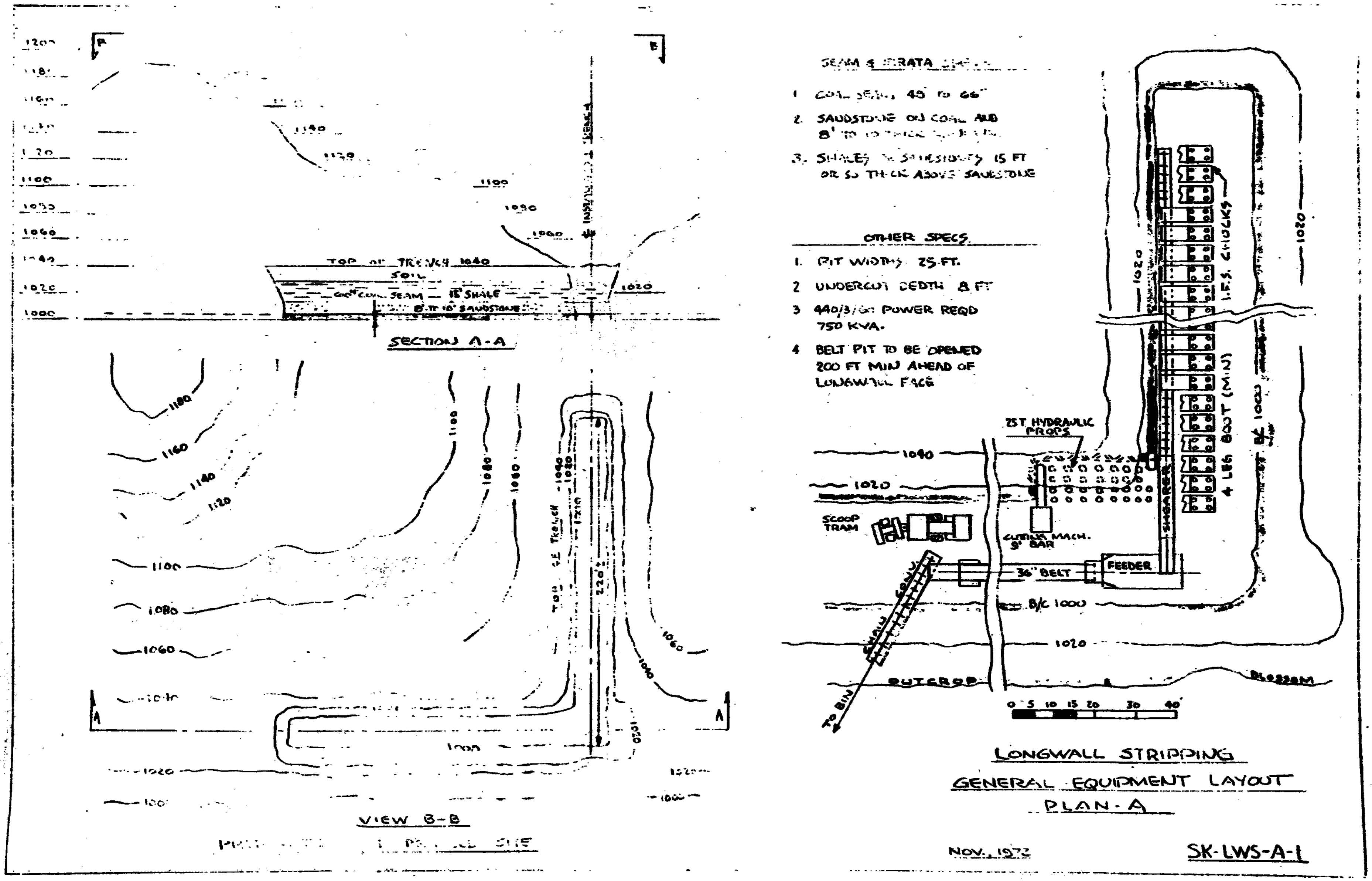
Through the efforts of Mr. David Struthers of the International Affairs Office of EPA, the American Embassy was contacted in Bonn where Dr. Clyde McClelland, Scientific Attache, arranged a visit to Rheinische Braunkohlenwerke (the "Brown Coal Region" of West Germany). Accompanying us from the Embassy was the Deputy Scientific Attache, Mr. Alan Hegburg. Mr. Berging H. Maucher, mining engineer of considerable experience in the Brown Coal Region, conducted the tour. Mr. Jan Kayser, a mining engineer from the Rhein Braun Consulting Firm, of the same company, was also available for a discussion period. Several pits were visited which were awesome in size and larger than any pits in America. These pits furnished brown coal to seven power plants and six briquette plants. Additionally, three thousand tons per day of sand and gravel are recovered for sale, together with three million tons of water per day some of which is sold to local towns for the water supply. It was expected that since the water quality was good, the water market would continue to grow.

