apparently reducing hydraulic conductivity below the normally expected range. The lowest values were obtained from measurements carried out on compacted dump surfaces (due to haul traffic) at void ratios less than 0.3.

Vandre (1995) has carried out large scale infiltration tests on mine spoil materials at western US metal mines. Figure 3.14 shows Vandre's data plotted as infiltration rate (equivalent to hydraulic conductivity at a gradient of 1) versus percentage of material finer than 2.5 cm (1 inch). Vandre's data shows that beyond the soil-like/rock-like material break, shown as 30% -2.5 cm (equivalent to 20% sand content), the infiltration rates are very high and greater than about 1 cm/sec.

Data on decreasing hydraulic conductivity due to fines generation from crushing, weathering, and fines migration was not found for this review. However some inferences based on the literature findings can be made as follows.

1. Rock-like spoils have very high hydraulic conductivity values. Thus it is unlikely that significant changes in hydraulic conductivity (notwithstanding point 3. below) with time would be apparent; even a 1 or 2 order of magnitude decrease in infiltration capacity would not significantly change seepage behaviour under the flux conditions expected due to infiltration. Talus slopes provide a natural analogue in this regard.

2. Non-cohesive soil-like spoils may exhibit changes in hydraulic conductivity due to decreasing void ratio and generation of fines during crushing. Based on an estimate of a 0.1 unit change in void ratio due to wetting and a 20% increase in sand content due to crushing (see Figure 3.13 and 3.15) it is estimated that non-cohesive soil like spoils could undergo a decrease in saturated hydraulic conductivity of about one order of magnitude (say from 10^{-3} to 10^{-4} cm/sec). This is a modest decrease.

3. Significant changes in hydraulic conductivity due to rapid breakdown of sulphide bearing waste rock spoils, resulting from acid rock drainage (ARD) reactions may be an important long term stability issue. Some insights could be readily obtained by examining grain size distributions of materials from ARD humidity cell tests.

4. Cohesive soil-like spoils could exhibit very significant changes in hydraulic conductivity as the material breaks down to its constituent particle size.

TABLE 3.4 TYPICAL HYDRAULIC CONDUCTIVITIES OF SOIL-LIKE SPOILS AND ROCK FILL

Location	Reference	Material	k (cm/sec)	Type of Test
B.C. Spoil piles (coal and metal mines)	Dawson & Morgenstern (1995)	End dumped waste rock (ground surface, crest)	$3x10^{-2}$ to $1x10^{-4}$	Surface infiltration
B.C. Coarse coal refuse (Elkview Coal Corp.)	HBT AGRA (1994)	Computed coal refuse	$4x10^{-4}$	In-situ tests in standpipes.
UK spoil piles	Thomson & Rodin (1972)	End dumped coarse discards.	Typical $1x10^{-3}$ to $1x10^{-4}$ (Range $5x10^{-2}$ to $5x10^{-7}$) "several orders lower"	In-situ tests in standpipes. Laboratory tests.
Horsley reclaimed pit, UK	Charles et al (1977)	end dumped mudstone and sandstone fragments, less than 10% passing 200 sieve.	$>1x10^{-2}$	In-situ in borehole.
Appalachian spoil piles	Shakoor & Ruof (1989)	end dumped spoil	$1x10^{-3}$ to $3x10^{-6}$	Laboratory tests
Balderhead rockfill dam	Penman & Charles (1976)	compacted shale	$1x10^{-3}$	In-situ in boreholes.
Llyn Brianne rockfill dam	Penman & Charles (1976)	compacted mudstone	$1x10^{-2}$ to $3x10^{-3}$	In-situ in boreholes.

TABLE 3.5 COMPARISON OF HYDRAULIC CONDUCTIVITY OF COARSE DISCARD IN LOOSELY PLACED AND COMPACTED HEAPS (from Thomson & Rodin, 1972)

Colliery	Method of tipping	k*, (cm/*sec*)
Blidworth	Aerial ropeway and side tipping Layered construction with scrapers	$8x10^{-5}$ and $6x10^{-3}$ $9x10^{-7}$
Gedling	Aerial ropeway and spread by dozer Layered construction (a) 1.5 m layers (b) 0.3 m layers	$1x10^{-3}$ $4x10^{-2}$-$6x10^{-2}$ $1x10^{-6}$-$5x10^{-4}$
Cortonwood	Layered construction (experimental heap) (a) 1.5 m layers (b) 0.3 m layers	 $4x10^{-3}$-$2x10^{-2}$ $7x10^{-4}$-$3x10^{-2}$

* In-situ permeability tests in standpipe piezometers.

4.0 DISCUSSION OF DUMPS IN DIFFERENT AREAS

4.1 SPOIL PILES IN BRITISH COLUMBIA

4.1.1 Dump Performance Surveys

Several studies in recent years have contributed to data bases of spoil pile classification and dump failures. Piteau (1991) has reviewed both metal and coal mines. Golder (1987, 1992) and Broughton (1992) have compiled records of dump failures at Rocky Mountain coal mines.

Piteau collected data from 31 mine sites which included 84 individual spoil piles. A total of 18 major failure events were reported as summarized in Table 4.1

TABLE 4.1 SUMMARY OF DUMP SURVEY BY PITEAU (1991)

Item	Coal Mines	Metal Mines	Total
Mine Sites	10	21	31
Spoil Piles	35	49	84
Failures (minor sloughs and slumps not included)	15	3	18
Failures with Runout in excess of 100 m	13	1	14

It can be seen that dump failures are inherently more frequent in coal wastes than in metal mine spoil piles. In 2 of the 3 metal mine failures the spoil contained significant fines contents. One was a mixture of 15 percent till overburden soil with 85 percent waste rock. The other, which was the high runout event (400 m), was 80 percent colluvium and landslide debris and 20 percent limestone rock.

Many of the coal mine failures were associated with poor quality spoil material. It can be seen therefore that material type, as related to the amount of fine particles, is a major factor in dump stability.

The above surveys collected data from active mining operations. They did not deal with long term stability and did not include abandoned spoil piles. It is of interest to note that active dumping was taking place for all of the failures noted in Piteau's survey. Golder (1992) reported a total of 42 dump failures. Active dumping was taking place at 33 of the sites.

Seven failures occurred up to 2.5 months after dumping and 2 events occurred 4 to 6 months after dumping. Some of the failures were associated with periods of high precipitation.

No case histories of failure of abandoned spoil piles in B.C. have been identified in this current review of the literature. This would imply that instability due to the processes identified in this report, has not as yet, become a problem at B.C. mine sites.

4.1.2 Coarse Coal Refuse Dump, Elkview Coal Corp. (HGT AGRA 1994)

The North Coarse Refuse Dump at Elkview Coal Corporation's mine in Sparwood, B.C. is well instrumented with piezometers and provides information on the development of a groundwater table in the base of a dump. In addition, testing to assess material degradation has been carried out.

The North Dump is up to 120 m high and 1050 m long. The slopes are benched with an average overall slope angle of 23°. The original valley slopes ranged between 16 and 19°, although up to 30° locally. The overburden soil was a relatively impermeable clay till material. Construction of the North Coarse Refuse Dump was started in 1979 and completed in 1990. The dump was constructed in lifts; initially 0.3 m thick and then increased to 1.8 m. The dump differed from waste rock dumps in that there was no segregated drainage layer at the base of the dump. However, a total of 7 french drains were installed at spacings of 50 to 200 m along the length of the dump.

Monitoring of groundwater levels in the base of the dump has been carried out on a continuous basis since 1981. In general the piezometers have remained fairly constant over the 14 year monitoring period. They have shown a thin perched water table at the base of the dump. Water levels in the coarse refuse in 1992 were typically up to 2 m above the till contact; although levels at 3.0 m and 4.0 m were measured at two locations. Seasonal fluctuations are typically up to 1.8 m. The highest levels were measured in 1991/1992 when a number of installations showed 3.0 m and one indicated 5.2 m above the till contact. Seepage can be observed along the toe of the dump and at the discharge points from the french drains.

In 1988 grain size tests were carried out on samples from different depths to check for signs of material degradation. A total of 7 samples from depths up to 24 m were obtained from 2 boreholes. While some deeper samples showed slightly finer gradations it was concluded that significant crushing of the coarse coal refuse was not occurring at depth in the dump.

In 1991, petrographic analyses were conducted on samples from depths of 13 and 75 m. These tests were undertaken to establish if chemical weathering had occurred at depth. The results of x-ray diffraction indicated no significant difference between the two samples. They indicated high contents of calcite and dolomite in both samples, suggesting that significant chemical weathering had not taken place.

4.2 COAL MINE SPOIL PILES IN THE UNITED KINGDOM

4.2.1 General

A major program of site investigations and research projects was established by the National Coal Board following the Aberfan flowslide disaster in 1966. The program was essentially completed by 1981. The results were summarized in Thomson and Rodin (1972), Taylor (1984), and Taylor (1987).

The spoil piles comprise coarse discard from underground coal mining operations. The material comprises coal and Coal Measures rocks from the roof and floor of the mined seam. The coarse discard leaving the washing plant is typically 75 to 100 mm minus. The spoil piles were traditionally constructed by end dumping or aerial ropeway.

The range of gradations found in the spoil piles is shown in Figure 2.2. Table 2.5 indicates the mineralogy and shows an average clay mineral content of approximately 70 percent.

Thomson and Rodin in 1972 indicate "... a significant proportion of spoil in existing heaps with densities less than 90 to 95 percent of the maximum BS compaction density". In 1987 Taylor indicates ".....the old loose tips compacted under self weight to an average void ratio of 0.34. Indeed, the average compaction achieved in this manner was about 95 to 96 percent of the average obtained in BS compaction test (2.5 kg rammer)". Taylor and Spears (1972) based on observations of two spoil piles at Yorkshire Main mine and in Durham state "... that 90 percent maximum dry density can be achieved by natural end-tipping methods. The results do, however, emphasize the low relative densities (82 to 83 percent maximum) for Tip 7, Aberfan."

Taylor (1987) indicates that shear strength results fall into three statistical groupings. The groups depend on the "rank" of the coal seam which in turn is a function of the depth of burial. The mean friction angles range from 29.5 to 34°. Thomson and Rodin indicate a lower bound of 25°.

The distribution of in-situ hydraulic conductivity in spoil piles was reported by Taylor (1987) bimodal with two distinct peaks at 1×10^{-1} to 10^{-2} cm/sec and 1×10^{-5} to 10^{-6} cm/sec. Values calculated from standard oedometer tests were up to four orders of magnitude lower than field tests.

Before the research on spoil piles began, it was common opinion in the industry that degradation of coarse discard occurred primarily because of weathering or physio-chemical changes in the dump. The extent of mechanical breakdown during transportation and tipping and even after spreading on the spoil pile was not appreciated. This was confirmed in tests on an experimental spoil pile at Askern (Thomson and Rodin, 1972) which showed an increase in material finer than 5 mm (sand/silt sizes) from 20 to 50 percent and in silt/clay sizes from 8 to 22 percent.

Experience indicated that degradation caused by weathering of the siltstones and mudstones starts within a few days, weeks or months on the surface of the dump depending on the character of the parent rock. The first effect is the relatively quick degradation of the larger particles into fine gravel and sand sized particles. The formation of silt and clay sized particles is a much slower process. These observations in Thomson and Rodin are essentially the same as conclusions as drawn by Andrews et al (1980) on U.S. Appalachian spoil piles.

Visual examination of the spoil in trial pits excavated in old tips in Durham, Yorkshire Nottinghamshire and South Wales indicated little if any physical breakdown caused by weathering below a depth of about 1 m.

Thomson and Rodin (1972) concluded with the following statement on degradation in coarse discard spoil piles: "So far as weathering is concerned, physical weathering appears to be more important than chemical weathering. Below a depth of 1 m physical weathering occurs slowly if at all."

4.2.2 Yorkshire Main Colliery (Spears et al, 1970; Taylor and Spears, 1972)

Detailed studies of a 50 year spoil old pile at the Yorkshire Main Colliery were undertaken to determine whether degradation was taking place within the body of the pile. The spoil pile was constructed by aerial ropeway placement and was about 40 m high. The material was 75 mm minus with fines content (silt/clay) of 5 to 25 percent. It is noteworthy that some of the samples contained a higher content of mixed-layer clay than samples from other UK spoil piles considered above, i.e. the material would be more susceptible to physical breakdown. In-situ densities were 95 percent in the top 18 m and 92 to 95 percent of maximum dry density below this (BS Low standard test 2.5 kg rammer).

Thin sections from SPT samples were examined under the microscope. No evidence emerged to suggest that the proportion of matrix to rock fragments changed systematically with depth. Moreover, there was no systematic variation of grain size with depth.

Based on a mineralogical study (Spears et al 1970), it was concluded that most colliery discard may well reach its level of degradation relatively quickly and that once buried in the tip the material as a whole changes very little. Taylor et al (1972) reviewed mechanical properties (gradation, density, shear strength and permeability) and reached a similar conclusion that little change had occurred within the body of the dump.

