KINGSTON ENVIRONMENTAL ASSESSMENT
FOR FLY ASH DISPOSAL

by

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GROUNDWATER AND SURFACE WATER QUALITY ASSESSMENT

Introduction

TVA plans to develop three new areas for the disposal of coal combustion waste for Kingston Fossil Plant (KFP). The ash products will be stacked on the new area in a dry form (approximately 20 percent solids). Changing to a dry ash disposal system has several potential environmental effects. The development of new disposal areas has the potential for groundwater contamination and possible impact on nearby well water users. Changes in ash disposal will also alter the characteristics of the ash pond discharge to the river. Additionally, runoff and leachate from the dry ash stack must be collected and provisions made for its discharge. This assessment addresses the impacts to groundwater and surface water quality that will occur as a result of development of the new disposal areas. Information needed for design of the disposal areas and changes in wastewater treatment systems are also identified.

Location, Topography, and Geology

Kingston Fossil Plant is located on a peninsula formed by the confluence of the Clinch and Emory Rivers in Roane County, Tennessee. The plant is in the Valley and Ridge physiographic province, which is characterized by parallel ridges and valleys striking northeast. The broad rolling ridge crests in the plant area are underlain by cherty dolomite. Existing ash disposal areas and plant facilities are underlain by shale and limestone lenses.

The three new disposal areas 1, 3, and 4 (area 2 was deleted from consideration) are located on a peninsula east of the plant (see

Figure 1). A ridge runs east-west for most of the length of the peninsula. Topography ranges from the crest of the ridge, approximately MSL 920, to the water bodies on three sides, approximately 740 MSL. Most of the areas to be used for ash disposal are gently sloped. However, as the areas approach the crest, slopes increase.

The upper geologic formations are of ordovician-cambrian era and consist of Maynardville limestone and other calcium magnesium carbonates of the Knox Group. The eastern end of the peninsula has been identified as being part of the Rome Formation, but has not been confirmed. The disposal areas are all in the Maynardville Limestone or Knox Group formations. These formations are typically referred to as Karst and are characterized by streaks of almost pure limestone. The pure limestone zones are soluble and solution cavities within the formations are common. All of the disposal areas are underlain by Karst formations and some sinkholes are evident in the areas. Additionally where sections of the areas have been used for borrow material, the weathered limestone protrudes upward in irregular pentacles.

Because of the known limestone geologic formations and occurrence of sinkholes in the disposal areas, extensive soil investigations were undertaken.

Soils Investigation

The soils overlaying the disposal areas appeared to be of good quality from site inspections. Because of the vulnerability of the geologic structures beneath the soils, the thickness of the soils and their ability to retard leachate were considered to be the most critical aspects of defining potential impacts to groundwater. This information is also important to determine appropriate design needs to assure groundwater protection.

Three methods, boring and core holes, seismic refraction, and electromagnetic waves, were proposed to determine the depth of soils in the three disposal areas. A grid system of boring and core holes to measure actual depth of soils and depth to the water table was developed. The borings were used to characterize the soils and samples
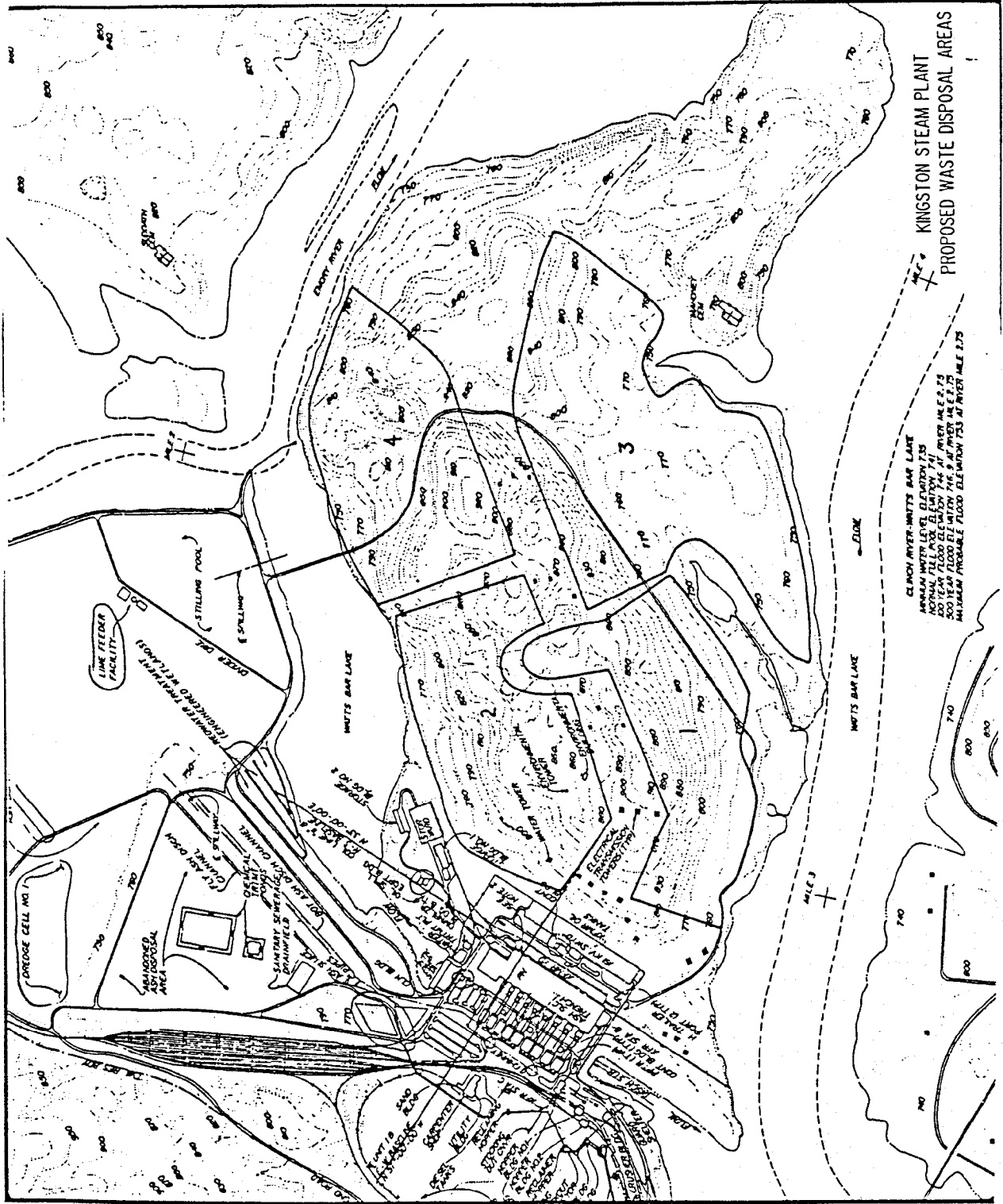
Figure 1. Disposal Area Locations.

were collected for physical analysis. Depth to rock measurements were also used to calibrate and verify seismographic measurements of soil depths.

Seismic refraction lines were run between the core holes. Electromagnetic waves were to be used to interpret between the seismic refraction lines. The combination of boring and core holes, seismographic measurements and electromagnetic waves would provide a two-dimensional description of the top of rock contours and therefore the depth of soils in the three disposal areas.

Fifteen borings were completed and sampled. The depth of soils were found to be considerably greater at many locations than estimated. This factor increased the cost of completing both the borings and core holes. The greater depths also changed the scope of the seismographic and electromagnetic geophysical investigations. In particular, the electromagnetic waves are considered less accurate at greater depths. Because of budget restrictions and time limitations, the electromagnetic portion of the geophysical investigation was discontinued. Also, a reduced number of corings were completed for the same reasons. However, sufficient corings were finished to provide five seismic refraction lines spaced out over the three disposal areas.

