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Designing a Pullback Dragline Panel for Dipping Coal Seam Conditions

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ABSTRACT: This study, in a broad sense, fills in the missing parts in previous efforts at pullback stripping mode design with a dipping coal seam. Three different spoiling procedures have been developed: the normal mode, where the coal seam is flat/nearly flat; the uphill mode, where the coal seam is dipping and the dragline spoils uphill; and the downhill mode, where the coal seam is again dipping but the dragline spoils downhill. The spoiling pattern has a great impact on dragline efficiency. The waste can be spoiled near the set on which the dragline sits or near the set on which the dragline digs Each pattern has been analysed in pit geometry design. The study of pullback design has been extended to cover key cut waste placement in order to operate with various pit width values and spoil-side concerns to control spoil-bound conditions.

1 INTRODUCTION

Pullback stripping is generally applied when the operating dimensions of a dragline are inappropriate for uncovering coal seams without rehandling. The main advantage of this method is that it enables a dragline which has a limited operating radius to handle overburden covers of greater depth than would normally be contemplated. Overburden removal can be performed with a single dragline or a tandem dragline system. When a single dragline is utilized, the dragline takes periodic sojourns across on the spoil pile, getting there either on a section of extended bench or bridge, or around the end of the pit. When a tandem system is used, one machine operates on the highwall side, while the other strips the rehandle material and the barrier left on the highwall side.

Of the previous studies of this topic, that of Cook & Lappİ (1979) can be mentioned İn that it exposed the geometrical interaction between relative dimensions of die dragline and *the* pit with a set of equations for the horseshoe method. Satchwell (1985) studied the pit geometry of the double pass method with rehandle, in which each one of two draglines would be deployed on either side of the pit in an effort to design a dragline pit for the Turkish Coal Enterprises' (TKJ) Elbistan-B open-pit lignite mine. Later, Erdem (1996), Erdem & Çelebi (1998) and Erdem et al. (1999) introduced design guidelines for the pullback stripping method for a flat-lying coal seam on one and two benches, respectively. Duran (2000) improved upon me above-mentioned studies, mainly by incorporating design guidelines for inclined coal seams, different spoiling patterns, key cut excavation and placement procedures. This study presents a pullback model developed for optimal dragline selection.

2 THE PULLBACK MODEL

In pullback stripping, the spoil pile is allowed to ride up the highwall as rehandling is an inherent characteristic of this method. As the dragline is positioned on the set behind the one to be dug, there exist two spoiling pattern alternatives. In the first of these, the waste is dumped into the empty pit near the set on which the dragline is located (Figure 1). This is called the dump-near-sit (DNS) partem. The dimensions used İn the design stage are illustrated in Figures 1-2 and given in the nomenclature. In the second pattern, the waste is dumped into the empty pit near the set which the dragline digs (Figure 3). This is called the dump-near-dig (DND) pattern.

The model comprises of three operating modes (Level, Downhill and Uphill) in each of which two spoiling patterns (DNS and DND) are embedded. In the case of an inclined coal seam, the model analyses downhill and uphill operating principles. In addition, each spoiling partem includes three key cut waste placement procedures (dumping at the toe of the previous spoil piIe=>W_{mm}; dumping within pit=>W_m,u; and dumping at the toe of the coal seam^Wmax). Finally, the model can study 18 different operational scenarios for pullback stripping.

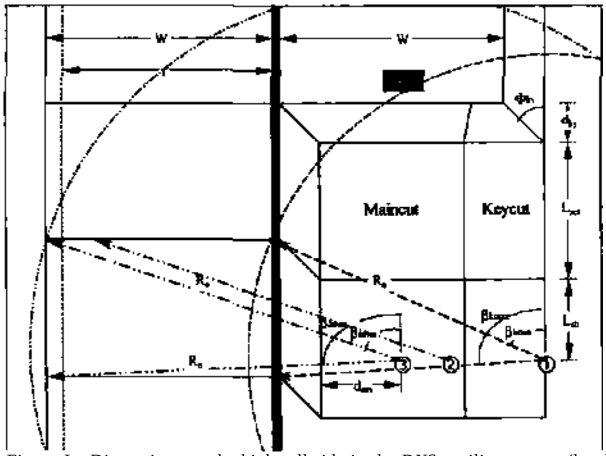

Figure I. Dimensions on the highwall side in the *DNS* spoiling pattern (level coal seam, W^,,).