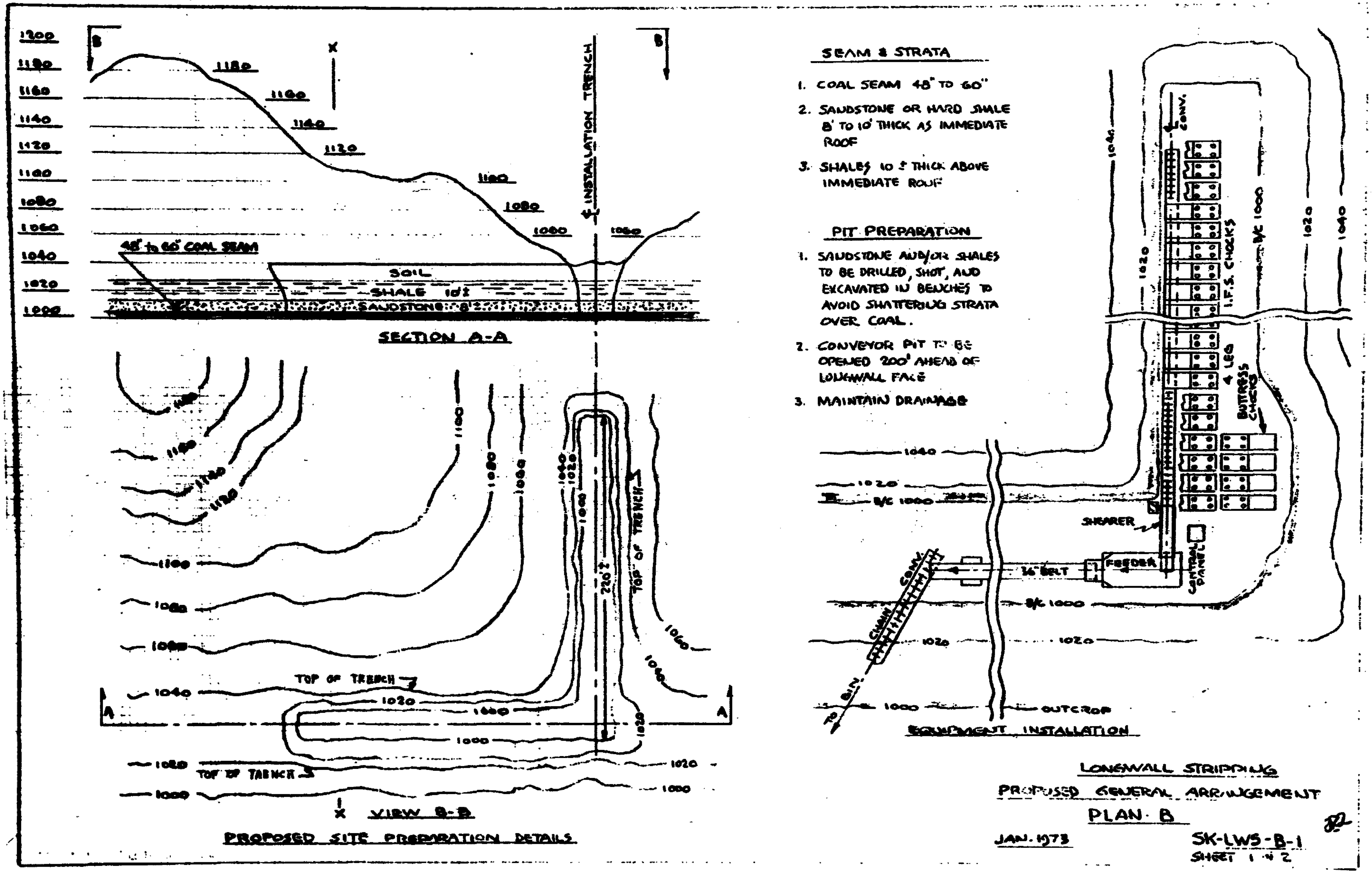
Several things, besides the size and magnitude of the mine were of interest. (1) The earth that was being moved was soft and easy to dig so that no blasting, drilling or other rock shattering procedures were necessary. (2) At one pit, 600 meters of material was removed to recover 50 meters of brown coal. (3) A high degree of good engineering, planning and sound management was practiced. (4) The power of eminent domain allows them to acquire all surface land. (5) The people who were displaced from homes were given the opportunity of choosing a home of higher value than the one they were displaced from, pay more money to improve their housing quality, or take money in exchange for a small home or smaller land acreage. (6) Total resource recovery was being practiced and the land was returned to a condition that was equal or better to the previous condition. (7) Good engineering management, good land use practices and government-industry cooperation can achieve these same results in America.

While these findings may not be directly applicable to all of the coal fields in America, benefits from the technology observed in the Brown Coal Region can be utilized to improve our mining environment technology. "Daylighting" in these regions may merit further consideration. The Brown Coal area is, without a doubt, one of the best examples of balancing mineral resource recovery, "mining" with the "environment."

The above is a report on the information obtained during the visit to England, France and Germany. Since this visit the information required to complete the study has been finalized. Additionally, a grant application has been received by EPA from the West Virginia Surface Mining and Reclamation Association to cooperatively demonstrate "longwall stripping."