Visual evidence showed the zone of intense weathering to be limited to a depth of one metre. Pyrite breakdown did not extend below a depth of 3 m. It was concluded that the survival of pyrite without any systematic decrease with depth provided a good illustration that chemical weathering is usually restricted in the loose dumped UK spoil piles.

Table 4.1 compares the results of shear strength tests on intensely weathered material from near ground surface with specimens fabricated to the same water content and gradation, but from fresh parental rock from the underground workings. The table shows only a small drop in the angle of shearing resistance (taking $c' = 0$). Over 50 years; intense chemical weathering at ground surface had only reduced ϕ by 1.5°.

TABLE 4.1 COMPARISON OF SHEAR STRENGTH PARAMETERS - YORKSHIRE MAIN TIP. STATISTICAL FIT - LINEAR ENVELOPE

		c' (kN/m^2)	ϕ' (degrees)	ϕ' (degrees) (c' taken to be zero)
(1)	Spoil heap (49 specimens)	14.82	33.5	35.0
(2)	Fabricated specimens of fresh roof and floor measures from underground			
	(a) Combination 1	18.48	32.5	34.5
	(b) Combination 2 (19 specimens)	6.48	33.0	33.5
	(c) Combination 3 (15 specimens)	3.93	34.0	34.0
(3)	Tip surface (0.76 to 1.22 m)	23.51	30.5	33.5

Two *in-situ* permeability tests gave values of 2.7×10^{-3} and 4.0×10^{-3} cm/sec. These results were about an order of magnitude higher than the mean of the laboratory tests. Taylor and Spears (1972) concluded that the body of the tip was relatively impermeable to precipitation and that the outer 3 m zone could well represent the limit of shallow percolation. The lack of evidence relating to leaching of soluble materials also supported the opinion that there was a lack of any great water movement through the spoil pile.

Taylor and Spears conclude with the following definitive statements:

"... it is clear that major changes in physical and mechanical properties have not occurred within the body of the tip during 50 years...."

Comparison of strengths of spoil and fresh material ... "provide convincing evidence that weathering or degradation processes are unlikely to be a live issue in the body of unburnt spoil-heaps."

"... there is apparently no obvious justification for believing that unburnt spoil buried within the more typical colliery tips is likely to be subject to long-term degradation effects".

4.2.3 UK Experience with Rapid Failures of Colliery Spoil Heaps

Experience with flow slides in coarse coal discard spoil piles in the South Wales Coalfield has been summarized by Siddle et al (1995). They identified 23 rapid failures that have occurred since 1900, the most recent being the disastrous 1966 slide at Aberfan. The spoil piles were typically 30 to 75 m high with dump faces at 25 to 33°. The original valley slopes ranged from 10 to 23°. Four different types of rapid failure were identified: flowslide outburst, debris slide, and debris flow.

The reasons for these flowslides are identified as:

- high rainfall
- steep topography
- no compaction of spoil
- no foundation preparation or drainage measures.

Most flowslides occurred on active or recently active dump faces. Of the 16 flowslide events, 11 occurred on active tips, 2 on probably active tips and one each on tips where tipping in the area had been stopped 2 months, 6 months and 4 years before the flowslide took place. Based on *in situ* density data reported by Taylor, 1987 (see Section 4.2.1 above), Siddle et al state "It appears that in the older tips self weight compaction increases the average dry density sufficiently for the flow slide hazard to be reduced or even removed."

Two of the failures were identified as having been due to an outburst of concentrated seepage water as a result of impeded drainages. At Fernhill, an outburst occurred some 15 years after tipping ceased. The failure left a 50 m wide hollow in the waste pile and was coincident with exceptionally heavy rainfalls that occurred in South Wales during December, 1960. This event is particularly significant due to the length of time that it occurred following waste placement.

4.2.4 Horsley Restored Opencast Coal Mining site, UK (Charles et al 1977)

The Horsley site provided an opportunity to investigate the effect of a rising water table on the settlement of a weak rock backfill material. The site was of particular interest as, for a period after backfilling was complete, the groundwater table was kept down close to the base of the fill by pumping. The backfill was predominantly a cohesionless fill of sandstone and mudstone fragments up to 70 m deep.

The pit was backfilled in the period 1961 to 1970 either by end dumping with dump tracks or casting with a dragline. This gave rise to segregation in the backfill and a high degree of variability in engineering properties. Settlement monitoring was established in 1973. The pumping was terminated early in 1974 and the monitoring carried out for 3 years after this.

The backfill comprised discrete mudstone and sandstone fragments with less than 10 percent boulder sizes (200 mm). The average silt content was less than 10 percent. Cavities up to 500 mm deep were encountered during the drilling. The void ratio was estimated at 0.25 to 0.65. Much of the fill was determined to be in a loose condition with a low degree of saturation. The density range of the fill was similar to that encountered in colliery spoil tips as reported by Thomson and Rodin (1972).

Creep settlements in the backfill were monitored at some locations in 1973 prior to turning the pumps off. These were typically about 12 mm per year except at a lagoon site where the rate was 50 mm per year. The lower rate corresponds to a compression strain of about 0.03 percent per year. In terms of Sowers et al's (1965) $\propto$ value for the compression strain per log cycle of time, there is not enough data in the paper for an accurate assessment. However it probably corresponds to the lower end of the range for dumped rockfill with a value in the order of about 0.3.

When the pumping was terminated the water level rose fairly quickly. Over the 3 year monitoring period the lower 40 m of backfill became saturated. Magnet extensometers (settlement gauges) had been installed at discrete depths, such that compressive strains could be measured as the zone between the magnets became saturated. In nearly all cases significant settlement occurred on saturation; settlement rates generally slowed down after this initial saturation. Compressive strains of up to 1.4 percent over a 6 m thick zone were measured, with total strain of 0.5 percent over the thickness of fill inundated by the rising water table.

Because of the sudden increase in settlement on wetting, Charles et al use the term 'collapse' settlement to describe this response. They consider this behaviour a similar mechanism as that described by Terzaghi (1960) at the Cogswell Dam.

4.3 APPALACHIAN COAL MINE SPOIL PILES - EASTERN USA

4.3.1 Study of Spoil Degradation (Andrews et al 1980)

This study comprised a detailed evaluation of the mode of breakdown of weak sedimentary rocks at four mine sites covering the Appalachian region from Pennsylvania to Alabama. The mine spoils were up to 10 years old. The study included observations of samples from within the dumps and intensely weathered material at ground surface. These observations were compared with the results of various laboratory slaking tests.

All four sites were surface mines. At two mines draglines were used to dump the spoils in 25 to 35 m high ridges. The third was a truck and shovel operation, end dumping spoils into an abandoned pit. The fourth was a truck and shovel operation with the spoil pile constructed in 1.2 m lifts using dozers.

The waste rock material comprised the following:

- Mudstone (σ_c = 1 to 20 MPa)
- Shale and siltstone (σ_c = 3 to 30 MPa)
- Sandstone and limestone (σ_c = 40 to 200 MPa)

The proportion of mudstone in the spoils ranged from less than 10 percent at Site B to 80 percent at Site D. Spoil material was generally 500 mm minus, although it did contain occasional larger particles. Significant breakdown was attributed to blasting, and mechanical handling of the material. Field observations of durability and modes of breakdown were generally consistent with laboratory test results.

Gradations showing the differences between fresh, 2, 5, and 10 year old spoils for sites B and D are shown in Figure 4.1. The spoils at Site B were largely shale and siltstone that displayed a chip type degradation mode. The negligible change in gradation indicates that material breakdown with time was insignificant at this site. At Site D where the spoils contained a high proportion of slake prone materials, the effects of time on material breakdown was more apparent. It can be seen that the fines content (silt/clay sizes) in the 10 year old spoil was 40 percent compared with 25 percent in fresh spoil.

Based on the overall study Andrews et al (1980) concluded that material breakdown appeared to be minimal below a depth of 1.5 m. This was attributed to the stable moisture regime below this depth. However, based on the results of Site D it would appear that in clay rich mudstones that produce cohesive soil-like spoil, there was evidence of degradation with time.

They also concluded that mechanical breakdown during handling causes a fine spoil material that, especially if compacted, is more resistant to long term degradation than loose, coarse spoils.

Spoils in which chip, slab or block slacking modes dominated showed no evidence of slope stability problems. Spoils which slake to inherent grain size may have stability problems as evidenced by slips, bulges etc.

As a general finding the authors noted that although many of the lithologies studied in the project might be considered problematic on initial examination, few adverse effects were observed. They also noted that the degradation of mine spoils appears to be minimized by the mixing of slakeable and non slakeable materials that often occurs in the spoiling operations. A typical example is Site D with 60 to 70 percent mudstone. Both in the field (near surface) and in the laboratory this would degrade to clay soil. However, in the spoil piles there was little effect. There was some increase in fines as shown in Figure 4.2 but not a complete disintegration of the material.

Field observations of durability and modes of breakdown were generally consistent with laboratory test results.

4.3.2 Spoil Pile Stability and Groundwater Tables

Instability in reclaimed coal mine waste embankments in the Eastern USA is described by Shakoor & Ruof (1989), Swanson et al, and Bell and Daniels (1985). In most cases a contour strip mining approach was used with the spoils 'rolled back' against the highwall to give slopes that approximate the original topography. The spoils were generally handled only once and received minimal compaction from the mining equipment.

Shakoor & Ruof indicated that shallow (4 to 6 m deep) slumps were the predominant type of slope failure in their study area in east-central Ohio. Build up of water pressures in the dump material gave long term instability. This arose from overtopping of the diversion ditches at the top of the embankment with infiltration of surface runoff into cracks that formed near the spoil/highwall contact. In addition the spoils were often recharged from natural groundwater seepage from the highwall strata.. Karfakis et al (1992) emphasized these same recharge mechanisms in causing instability in coal spoil embankments (pre-1977 mining practices) in southwest Virginia.

Swanson et al looked at 11 sites throughout the Appalachian area. Most of the dumps were soil-like fill and all experienced slope failure long after initial construction. They concluded that the long term condition, when groundwater levels reached equilibrium, was the critical design case.

The four dumps described by Bell and Daniels were constructed to 'approximate original contour' and experienced slope instability very soon after construction. The spoil material contained from 20 to 55 percent passing the No. 200 sieve. The instabilities were largely explained by the steep final slopes (about 33°) and the low strength of the cohesive soil-like fill.

In Shakoor and Ruof's study, the objective was to investigate the variability of engineering properties of old and new spoil. They looked at 12 dumps representing 4 different geologies. In each case two of the dumps were 'new' (less than one month) and one was 'old' (older than 7 years). Only near surface samples were obtained. The range of gradations representing 10 of the dumps are shown in Figure 2.1. This indicated 45 to 60 percent finer than 5 mm. The range is similar to the gradation of the sandy gravel found in layers of poor quality material in the Rocky Mountain coal mines. Two of the dumps were significantly finer grained with up to 55 percent passing the No. 200 sieve (0.07 mm).

Based on *in-situ* density tests and a limited number of laboratory Proctor compaction tests, they concluded that *in-situ* densities correspond to less than 90 percent of Standard Proctor Compaction. However, these data may not be completely reliable due to the problems associated with variable specific gravity in high coal content spoils and also the near surface location of the density measurements. In comparing the samples, Shakoor and Ruof concluded that there was no significant differences in engineering properties between the old and new spoil.

Phelps (1991) carried out numerical analysis to model buildup of groundwater tables in spoil piles in Appalachian coal mines. In parametric analyses he used the ratio of saturated hydraulic conductivity and effective average rainfall as a diagnostic parameter. He found that when the ratio was 1.0 or less spoils are more sensitive to buildup of groundwater pressures with time. He compared the results with three case histories. The case histories were contour strip mining spoil piles, comprising soil-like material with more than 40 percent fines (passing the No. 200 sieve). Hydraulic conductivities were in the 1×10^{-6} to 5×10^{-6} cm/sec. range. Annual effective precipitation was approximately 1200 mm per year (4×10^{-6} cm/sec.). While there were some difficulties in matching parameters and recharge from seepage, the analyses did indicate the observed trend of rising water level with time.

4.4 DURABILITY OF SHALE FILL, BALDERHEAD DAM, UK (Kennard et al, 1967)

Concerns over the durability of weakly cemented shale was an issue during the design of the Balderhead Dam. The gradation of the material was 100 mm minus with 15 to 25 percent finer than 2 mm.

As there was the unknown risk of deterioration of the strength of the comparatively weakly cemented shale, a detailed study was made of the mechanisms by which this could occur.

Three mechanisms were recognized. First, mechanical weathering was found to occur because of wetting and drying cycles. Breakdown ceased when a particle size of the order of 10 mm was reached. Second, chemical weathering due to leaching of carbonate cementation was found to be very slow. Third, mechanical degradation due to placement was feared.

Laboratory triaxial tests on fresh fill indicated the angle of friction ranging between 32° and 38°. These tests were on 20 m minus material. Similar tests on material finer than 3 mm plotted in the same range, indicating that the maximum particle size was not critical.

