## Summary

The flexibility of Reserve's overall control system is greater than at first thought achievable with the extensive use of commercially available preprogrammed control systems.

The distributed control system does an extensive and reliable job in monitoring and controlling many plant functions. What cannot be easily accomplished in the basic TDC-2000 equipment can be implemented in either of the two control room computer systems. As portions of the plant control system were brought on line, changes in control philosophy were easily accomplished by simple configuration changes.

We believe this control system will be able to adapt to any future changes required to further improve Reserve's product. ■

# Multiple Seam Mining at the Glenharold Mine

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**Abstract**—*The Glenharold mine is a multiple seam dragline operation where many different stripping methods are employed. This paper describes the production operations of overburden removal, coal loading, and haulage. Emphasis is placed on the methods used to uncover five seams using draglines, scrapers, and a small shovel.*

## Introduction

The Glenharold mine is a surface mine owned by Basin Cooperative Services, a subsidiary of Basin Electric Power Cooperative, and operated by Consolidation Coal Co. It is located about 90 km (55 miles) northwest of Bismarck, and 3 km (2 miles) southeast of Stanton in west central North Dakota.

Glenharold has a nominal design capacity of 3.0 Mt/a (3.3 million stpy). With the exception of local coal sales of 18,000 Mt/a (20,000 stpy) this production supplies fuel for Basin Electric's Leland Olds generating station, a mine mouth power plant. The mine has 175 hourly and 50 salary employees.

The Glenharold reserve extends over 210 $km^2$ (80 sq miles). The mining area is on a dissected plateau between the broad, flat Missouri River flood plain to the north and the gently rolling uplands to the south. Erosion by intermittently flowing streams has produced many narrow, steep-walled drainage ways. Mining begins at the 6 m (20 ft) cover line and continues to the economic recovery line.

The coal seams at Glenharold are part of the Sentinel Butte formation, in the Fort Union group of the Tertiary Period. The average thickness of the Butte formation is 170 m (550 ft). The formation consists of alternating beds of silt, clay, sand, and lignite.

Glenharold is a multiple seam operation with up to five seams being recovered. In the present mining areas the lowest recoverable seam is the 2 seam Hagel. The 2 seam is the thickest seam in the area with a range of 2.1-2.7 m (7-9 ft). The Keuther-1 (310 seam), the first major seam above the 2 seam, has an average thickness of 2 m (6.5 ft).

In most areas the 310 seam is split into two seams. The upper split, the 31A, is 0.9-1.1 m (3-3.5 ft) thick and the lower split, the 31C, is 1.1-1.2 m (3.5-4 ft) thick. The thickness of the parting between the splits ranges from 0-9 m (0-30 ft). A 0.6 m (2 ft) thick seam, the 311, about 0.5 m (1-2 ft) below the Keuther-1 is also recovered. The second major seam above the 2 seam is the Keuther-2 (320 seam) with an average thickness of 1.8 m (6 ft).

In both mining areas the 320 is split into two seams, the 32A and 32B. Both splits are about 0.9 m (3 ft) thick and only the 32B is recovered. The 32A is not recovered because of its poor quality. Cross sections illustrating seam correlation in the active mining areas are shown in Figs. 1 and 2.

## Overburden Removal

The overburden is composed of silt, clay, and sand. These materials are soft and can be removed by the draglines without blasting.

The major pieces of stripping equipment at Glenharold are a Page 762 dragline and a Bucyrus-Erie 1250 dragline. A summary of the operating statistics for these machines is shown in Table 1. The draglines work in separate pits and move most of the yardage stripped. They operate three shifts a day 363 days a year.

In both pits, the thin intervals between seams are stripped using 23.7 $m^3$ (31 cu yd) scrapers. A 12.2 $m^3$ (16 cu yd) shovel is used to strip a thin interval in the 762 mining area. These auxiliary stripping pieces are scheduled as required.