Soils Data

Soil borings were utilized to delineate the local attenuation zone, identify different lithology groups, determine depth to bedrock, and establish water table elevations. Fifteen locations were selected and bored (see Figure 2). These locations were spaced between core locations to yield the maximum amount of information and to correlate data obtained from geophysical investigations. Standard Penetration Tests were used at each location to determine lithology and provide samples for laboratory testing. Boring locations, water and rock elevations are summarized in Table 1.

Topsoil covered 90 percent of the site and varied from 1 to 5 feet in depth. Overburden ranged from 10.3 to 52 feet with an average of 30 feet. Field classification revealed four basic groups of material.

Figure 2. Location of Seismic Refraction Lines.

TABLE 1

Boring Location and Elevation Data

Boring	Surface El	Coordinates Station	Coordinates Range	Refusal Depth	Refusal El	Water Table 1 h Depth	Water Table 1 h El	Water Table 24 h Depth	Water Table 24 h El
1	765.7	29+00	1000' lt	29.0	736.0			27.5	738.2
2	763.9	23+00	800' lt	52.0	711.9	27.5	736.4	26.0	737.9
3	750.7	17+00	800' lt	41.5	709.2	13.2	737.5	13.0	737.7
4	783.5	11+00	400' lt	21.5	762.0	Dry		--	
5	795.8	17+00	Base line	49.3	746.5	Dry		--	
6	Omit								
7	815.3	23+00	200' rt	44.0	771.3	22.7	792.6	20.2	795.1
8	764.0	35+00	100' lt	33.5	730.5	Dry		31.3	732.7
9	770.0	45+00	550' rt	13.0	757.0	Dry			
10	767.5	49+00	1050' rt	41.5	726.0			29.0	738.5
11	844.0	45+00	1050' rt	11.5	832.5	Dry			
12	869.5	35+00	600' rt	39.1	830.4			35.7	833.8
13	760.4	35+00	88' lt	25.5	734.9	Dry			
14	795.2	5+00	1350' rt	20.5	774.7	Dry			
15	817.5	5+00	750' rt	21.5	796.0	Dry			
16	811.5	0+00	959' rt	10.3	801.2	Dry			

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Site materials consisted of clays ranging from fat to silty with colors from dark brown to red to light yellow. Layers of silty clay chert along with seams of sandy clay were also encountered. The predominant overburden soils were red medium to fat clays, yellow medium silty clays with weathered chert gravel, and yellow medium to fat clay.

Groundwater was encountered in 7 of the 15 boreholes at elevations ranging from 732.7 to 833.8.

Samples were collected from each lithology group (excluding the topsoil) for analysis. Moisture content, grain-size analysis, specific gravity, unit weight, loss on ignition, and permeability were determined (see Table 2). Because of the difficulty in collecting a sample and the small volume of sample of the lowermost soil layer, only grain-size distribution and moisture content was determined. Most notable, the two major lithology layers contained very little organic matter and had a coefficient of permeability of 10^{-8} cm/s. The lowermost soil layer contained a high percentage of gravel which would indicate a higher permeability.

Seismic refraction lines were conducted between 11 corings. These lines provide relatively accurate top of rock contours and can be used to determine where shallow soil areas will need additional investigations. Figure 2 shows the locations of the 5 refraction lines that were completed. Figures 3-7 show the surface and rock contours.

Tables 3-8 provide digital data. Soil depths are sufficiently deep at most locations to provide good protection of groundwater.

Some discrepancies between the soil boring data and the seismic refraction line data are apparent. Seismic refraction line C-C2, Figure 3, indicates that the depth to rock is greater than the soil borings would indicate. Soil borings 9 and 11 indicate soil depths of 13 and 11.5 feet; both of which are much shallower than determined by soundwaves. In this particular case the borings indicated refusal prematurely, i.e., the borings did not reach rock but encountered resistance in a very tough zone of chert and gravel. This layer was also noted by the core drillings. Nearby borings 8, 10, and 12 were 33.5, 41.5, and 39.1 feet to top of rock which further substantiates this claim.

TABLE 2

Soil Physical Data

Elevation	Sample	Nat Moist %	% Sat	Gravel-Size Analysis Gravel %	Sand %	Silt %	Clay %	D_{10} mm	Liq Limit %	Plas Index %	Dry Dens pcf	Porosity	Loss on Ignition %	Coefficient of Permeability K_v cm/sec
Boring US-2, Station 23+99, 800' Lt, Surface El 763.9														
753.4-752.4	3W	21.5	83.8	0	37	24	39	--	--	--	99.8	0.410	4.02	3.5×10^{-8}
748.4-748.1	4W	24.6	83.9	0	38	16	46	--	--	--	94.2	0.443	3.59	8.6×10^{-8}
747.7-747.4	4W	24.6	--	36	34	11	19	--	--	--	--	--	--	--

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KINGSTON S.P. ASH POND- SEISMIC REFRACTION LINE 45+00 (C-C2)
JUNE 23, 1988