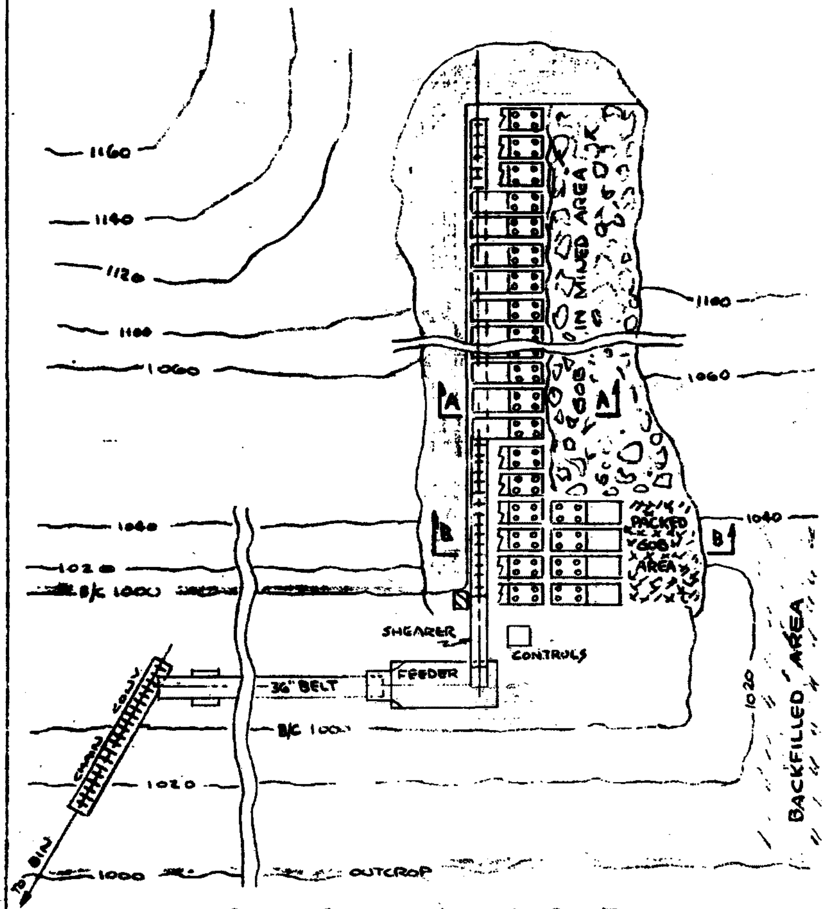
Appendix C is a compilation of the various engineering drawings that were conceived during the progress of this study.


TOP OF TRENCH 1040
SOIL
SECTION A-A
1. PIT WIDTH 25 FT.
2 UNDERCUT DEPTH 8 FT
3 440/3/60 POWER REQD 750 KVA.
4 BELT PIT TO BE OPENED 200 FT MIN AHEAD OF LONGWALL FACE
OTHER SPECS.
25T HYDRAULIC PROPS
SCOOP TRAM
CUTTING MACH. 9' BAR
36" BELT
FEEDER
SHEARER
4 LEG BOLT (MIN)
B/C 1000
OUTCROP
BLOSSOM
TO BIN
VIEW B-B
LONGWALL STRIPPING
GENERAL EQUIPMENT LAYOUT
PLAN-A
NOV., 1973
SK-LWS-A-1

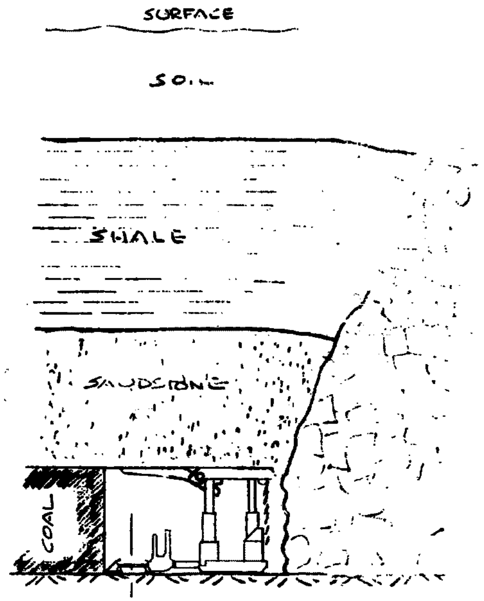

SECTION A-A
48" to 60" COAL SEAM
SOIL
SHALE 10'±
SANDSTONE 8'
℄ INSTALLATION TRENCH
VIEW B-B
TOP OF TRENCH
220'±
PROPOSED SITE PREPARATION DETAILS
SEAM & STRATA
1. COAL SEAM 48" TO 60"
2. SANDSTONE OR HARD SHALE 8' TO 10' THICK AS IMMEDIATE ROOF
3. SHALES 10 ± THICK ABOVE IMMEDIATE ROOF
PIT PREPARATION
1. SANDSTONE AND/OR SHALES TO BE DRILLED, SHOT, AND EXCAVATED IN BENCHES TO AVOID SHATTERING STRATA OVER COAL.
2. CONVEYOR PIT TO BE OPENED 200' AHEAD OF LONGWALL FACE
3. MAINTAIN DRAINAGE
CONV.
I.F.S. CHOCKS
4 LEG
BUTTRESS CHOCKS
B/C 1000
SHEARER
FEEDER
36" BELT
CONTROL PANEL
CHAIN CONV.
TO BIN
OUTCROP
EQUIPMENT INSTALLATION
LONGWALL STRIPPING
PROPOSED GENERAL ARRANGEMENT
PLAN B
JAN. 1973
SK-LWS-B-1
SHEET 1 of 2