An indication of the strength of the shale if fully degraded to clay was obtained by testing remoulded samples of shale which had suffered surface chemical weathering. This material had a 40% clay fraction, a liquid limit of 72% and a plastic limit of 39%. A significant drop in strength to a friction angle of 26° was measured.

These results bracketed the range of possible strengths and highlighted the issue of whether the fill strength could tend to the lower value either with breakdown during placement or due to long term weathering. The strength of the shale after severe mechanical degradation as measured or samples from the surface of the site access roads conformed to the lower bound of the results for the fresh fill. Continuous grinding of samples for 2 hours was required in order to reduce the strength to that of the chemically weathered shale i.e. clay soil.

The effect of mechanical weathering and time are shown by the strength found for material exposed on the surface of the embankment for three months, for similar shale from the Burnhope Dam (30 years old) and for shale from the surface of a local tip of tunnel spoil (50 years old). The results obtained were within the range of the results obtained for the fresh fill. i.e. showing noticeable degradation with time.

This case history shows that shale fills will retain their granular, frictional nature until such time as their cementation is leached by chemical weathering. In the body of a fill it would appear that this is a very slow process.

5.0 CONCLUSIONS

The review conducted for this report provides information on processes and relevant experience with long term geotechnical stability in mine waste dumps. Two broad categories of mine waste materials were identified:

- rock-like spoil
- soil-like spill.

For practical purposes the distinction between rock-like and soil-like fill can be made based on sand content. Rock-like spoil exhibits sand contents less than about 20% by weight. Soil-like spoil contains greater than 20% sand content and can be considered as a sandy gravel material. Soil-like spoil can be further divided into cohesionless and cohesive spoil types. Cohesive soil-like spoils were not carefully evaluated in this report as, it was assumed, that for the most part BC mine waste dumps contain mostly rock-like and cohesionless soil-like materials. Comparisons between the effects of long term processes on the geotechnical properties were made to illustrate the importance in distinguishing between these two types of materials.

Three processes were identified with respect to their potential for affecting time dependent geotechnical properties of mine waste spoils. A summary of findings for each of these processes is as follows:

1. Self Weight Compaction results due to overburden loading. Time dependent settlement of mine spoils results both due to "dry" crushing and wetting. Measurements in rockfill embankments and mine spoil piles indicates that wetting can lead to large settlements in some cases. Laboratory measurements for non-cohesive spoils from Australian coal mine indicates saturation settlement of 6 to 8% for sandstones and 12 to 13% for mudstones (at normal stress levels varying from 0.5 to 1.5 MPa). Self weight compaction can also generate fines as a result of crushing. Significant increases in sand content due to crushing has been observed. It is estimated that decreases in hydraulic conductivity of up to one order of magnitude could occur due to time dependent processes in non-cohesive soil-like spoils.

2. Degradation results due to physical and chemical weathering. Physical weathering seems to be most important in argillaceous rocks where two distinctly different processes have been identified. Breakdown of non-cohesive argillaceous spoil material results mainly due to capillary action. This process is most prevalent where extreme drying occurs and results in material breakdown to a block and chip sized material (25 mm). Breakdown of cohesive argillaceous spoil results due to swelling and can cause disintegration down to the constituent particle size (clay sized).

   In terms of engineering time (50-100 years), chemical weathering is most important where spoils are susceptible to acid rock drainage (ARD) reactions. Information related to degradation of ARD producing mine waste was not found for this review.

3. Erosion can be both external due to surface runoff and internal due to seepage and fines migration. Field (surface erosion) studies of mine spoil piles indicates, that with time, finer particles tend to migrate into the spoil surface leaving behind a relatively permeable, erosion resistant outer mantle layer. Limiting conditions(slope length, slope angle, material gradation, runoff rate) for this "self-healing" process remain to be defined.

The broad grading of mine spoil materials suggests that fines migration due to seepage erosion is a potentially important process. Field observations indicate that fines migration may be important where saturated seepage zones are present with gradients acting across alternating layers of soil-like and rock-like spoil materials.

A review of experiences related to waste pile instability tended to support findings related to time dependent processes. Key findings are summarized as follows:

1. Review of statistics related to flowslides in BC rocky Mountain coal mine dumps and UK coarse discard piles show a marked decrease in occurrence following dump construction. The longest time period following active dumping, for which a flowslide occurred was 4 years; at a South Wales colliery spoil heap. It is surmised that wetting induced settlement is an important process for reducing brittleness in loosely placed soil-like spoils.

2. Studies related to degradation of non-cohesive soil-like coal mine spoils in the Eastern USA and Australia show that weathering is limited to the upper 1-2 m near-surface zone. Material breakdown to chip sizes has been observed in this "weathered" zoned, presumably as a result of intense drying, followed by wetting and capillary action breakage.

3. Work in the Eastern USA coalfields has determined that instabilities in reclaimed coal mine spoil piles are mostly due to build up of water tables in soil-like fills. The buildup is assumed to occur both due to modest decreases in hydraulic conductivity and due to regional groundwater table re-adjustment as seepage patterns seek equilibrium due to the new boundary conditions imposed by mining.

A key geotechnical issue related to reclamation of mine waste spoils is the configuration of the final slope prior to abandonment. Angle-of-repose slopes are often re-sloped to increase stability, reduce erosion, and permit re-vegetation. Work presented here suggests that from a geotechnical standpoint, final slope configuration should be determined based on the properties and distribution of soil-like and rock-like materials in the pile. Further research should be focussed on waste pile stratigraphy and the associated potential for water table development with time.

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FIGURES

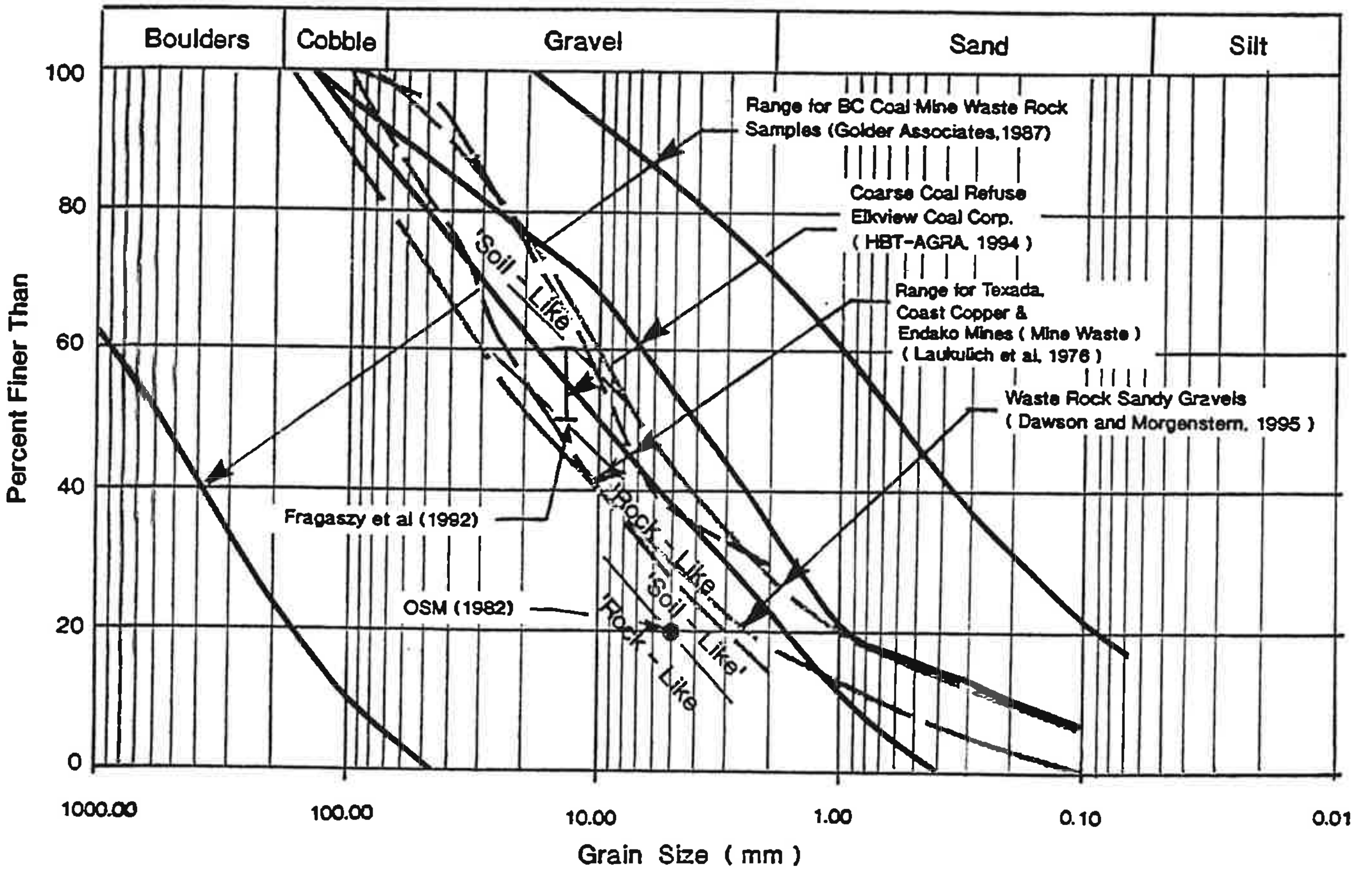


Fig. 2.1 GRAIN SIZE DISTRIBUTION FROM BC MINE WASTE ROCK DUMPS

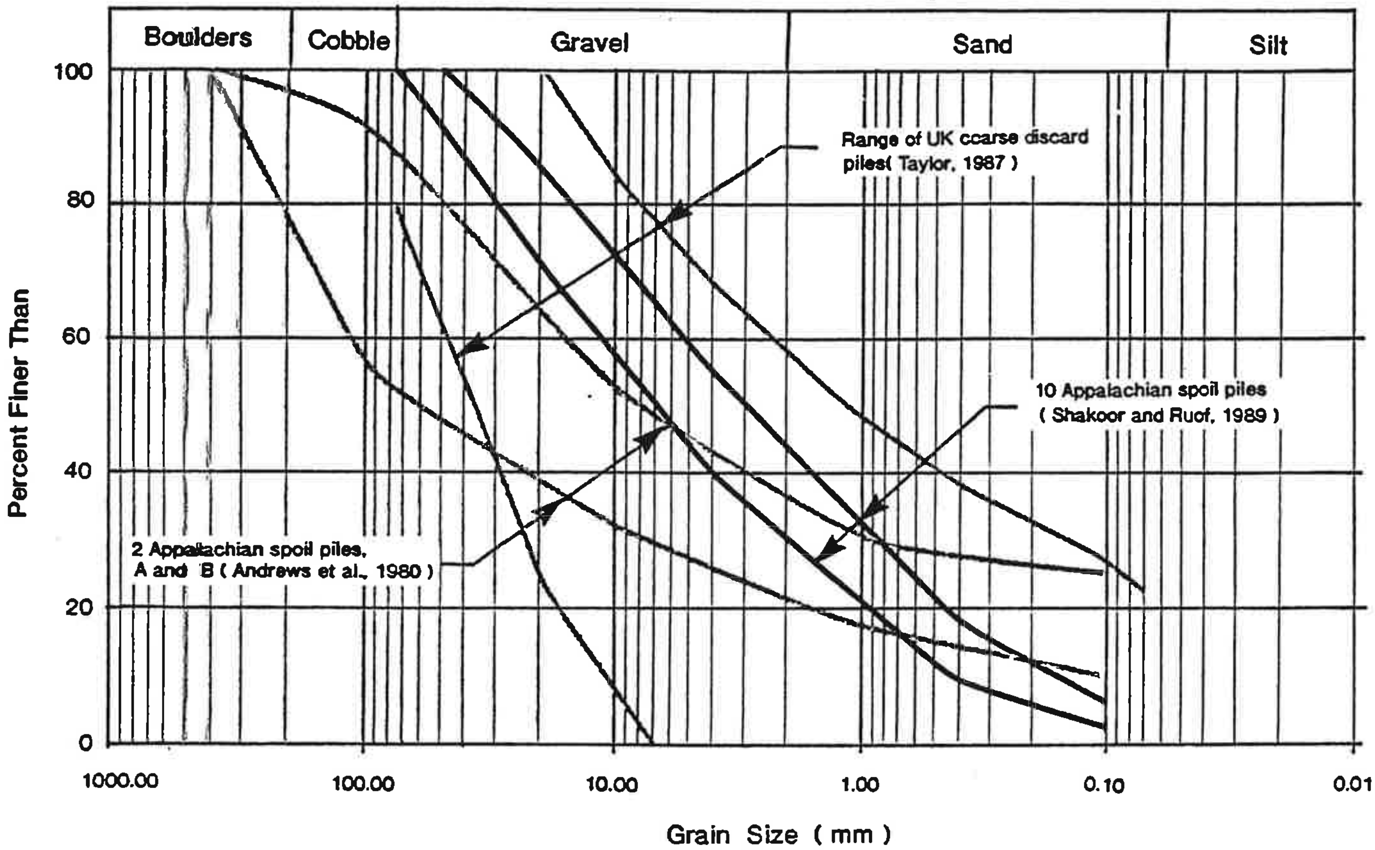
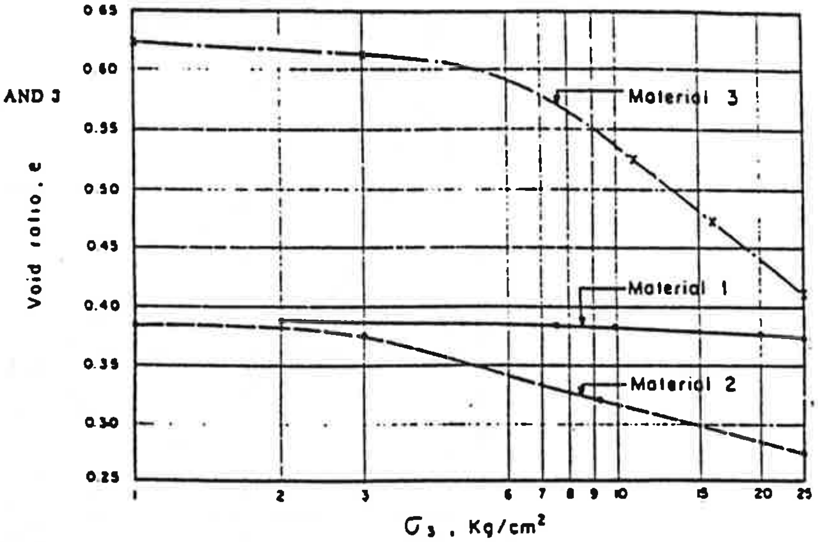
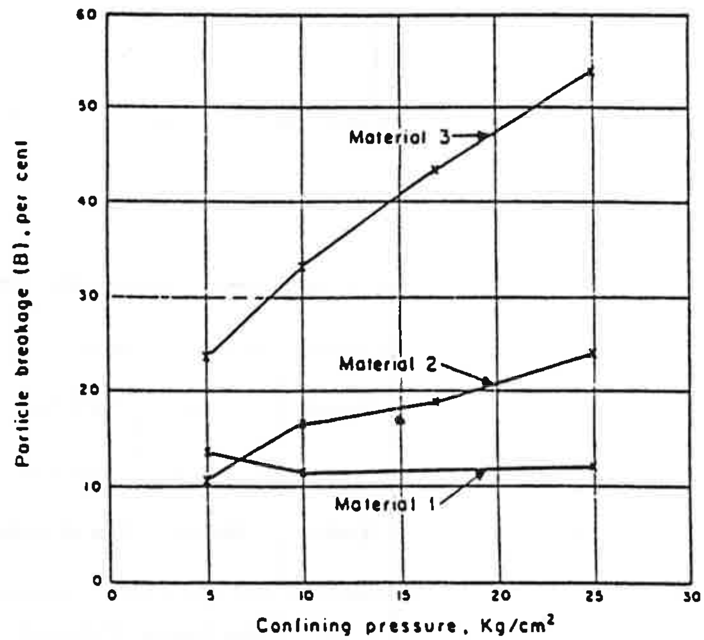