T.R. DEPTH=TCAVG×INTERPOLATED OVERBURDEN VEL
NMO CALCULATED STATION BY STATION:
INITIAL FORWARD ROCK VEL = 18742.2 ft/sec
INITIAL REVERSE ROCK VEL = 17773.2 ft/sec
ASSUMED OVERBURDEN VEL AT:0+00.0IS: 2000 ft/s
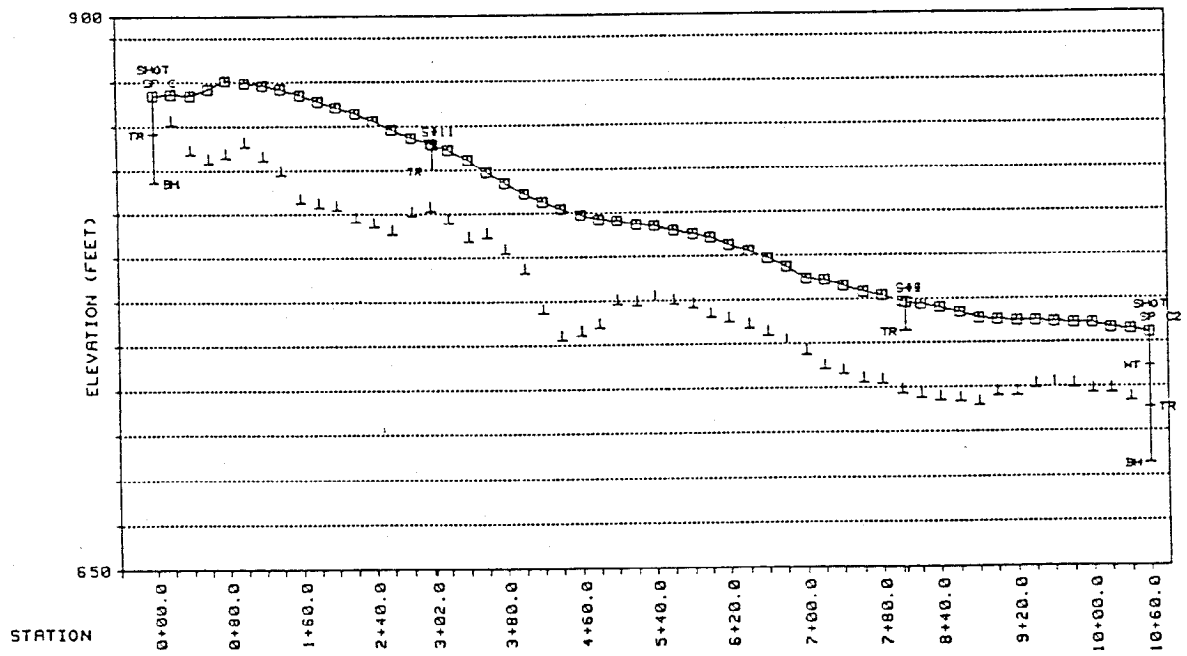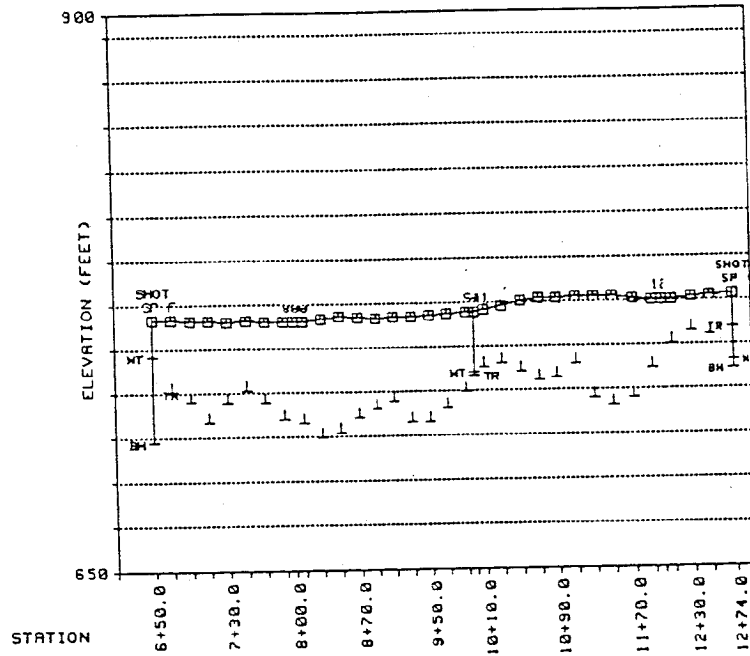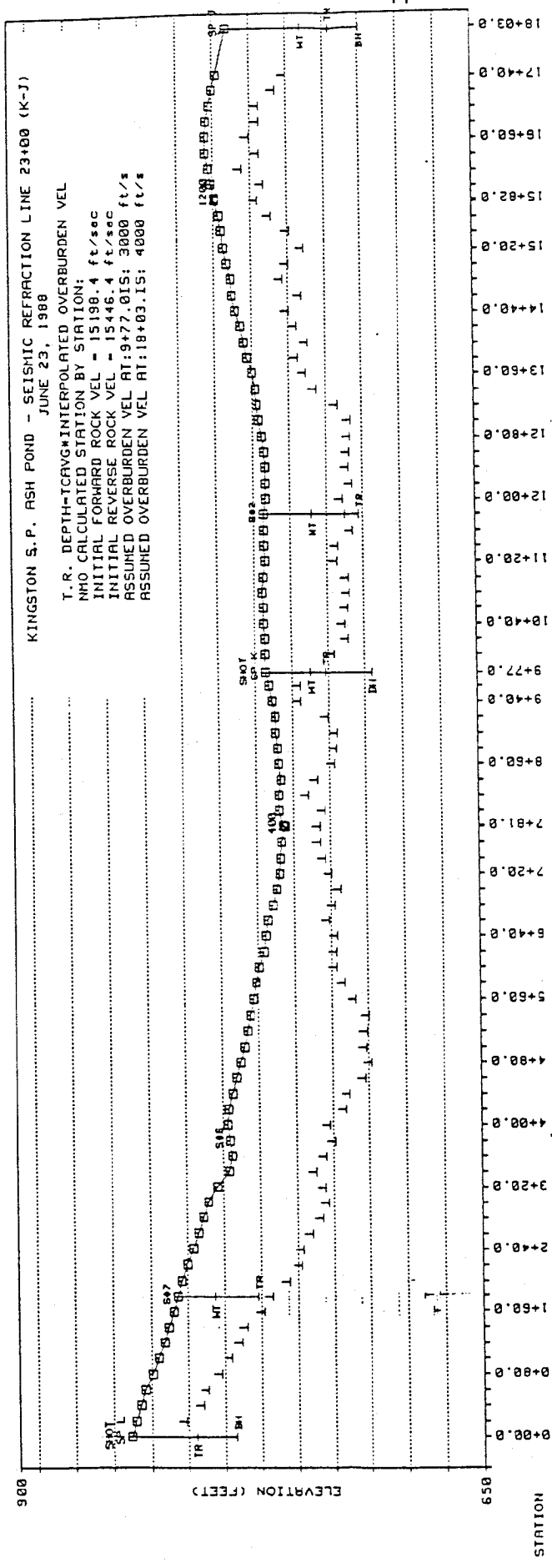ASSUMED OVERBURDEN VEL AT:10+60.IS: 2500 ft/s

Figure 3. Seismic Refraction Line C-C2.

KINGSTON S.P. ASH POND - SEISMIC REFRACTION LINE 29+00 (F-E)
JUNE 23, 1988

T.R. DEPTH = TCAVG * 3000 ft/sec
NMO CALCULATED STATION BY STATION:
INITIAL FORWARD ROCK VEL = 20010.7 ft/sec
INITIAL REVERSE ROCK VEL = 15155.6 ft/sec
ASSUMED OVERBURDEN VEL = 3000.0 ft/sec

Figure 4. Seismic Refraction Line F-E.

KINGSTON S.P. ASH POND - SEISMIC REFRACTION LINE 23+00 (K-J)
JUNE 23, 1988

T.R. DEPTH=TCAVG*INTERPOLATED OVERBURDEN VEL
NMO CALCULATED STATION BY STATION:
INITIAL FORWARD ROCK VEL - 15198.4 ft/sec
INITIAL REVERSE ROCK VEL - 15446.4 ft/sec
ASSUMED OVERBURDEN VEL AT:9+77.0IS: 3000 ft/s
ASSUMED OVERBURDEN VEL AT:18+03.IS: 4000 ft/s

KINGSTON S.P. ASH POND - SEISMIC REFRACTION LINE 23+00 (L-K)
JUNE 23, 1988

T.R. DEPTH - TCAVG * 3000 ft/sec
NMO CALCULATED STATION BY STATION:
INITIAL FORWARD ROCK VEL - 20314.5 ft/sec
INITIAL REVERSE ROCK VEL - 13608.2 ft/sec
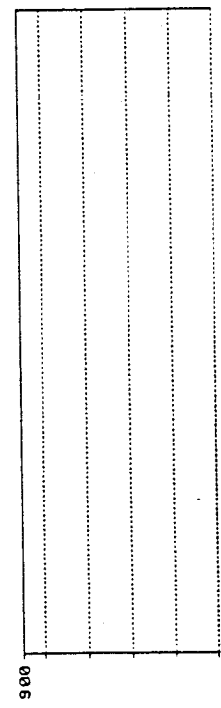ASSUMED OVERBURDEN VEL - 3000.0 ft/sec

ELEVATION (FEET)

STATION

Figure 5. Seismic Refraction Line L-K and K-J.