Multiple seam stripping using draglines requires careful pit planning and close dragline supervision. To uncover the multiple seams it is necessary for the draglines to make several stripping passes when mining each pit, requiring the dragline be operated from different levels and positions on each pass. Descriptions of the stripping operations used in each mining area are outlined in the following paragraphs.

Table 1—Dragline Operating Statistics

| | | 762 | 1250 |
|---|---|---|---|
| Bucket Size | ($m^3$) | 46 | 25 |
| | (cu yd) | 60 | 33 |
| Boom Length | (m) | 91 | 61 |
| | (ft) | 297 | 200 |
| Operating Radius | (m) | 88 | 56 |
| | (ft) | 290 | 185 |
| Productivity | | | |
| From Highwall | ($m^3$/d) | 32,900 | 25,200 |
| | (cu yd/d) | 43,000 | 33,000 |
| From Spoil | ($m^3$/d) | 25,200 | 19,100 |
| | (cu yd/d) | 33,000 | 25,000 |

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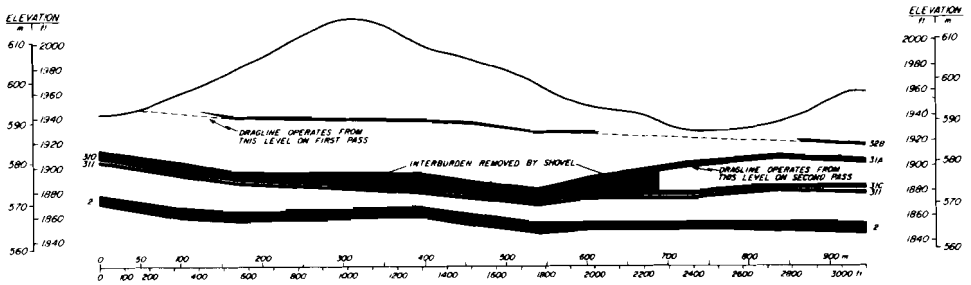


Fig. 1—Longitudinal section 762 mining area

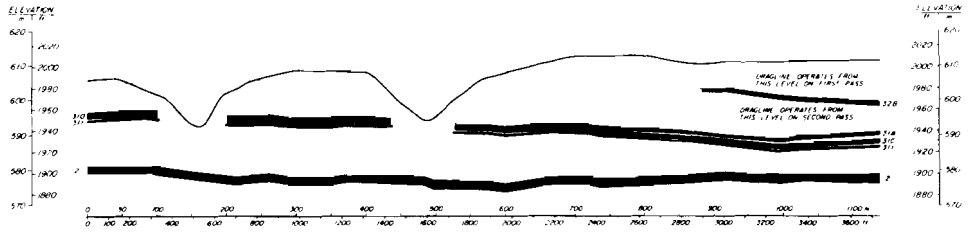


Fig. 2—Longitudinal section 1250 mining area

*762 Mining Area*

The 762 makes three stripping passes during the mining of each pit. A cross section of the first pass is illustrated in Fig. 3-1. On this pass, the dragline operates from the level of the 32B seam, as shown on Fig. 1, and uncovers two seams. To the side, the overburden above the 32B seam is removed by chopping, and in front, the interburden above the 310-31A seams is stripped using the simple side casting method.

After ramping down to the level of the 31A seam, the 762 makes a second pass in an area where the interval between the 31A and 31C seams exceeds 4 m (13 ft). Figure 3-2 is a cross section illustrating the second pass. A 25 m (80 ft) wide bench is left at the level of the 31A seam to give the 762 sufficient operating room when digging from the key cut position. The dragline shown on the cross section is operating from the key cut position. The key cut is the small wedge of material outlined by the dashed line. After digging the key cut, the dragline will move over closer to the spoils and remove the remaining material in the cut.

In areas where the interval between the 31A and 31C seams is less than 4 m (13 ft), a 12.2 $m^3$ (16 cu yd) coal loading shovel is used to strip the interburden. The limited reach of the shovel makes it necessary to strip the interval in two passes.
A 19.8 m (65 ft) wide cut along the spoil side is taken first. This material is dumped into the open area between the dragline spoils and the highwall, as shown on Fig. 4-1. Any remaining interval is stripped on the second pass, and spoiled on the coal adjacent to the first pass spoil. A cross section of the second pass is illustrated in Fig. 4-2. A crawler-type dozer is used to rip the interburden and push the second pass spoil material off the coal and over the highwall.