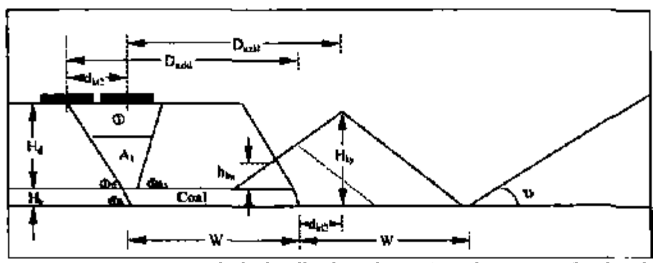

Figure 2. Dimensions on the highwall side in the DNS spoiling pattern (level coal seam, W™,).

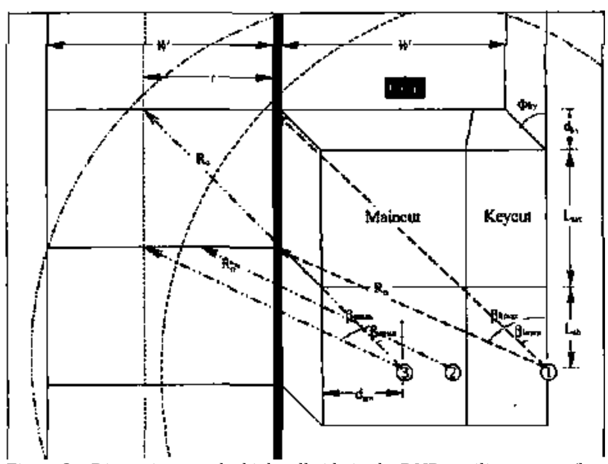

Figure 3. Dimensions on the highwall side in the DND spoiling pattern (level coal seam).

2.1. *Dragline selection*

The pullback model was tested on a virtual strip coal mine with the characteristics given in Table 1. Three draglines, whose main physical characteristics are given in Table 2, were used in the test procedure.

Table 1. Input data for the pullback model.

Overburden thickness	m	30
Coal seam thickness	m	4
Highwall slope angle		65
Coal seam bench angle		65
Angle of repose of waste in spoil pile		38
Swell factor		1.36
Coal seam inclination angle		10

Table 2. Data related to input draglines.

	Operating radius	Tub diameter	Digging depth	Dumping height
	m	m	m	m
#1	77.7	19.4	29.0	38.1
#2	83.8	19.4	33.5	42.7
#3	91.1	19.4	44.2	32.0

The model was executed for all operating modes and spoiling patterns towards reaching common conclusions and rules so that generic operating guidelines for pullback stripping could be formulated. Therefore, me test was conducted for each individual combination of a total of 18 cases. These are given below:

1. Level mode, DNS pattern, W_{min} (Table 3)
2. Level mode, DNS pattern, W_{mjd} (Table 3)
3. Level mode, DNS pattern, W_{max} (Table 3)
4. Level mode, DND pattern, W_{min} (Table 4)
5. Level mode, DND pattern, W_{mid} (Table 4)
6. Level mode, DND pattern, W™« (Table 4)
7. Downhill mode, DNS pattern, W™ (Table 5)
8. Downhill mode, DNS pattern, W_{mid} (Table 5)
9. Downhill mode, DNS pattern, W_{max} (Table 5)
10. Downhill mode, DND pattern, W_{min} (Table 6)
11. Downhill mode, DND pattern, W_{mLd} (Table 6)
12. Downhill mode, DND pattern, W™* (Table 6)
13. Uphill mode, DNS pattern, W_{miD} (Table 7)
14. Uphill mode, DNS pattern, W_{mi}d (Table 7)
15. Uphill mode, DNS pattern, W_{max} (Table 7)
16. Uphill mode, DND pattern, W_{min} (Table 8)
17. Uphill mode, DND pattern, W_{mid} (Table 8)
18. Uphill mode, DND pattern, W_{max} (Table 8)