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KINGSTON S.P. ASH POND - SEISMIC REFRACTION LINE 11+00 (Q-P)
JUNE 23, 1988
T.R. DEPTH=TCAVG*INTERPOLATED OVERBURDEN VEL
NMO CALCULATED STATION BY STATION:
INITIAL FORWARD ROCK VEL = 18956.9 ft/sec
INITIAL REVERSE ROCK VEL = 18250.1 ft/sec
ASSUMED OVERBURDEN VEL AT:0+00.0IS: 3000 ft/s
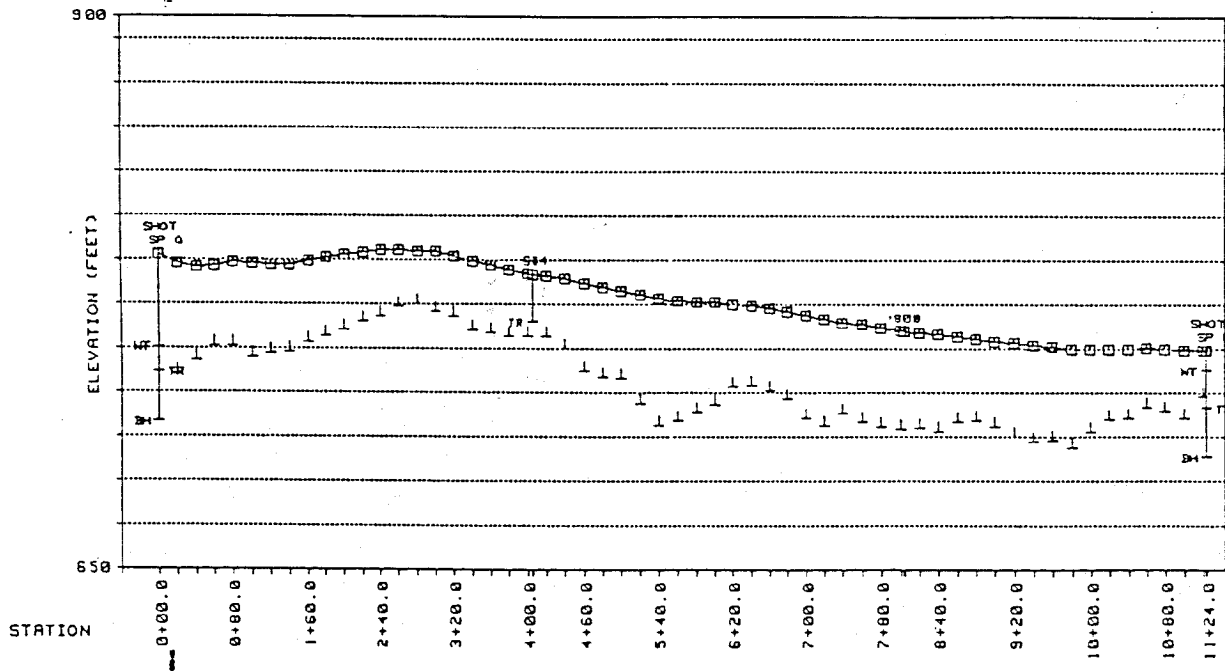ASSUMED OVERBURDEN VEL AT:11+24.IS: 3500 ft/s

Figure 6.   Seismic Refraction Line Q-P.

TABLE 3

Seismic Refraction Line C-C2 Data

STATION	OVB VELOCITY (FT/SEC)	CORRECTED TIME (MS)	SURFACE ELEV. (FEET)	TR ELEV. (FEET)	TR DEPTH (FEET)
0+00.0	2000		864		
0+20.0	2009	6.7 M	864	851	14
0+40.0	2019	13.3 M	864	837	27
0+60.0	2028	16.6 M	867	833	34
0+80.0	2038	17.2 M	871	836	35
1+00.0	2047	14.4 M	870	840	29
1+20.0	2057	16.4 M	868	834	34
1+40.0	2066	18.8 M	866	828	39
1+60.0	2075	23.5 M	864	815	49
1+80.0	2085	23.2 M	861	813	48
2+00.0	2094	22.2 M	858	812	46
2+20.0	2104	23.4 M	855	806	49
2+40.0	2113	22.9 M	852	804	48
2+60.0	2123	22.3 M	848	801	47
2+80.0	2132	16.6 M	845	809	35
3+00.0	2142	14.4 M	842	811	31
3+02.0	2142		841		
3+20.0	2151	15.4 M	839	806	33
3+40.0	2160	17.2 M	834	797	37
3+60.0	2170	13.8 M	829	799	30
3+80.0	2179	14.9 M	824	792	32
4+00.0	2189	16.7 M	819	783	37
4+20.0	2198	23 M	815	765	51
4+40.0	2208	26.9 M	812	752	59
4+60.0	2217	24.6 M	809	754	55
4+80.0	2226	22.1 M	807	758	49
5+00.0	2236	16.9 M	806	768	38
5+20.0	2245	16.4 M	805	768	37
5+40.0	2255	15.1 M	804	770	34
5+60.0	2264	14.7 M	802	768	33
5+80.0	2274	14.7 M	800	766	33
6+00.0	2283	15.6 M	798	762	36
6+20.0	2292	15.4 M	795	760	35
6+40.0	2302	15.3 M	792	757	35
6+60.0	2311	15.1 M	789	754	35
6+80.0	2321	15.1 M	785	750	35
7+00.0	2330	15 M	788	745	35
7+20.0	2340	17.4 M	779	738	41
7+40.0	2349	17 M	776	736	40
7+60.0	2358	17.5 M	773	732	41
7+80.0	2368	16.9 M	771	731	40
8+00.0	2377	17.6 M	769	727	42
8+05.0	2380		769		
8+20.0	2387	17.8 M	768	725	43
8+40.0	2396	17.7 M	766	724	42
8+60.0	2406	17 M	764	723	41
8+80.0	2415	16.3 M	761	721	39
9+00.0	2425	14.3 M	761	726	35
9+20.0	2434	13.9 M	760	726	34
9+40.0	2443	12.5 M	760	730	30
9+60.0	2453	12.1 M	760	730	30
9+80.0	2462	12.1 M	759	729	30
10+00.0	2472	12.8 M	759	727	32
10+20.0	2481	11.9 M	757	727	30
10+40.0	2491	13.1 M	756	724	33
10+60.0	2500		754		

NOTE: TOP OF ROCK DEPTH = TIME * ASSUMED OVERBURDEN VELOCITY

TABLE 5

Seismic Refraction Line L-K Data

STATION	SURFACE ELEVATION (FEET)	TOP OF ROCK ELEVATION (FEET)	TOP OF ROCK DEPTH (FEET)
0+00.0	840.8		
0+20.0	838.3	810.9	27.4
0+40.0	835.8	801.6	34.2
0+60.0	833.2	798.8	34.4
0+80.0	829.5	791.8	37.7
1+00.0	826.2	786	40.2
1+20.0	823.0	780.6	42.4
1+40.7	820.7	777.7	43
1+60.0	817.8	768.5	49.3
1+80.0	815.4	763.9	51.5
2+00.0	813.2	754.6	58.6
2+20.0	809.9	747.6	62.3
2+40.0	806.6	746.8	59.8
2+60.0	803.9	741.4	62.5
2+80.0	800.9	735.8	65.1
3+00.0	798.4	732.9	65.5
3+20.0	793.5	734.7	58.8
3+40.7	786.7	739.5	47.2
3+60.0	784.9	733.9	51
3+80.0	785.9	728.8	57.1
4+00.0	787.0	731.9	55.1
4+20.0	786.6	723	63.6
4+40.0	784.2	720.6	63.6
4+60.0	782.0	711.8	70.2
4+80.0	779.8	708.5	71.3
5+00.0	777.8	711.3	66.5
5+20.0	775.9	710.4	65.5
5+40.0	774.4	709.7	64.7
5+60.0	772.9	716.8	56.1
5+80.0	771.3	722.5	48.8
6+00.0	769.4	726.9	42.5
6+20.0	766.7	726.9	39.8
6+40.0	765.6	726.6	39
6+60.0	764.3	731	33.3
6+80.0	761.8	727.8	34
7+00.0	759.4	724.7	34.7
7+20.0	757.9	729.7	28.2
7+40.0	757.2	732.8	24.4
7+60.0	756.5	735.6	20.9
7+80.0	754.3	735.7	18.6
7+81.0	755.8		
8+00.0	757.9	733	24.9
8+20.0	758.0	741.5	16.5
8+40.0	756.6	736.7	19.9
8+60.0	758.0	727.2	30.8
8+80.0	758.6	726.2	32.4
9+00.0	759.4	725.7	33.7
9+20.0	759.6	730.5	29.1
9+40.0	761.3	745.6	15.7
9+60.0	762.5	745.4	17.2
9+77.0	764.3		