LONGWALL STRIPPING
PROPOSED GENERAL ARRANGEMENT
PLAN B

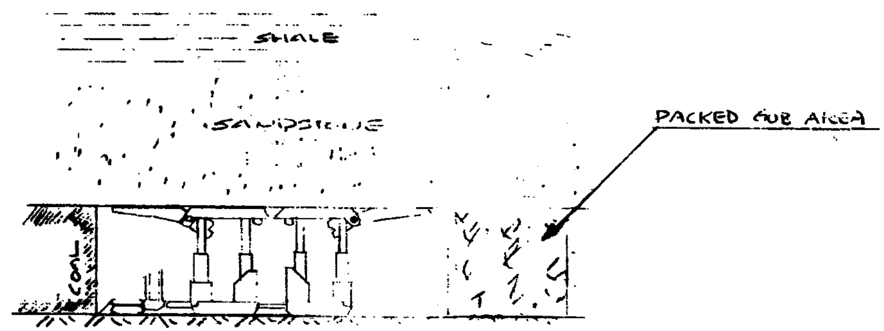
JAN 1973 SK-LWS-B-1
SHEET 2 of 2



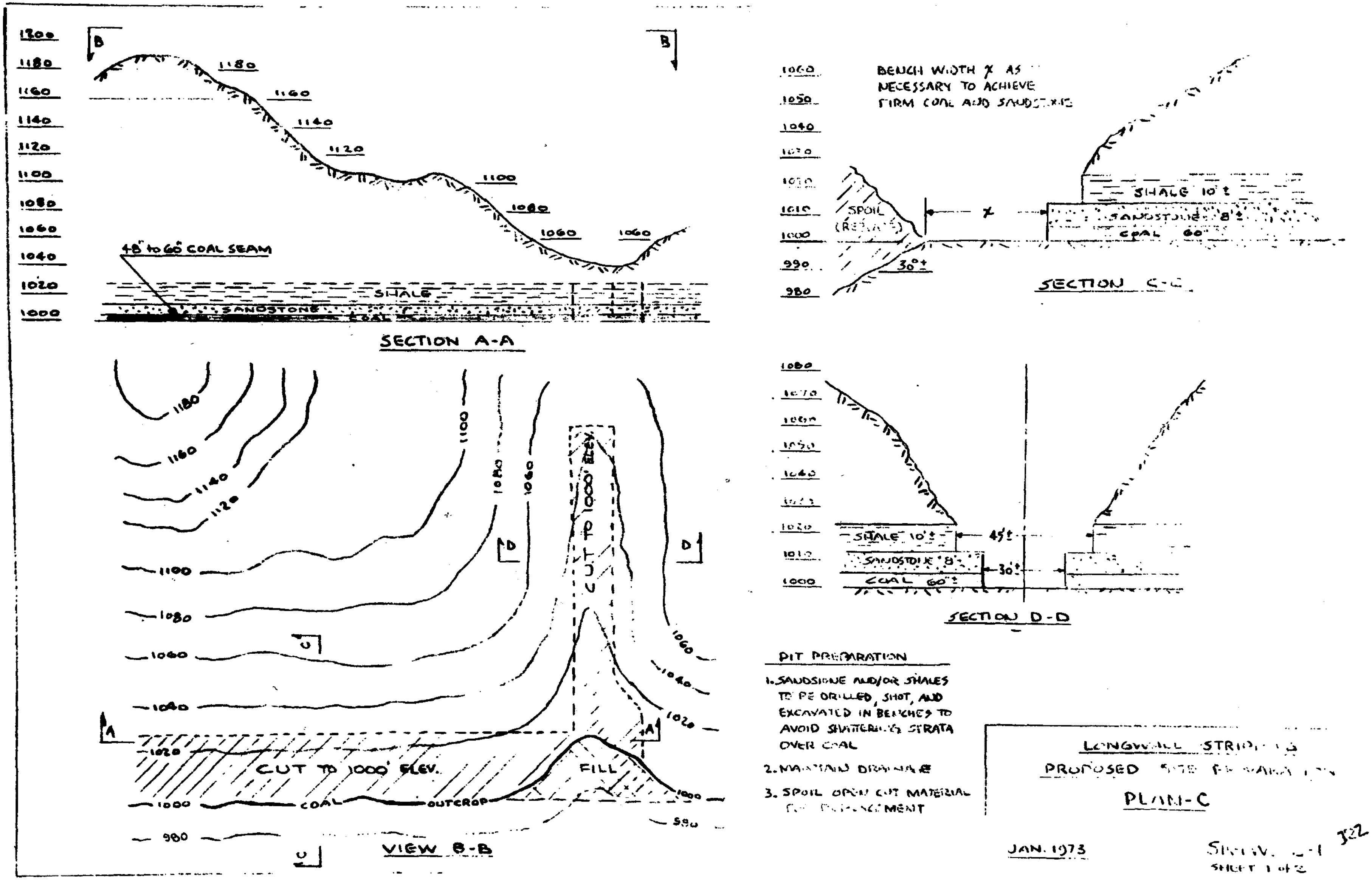
PLAN VIEW OF LONGWALL EQUIPMENT
AT
X-X DWG SK-LWS-B-1