3 MODEL RESULTS

3.1. *Results of the DNS spoiling pattern*

1. Pit width can be assigned an interval (Wnm^WmHj^Wm,,;,) instead of a single value. However, the downhill mode offers a wider interval than the uphill mode.

2. In level seams and downhill spoiling of inclined seams, the required (Ruzki) and available reach (D_{uz}iti) at the key cut position are independent of pit width and take constant values. In contrast, in uphill spoiling of inclined seams, the required and available reach at the key cut position and the available reach at the main cut position (D^an) are inversely proportional to pit width.

3. Set area (A J is directly proportional to pit width. It increases as the pit width increases and is maximized at the largest pit.

4. In level seams and downhill spoiling of inclined seams, average swing angles at the key cut (ßkey) and main cut positions (ßmain) are directly proportional to pit width. A rise in pit width increases swing angles. Conversely, in uphill spoiling, a rise in pit width decreases swing angles.

Table 3. Results of the piillback model (pattern = dumpi near sit, coal seam = level).

Variable	Dragline #1			Dragline #2			Dragline #3		
	W_{mID}	W_{mid}	W^	$W_{m,,,}$	W_{mid}	W «	W_{min}	W*	W™
W	24.25	34.00	44.12	25.92	39.00	51.84	30.34	45.00	60.69
dk.1	19.87	10.12	0.00	0.00	12.84	0.00	0.00	15.69	0.00
Ruzkl	59.97	59.97	59.97	67.69	67.69	67.69	76.54	76.54	76.54
Duikl	59.97	59.97	59.97	67.69	67.69	67.69	76.54	76.54	76.54
H*	2.12	*9.65*	Î7.82	-0.34	7.48	17.86	-1.53	*5.54*	18.09
R.™	88.69	91.13	93.66	89.11	92.38	95.59	90.21	93.88	97.80
D_{uan}	59.97	59.97	59.97	67.69	67.69	67.69	76.54	76.54	76.54
D_y	0.21	3.56	6.78	3.07	6.77	10.28	7.13	10.36	13.96
r	29.57	29.57	29.57	37.29	37.29	37.29	46.14	46.14	46.14
Hba	4.14	6.60	8.95	1.82	4.53	7.10	-0.28	2.09	4.74
sp	2	3	3	2	3	3	2	3	3
dm2	0.00	13.97	10.65	000	16.83	13.18	0.00	20.79	16.81
L«,	25.32	26.28	27.22	30.47	31.82	32.07	36.95	38.23	37.26
A«,	614.04	893.46	1201.00	789.70	1241.10	1662.54	1121.30	1720.53	2261.31
ft*	59.32	59.72	60.11	64.13	64.66	64.76	68.96	69.43	69.08
ft™	59.32	59.72	60.11	64.13	64.66	64.76	68.96	69.43	69.08
Hpp	26.70	27.30	27.74	30.02	30.25	30.37	33.93	33.49	33.13
Wp,	38.47	52.50	66.74	36.08	53.90	71.22	36.84	55 63	75.94
Pr*	33.19	30.49	28.21	26.14	24.71	23.41	16.84	17.68	17.91
R*	57.82	62.88	67.56	58.01	63.05	67.68	59.36	62.93	67.09
L*	103.82	91.28	76.77	120.94	110.41	98.83	138.22	131.74	123.26
Ddh	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
D*	26.70	27.30	27.74	30.02	30.25	30.37	33 93	33.49	33.13
Rv	97.07	98.31	99.78	93.92	95.96	98.07	91.15	96.26	103.80

Table 4. Results of the pullback model (pattern = dump near dig, coal seam = level).