NOTE: TOP OF ROCK DEPTH = TCAVG * ASSUMED OVERBURDEN VELOCITY

TABLE 6

Seismic Refraction Line K-J Data

STATION	OVB VELOCITY (FT/SEC)	CORRECTED TIME (MS)	SURFACE ELEV. (FEET)	TR ELEV. (FEET)	TR DEPTH (FEET)
9+77.0	3000		764		
9+80.0	3004		765		
10+00.0	3028	12.5 M	764	726	38
10+20.0	3052	15 M	765	719	46
10+40.0	3076	14.5 M	765	720	45
10+60.0	3100	15 M	765	718	47
10+80.0	3125	15.2 M	766	718	48
11+00.0	3149	14.9 M	765	718	47
11+20.0	3173	12.5 M	764	724	40
11+40.0	3197	12.7 M	764	723	41
11+60.0	3222	15.2 M	765	716	49
11+80.0	3246	13.7 M	764	720	44
12+00.0	3270	12.9 M	763	721	42
12+20.0	3294	14.5 M	763	715	48
12+40.0	3318	13.8 M	764	718	46
12+60.0	3343	14 M	764	717	47
12+80.0	3367	14.2 M	765	717	48
13+00.0	3391	14.8 M	766	716	50
13+20.0	3415	12.9 M	768	724	44
13+40.0	3439	9.7 M	769	736	33
13+60.0	3464	8.5 M	770	741	29
13+80.0	3488	7.9 M	773	745	28
14+00.0	3512	10 M	775	740	35
14+20.0	3536	8.6 M	776	746	30
14+40.0	3561	8.4 M	779	749	30
14+60.0	3585	10.6 M	781	743	38
14+80.0	3609	7.9 M	781	752	29
15+00.0	3633	9.2 M	783	750	33
15+20.0	3657	12 M	785	741	44
15+40.0	3682	10.2 M	786	748	38
15+60.0	3706	7.7 M	787	759	28
15+80.0	3730	6.2 M	789	766	23
15+82.0	3732		789		
16+00.0	3754	7.6 M	791	763	28
16+20.0	3778	4.9 M	793	774	19
16+40.0	3803	7.7 M	794	765	29
16+60.0	3827	6.3 M	795	771	24
16+80.0	3851	7.6 M	794	765	29
17+00.0	3875	7.1 M	792	765	27
17+20.0	3900	8.8 M	791	757	34
17+40.0	3924	9.8 M	789	751	38
18+03.0	4000		783		

NOTE: TOP OF ROCK DEPTH = TIME * ASSUMED OVERBURDEN VELOCITY

TABLE 7

Seismic Refraction Line Q-P Data

STATION	OVB VELOCITY (FT/SEC)	CORRECTED TIME (MS)	SURFACE ELEV. (FEET)	TR ELEV. (FEET)	TR DEPTH (FEET)
0+00.0	3000		792		
0+20.0	3009	16.7 M	789	738	50
0+40.0	3018	13.9 M	787	745	42
0+60.0	3027	12 M	787	751	36
0+80.0	3036	12.4 M	789	751	38
1+00.0	3044	14 M	789	746	43
1+20.0	3053	13.1 M	788	748	40
1+40.0	3062	12.9 M	788	748	39
1+60.0	3071	11.9 M	789	753	37
1+80.0	3080	11.6 M	791	755	36
2+00.0	3089	10.9 M	792	759	34
2+20.0	3098	10.2 M	794	762	32
2+40.0	3107	9.6 M	794	764	30
2+60.0	3116	8.1 M	794	769	25
2+80.0	3125	7.7 M	794	770	24
3+00.0	3133	8.6 M	794	767	27
3+20.0	3142	8.7 M	792	764	27
3+40.0	3151	9.9 M	790	758	31
3+60.0	3160	9.7 M	788	757	31
3+80.0	3169	9.5 M	786	756	30
4+00.0	3178	8.9 M	784	755	28
4+05.0	3180		784		
4+20.0	3187	8.5 M	783	755	27
4+40.0	3196	9.8 M	782	750	31
4+60.0	3205	.12.3 M	779	740	39
4+80.0	3214	12.6 M	778	737	41
5+00.0	3222	12.3 M	776	736	40
5+20.0	3231	15.3 M	775	725	49
5+40.0	3240	17.7 M	773	715	57
5+60.0	3249	16.7 M	771	717	54
5+80.0	3258	15.3 M	771	721	50
6+00.0	3267	14.4 M	771	724	47
6+20.0	3276	11.4 M	770	733	37
6+40.0	3285	11 M	769	733	36
6+60.0	3294	11.3 M	768	731	37
6+80.0	3302	12.1 M	767	727	40
7+00.0	3311	14.2 M	765	718	47
7+20.0	3320	14.5 M	764	715	48
7+40.0	3329	12.4 M	762	721	41
7+60.0	3338	13.4 M	761	717	45
7+80.0	3347	13.5 M	760	714	45
8+00.0	3356	13.3 M	758	714	45
8+05.0	3358		758		
8+20.0	3365	13 M	757	714	44
8+40.0	3374	13.1 M	756	712	44
8+60.0	3383	11.4 M	755	717	39
8+80.0	3391	11 M	754	717	37
9+00.0	3400	11.4 M	753	714	39
9+20.0	3409	12.5 M	753	710	42
9+40.0	3418	12.8 M	752	708	44
9+60.0	3427	12.5 M	751	708	43
9+80.0	3436	13.1 M	750	705	45
10+00.0	3445	11 M	750	712	38
10+20.0	3454	9.3 M	750	718	32
10+40.0	3463	9.2 M	750	718	32
10+60.0	3472	7.8 M	750	723	27
10+80.0	3480	8.1 M	750	722	28
11+00.0	3489	9 M	750	718	31
11+20.0	3498	6.1 M	749	728	21
11+24.0	3500		750		

NOTE: TOP OF ROCK DEPTH = TIME * ASSUMED OVERBURDEN VELOCITY

TABLE 8

Seismic Refraction Line U-T Data

STATION	SURFACE ELEVATION (FEET)	TOP OF ROCK ELEVATION (FEET)	TOP OF ROCK DEPTH (FEET)
0+16.0	801.0		
0+20.0	800.1	789.2	10.9
0+40.0	799.3	786.8	12.5
0+60.0	798.5	785.6	12.9
0+80.0	798.0	784.9	13.1
1+00.0	797.3	791.8	5.5
1+20.0	796.2	784.6	11.6
1+40.0	796.0	784	12
1+60.0	795.0	781.5	13.5
1+80.0	794.0	776.7	17.3
2+00.0	792.9	771.9	21
2+20.0	796.7	772.3	24.4
2+40.0	800.8	770.8	30
2+60.0	806.6	764.9	41.7
2+80.0	811.9	779.8	32.1
3+00.0	816.3	788.6	27.7
3+20.0	820.4	796.2	24.2
3+40.0	823.8	798.8	25
3+60.0	826.9	802	24.9
3+80.0	829.0	802.6	26.4
4+00.0	831.2	795.6	35.6
4+20.0	832.7	798	34.7
4+40.0	834.0	796.2	37.8
4+60.0	835.2	794.3	40.9
4+80.0	839.4	796.5	42.9
5+00.0	837.2	791.1	46.1
5+20.0	838.1	791.7	46.4
5+40.0	838.3	798	40.3
5+60.0	839.1	797.4	41.7
5+80.0	840.0	802.1	37.9
6+00.0	840.7	812.5	28.2
6+20.0	841.7	815	26.7
6+40.0	839.7	818.8	21
6+60.0	839.6	819.6	20
6+80.0	838.2	816	22.2
7+00.0	836.0	813.9	22.1
7+20.0	833.2	814.4	18.8
7+40.0	832.5	822.4	10.1
7+60.0	832.4	816.3	16.1
7+80.0	833.2	815.7	17.5
8+00.0	834.1	814.7	19.4
8+20.0	834.5	814	20.5
8+40.0	835.3	818	17.3
8+60.0	835.8	822.9	12.9
8+80.0	837.3		

NOTE: TOP OF ROCK DEPTH = TCAVG * ASSUMED OVERBURDEN VELOCITY

Soil boring 16 plotted on seismic refraction line U-T, Figure 7, also indicated rock was shallower than the soundwaves. One cause of this discrepancy is that the seismic refraction line was moved over due to location obstructions and boring 16 is not centered on the line. The downdip of the strata could explain the deviation.