The parting above the 311 seam is stripped by scrapers, and hauled to a location along the spoil bench. A dozer is used to rip the parting and push load the scrapers. Normally one dozer and two scrapers are operated together.

After the spoils from dragline passes one and two have been leveled to prepare a bench, the 762 moves onto the spoils and uncovers the 2 seam. Several methods of moving the dragline onto the spoil bench have been used depending on the pit's characteristics and limitations. Two of these methods are:

- When the dragline is operating from a bench and making the final highwall pass, and the elevations of the highwall and spoil benches are about equal, as shown in Fig. 3-2. The dragline can use the parting material above the 3C1 seam to build a ramp from the highwall bench to the spoil bench.
- In situations where it is necessary to move the dragline directly from the highwall to the spoils, dozers and scrapers are used to build a ramp from the highwall to the spoils.

A cross section of the spoil pass is shown in Fig. 3-3. When operating from the spoils, the draglines experience a 25% decrease in productivity. This decrease in productivity is caused by:

- The majority of the material being chopped because the dragline does not have an open face in which to dig;
- The angle of swing increasing from 90° to about 160°; and
- The machine spending time preparing the bench.

The decrease in productivity does not reflect rehandle, which can approach 100% of interval yardage.

*1250 Mining Area*

On the first of three passes, the 1250 operates from the upper bench, shown as a dashed line on Fig. 2. Chopping in at the end of the pit, the dragline uncovers the 32B seam until an area of poor quality coal is encountered. At this point a ramp is dug from the top of the coal to the upper bench. Later, the dragline will deadhead down this ramp to the level of the 32B seam and chop in at the end of the pit and uncover the 31A seam. A bench, 17 m (55 ft) wide, is left at the 32B level to give the dragline sufficient operating room when digging from the key cut position. Cross section showing the two passes taken in this area are illustrated in Figs. 5-1 and 5-2. As the dragline uncovers the 31A seam, it will move up the ramp and uncover the remaining 31A seam from the upper bench as shown in Fig. 6-1.

The 0-3 m (0-10 ft) of interburden between the 31A and 31C seams and the 0.8 m (2-3 ft) of interburden between the 31C and 311 seams are ripped by dozers and removed by scrapers. This material is dumped between the highwall spoils and the previous spoil bench, as shown in Fig. 5-3. Dozers are used to create short circular hauls by dozing ramps through the highwall spoils and building a road between the highwall spoils and the previous bench. Parting material may also be dumped on the spoil bench or used to build up inclines.

As in the 762 pit, the 1250 will move onto the spoils to uncover the 2 seam. Due to the machine's short operating radius, it is necessary to extend the spoil bench out over the parting above the 2 seam, as illustrated in Figs. 5-3 and 6-2. When this material is dug, the slope to the spoil bench is at a 55° angle. The draglines experience a 25% decrease in productivity when operating from the spoils.