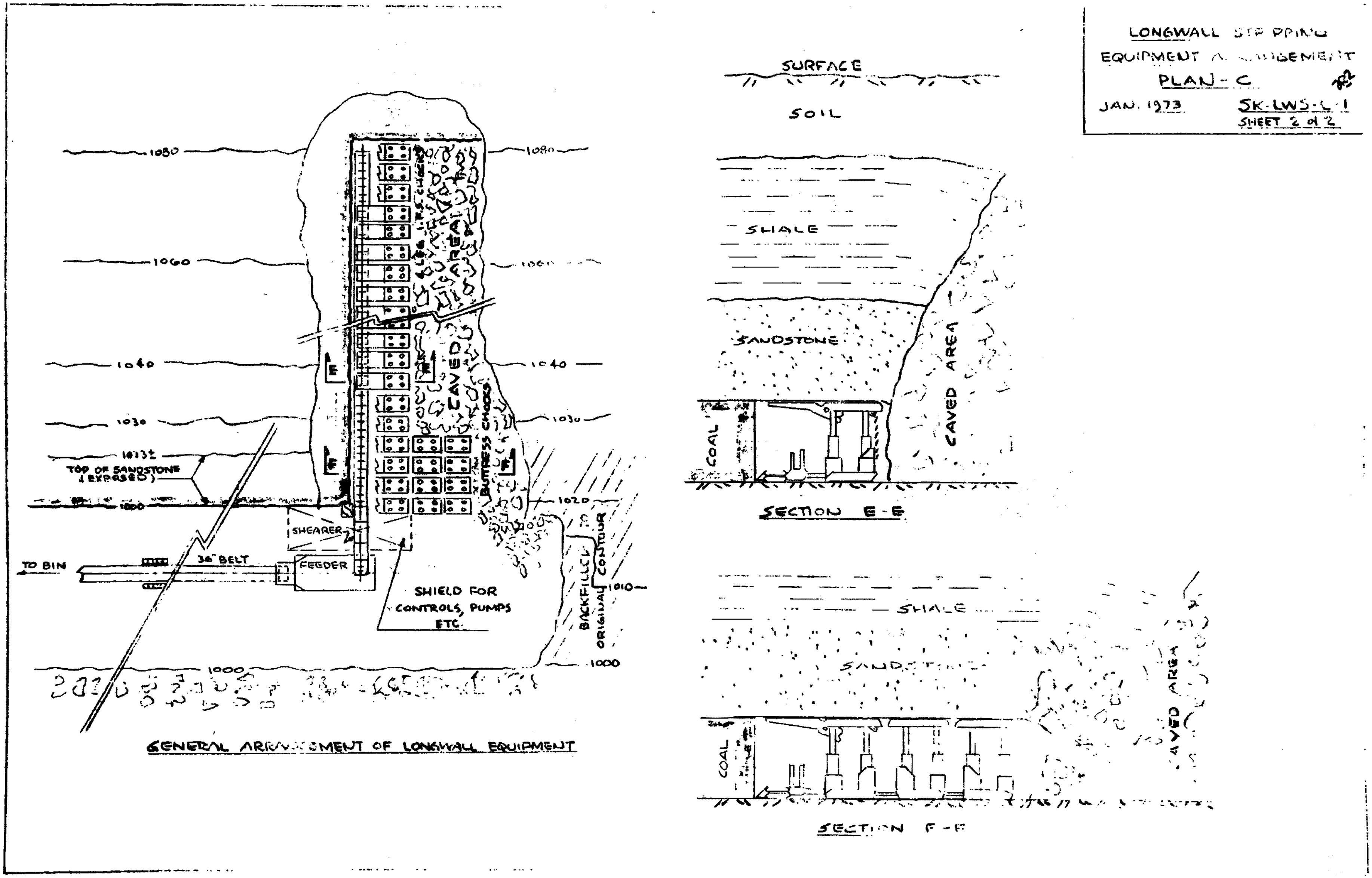


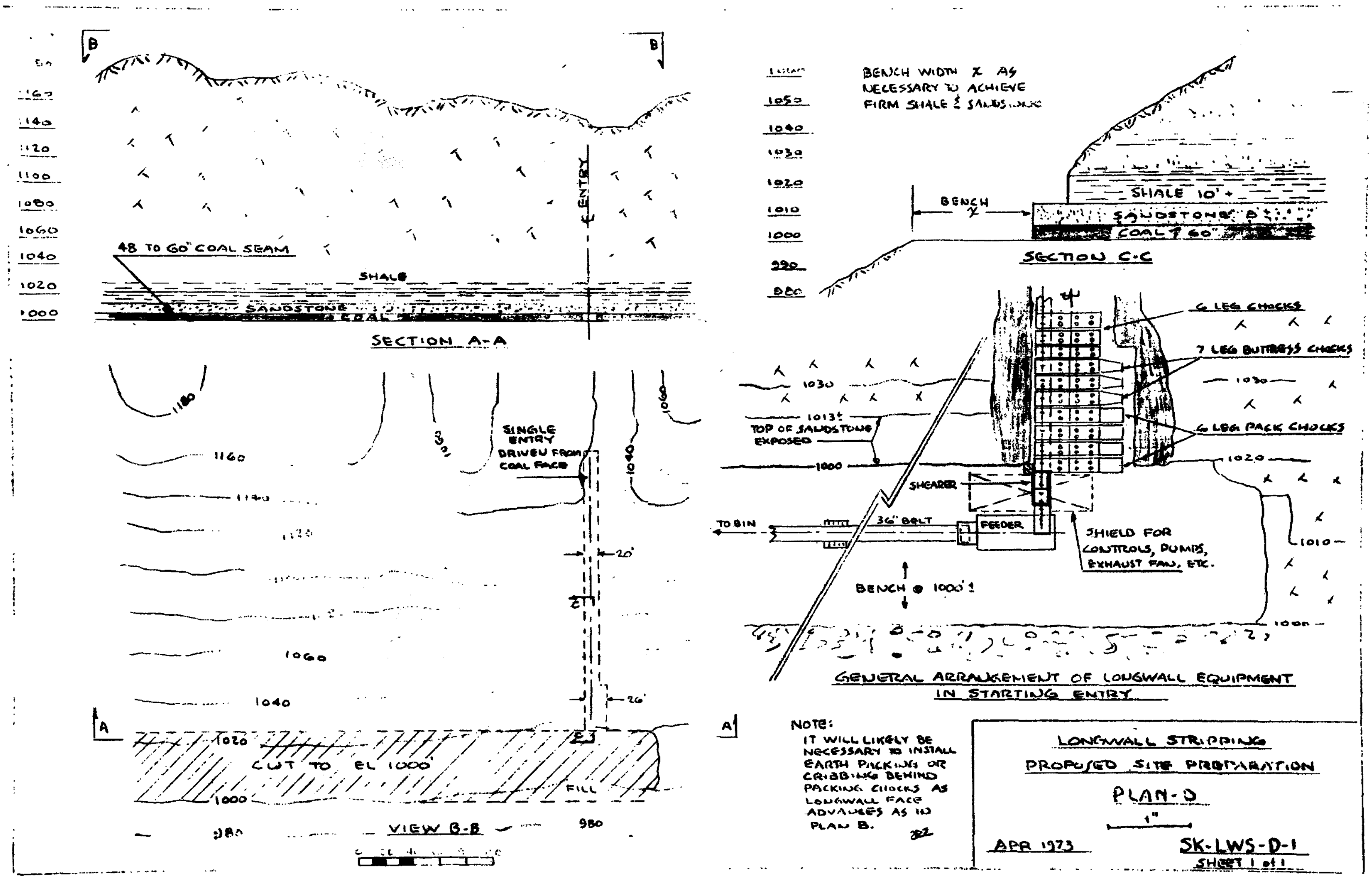
SECTION A-A

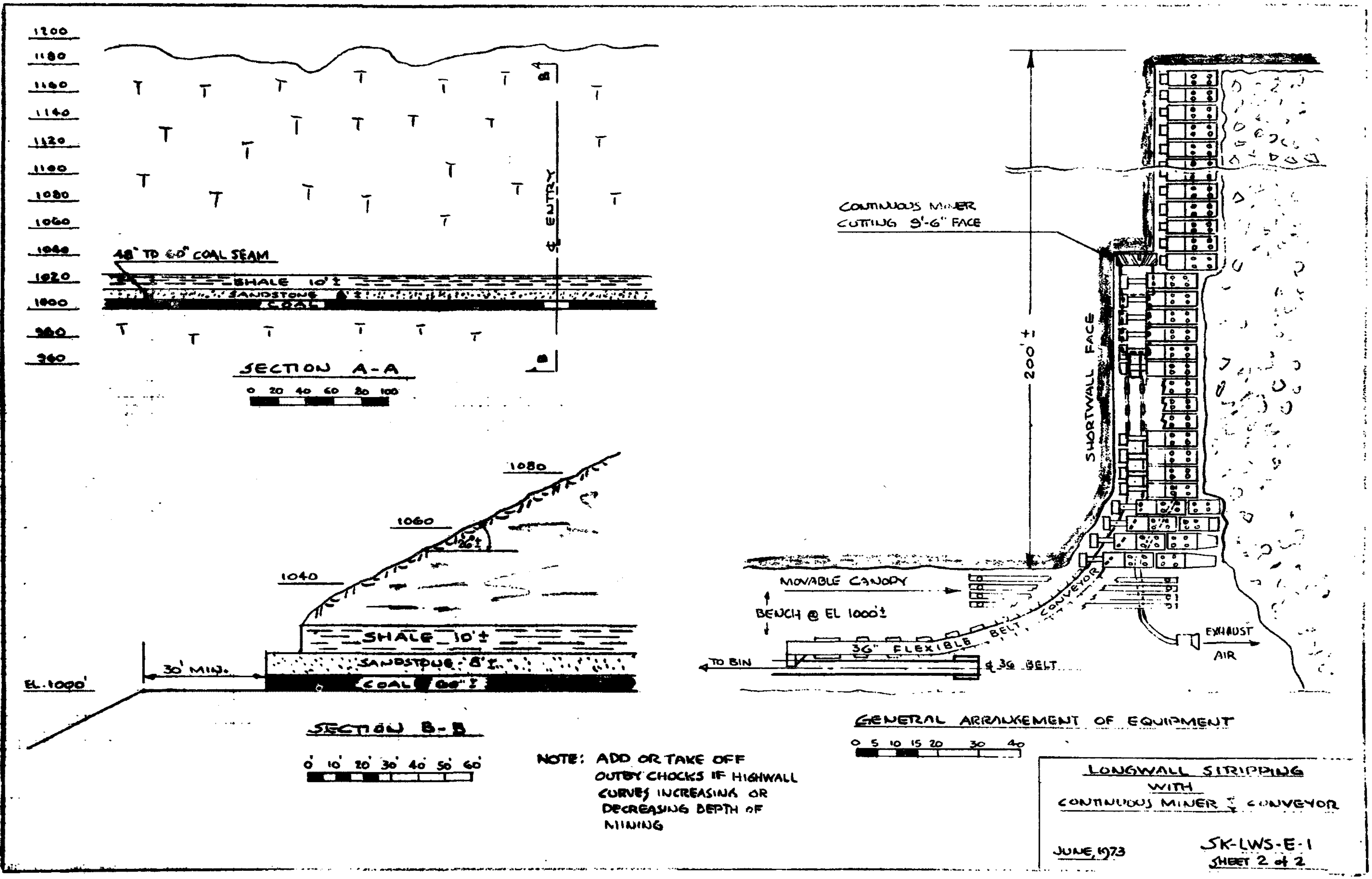


SECTION B-B

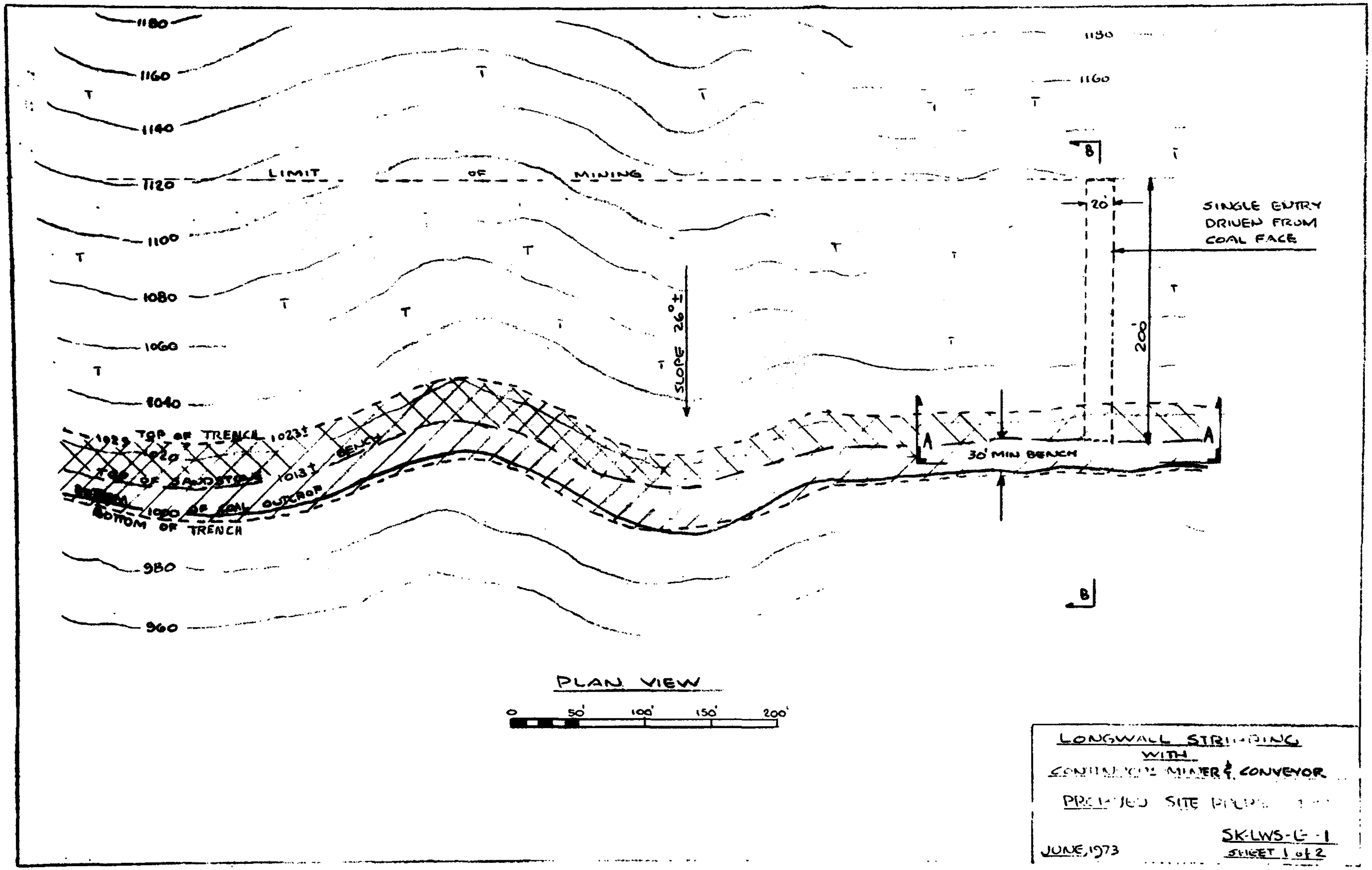

SECTION A-A
48" to 60" COAL SEAM
SHALE
SANDSTONE
COAL
VIEW B-B
CUT TO 1000' ELEV.
FILL
COAL
OUTCROP
BENCH WIDTH X AS NECESSARY TO ACHIEVE FIRM COAL AND SANDSTONE
SPOIL
SHALE 10'±
SANDSTONE 8'±
COAL 60"±
30°±
SECTION C-C
SECTION D-D
45°±
30°±
PIT PREPARATION
1. SANDSTONE AND/OR SHALES TO BE DRILLED, SHOT, AND EXCAVATED IN BENCHES TO AVOID SHATTERING STRATA OVER COAL
2. MAINTAIN DRAINAGE
3. SPOIL OPEN CUT MATERIAL
PROPOSED
PLAN-C
JAN. 1973