Fig. 2.2 GRAIN SIZE DISTRIBUTIONS FROM APPALACHIAN AND UK COAL MINE SPOILS

(A) COMPRESSIBILITY DATA ON MATERIALS 1, 2, AND 3 (TRIAXIAL TESTS)



(B) PARTICLE BREAKAGE IN TRIAXIAL TESTS



Material		Grading		Initial Void Ratio
			Cu	
1	basalt	well graded	19	0.30
2	gneiss	well graded	14	0.32
3	gneiss	uniformly graded	2.5	0.62

(C) GRADATIONS OF MATERIALS 1, 2, AND 3 (AFTER TRIAXIAL TESTING)

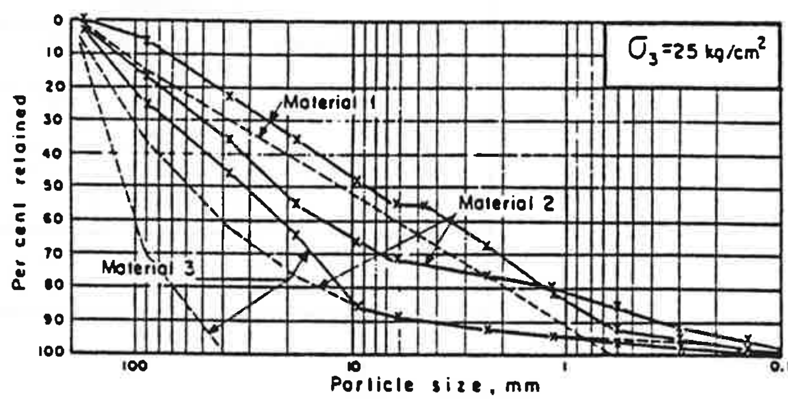
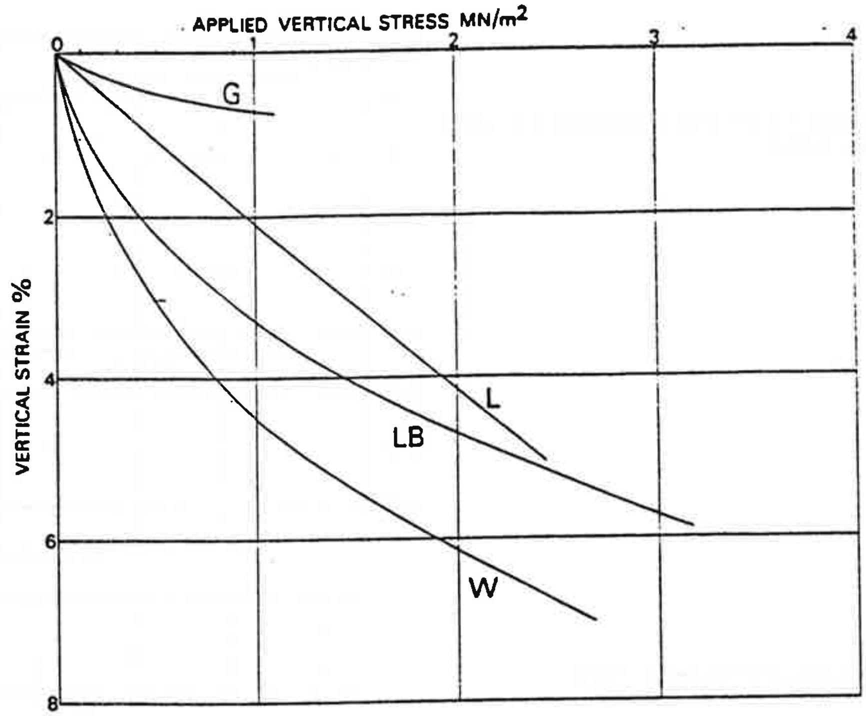


Fig.3.1 TRIAXIAL COMPRESSION TESTS ON COMPACTED ROCKFILL (MARSAL, 1967)



Oedometer tests on fill

Symbol	Dam	Rock type	Strength index (I_A) (*) of rock	Initial dry density	Water content as placed	Porosity
Symbole	*Barrage*	*Type de roche*	*Indice de résistance des rocs* (MN/m²)	*Densité initiale à sec* (Mg/m³)	*Teneur en eau en place* (%)	*Porosité* (%)
LB	Llyn Brianne	Palaeozoic mudstone	57 (**)	2.34	4.5	15
W	Winscar	Carboniferous sandstone	120	2.06	7	21
L	Lefkara	Sheeted diabase	252	1.85	3	30
G	—	Thames gravel	—	2.06	2	22

(*) Hobbs (1963).
(**) Pigeon (1969).

Fig. 3.2 OEDOMETER COMPRESSION TESTS ON COMPACTED ROCKFILL –1m DIAM.SAMPLES–(PENMAN & CHARLES, 1976)

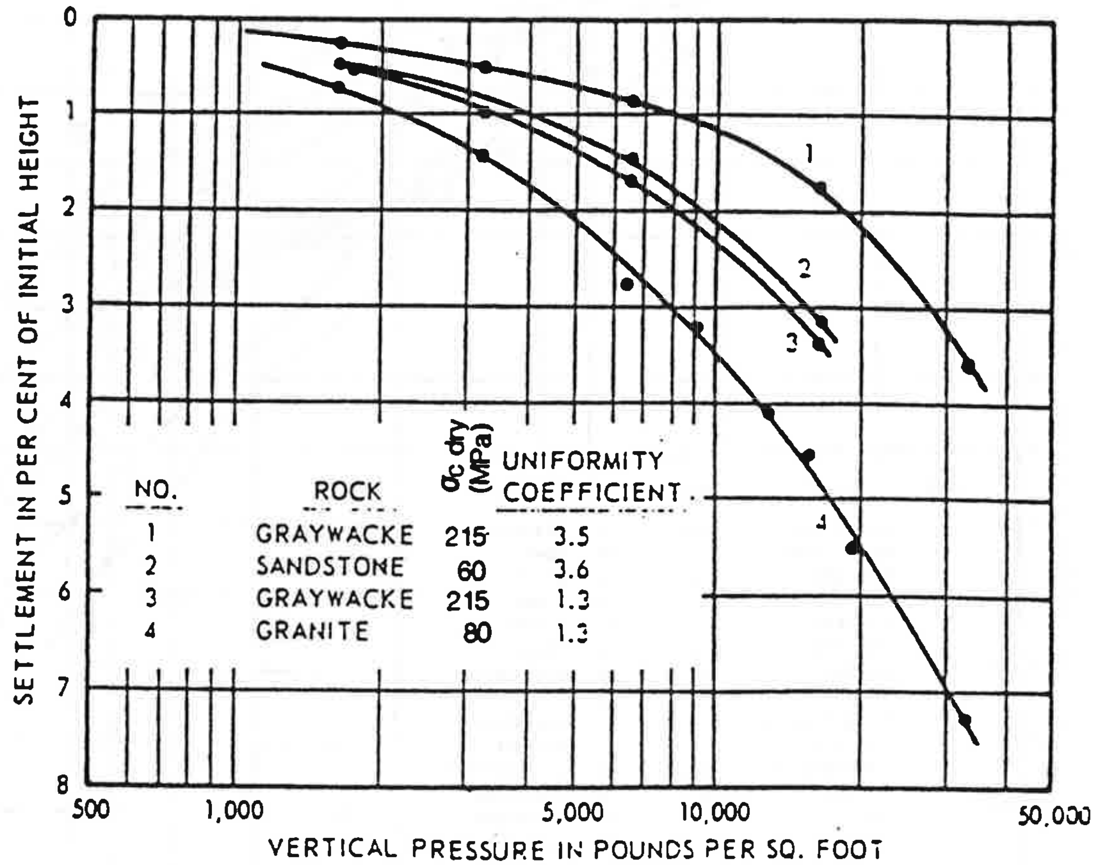


Fig.3.3 SETTLEMENT-LOG PRESSURE CURVES FOR LABORATORY CONFINED COMPRESSION TESTS ON DRY BROKEN ROCK 200mm DIAM.SAMPLES (from SOWERS et al,1965)