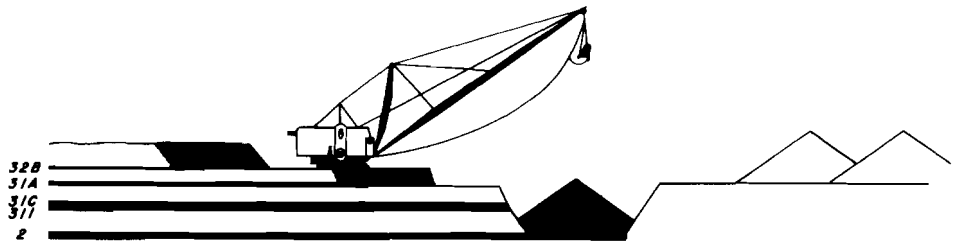


Fig. 3-1—First pass

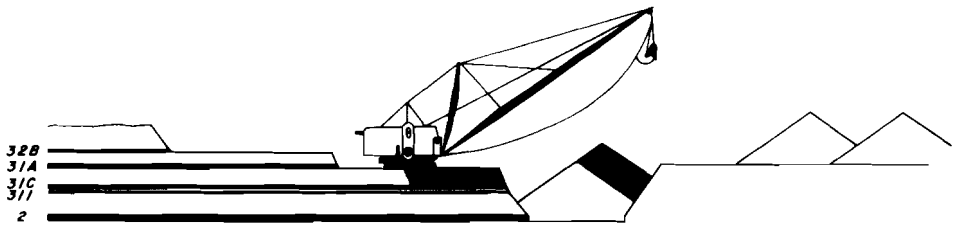


Fig. 3-2—Second pass

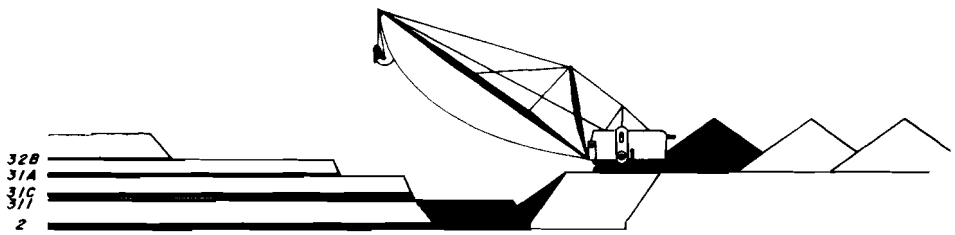


Fig. 3-3—Third pass

Cross Sectional Views Illustrating the 762
Five Seam Stripping Method

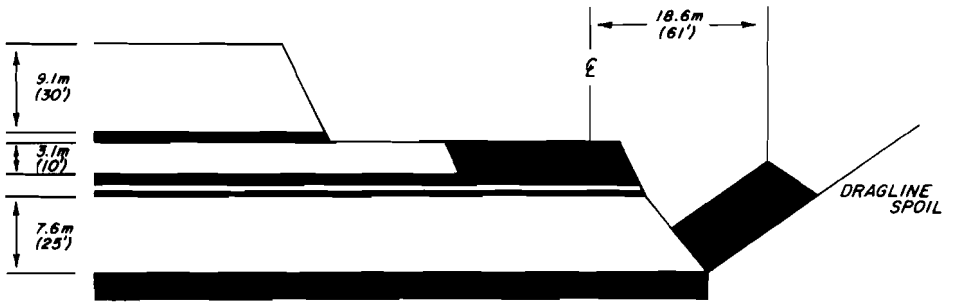


Fig. 4-1—First pass

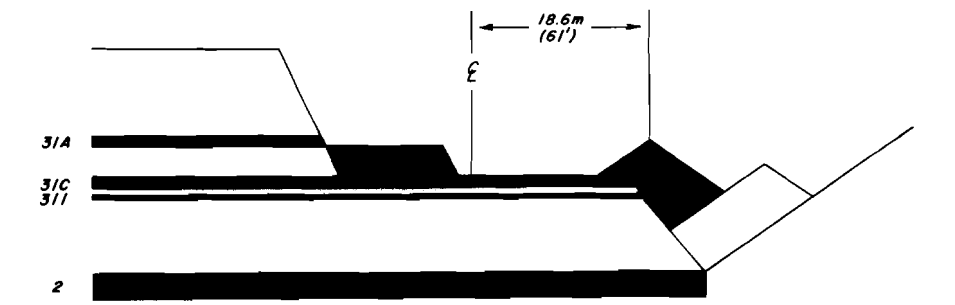


Fig. 4-2—Second pass

Cross Sectional Views Showing the Interval Material Moved
by the Shovel in a Two-Pass Stripping Operation

## Coal Shooting and Ripping

Since Glenharold's product is raw coal, it is necessary to take precautions to prevent out-of-seam dilution from adversely affecting product quality. Before the coal is prepared for loading, its surface is cleaned, using a small front-end loader. The amount of material removed by the loader is small, but has a dry ash content of about 85%. When production is from the thin seams, (i.e., thickness less than 0.6 m (2 ft), the pit dilution material will increase the ash content and decrease the Btu content of the coal significantly.