Variable	Dragline #1			Dragline #2			Dragline #3		
	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}
W	-	-	-	24.25	28.00	31.99	24.25	34.00	43.86
d_{kt1}	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00
R_{uzkl}	-	-	-	40.10	43.85	47.84	40.10	49.85	59.71
D_{uzkl}	-	-	-	40.10	43.85	47.84	40.10	49.85	59.71
H_{bk}	-	-	-	15.36	16.51	17.86	15.43	18.09	18.09
R_{uzan}	-	-	-	88.69	89.63	90.62	88.69	91.13	93.59
D_{uzan}	-	-	-	40.10	43.85	47.84	40.10	49.85	59.71
D_y	-	-	-	-3.99	-1.70	0.58	-3.99	1.68	6.65
r	-	-	-	9.70	13.45	17.44	9.70	19.45	29.31
H_{ba}	-	-	-	12.44	11.97	11.36	12.44	11.01	9.01
sp	-	-	-	3	3	3	3	3	3
d_{kt2}	-	-	-	2.86	4.76	7.20	2.96	7.86	10.31
L_{set}	-	-	-	24.18	22.01	19.40	32.40	26.85	19.40
A_{set}	-	-	-	586.37	616.25	620.58	785.64	912.83	850.87
β_{key}	-	-	-	33.83	36.58	39.45	32.59	39.22	45.68
β_{main}	-	-	-	33.83	36.58	39.45	32.59	39.22	45.68
H_{pp}	-	-	-	19.67	21.38	23.09	19.67	23.91	27.65
W_{pp}	-	-	-	52.96	55.89	58.81	52.96	60.21	66.58
P_{reh}	-	-	-	40.80	38.42	35.88	40.80	34.60	28.38
R_g	-	-	-	63.32	64.68	65.80	63.32	66.25	67.54
L_{ys}	-	-	-	109.79	106.55	103.78	131.00	125.06	122.27
D_{dh}	-	-	-	30.00	30.00	30.00	30.00	30.00	30.00
D_{ds}	-	-	-	19.67	21.38	23.09	19.67	23.91	27.65
β_y	-	-	-	102.80	101.92	101.09	101.76	99.84	98.36

Table 5. Results of the pullback model (pattern = dump near sit, coal seam = inclined, downhill spoiling).