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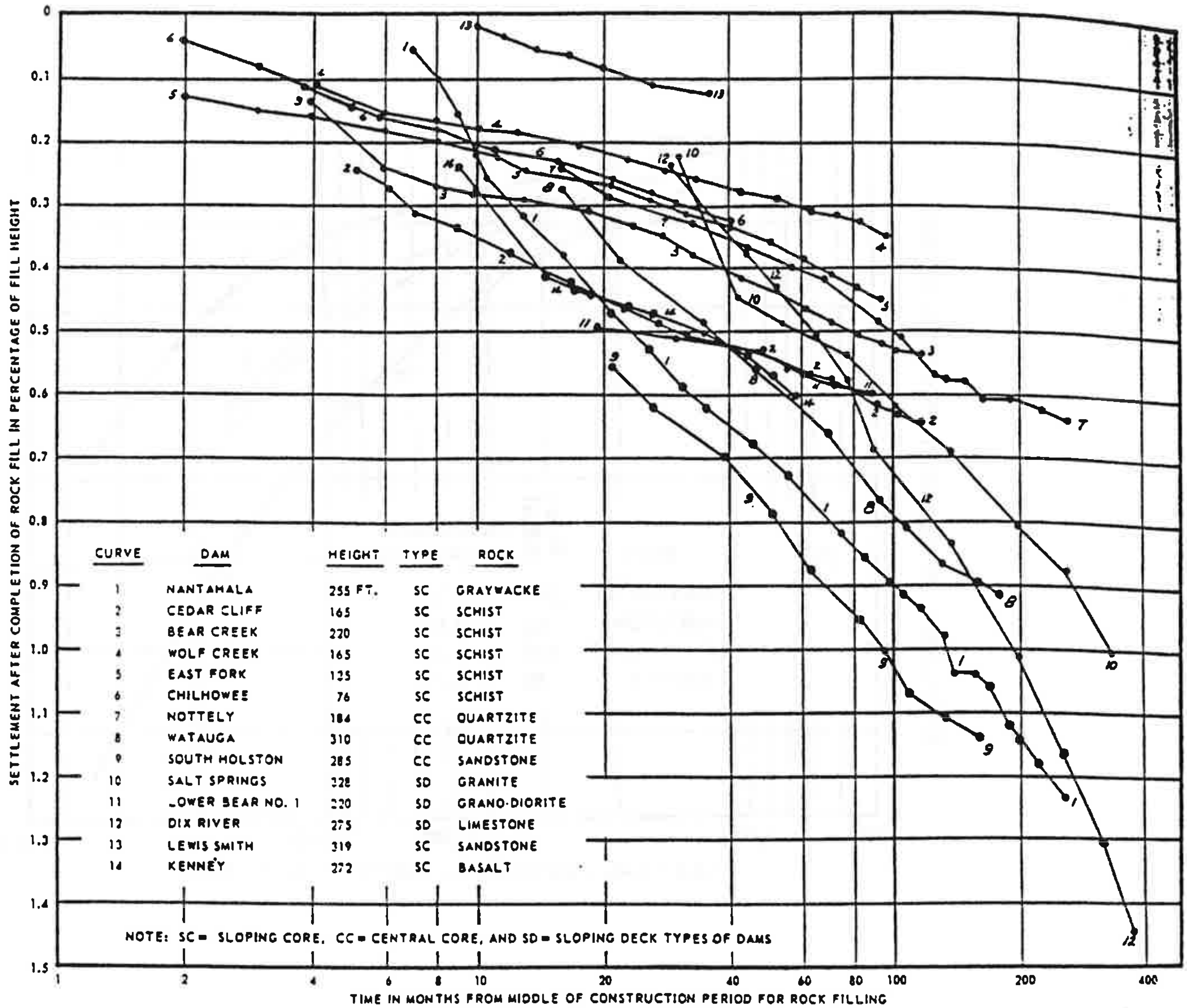


Fig.3.4 OBSERVED SETTLEMENT OF ROCKFILL DAMS AFTER COMPLETION OF CONSTRUCTION

(from SOWERS et al, 1965)

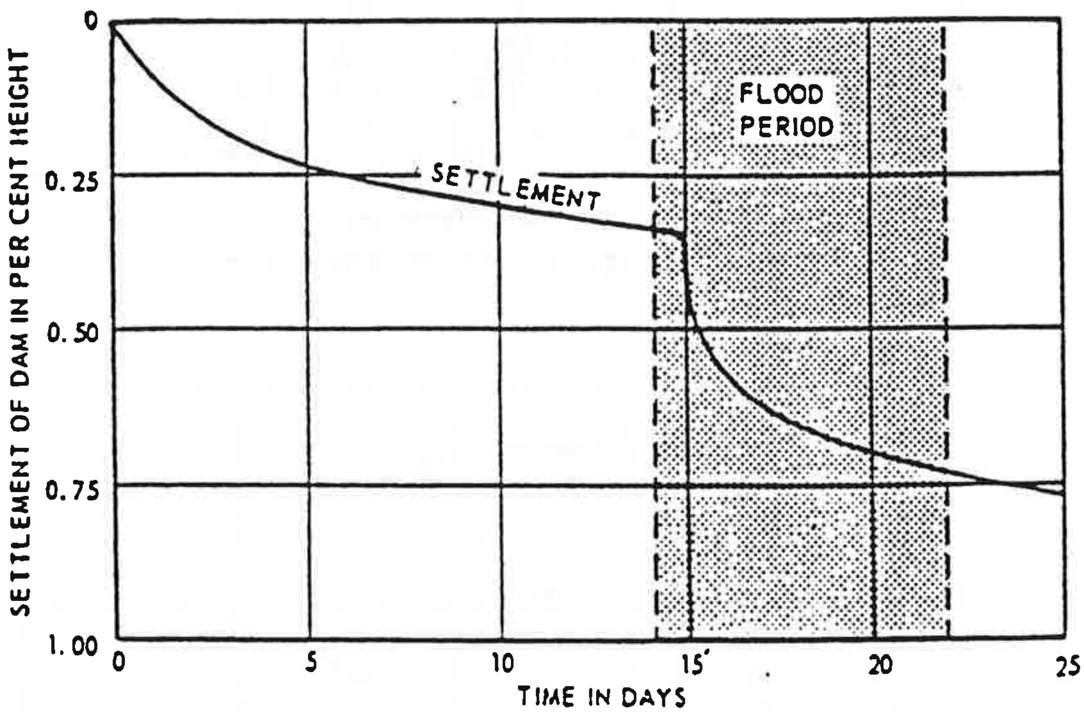
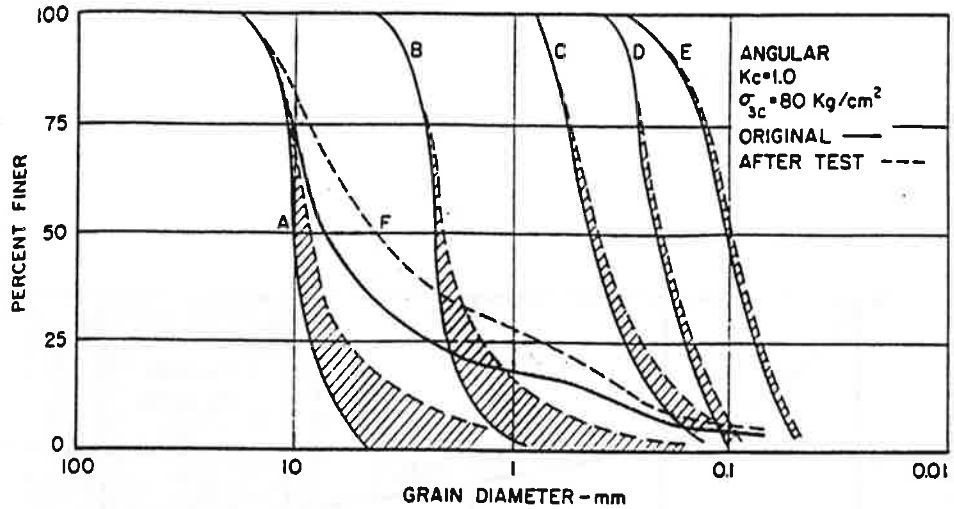
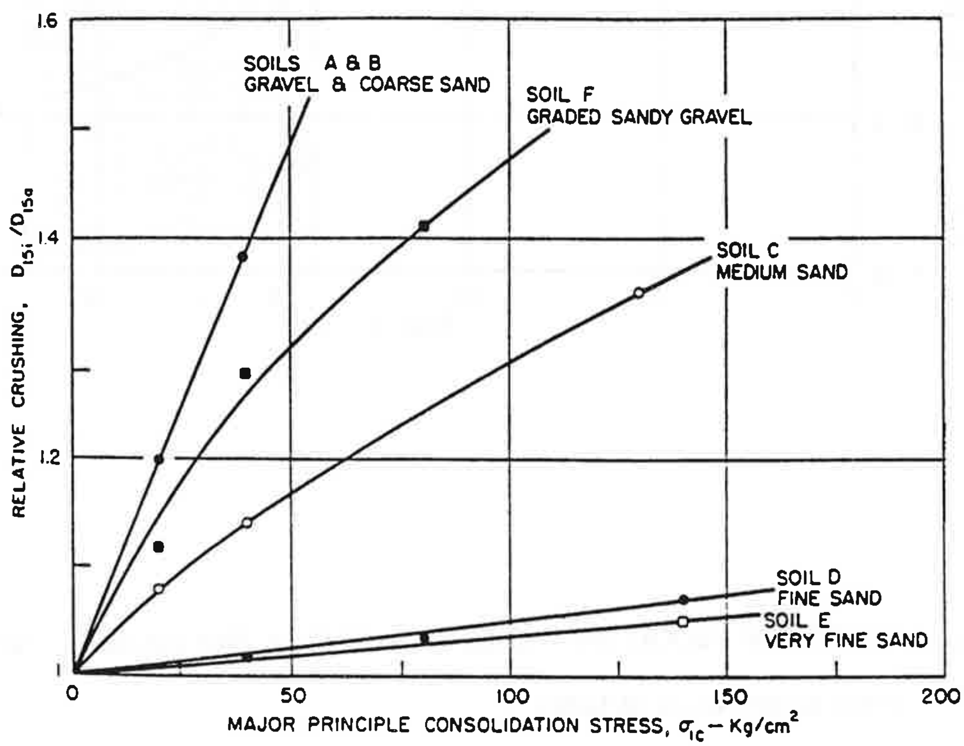


Fig.3.5 EFFECT OF FLOOD ON THE SETTLEMENT OF THE DIX RIVER DAM

(from SOWERS et al, 1965)

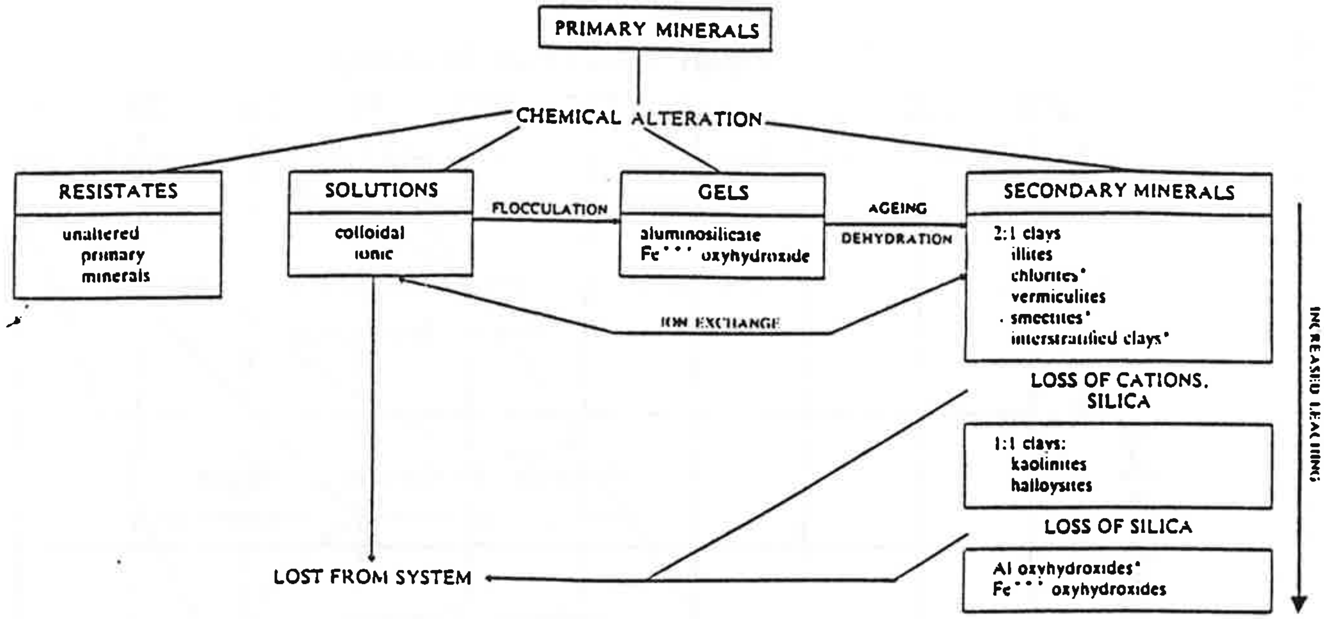


(A) Comparison of crushing of soils with different initial grain sizes



(B) Comparison of relative crushing of different initial grain sizes; angular, Kc=1.0

Fig. 3.6 PARTICLE BREAKAGE IN COMPRESSION TESTS ON SAND AND SAND AND GRAVEL (from LEE and FARHOOMAND, 1967)



(A) Processes and products of chemical alteration (from Mellon 1985). * indicates those processes considered to be most applicable to an engineering timescale.