After its surface has been cleaned, the coal is ripped or shot in preparation for loading. Seams thicker than 1.5 m (5 ft) are drilled using twin-masted coal drills. These drills are capable of drilling a hole with a diameter of 70 mm (2.75 in.), to a depth of 4.6 m (15 ft). The holes are drilled the depth of the coal on a 3 m (10 ft) square pattern. The holes are loaded with about 4.5 kg (10 lb) of ANFO and a cartridge of high explosives attached to a detonating cord downline. In areas where holes are wet, two or three additional cartridges are used in place of the ANFO. The holes are stemmed with coal cuttings. A detonating cord trunk line connects all the holes in a series with 17 m sec delays inserted between alternate rows. An electric blasting cap is attached to one end of the trunk line. It is detonated by an electric blasting machine. Sufficient coal is shot on one shift to satisfy the day's loading requirements.

Only the thick seams are shot. The thin seams, less than 1.5 m (5 ft), are ripped by a crawler-type dozer equipped with a single shank ripper. The coal is ripped in three directions—parallel with the pit, perpendicular to the pit, and diagonal across the pit. The spacing between passes varies from 0.9-1.5 m (3-5 ft). The thicker seams are not ripped because the dozers cannot effectively break up the lower parts of the seam.

## Coal Loading

Two shovels, a 12.2 $m^3$ (16 cu yd) and a 10.7 $m^3$ (14 cu yd), along with a 7.6 $m^3$ (10 cu yd) front-end loader are used for coal loading. One shovel is assigned to each pit, and the front-end loader operates in either pit as required.

Coal loading scheduled two shifts a day, five days a week. Two shovels are operated on day shift and one on afternoon shift. The front-end loader is operated on day or afternoon shifts as required. By loading from two or three seams on each shift, poorer quality coal from the thin seams can be blended with better quality coal from the thick seams to yield a more uniform product.

## Coal Transportation

The coal is transported about 6.4 km (4 miles) from the pit to the plant by a fleet of six tractor trailer-type haulage trucks.