Variable	Dragline #1			Dragline #2			Dragline #3		
	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}
W_y	24.25	31.63	39.65	24.25	36.15	47.70	27.20	42.48	56.84
d_{kt1}	15.40	8.02	0.00	23.45	11.55	0.00	0.00	14.36	0.00
R_{uzkl}	57.20	57.20	57.20	65.24	65.24	65.24	74.39	74.39	74.39
D_{uzkl}	57.20	57.20	57.20	65.24	65.24	65.24	74.39	74.39	74.39
H_{bk}	1.32	6.34	11.77	-2.86	3.06	10.97	-5.23	0.46	10.22
R_{uzan}	77.43	78.07	78.75	77.43	78.45	79.44	77.69	79.00	80.23
D_{uzan}	57.20	57.20	57.20	65.24	65.24	65.24	74.39	74.39	74.39
D_y	-7.24	-5.28	-3.41	-5.81	-3.62	-1.71	-3.21	-1.81	-0.38
r	25.10	25.10	25.10	33.15	33.15	33.15	42.29	42.29	42.29
H_{ba}	3.18	4.50	5.75	-0.09	1.39	2.67	-3.15	-2.20	-1.24
sp	2	3	3	2	3	3	2	3	3
d_{kt2}	0.00	10.59	7.29	0.00	13.99	10.32	0.00	18.35	14.82
L_{set}	20.94	21.61	22.19	25.59	26.44	27.11	31.55	32.15	32.72
A_{set}	507.91	683.64	879.89	620.55	955.77	1293.13	858.37	1365.61	1859.88
β_{key}	54.22	54.48	54.70	59.32	59.64	59.90	64.47	64.69	64.89
β_{main}	54.22	54.48	54.70	59.32	59.64	59.90	64.47	64.69	64.89
H_{pp}	31.89	33.07	34.11	35.13	36.15	36.92	39.46	39.47	39.56
W_{pp}	46.16	58.53	71.63	39.94	58.65	76.51	38.07	60.27	81.28
P_{reh}	23.82	20.73	17.91	16.21	13.91	11.98	4.12	4.86	4.96
R_g	48.89	50.35	51.41	47.20	47.62	47.58	46.25	43.96	42.02
L_{ys}	120.78	118.36	116.52	138.49	137.90	137.96	156.97	159.58	161.66
D_{dh}	33.19	33.19	33.19	33.19	33.19	33.19	33.19	33.19	33.19
D_{ds}	21.36	20.90	20.21	24.00	22.55	20.96	26.97	24.04	21.36
β_y	92.55	96.33	103.71	92.26	102.08	112.48	98.38	110.33	123.00

Table 6. Results of the pullback model (pattern = dump near dig, coal seam = inclined, downhill spoiling).

Variable	Dragline #1			Dragline #2			Dragline #3		
	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}
W_y	-	-	-	24.25	25.00	25.35	24.25	31.00	38.28
d_{kt1}	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00
R_{uzkl}	-	-	-	41.79	42.54	42.89	41.79	48.54	55.82
D_{uzkl}	-	-	-	41.79	42.54	42.89	41.79	48.54	55.82
H_{bk}	-	-	-	11.54	11.78	11.90	11.76	12.92	12.16
R_{uzan}	-	-	-	77.43	77.50	77.53	77.43	78.01	78.64
D_{uzan}	-	-	-	41.79	42.54	42.89	41.79	48.54	55.82
D_y	-	-	-	-8.47	-8.16	-8.01	-8.47	-5.91	-3.76
r	-	-	-	9.70	10.45	10.80	9.70	16.45	23.73
H_{ba}	-	-	-	10.45	10.26	10.18	10.45	8.62	6.24
Sp	-	-	-	3	3	3	3	3	3
d_{kt2}	-	-	-	1.89	2.38	2.62	2.22	5.51	7.16
L_{set}	-	-	-	20.04	19.61	19.40	28.36	24.50	19.40
A_{set}	-	-	-	486.06	490.17	491.78	687.65	759.46	742.73
β_{key}	-	-	-	34.19	34.74	34.99	32.89	37.45	42.25
β_{main}	-	-	-	34.19	34.74	34.99	32.89	37.45	42.25
H_{pp}	-	-	-	27.07	27.48	27.66	27.07	30.47	33.58
W_{pp}	-	-	-	59.99	60.64	60.95	59.99	65.53	70.73
P_{reh}	-	-	-	29.12	28.58	28.32	29.12	24.21	18.91
R_g	-	-	-	55.13	55.09	55.07	55.13	54.19	51.95
L_{ys}	-	-	-	126.22	126.29	126.33	145.05	146.46	149.66
D_{dh}	-	-	-	33.19	33.19	33.19	33.19	33.19	33.19
D_{ds}	-	-	-	17.43	17.61	17.70	17.43	18.90	20.04
β_y	-	-	-	95.81	95.69	95.64	95.35	94.52	100.25

Table 7. Results of the pullback model (pattern = dump near sit, coal seam = inclined, uphill spoiling).