Conclusions/Recommendations

Physical investigations and data indicate adequate protection of groundwater can be achieved on the new disposal areas. Good soil depths overlay most of the areas to be used. The soils tested were predominantly fat or silty clays with a low permeability. Except for gravel and chert found immediately over the irregular rock formations and in a thin layer within the soils, the overburden materials should provide an excellent liner to retard leachate migration from entering the bedrock formations. Assuring the thickness of clay soils over bedrock is the most critical aspect of the final design plan for the new disposal areas. Following are recommendations for the design phase of this project.

1. Areas for the disposal of dry fly ash should be identified and prioritized. The size of the areas should be small so that stacking and final cover can proceed quickly. Leachate development modeling (reference dry stack study at Bull Run Fossil Plant) can be used to determine recommended sizes of stack areas.

2. Topsoil and overburden should be removed to approximate final contours. Soils should be stockpiled for later use as cover materials.

3. Geophysical testing should be conducted to determine depth of soils over the rock formations. Both seismic refraction lines and electromagnetic wave geophysical tests should be conducted to determine where the rock formations protrude upward into the soil overburden. A minimum of 3 to 4 feet of the clay soils should cover the uppermost rock formations.

4. All layers of gravel and chert encountered in grading of the sites should be removed.

5. Final contours of the disposal areas should slope toward collection basins designed to retain both runoff and leachates.

6. A clay cover and topsoil should be placed on the dry stacked fly ash immediately following stack development.

PREDICTED CHANGES IN ASH POND

Introduction

Removal of the fly ash from the Kingston ash pond could change the discharge pH from its historical levels. Metals presently leached from the fly ash in the ash pond would no longer be present in the ash pond discharge. Changes in the ash pond pH would also change the form in which the metals leached from the bottom ash would be discharged to the river.

Because the other plant wastewater discharges are routed through the ash pond, their effect on the ash pond would be altered without the presence of the fly ash in the pond.

Approach

The pH in the ash pond discharge has historically fluctuated with the season of the year (pH ranges of from 3 to 4 and 7 to 8 are commonly observed). The question of what would happen if the fly ash were no longer diverted to the ash pond focuses on what would happen to the pH of the pond and, in particular, what would happen during the periods when the pH was normally in the low range. A pH adjustment system has been installed to increase the pH when it is low.

The pH question was investigated by collecting samples of river water, fly ash sluice water, and bottom ash sluice water. Alkalinity, acidity, pH, and total suspended solids were measured to determine how the fly ash and bottom ash affected the pH of the river water.

The effect of removing the fly ash from disposal in the pond was examined in two ways. The first was to consider that both the fly ash and its sluice water would be diverted before going to the ash pond. The second was to consider that only the fly ash would be diverted from the ash pond but that river water in volumes equivalent to the existing fly ash sluice volumes would continue to flow to the ash pond. The first assumption would be consistent with an ash collection system that was operated by vacuum pumps, while the second would be consistent with a hydraulic ash collection system using water educators.

A third alternative for fly ash handling would be to continue with the present method of initial disposal of fly ash in the ash pond and then dredge the ash from the pond and haul the ash to the new disposal site. It was considered that this would not represent a significant variation from present ash pond operation and its impacts on the ash pond were, therefore, not investigated.

Other factors investigated in relation to the ash pond were the change in metals concentrations as a function of pH and the effect of other waste streams such as the coal pile drainage.

Findings

The fly ash reacts with the alkalinity of the sluice water and tends to lower the pH of the sluice water. Limited data suggest that the bottom ash will have little effect on sluice water alkalinity or pH. However, there is the possibility that the bottom ash could add some alkalinity to the sluice water, thereby acting to raise the pH. These factors taken together suggest that in the absence of other ash pond inputs, removing the fly ash from the ash pond could raise the pH from the low levels commonly observed during a portion of the year.

However, even though the fly ash consumes alkalinity and acts to depress pH, the fly ash sluice water at the present often contains residual alkalinity to help buffer the acidic coal pile drainage. In addition, the fly ash matrix itself might help neutralize the coal pile drainage. The acidity of the coal pile drainage appears to possibly react with the alkaline oxides in the fly ash which might not dissolve unless the pH is depressed. Removal of both the fly ash and its sluice water will, therefore, allow the coal pile drainage to become significantly more important to the ash pond pH than it presently is. The result might be an exacerbation of the pH swings which are presently observed in the ash pond. During periods of high coal pile drainage flow into the ash pond combined with low river water alkalinity and pH, the ash pond pH might be pushed even lower than at the present. If only the fly ash were removed from the ash pond but the fly ash sluice water (in this case used only for ash system collection vacuum and would carry no

ash) remained flowing through the pond, the impact of the coal pile drainage would be less than at the present. During dry periods, when there was no coal pile drainage and the fly ash and its sluice water were removed, the pH might also become very high should it be found that the bottom ash does indeed add alkalinity to the sluice water. If only the fly ash were removed and the sluice water remained, this effect would be insignificant.

Should the low end of the ash pond pH range be raised to levels higher than the historical low pHs, the metal species now in the ash pond would be shifted toward species which tend to be less soluble. As the pH is raised from acid conditions to alkaline conditions, many of the metals move from the free ion state to soluble complexes and might even form precipitates. One exception to this generalization is selenium. Although selenium's solubility increases with pH, selenium is associated more with fly ash than bottom ash. Therefore, its total concentration should be less if the fly ash were removed from the ash pond. If the coal pile drainage holds the pH low, most of the metals discharged to the river will be in their more soluble forms. However, the total mass of metals discharged could be reduced if the fly ash were removed from the ash pond.

IMPACTS RESULTING FROM COLLECTED
LEACHATE AND RUNOFF

Introduction

Leachate quality was estimated for two reasons. A portion of the leachate might be collected and its needs for treatment prior to discharge to the river needed to be assessed. The leachate might also reach the groundwater.

Leachate Characteristics

Leachate quality was estimated in several ways. The first was to use Kingston fly ash elemental analyses supplemented with literature values to determine the mass of elements present in the fly ash and the amount which might be leached from the fly ash. Analyses of rainwater collected at Kingston and physical parameters of the stack were then used with a prerelease version of FOWL to generate an estimate of leachate quality. FOWL is the Electric Power Research Institute's computer code which calculates the quantities, aqueous concentrations, and release durations of selected inorganic elements leached from fossil fuel wastes. The code uses a thermodynamic approach to calculate the aqueous concentrations of elements which are in equilibrium with the solid phase of the elements in the fly ash matrix.

Two steady-state concentrations were predicted by FOWL based on a pH of 3 and another of 4. The predictions are shown in Table 9. Also shown in Table 9 are data from other sources which can be used to determine whether the FOWL predictions are reasonable. The first estimate is the range of two samples taken from eleven groundwater wells in and around the Kingston ash pond during 1976 and 1977. The second data set is the 1977 well sample which most closely matched the predicted pH of the leachate and was supplied as input to FOWL Run 1. The third data set is from well samples obtained in March of 1988 from the same well in the ash pond dike as sampled in 1977 and the fourth is from another well in close proximity. Two borings were made through the Bull Run dry ash stack and the water near the bottom of the stack was collected and analyzed. These data are shown as the fifth and sixth data