LONGWALL STRIPPING
EQUIPMENT ARRANGEMENT
PLAN - C
JAN. 1973
SK-LWS-C-1
SHEET 2 of 2
1080
1060
1040
1030
1020
1010
1000
TOP OF SANDSTONE (EXPOSED)
CAVED AREA
BUTTRESS CHOCKS
SHEARER
FEEDER
TO BIN
36" BELT
SHIELD FOR CONTROLS, PUMPS ETC.
BACKFILLED TO ORIGINAL CONTOUR
GENERAL ARRANGEMENT OF LONGWALL EQUIPMENT
SURFACE
SOIL
SHALE
SANDSTONE
COAL
CAVED AREA
SECTION E-E
SHALE
SECTION F-F


48 TO 60" COAL SEAM
SHALE
SANDSTONE
COAL
ENTRY
SECTION A-A
SINGLE ENTRY DRIVEN FROM COAL FACE
CUT TO EL 1000'
FILL
VIEW B-B
BENCH WIDTH X AS NECESSARY TO ACHIEVE FIRM SHALE & SANDSTONE
BENCH X
SHALE 10'+
SANDSTONE
COAL 60"
SECTION C-C
6 LEG CHOCKS
7 LEG BUTTRESS CHOCKS
6 LEG PACK CHOCKS
1013± TOP OF SANDSTONE EXPOSED
SHEARER
TO BIN
36" BELT
FEEDER
SHIELD FOR CONTROLS, PUMPS, EXHAUST FAN, ETC.
BENCH @ 1000'±
GENERAL ARRANGEMENT OF LONGWALL EQUIPMENT IN STARTING ENTRY
NOTE:
IT WILL LIKELY BE NECESSARY TO INSTALL EARTH PACKING OR CRIBBING BEHIND PACKING CHOCKS AS LONGWALL FACE ADVANCES AS IN PLAN B.
LONGWALL STRIPPING
PROPOSED SITE PREPARATION
PLAN-D
APR 1973
SK-LWS-D-1
SHEET 1 of 1



SECTION A-A
48" TO 60" COAL SEAM
SHALE 10'±
SANDSTONE
COAL
℄ ENTRY
1200
1180
1160
1140
1120
1100
1080
1060
1040
1020
1000
980
960
0 20 40 60 80 100
SECTION B-B
1080
1060
1040
SHALE 10'±
SANDSTONE 8'±
COAL 60"±
30' MIN.
EL. 1000'
0 10 20 30 40 50 60
NOTE: ADD OR TAKE OFF OUTBY CHOCKS IF HIGHWALL CURVES INCREASING OR DECREASING DEPTH OF MINING
CONTINUOUS MINER CUTTING 9'-6" FACE
200'±
SHORTWALL FACE
MOVABLE CANOPY
BENCH @ EL 1000'±
36" FLEXIBLE BELT CONVEYOR
TO BIN
℄ 36 BELT
EXHAUST AIR
GENERAL ARRANGEMENT OF EQUIPMENT
0 5 10 15 20 30 40
LONGWALL STRIPPING WITH CONTINUOUS MINER & CONVEYOR
JUNE, 1973
SK-LWS-E-1
SHEET 2 of 2



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5. Report Date

6.

8. Performing Organization Report No.

7. Author(s)

Moomau, H.F., Zachar, F.R. & Leonard, J.W.

10. Project No.

9. Organization

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Petersburg, West Virginia

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Report No. 670/2-74-002

16. Abstract

"Longwall stripping" is a new surface mining concept developed by the Environmental Protection Agency. Longwall stripping adapts existing underground longwall mining technology for use in recovering shallow cover coal without the total environmental disturbance often associated with surface mining. This study investigated the environmental, mining and economic feasibility of longwall stripping.

Longwall stripping was determined to be a feasible method for mining coal under shallow cover. A discussion of the criteria that is necessary to consider in selecting a site and developing the mining plan is included. Additionally, alternate methods of the longwall stripping concept are discussed.

This report was submitted in fulfillment of Contract 68-01-0763 under the sponsorship of the Office of Research and Development, Environmental Protection Agency.

17a. Descriptors

*Environmental disturbance, *Surface mining, *Strip mining, *Auger mining, *Longwall mining, *Shortwall mining, *Open-end outby, *Fresh-air outby, *Shallow cover mining, *Roof-support, *Shearers, *Chocks, *Conveyors, *Continuous miner, *Packwalling, *Bench, *Stowing, *Highwall

17b. Identifiers

Longwall Stripping, Feasibility

17c. COWRR Field & Group

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