Variable	Dragline #1			Dragline #2			Dragline #3		
	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}
W_y	24.25	28.78	33.04	26.48	34.10	41.57	30.93	41.57	53.29
d_{kt1}	19 06	13.87	8.97	0.00	15.84	7.37	0.00	16.69	3.51
R_{uzkl}	58.18	57.52	56.88	65.82	64.83	63.81	74.39	73.13	71.68
D_{uzkl}	58.18	57.52	56.88	65.82	64.83	63.81	74.39	73.13	71.68
H_{bk}	6.12	10.56	15.73	4.13	11.26	18.58	3.69	11.90	23.55
R_{uzan}	109.58	111.76	113.81	110.65	114.33	117.92	112.80	117.92	123.56
D_{uzan}	58.18	57.52	56.88	65.82	64.83	63.81	74.39	73.13	71.68
D_y	4.66	6.41	8.02	8.54	11.16	13.66	13.67	16.85	20.41
r	28.76	28.09	27.46	36.40	35.40	34.38	44.96	43.71	42.25
H_{ba}	7.12	8.92	10.59	5.46	8.15	10.77	4.22	7.52	11.25
sp	2	3	3	2	3	3	2	3	3
d_{kt2}	0.00	16.49	16.36	0.00	20.97	18.03	0.00	23.78	19.22
L_{set}	23.94	23.12	22.34	29.80	28.42	27.07	36.39	34.48	32.36
A_{set}	580.65	665.34	738.25	788.98	969.19	1124.98	1125.69	1433.14	1724.45
β_{key}	56.57	55.45	54.40	61.62	59.91	58.23	66.23	64.11	61.73
β_{main}	56.57	55.45	54.40	61.62	59.91	58.23	66.23	64.11	61.73
H_{pp}	26.14	27.08	27.93	28.83	30.14	31.38	32.28	33.72	35.36
W_{pp}	35.39	41.54	47.27	34.31	44.11	53.67	35.50	48.43	62.83
P_{reh}	47.91	46.92	46.07	42.97	42.35	41.75	36.80	37.27	37.43
R_g	69.08	73.55	77.63	70.86	77.38	83.65	74.56	82.27	90.99
L_{ys}	71.15	50.13	6.47	89.46	64.36	10.07	104.69	78.24	9.13
D_{dh}	32.10	32.84	33.53	32.46	33.71	34.92	33.19	34.92	36.83
D_{ds}	29.65	30.20	30.68	33.74	34.44	35.08	38.64	39.29	40.04
β_y	110.85	112.02	113.16	106.28	108.27	110.28	102.27	105.04	108.12

Table 8. Results of the pullback model (pattern = dump near dig, coal seam = inclined, uphill spoiling).

Variable	Dragline #1			Dragline #2			Dragline #3		
	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}	W_{min}	W_{mid}	W_{max}
W_y	-	-	-	24.25	26.00	28.64	24.25	31.00	39.18
d_{kt1}	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00
R_{uzkt}	-	-	-	39.13	40.88	43.52	39.13	45.88	54.06
D_{uzkt}	-	-	-	39.13	40.88	43.52	39.13	45.88	54.06
H_{bk}	-	-	-	19.37	20.02	21.26	19.43	22.51	24.99
R_{uzan}	-	-	-	109.58	110.42	111.69	109.58	112.83	116.77
D_{uzan}	-	-	-	39.13	40.88	43.52	39.13	45.88	54.06
D_y	-	-	-	-1.49	-0.10	1.94	-1.49	3.73	9.69
r	-	-	-	9.70	11.45	14.09	9.70	16.45	24.63
H_{ba}	-	-	-	14.05	14.06	14.05	14.05	14.01	13.67
sp	-	-	-	3	3	3	3	3	3
d_{kt2}	-	-	-	6.70	7.41	8.90	6.79	10.53	13.87
L_{set}	-	-	-	22.61	21.37	19.40	30.77	26.11	19.40
A_{set}	-	-	-	548.19	555.62	555.64	746.19	809.31	759.98
β_{key}	-	-	-	32.53	33.74	35.55	31.33	35.67	40.73
β_{main}	-	-	-	32.53	33.74	35.55	31.33	35.67	40.73
H_{pp}	-	-	-	21.66	22.54	23.84	21.66	24.97	28.68
W_{pp}	-	-	-	46.57	47.85	49.72	46.57	51.34	56.64
P_{reh}	-	-	-	53.00	52.12	50.77	53.00	49.57	45.47
R_g	-	-	-	72.85	74.34	76.47	72.85	78.27	83.85
L_{ys}	-	-	-	82.82	77.34	68.54	109.39	93.24	71.21
D_{dh}	-	-	-	32.10	32.38	32.81	32.10	33.20	34.53
D_{ds}	-	-	-	21.31	22.45	24.13	21.31	25.61	30.53
β_y	-	-	-	117.22	116.75	116.07	114.88	113.33	111.72