(B) *Factors and processes important in weathering (based on Brunsden 1979) (* indicates those processes considered to be most applicable to an engineering timescale)*

Main controls			*Physical weathering*		*Response of material*
Weathering environment Climate Atmospheric Hydrospheric Local factors e.g. topography drainage water table	The physical environment	→	Crystallization processes* Wetting and drying* Colloid processes (Organic processes) (Sheeting, unloading and spalling)* Insolation*	→	Disintegration Comminution Volume change Grain size change Surface area change Consolidation
			Chemical weathering		
Lithosphere Lithology Parent rock Structure Climate Atmosphere	The chemical environment	→	Hydration Hydrolysis Solution* Oxidation* Reduction* Carbonation*	→	Unaffected minerals due to lack of time or weak agents Decomposition, recombination, and cation exchange reactions
Hydrosphere Crystal structure			Chelation Fixation		Leaching Dissolved ions

Fig. 3.7 CHEMICAL WEATMERING PROCESSES (from Fookes et al, 1988)

Main Menu Search

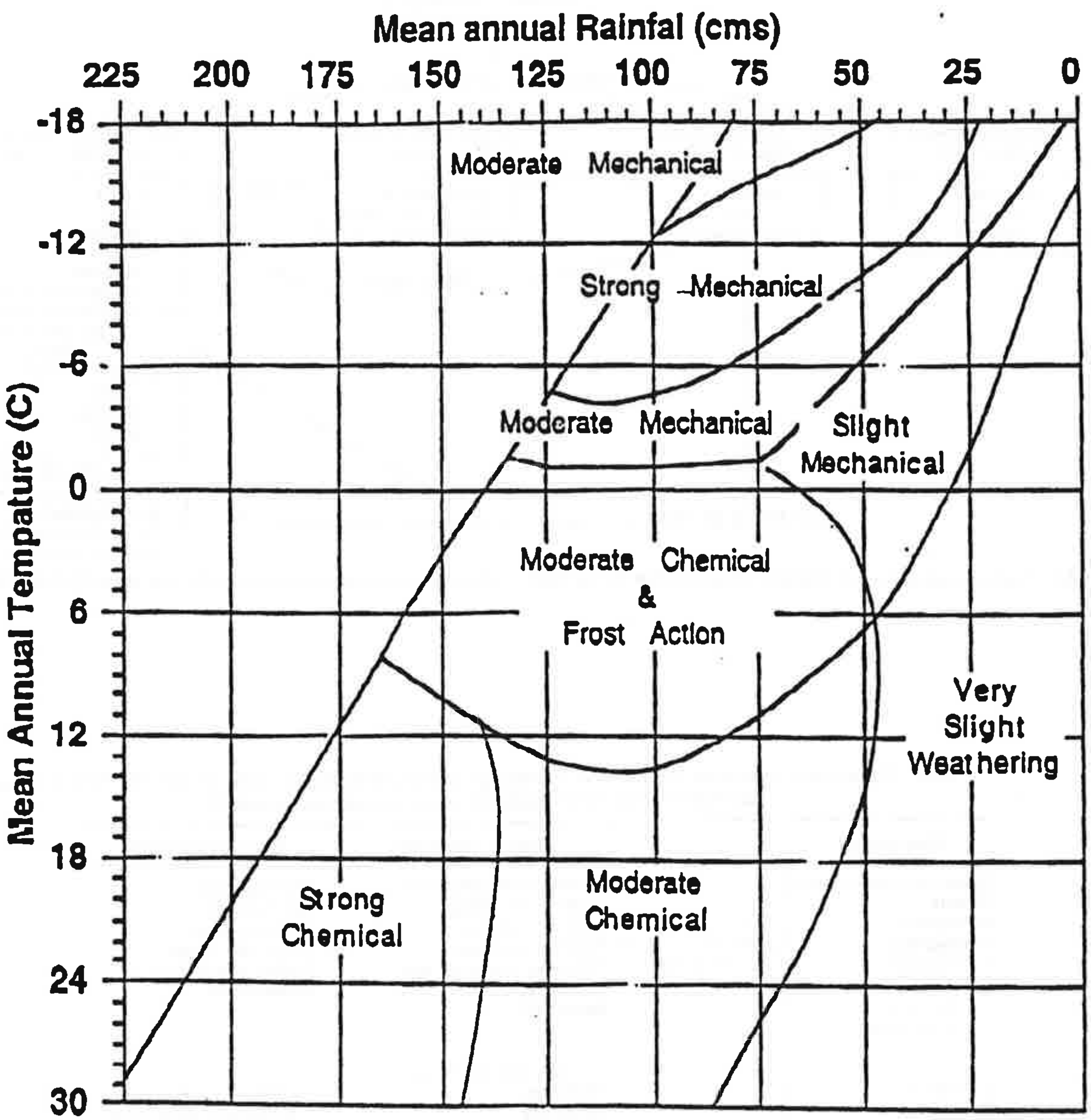


Fig. 3.8 DIAGRAM DELINEATING WEATHERING ENVIRONMENTS ACCORDING TO TEMPERATURE AND RAINFALL CONDITIONS (from OLIVIER, 1984)

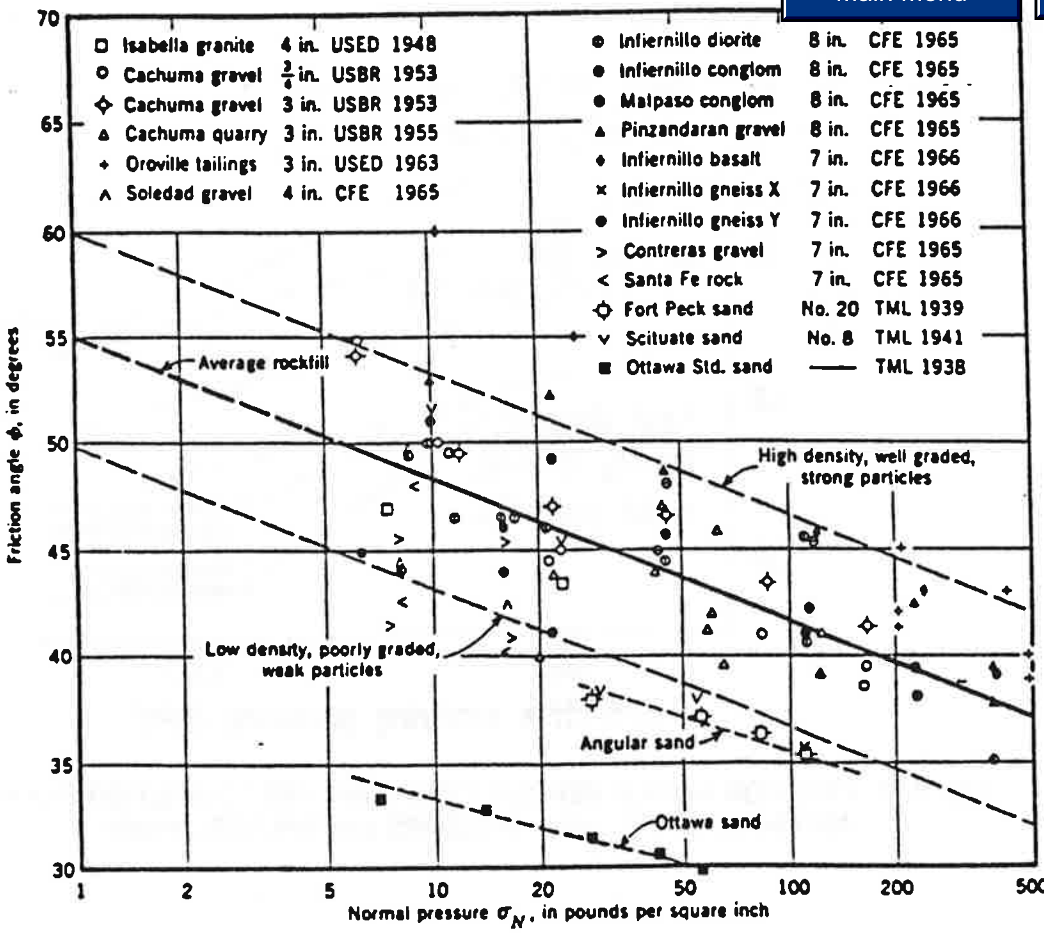


Fig. 3.9 SHEARING STRENGTH OF ROCKFILL FROM TRIAXIAL TESTS (after LEPS, 1970)

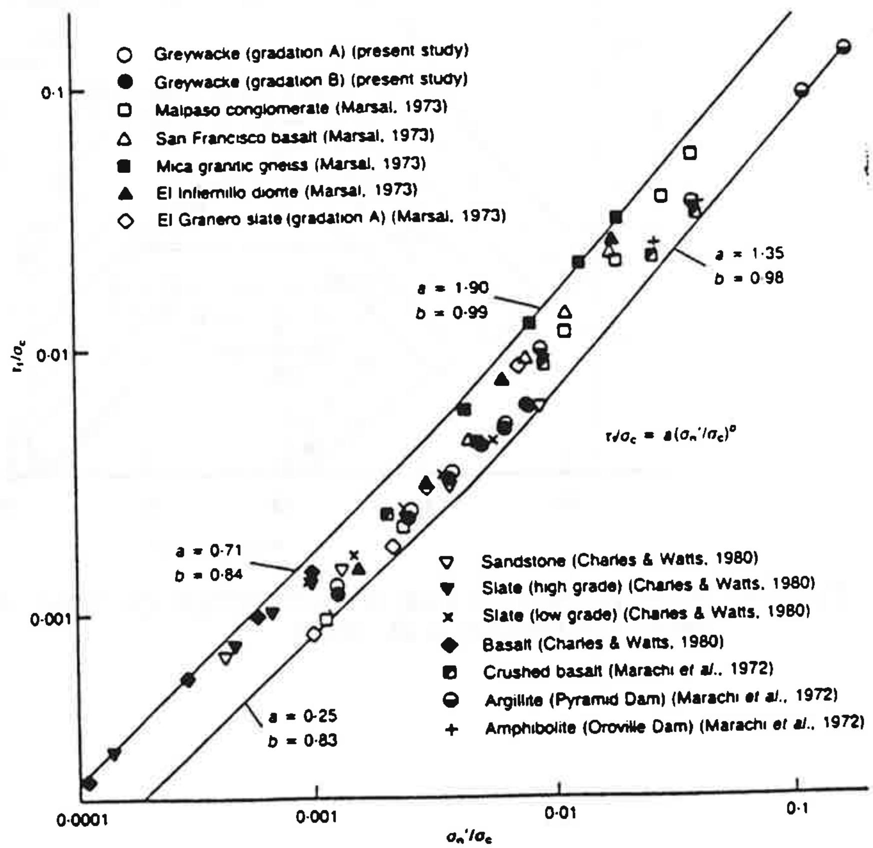


Fig. 3.10 NORMALIZED SHEAR STRENGTH-NORMAL STRESS RELATIONSHIP FOR VARIOUS ROCKFILLS (after INDRARATNA et al, 1993)

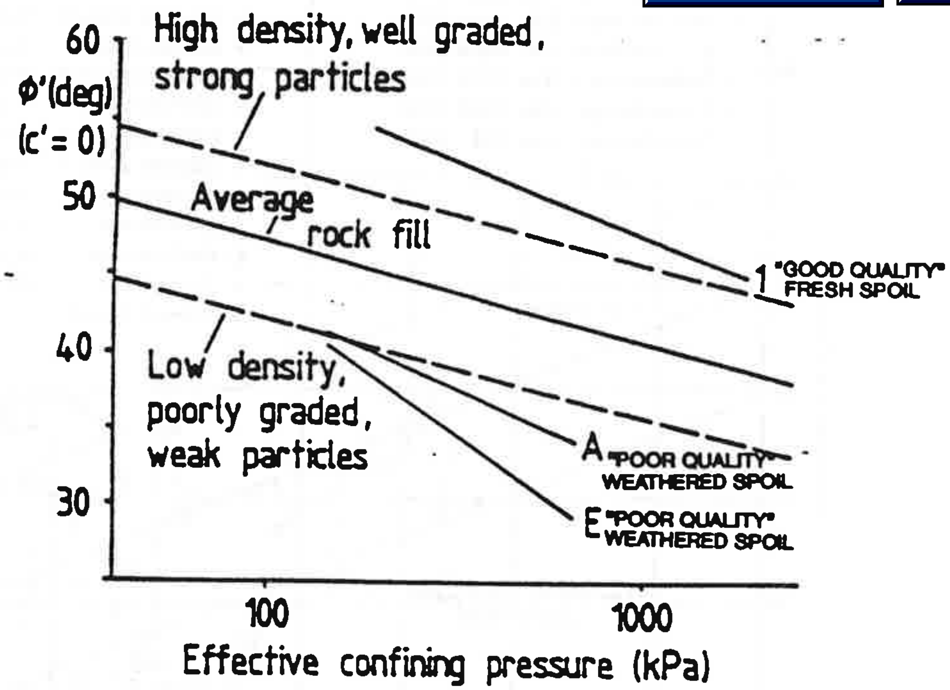


Fig. 3.11 FRICTION ANGLE VERSUS CONFINING PRESSURE FOR ROCKFILL AND MINE SPOIL (after WILLIAMS and WALKER, 1985)