TABLE 9

Comparison of Leachate Quality Estimates

Parameter	Kingston wells range 1976-1977	Well J5B 3/9/77	Well J5B 3/2/88	Well J5A 3/2/88	Bull Run dry ash stack pore water	Bull Run well E 11/87	Bull Run dry ash stack runoff	Run 1 FOWL	Run 2 FOWL	Kingston ash pond discharge 1973-1974 Range	DWS
Aluminum, mg/L	0.2-520	0.4	<0.05	<0.05	0.12	0.01	0.05	4.1	4.0	0.4-7.6	—
Barium, mg/L	0.1	0.1	0.03	0.1	0.06	0.09	0.09	0.3	0.2	0.1-0.3	1
Calcium, mg/L	18-520	18	300	44	291-423	69	211	394	394	23-57	
Chromium, mg/L	0.005-0.12	0.005	<0.001	<0.001	0.015	0.01	0.01	4.2	0.05	0.005-0.007	0.05
Molybdenum, mg/L	—	—	—	—	4.8	0.01	1.4	14.5	1.9	—	
Silica, mg/L	—	—	—	—	—	—	—	26	27	3.5-7.9	
Strontium, mg/L	—	—	—	—	2.8	0.56	1.7	1.7	1.6	—	
Sulfate, mg/L	65-3400	130	3200	110	1085	30	550	1114	960	90-170	250
Boron, mg/L	0.09-5.6	0.13	4.4	<0.05	7.2	0.2	2.7	2.4	2.9	—	
Cadmium, mg/L	0.001-0.003	0.001	0.003	0.0007	0.01	0.01	0.01	0.2	0.3	0.001-0.002	0.01
Copper, mg/L	0.01-1.4	0.02	0.2	0.02	0.025	0.01	0.01	2.4	0.2	0.02-0.18	1
Iron, mg/L	0.05-2200	3.7	1100	8.6	0.01	0.01	0.01	2.5	0.5	0.1-9.4	0.3
Magnesium, mg/L	10-120	10	100	13	52	20	17	16.1	8.8	3.9-9.3	
Sodium, mg/L	—	—	9.9	6.6	13	13	3.6	7.4	8.5	—	
Selenium, mg/L	0.001-0.005	0.001	<0.001	<0.001	0.34	0.01	0.39	0.0001	0.001	0.001-0.006	0.01
Zinc, mg/L	0.01-0.2	0.2	0.2	0.02	0.035	0.01	0.03	6.5	0.7	0.02-0.12	5
Arsenic, mg/L	0.004-0.026	0.004	0.004	0.001	0.01	0.01	0.01	1.0	0.1	0.005-0.110	0.05
Nickel, mg/L	—	0.06	—	—	1.7	0.01	0.01	0.8	0.2	0.05-0.07	
Mn, mg/L	—	4.5	4.9	0.46	0.44	0.01	0.01	—	—	0.05-0.68	0.06
pH, std. units	3.3-10	3.3	5.1	6.0	—	—	8	3.0	4.0	3.3-8.4	
ORP, millivolts	—	200	50	390							
DO, mg/L	—	—	0	0.7							
Alkalinity, mg/L as CaCO3	—	—	28	37							
CO2-acidity, mg/L as CaCO3	—	—	1,160	86							

NOTE: FOWL Run 1 – pH = 3; FOWL Run 2, pH = 4.

sets. The next reference data set is that of the analysis of one sample of the runoff from the Bull Run dry ash stack. The last data set shows the range of concentrations observed in the Kingston ash pond discharge over the period 1973-1974 as measured with quarterly grab samples.

Table 10 compares the FOWL leachate predictions to the results of EP toxicity and TCLP extraction tests. The EP toxicity test is conducted at pH 5 with the pH adjusted during the course of the extraction. The TCLP extraction starts at pH 5 but the extraction is allowed to seek its own pH as the extraction proceeds. Sometimes a pH higher than 5 is observed at the end of the extraction. Runs 1 and 2 of FOWL are for pHs below 5. FOWL predicts increased leachate concentrations for most elements with decreasing pH. Because the FOWL leachate estimates are for lower pHs than used in the extractions, the FOWL leachate concentrations are higher than for the extractions. FOWL was run again at pH 5. The predicted leachate concentrations at this pH are closer to those of the extractions shown in Table 10.

The extraction test data shown in Table 10 indicates the fly ash to be a nonhazardous waste and suitable for disposal in landfills.

Disposal of Collected Leachate and Runoff

The collection of leachate at the new dry ash disposal facility at Kingston might be undertaken to reduce the flux of leachate into the groundwater. This would likely be done with an underdrain system installed beneath the stack during its construction. Regardless of whether or not leachate is collected, runoff from the stack will be collected. The implications of its disposal will be discussed as well.

Although an underdrain system might be used to collect leachate from the dry stack, leachate might still be collected even if an underdrain system were not used. The subbase might be constructed to be highly impermeable. Leachate encountering the low permeability of the subbase might then follow the natural slope of the site from the hillside toward the river. Near the river at the toe of the stack, a ditch might be provided to prevent site runoff from flowing directly to the river. Substantial volumes of leachate might also find their way to such a ditch even if no underdrain system were provided.

TABLE 10

Fowl Leachate Predictions Compared
to Extraction Concentrations

Parameter	FOWL pH=3	pH=4	pH=5	EP toxicity	TCLP
Aluminum, mg/L	4.1	4.0	0.5		
Barium, mg/L	0.3	0.2	0.2	<0.1	<0.1
Calcium, mg/L	394	394	396		
Chromium, mg/L	4.2	0.05	0.002	<0.05	<0.003-0.10
Molybdenum, mg/L	14.5	1.9	0.75		
Silica, mg/L	26	27	27		
Strontium, mg/L	1.7	1.6	1.6		
Sulfate, mg/L	1114	960	950		160-340
Boron, mg/L	2.4	2.9	3.3		
Cadmium, mg/L	0.2	0.03	0.009	<0.005-0.02	<0.002
Copper, mg/L	2.4	0.2	0.02		
Iron, mg/L	2.5	0.5	0.1		<0.005
Magnesium, mg/L	16.1	8.8	4.8		
Sodium, mg/L	7.4	8.5	9.7		
Selenium, mg/L	0.0001	0.001	0.001	<0.002	<0.002
Zinc, mg/L	6.5	0.7	0.3		
Arsenic, mg/L	1.0	0.1	0.1	<0.002	<0.002
Manganese, mg/L					0.29-0.44
Nickel, mg/L	0.8	0.2	0.5		0.1-0.15
Mercury, mg/L				<0.0002	<0.0002
Lead, mg/L				<0.05	<0.01
Silver, mg/L				<0.01	<0.002
Thallium, mg/L					<0.05-0.1
Beryllium, mg/L					<0.002
Antimony, mg/L					<0.04

The FOWL concentrations at pH 3 (Run 1) exceed those observed in the one sample of the Bull Run runoff. Therefore, the estimates from FOWL (Run 1) were used as a conservative estimate of the runoff from the Kingston dry ash stack.

One way to treat the collected leachate/runoff would be to route it into the ash pond. Should the arsenic, cadmium, and chromium estimates made by FOWL turn out to be appropriate, a dilution of these elements with the bottom ash sluice water would, on a yearly average, be greater than 100 to 1. This would be sufficient to provide concentrations below the DWS. It was assumed that the maximum runoff, plus leachate collected, would be about 20 percent of rainfall. If little storage were provided for the leachate/runoff such that the dilution by the bottom ash sluice water were only 10 to 1 during heavy rains, cadmium and chromium might be 2 to 8 times the DWS during storm events. Although a higher pH in the ash pond than assumed for the leachate/runoff might reduce these concentrations, the storm event concentrations would appear to increase the concentrations above what has historically been observed in the ash pond discharge. If water volumes equivalent to those presently used for fly ash disposal were maintained, the cadmium and chromium concentrations should be less than the DWS. Under this scenario, the leachate/runoff effects on the ash pond would probably be insignificant.

If treatment prior to pumping to the ash pond were needed, the arsenic could be precipitated with barium. Providing a pH between approximately 7 to 11 would theoretically reduce the solubility of chromium to less than the DWS. Theoretically, the solubility of cadmium could be reduced to the DWS by providing a pH of 8 or greater. Raising the pH out of the acidic range would reduce the iron concentrations and sulfate and zinc could be diluted by the bottom ash flow.