5. In level seams and downhill spoiling of inclined seams, the effective reach (r) is independent of pit width and takes constant values. In contrast, in uphill spoiling of inclined seams, it is inversely proportional to pit width.

6. In level seams and downhill spoiling of inclined seams, set length (L_{Kt}) is directly proportional to pit width. However, marginal increase in the set length is less than that in the pit width. In uphill spoiling of inclined seams, set length is inversely proportional to pit width.

7. The rehandle percentage ($P_{re}h$) decreases as pit width increases. It is lower in downhill mode than in uphill mode for the same operating conditions.

8. The height the key cut spoil (Hbk) and the main cut spoil (Hba) climb on the highwall increases with the pit width. Here, marginal increase in Hbk is more than that in Hba- This indicates that die wider the pit is, the larger the part of the coal seam that is buried under the waste barrier.

9. As the pit gets wider, the number of points on which the dragline is positioned (sp) increases from 2 to 3 due mainly to excavation of the key cut from 2 points.

10. As the pit gets wider, the required reach on the spoil side (Rg) increases, but the set length on the spoil side (Lys) decreases. In addition, R_g is longer in uphill mode than downhill mode for the same operating condi tions. Therefore, draglines with limited reach may easily fail to operate on the spoil side in uphill mode.

11. The swing angle on the spoil side ($ß_y$) is directly proportional to pit width.

12. In uphill spoiling of inclined seams, the required reach at the main cut position is greater than that in downhill mode.

13. Draglines with limited dumping height capability fail to operate in uphill spoiling mode.

3.2. *Results of the DND spoiling pattern*

1. The required and available reach at the key cut position and the available reach at the main cut position increase with pit width. The required reach at the main cut position is directly proportional to pit width.

2. The set area becomes greater to a certain level of pit width and then shrinks with greater pit width values. The cause of this is that the marginal decrease in set length corresponding to marginal increase in pit width İs less up to a certain value of pit width, and, consequently, set area gets larger. After a certain width, the situation is reversed and the set area shrinks.

3. Average swing angles at the key cut and main cut positions are directiy proportional to pit width.

4. The effective reach is directly proportional to pit width.

5. The height the main cut spoil climbs on the highwall decreases as pit width increases. The height the key cut spoil climbs on the highwall maintains an almost constant level except for narrow pits on flat seams.

6. The rehandle percentage ($P_{re}h$) decreases as pit width increases. It is lower in downhill mode than in uphill mode for the same operating conditions.

7. In some cases where the key cut cannot be formed, the dragline excavates the whole pit from on the main cut position.

8. Draglines with limited dumping height capability fail to operate in uphill spoiling mode in narrow pits.

9. The required reach on the spoil side is greater in uphill mode than in downhill mode for the same operating conditions. Therefore, draglines with limited reach may easily fail to operate on the spoil side in uphill mode.

3.3. *Results of the pullback model on the basis of spoiling patterns*

1. The swing angles at me key cut and main cut positions in the DND mode are smaller man those in the DNS mode for the same operating conditions.