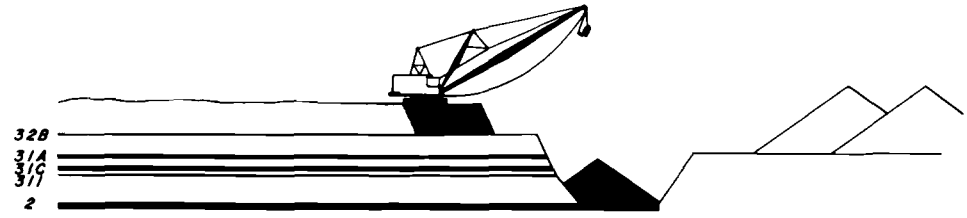

Fig. 5-1—First pass

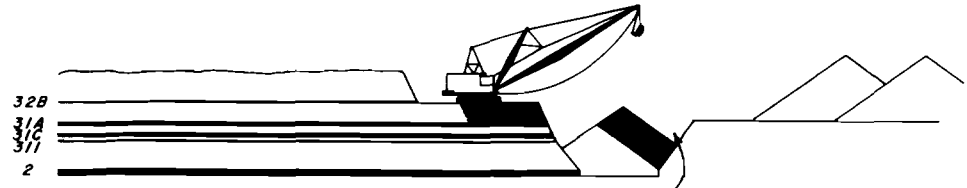

Fig. 5-2—Second pass

SCRAPERS DUMP PARTING MATERIAL IN THIS VOID

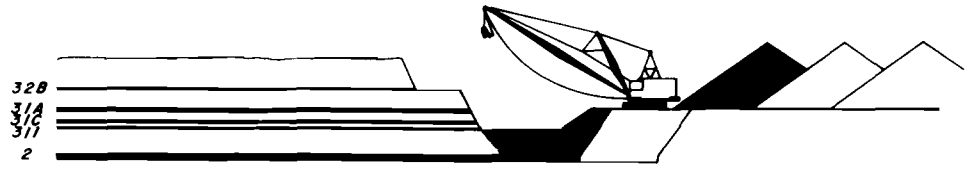

FIGURE 5-3: THIRD PASS

Cross Sectional Views Illustrating the 1250 Five Seam Stripping Method

These tractors are diesel powered with electric drive. The trailers are bottom dump with a rated capacity of 165 t (180 st).

Five trucks are scheduled per loading shift, and a sixth is operated if necessary. Normally, two or three trucks will haul from each shovel and one or two trucks from the front-end loader.

about 180° and spoils into an open pit. The remaining material below the bench is stripped using the simple side casting method.

At Glenharold, the bench is established at the elevation of the highest recoverable seam, enabling the dragline to uncover two seams at once. This method is illustrated in Fig. 3-1.

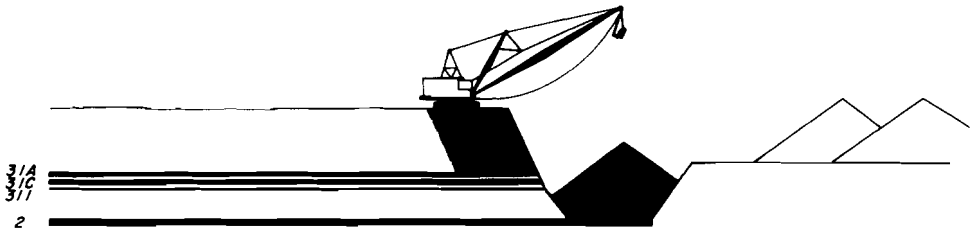


Fig. 6-1—First pass

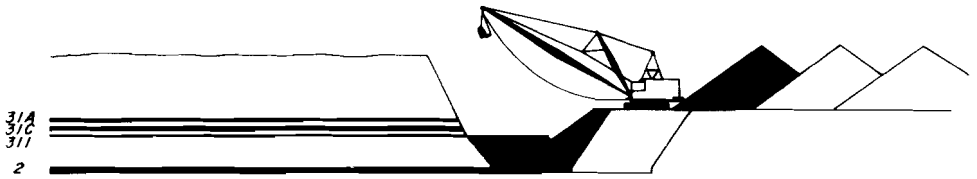


Fig. 6-2—Second pass

Cross Sectional Views Illustrating the 1250 Four Seam Stripping Method

## Summary

Initially the Glenharold dragline stripping operation may appear complicated, but the operation is actually combinations of the four relatively simple stripping methods: simple side casting, advance benching, terrace, and horseshoe.

The first two are the most common single seam stripping methods. In the simple side casting method, the dragline operates from the surface, digs down to the coal and spoils the overburden into an open pit to one side. The multiple seam equivalent of this method is shown in Fig. 6-1.

In the advance benching method, a modification of the simple side casting method, the dragline operates from a bench below the surface. To one side the machine removes the overburden above the bench by chopping. The dragline swings

When the terrace method is employed, the dragline will make at least two highwall stripping passes during the mining of each pit. The first pass is made using one of the methods described above. On the second pass, the machine operates from a bench and digs the material below the bench using the simple side casting method. It is necessary to leave a terrace or ledge at the bench level to give the dragline sufficient operating room. The simple side casting-terrace method is illustrated in Figs. 5-1 and 5-2. The advance bench-terrace method is illustrated in Figs. 3-1 and 3-2.

In the horseshoe sequence, the spoil from the highwall passes is leveled and the draglines move onto the spoils to uncover the bottom seam, as shown in Figs. 3-3, 5-3, and 6-2.

It should be noted that most complicated multiple seam dragline operations employ a combination of basic stripping methods in their stripping sequence. ■