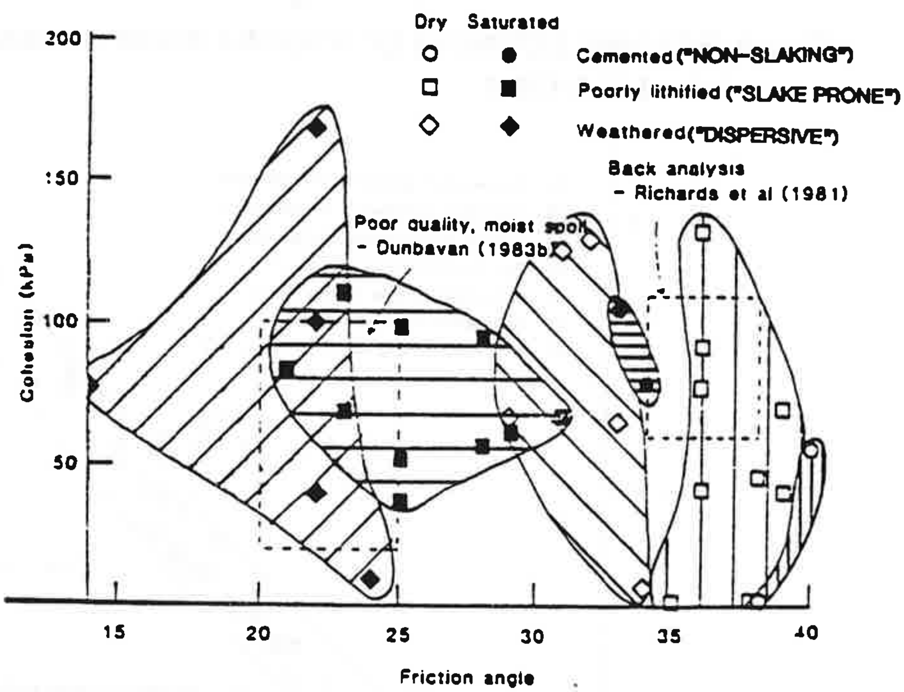


Fig. 3.12 STRENGTH LOSS DUE TO SATURATION OF COAL MINE SPOILS (after SEEDSMAN et al, 1988)

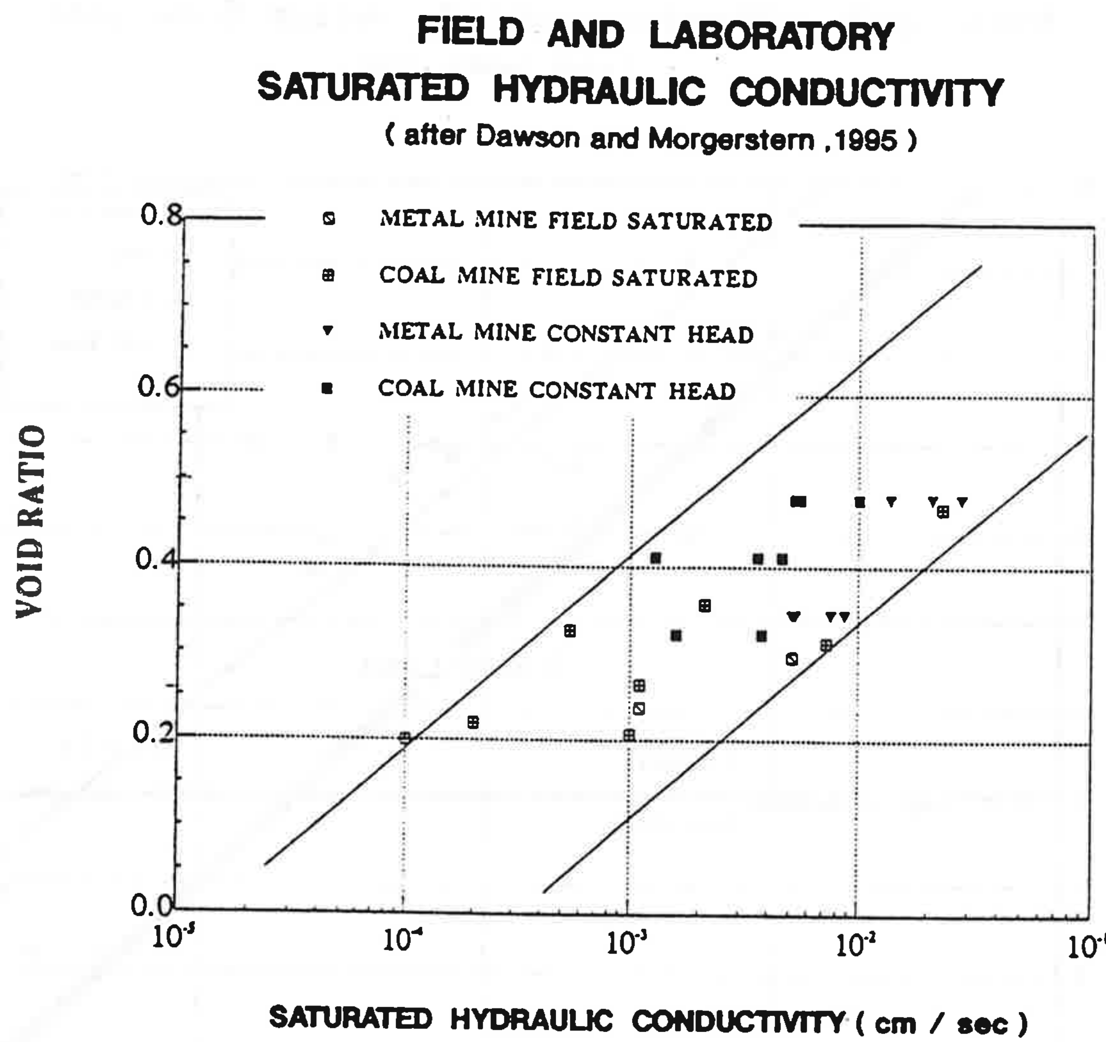


Fig. 3.13 SATURATED HYDRAULIC CONDUCTIVITY OF BRITISH COLUMBIA SOIL-LIKE SPOIL MATERIAL

Main Menu Search

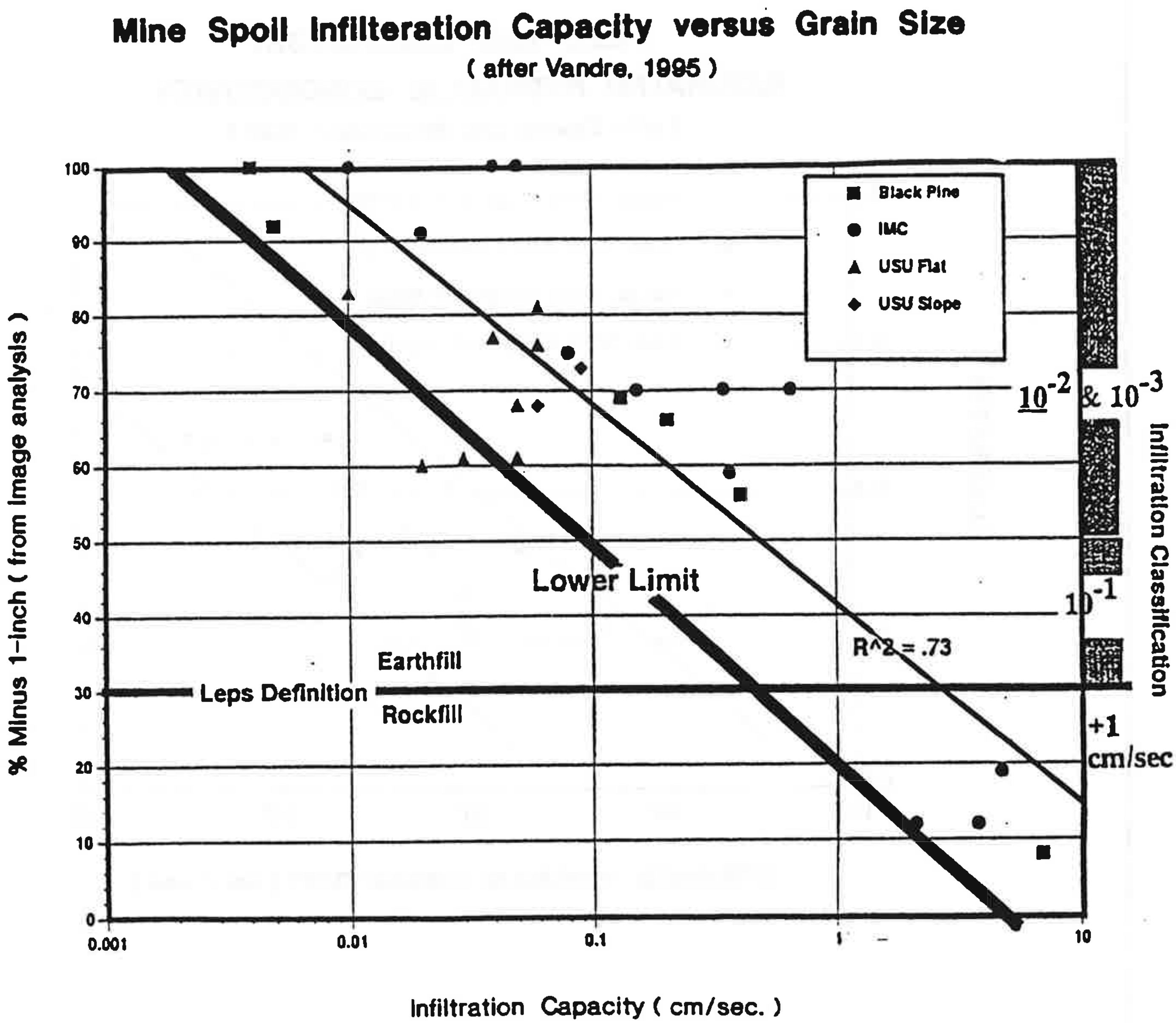


Fig. 3.14 INFILTRATION CAPACITY FOR MINE SPOIL MATERIALS

Main Menu Search

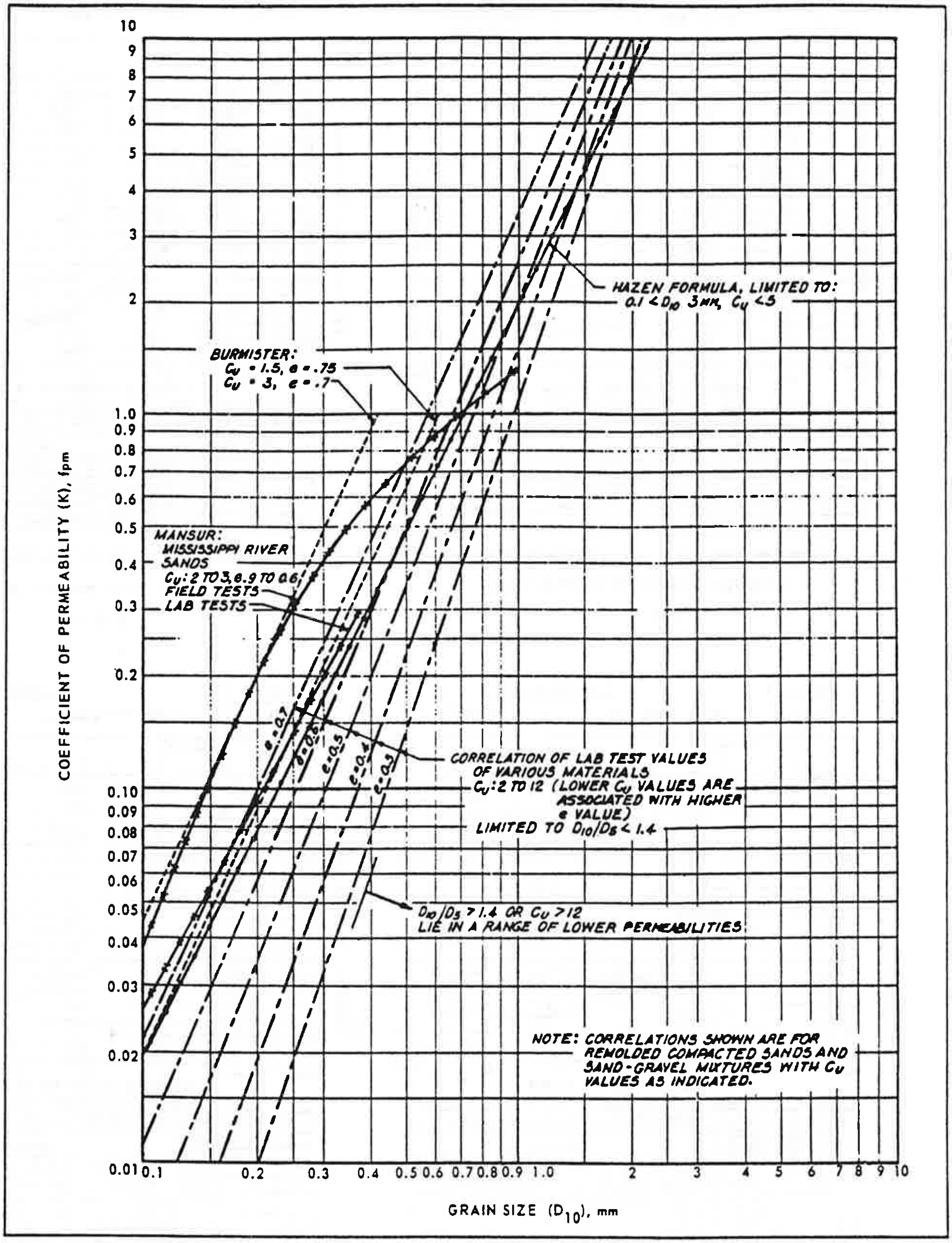
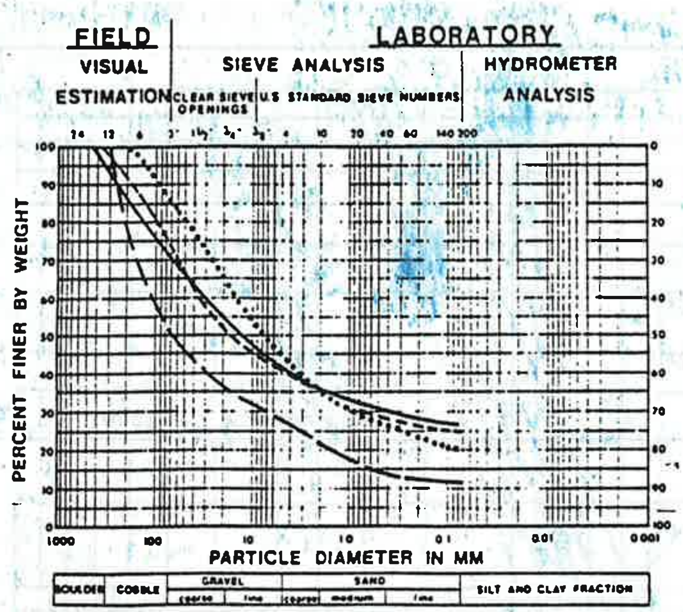