2. For a certain waste thickness, the DND mode imposes tighter constraints on draglines. Therefore, it is very likely that a dragline that has failed in the DND mode can operate with the DNS mode.

3. In DNS mode, a wider interval of pit width values is offered than in DND mode for the same operating conditions.

4. In DNS mode, greater reach from the key cut and main cut positions are available than in DND mode for the same operating conditions. Hence, the effective reach is also greater.

5. In DND mode, the rehandle percentage is greater than in DNS mode for the same operating conditions. The heights the key cut spoil and the main cut spoil climb on the highwall are greater.

6. In DNS mode, the effective reach is greater than in DND mode for the same operating conditions.

4 CONCLUSIONS

In this study a pullback model was developed for dragline stripping. The model is able to analyse situations in which a dragline operates on a bench that overlies one flat-lying or inclined coal seam.

The model comprises three operating modes (Level, Downhill and Uphill), İn each of which two spoiling patterns (DNS and DND) are embedded. Each spoiling pattern includes three key cut waste placement procedures (dumping at the *toe* of the previous spoil pile=*W_{min}; dumping within pit=>$W_m$id; and dumping at the toe of the coal seam=>W_{max}). Finally, the model can study 18 different operational scenarios for pullback stripping.

The main conclusions drawn from the study are as follows:

1. Draglines are allowed to dig thicker waste in downhill mode. For this reason, small-sized draglines may fail to operate in uphill mode.

2. The uphill mode requires that the dragline have a greater dumping height and the dragline cannot make good use of the available spoil room. Thus, the pit must be kept shorter in this operating mode than in me downhill mode.

3. In the case of an inclined coal seam, the downhill mode should be utilized. However, should stability be of concern, then the uphill mode can be applied as it offers a relatively safe operating environment. Another particular feature is the rehandle percentage. Uphill spoiling always produces higher percentages.

4. The DNS spoiling pattern is preferred. Although swing angles in this pattern are higher than mose in the DND pattern, they are more than compensated for, mainly by lower rehandle percentages and other dimensional benefits.

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NOMENCLATURE

β_{key}	Swing angle from key cut position (°)
β_{main}	Swing angle from main cut position (°)
β_{y}	Swing angle on spoil side (°)
Φ_{d}	Highwall angle (°)
Φ_{k}	Coal seam bench angle (°)
Φ_{ky}	Cut face angle (°)
θ_{y}	Angle of repose of waste in the spoil pile(°)
A_{set}	Area of set to be dug (m^3)
d_{em}	Safety margin from the highwall (m)
d_{ky}	Cut face distance (m)
D_{dh}	Required digging depth on highwall side (m)
D_{ds}	Required digging depth on spoil side (m)
d_{kt1}	Distance dragline reaches from on key cut position (m)
d_{kt2}	Distance between key cut excavation positions (m)
D_{uzan}	Available operating radius at main cut position (m)
D_{uzkl}	Available operating radius at key cut position (m)
D_{y}	Required dumping height on highwall side (m)
H_{bo}	Height to which main cut spoil climbs on highwall (m)
H_{bk}	Height to which key cut spoil climbs on highwall (m)
H_{ky}	Height of key cut spoil inthepit(m)
H_{pp}	Height of pullback pad (m)
L_{sb}	Setback distance (m)
L_{set}	Set length on highwall side (m)
L_{ys}	Set length on spoil side (m)
P_{reh}	Rehandle percentage (%)
r	Effective reach as measured from coal seam toe (m)
R_{g}	Required reach on spoil side (m)
R_{o}	Operating radius (m)
R_{uzan}	Required operating radius ai main cut position (m)
R_{uzkl}	Required operating radius at key cut position (m)
sp	Number of excavation positions on highwall side
W	Pit width (m)
W_{pp}	Width of puUback pad (m)
W_{y}	Pit width in the case of inclined coal seam (m)