Leachate Attenuation in the Soil

Introduction

There are two processes by which the migration of dissolved metals from the leachate can be attenuated by soils. The first is

precipitation and the second is adsorption. The solubility of some metals is controlled by the presence of the same metal in a mineral phase of the soil. High concentrations of a particular metal might, therefore, be precipitated because the pore water is already in equilibrium with a particular metal found in a soil mineral. Precipitates might also form as the pH or oxidation-reduction potential of this leachate changes as it moves through the soil. Soil minerals can also adsorb ionic species and remove them from further migration.

Kingston Soil Composition

X-ray powder diffraction and polarized-light microscopy were used to determine the soil minerals and to estimate their relative abundance in two Kingston soil samples. Two soil samples were obtained during the soil core drilling activity and were selected by the soils engineer onsite as being representative of the soil at the proposed dry ash stacking facility. The composition of the soil samples is shown in Table 11.

Using the mineral composition shown in Table 11, adsorption calculations were performed. They indicated the potential capacity to adsorb all the manganese, nickel, molybdenum, copper, and possibly zinc and chromium produced by the stack in 20 years in the first foot of soil beneath the stack.[1] Although calculations indicate that each cubic foot of clay beneath the stack has the capacity to hold at least 60 to 70 years' worth of iron produced by the stack, solubility calculations indicate that the goethite in the soil has the potential to dissolve in the presence of the acidic leachate thus releasing iron into solution.

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1. It might take more than 1 foot of soil to adsorb the metals and reduce the concentrations to background levels. More detailed adsorption studies would be needed to determine the actual concentrations passing through the soil as a function of depth.

TABLE 11

Mineral Composition of Soils

| | Percent Composition | |
Mineral	Sample 3W	Sample 4
Quartz	70-80	50-60
Kaolinite (primary) and halloysite (secondary)	20-30	40-50
Goethite	5-10	5-10

Therefore, iron is probably not attenuated at very low pH and reducing conditions. The capacity for selenium adsorption appears relatively low but most estimates indicate it will be of low concentration in the leachate.

The chemical equilibrium computer code MINTEQ was used to determine the solubility of the metals in the leachate. To be conservative, the initial concentration of leachate used was the FOWL estimate of pH 3 from Table 9. The lowest pH used in the speciation calculations was pH 4.

At pH 4, and under reducing conditions, most elements would be quite soluble although copper is expected to precipitate over the range of the oxidation-reduction potentials[1] examined. Also at pH 4, and under reducing conditions, goethite is expected to be soluble. Iron concentrations might, therefore, initially increase as the iron in the soil is dissolved. Aluminum concentrations also increase with the dissolution of the clay minerals. It is important to note that even under low pH and reducing conditions, chromium is expected to precipitate.

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1. Slightly reducing (-50 mV) to slightly oxidizing (+50 mV).

At pH 6, and with oxidizing conditions, arsenic, aluminum, barium, chromium, iron, and copper precipitate. In addition, a cadmium precipitate was supersaturated and could possibly precipitate. The pH 6 case shows that although the metals might be quite soluble when initially leachated from the stack, many will precipitate to below the DWS if the pH will rise. Dissolution of the goethite will consume protons and cause the pH to rise. Mixing of the leachate with groundwater would also cause an increase in pH.

The leach time estimates using FOWL indicate that the stack will continue to leach for many years. Once the depth of soil beneath the stack is determined in the design phase, the estimates of Bohac (1988)[1] could be used to determine the number of years the metals would be retarded before they would reach the groundwater. Eventually some metals might reach the groundwater. Adsorption would likely only slow their arrival. However, several feet of soil between the stack and the groundwater and holding the net infiltration to 15 percent of precipitation has the potential to retard the metals for many years. The combination of adsorption, dispersion, and precipitation with increasing pH should combine to make the time longer than that predicted by adsorption alone. Certainly chromium and copper are not expected to be very soluble at all. FASTCHEM may prove useful in evaluating the relative importance of these factors simultaneously.

Summary

By comparison the runoff and any leachate collected from a 50-acre active dry ash stack might be a maximum of 20 to 30 percent of the runoff from the coal pile drainage. Routing the runoff and leachate into the ash pond appears to be a feasible disposal alternative. If leachate and runoff from the dry stack were collected, further study of the actual leachate is recommended should it be desired to discharge the

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1. See attached supplement report, "Assessment of Kingston Fossil Plant Dry Ash Stacking on the Ash Pond and Groundwater Quality."

runoff and leachate directly to the river. Evidence does exist for the possibility of elevated concentrations of arsenic, cadmium, and chromium. These metals could be diluted by the bottom ash sluice water to reduce their concentrations to the same order of magnitude as the DWS if adequate storage were provided. If water volumes on the order of those presently used for fly ash sluicing were still diverted to the ash pond, the metals from the collected leachate/runoff should be diluted to concentrations below the DWS. However, pretreatment options are available if storage prior to pumping to the ash pond is desired or if it is found that the coal pile drainage needs pretreatment before being sent to the ash pond.[1]

Although the dry ash stack might eventually have some effect on the groundwater quality beneath the stack, the existing soils appear to have the ability to attenuate many of the metals for many years. Some metals, such as copper and chromium are expected to reach the groundwater only in very low concentrations. Once leachate reaches the groundwater, the pH will be raised from the assumptions used in the leaching analysis. This will precipitate additional metals and provide additional adsorption sites on the precipitates for metals breaking through from the soil adsorption.

Another option not directly considered was for initial disposal of the fly ash in the ash pond followed by dredging and hauling of the ash to the dry ash stack. The above analysis of leachate and runoff for the dry ash stack is likely conservative for this last option. Ash initially sluiced to the ash pond will be elutriated when hauled to the new ash disposal facility. The leachate from such ash might not have as low a pH as ash stacked dry and thus the metals in the leachate might be of lower concentration than those in leachate from ash stored dry.

Curtailment of fly ash disposal in the existing ash pond should have little effect on any offsite migration of leachate from the existing ash pond for many years.

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1. If the fly ash sluice water were diverted from the ash pond, the coal pile drainage will significantly depress the ash pond pH and thus pretreatment of the coal pile drainage might be considered.

IMPACT ON DOMESTIC USERS AND PROPOSED
SITE GROUNDWATER QUALITY

During the week of March 21, 1988, a survey was conducted along Swan Pond Road to determine the number and location of domestic wells. Twelve private wells used for potable water supply were identified. An analysis of plant groundwater data nearest these residences indicated no effect from the ash disposal activities in 1977.

If there were a potential for contamination of the domestic wells, it is more likely to occur from the existing disposal facilities than from the new dry stacking facility. It might be important to determine the potential effect of the existing ash disposal areas on the existing domestic wells in order to prove such a distinction, however. Discontinuing the sluicing of fly ash to the ash pond will likely not have a significant immediate effect on the domestic wells if the existing ash pond is affecting them.

RECOMMENDATIONS

1. Data are needed to verify the assumptions concerning the characteristics of the dry ash stack leachate and runoff. Because of the uncertainty surrounding their concentration, disposal through the ash pond or with pretreatment of the coal pile drainage should the coal pile drainage be proven to be a real problem, should be explored. Estimates used in this analysis are thought to be conservative; therefore, data on the collected leachate and runoff might indicate that direct discharge to the river would be appropriate. If the sluice water is withdrawn from the ash pond along with the fly ash, the following two additional studies are recommended.

2. An additional study on the effect of sluice water alkalinity by the bottom ash is needed.

3. A study concerning how the bottom ash will react with the coal pile drainage is also needed. Such data would be useful to determine whether additional alkaline oxides in the bottom ash matrix would react with the acidity in the coal pile drainage.

Alternative designs in which leachate would be retarded or possibly collected at the toe of the hill should be examined. Adsorption and precipitation have the potential to significantly retard the movement of metals in the leachate for many years. If some of the leachate can be directed to a surface collector, more detailed chemical and hydrogeologic analysis might show that any effect on groundwater would be minimal. In any event, monitoring of wells around the dry ash disposal site is recommended.