Fig.3.15 PERMEABILITY OF SANDS AND SAND–GRAVEL MIXTURES (from NAVFAC,1982)

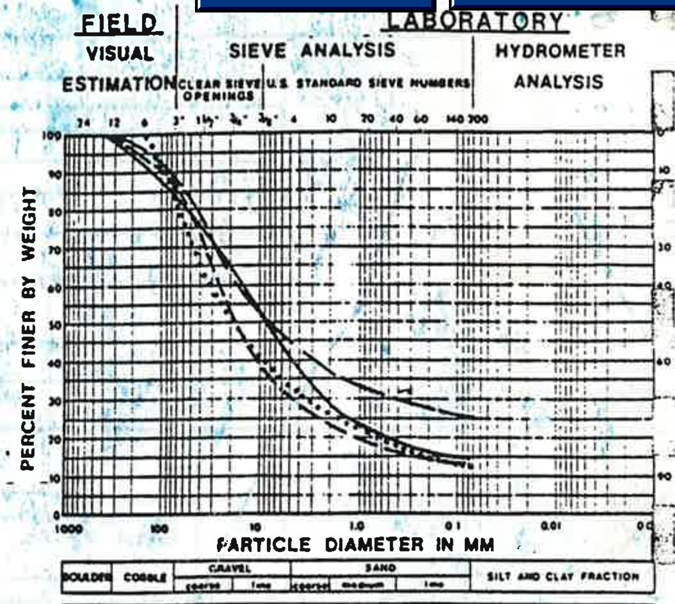


SYMBOL	SPOIL AGE YEARS	DEPTH IN	DEPTH CM	COMPOSITION
—— (solid)	0	46	117	20% SHALE; 80% MUDSTONE
— — (long dash)	2	36	91	20% BLACK SHALE; 80% SHALE
- - - (dash)	5	30	76	10% SANDSTONE; 20% BLACK SHALE; 70% MUDSTONE
······ (dotted)	10	30	76	30% MUDSTONE; 30% BLACK SHALE; 40% SHALE

NOTE: COMPOSITION IS BASED ON PARTICLE DIAMETERS > 5/64 INCH (2 mm)

SPOIL PILE GRAIN SIZE DISTRIBUTION

SITE A

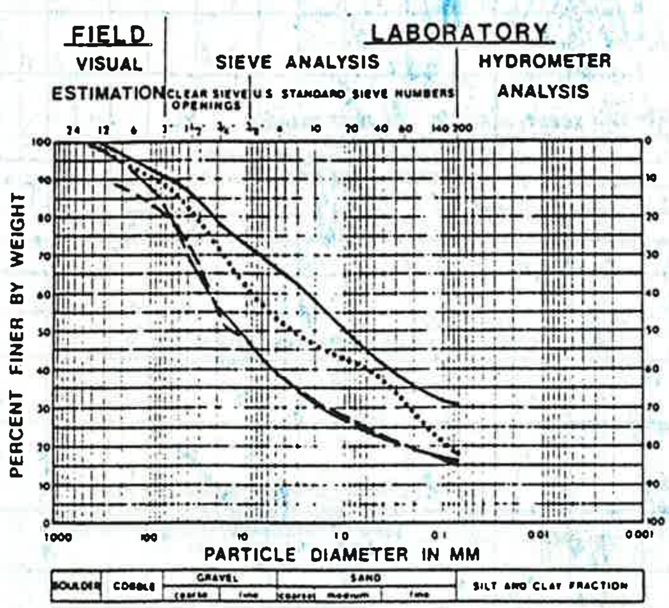


SYMBOL	SPOIL AGE YEARS	DEPTH IN	DEPTH CM	COMPOSITION
—— (solid)	0	40	102	30% SHALE; 70% SILTSTONE
— — (long dash)	2	34	86	20% SHALE; 80% SILTSTONE
- - - (dash)	5	46	117	30% SHALE; 70% SILTSTONE
······ (dotted)	10	48	122	10% MUDSTONE; 30% SHALE; 60% SILTSTONE

NOTE: COMPOSITION IS BASED ON PARTICLE DIAMETERS > 5/64 INCH (2 mm)

SPOIL PILE GRAIN SIZE DISTRIBUTION

SITE B

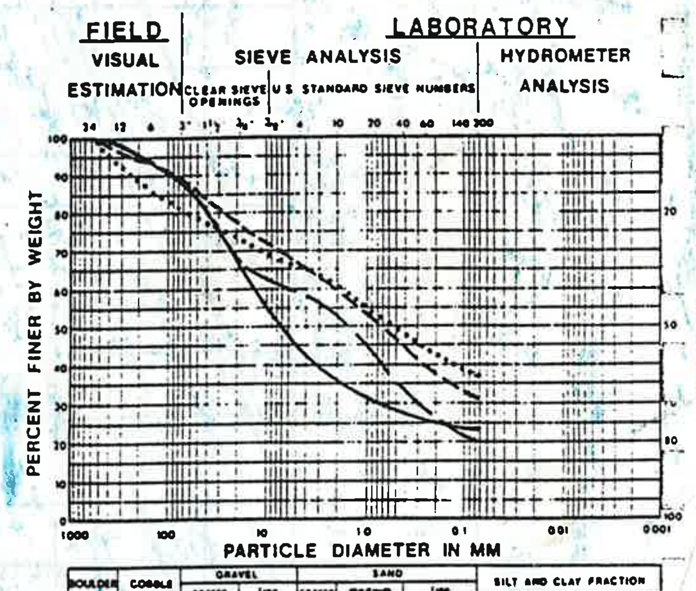


SYMBOL	SPOIL AGE YEARS	DEPTH IN	DEPTH CM	COMPOSITION
—— (solid)	0	24	61	20% BLACK SHALE; 30% SILTSTONE; 50% MUDSTONE
— — (long dash)	2	32	81	10% BLACK SHALE; 20% SANDSTONE; 70% SILTSTONE
- - - (dash)	5	42	107	10% BLACK SHALE; 40% SILTSTONE; 50% SANDSTONE
······ (dotted)	10	24	61	40% SILTSTONE; 60% SANDSTONE

NOTE: COMPOSITION IS BASED ON PARTICLE DIAMETERS > 5/64 INCH (2 mm)

SPOIL PILE GRAIN SIZE DISTRIBUTION

SITE C



SYMBOL	SPOIL AGE YEARS	DEPTH IN	DEPTH CM	COMPOSITION
—— (solid)	0	36	91	15% SANDSTONE; 25% SHALE; 60% MUDSTONE
— — (long dash)	2	60	152	20% LIMESTONE; 30% SHALE; 50% MUDSTONE
- - - (dash)	5	36	91	10% BLACK SHALE; 30% SHALE; 60% MUDSTONE
······ (dotted)	10	48	122	10% SANDSTONE; 20% SHALE; 70% MUDSTONE

NOTE: COMPOSITION IS BASED ON PARTICLE DIAMETERS > 5/64 INCH (2 mm)

SPOIL PILE GRAIN SIZE DISTRIBUTION

SITE D

Fig. 4.1 GRADATIONS OF APPALACHIAN COAL MINE SPOIL (from ANDREWS et al, 1980)

ESRD Appendix 20

POTENITAL REVISIONS TO THE PROPOSED DEVELOPMENT PLAN WITH RESPECT TO WATERCOURSES & END PIT LAKE LAYOUT

POTENITAL REVISIONS TO THE PROPOSED DEVELOPMENT PLAN WITH RESPECT TO WATERCOURSES & END PIT LAKE LAYOUT

Since submission of the Robb Trend Project (Project) application CVRI has continued stakeholder consultation and review of the Project development plans both internally and with regulatory agencies. Various options and alternatives have been identified which would lessen environmental impacts and add greater mitigation. Several of these ideas where presented in ESRD SIR Appendix 86 as part of the first round of SIR responses. Subsequently, additional alternatives aimed to reduce risks of fish habitat loss or alteration have been developed. The following discussion provides a summation of these alternatives and presents them within a logical framework for review.

The modifications addressed represent a ‘proactive’ and ‘adaptive’ response to concerns raised during the EIA review. CVRI submits these revisions as an update to the proposed development plan.

Watercourses

Multiple minor development revisions are presented as improvements to the proposed Project plan in order to lessen impacts within watercourses and lower risks of fish habitat alteration or loss. Several of these concepts where presented within ESRD SIR Appendix 86 while additional alternatives have been more recently identified.

Eight potential ‘modifications’ have been identified throughout the Project area which effect changes to handling of watercourses and ultimate reclamation profiles for continued stream flows. The locations of these revisions and the corresponding modification of the reclaimed landscape are identified in Figure 1 and 2.

These potential revisions include:

1. Bryan Creek

   The initial Project plan presented a diversion of Bryan Creek and final routing through Lake 2. The projected HADD was 14,208 m2.

Revision A

ESRD SIR Appendix 86 described an alternative mine sequence which would reduce impact to Bryan Creek flows, fish habitat and final reclamation profile. This plan would include the following sequence:

- Short ’meandering sections’ of the existing channel would be short-circuited to keep the creek out of the Mynheer Pit limit.
- The Mynheer Pit would be mined and reclaimed with the creek flowing around the pit within the natural channel. Natural flows could be retained and fish habitat disruption eliminated.
- The Mynheer Pit would be reclaimed. A constructed creek channel, with fish habitat provisions would be developed in the pit bottom.
- The Bryan Creek would be re-routed through the reclaimed channel as a permanent route.

- Lake 2 would outflow into Bryan Creek. The outlet would be constructed to permit fish passage in/out of the lake.

This 'revised' plan would reduce the projected fish habitat alteration. The original scheme resulted in a habitat loss of loss 14,208 m^2 and a reconstructed channel habitat of 4,891 m^2. The revised plan will provide no loss of habitat by replacement of the entire 19,079 m^2 with reconstructed stream habitat.

2. Hay Creek

   The initial Project plan presented loss of a portion of the headwaters of Hay Creek through mining of the area. An end pit lake would be established that would connect to Hay Creek. The projected HADD was 1,804 m^2.

   No revisions to the plan have yet been identified.

3. Erith River

   The initial Project plan presented diversions of portions of the Erith River and tributaries with inclusion of several end pit lakes as part of the reclamation plan. Total HADD within the Erith River system was projected to reach (67,485 + 5,834 + 102 + 406 + 7751) 81,578 m^2.

Revision A

The initial development plan for the Erith River included diversion of nearly 5 km with reclamation replacing the channel with an end pit lake. HADD was projected at 67,485 m^2.

ESRD SIR Appendix 86 described several alternatives which could result in reduced diversion lengths or fish habitat disruption.

Revision B

CVRI is prepared to follow a revised plan which would further reduce stream alterations. The sequence would involve the following:

- Mining would commence in the Val d'Or and McPherson Pits in Robb Main/Center. Development of the McPherson Pit would require short meandering sections of Erith River to be short-circuited to remove the river from the pit area. Constructed channels complete with fish habitat provisions would be constructed to replace re-alignments.
- The McPherson Pit would be mined and a constructed channel placed in the pit floor. This channel would provide appropriate fish habitat provisions. The Erith River would then be re-routed through this constructed channel thereby maintaining natural flows, fish habitat and fish passage.
- As the Erith River has been removed from the Mynheer Seam area the Mynheer Pit could then be developed and reclaimed. The reclamation profile would provide a constructed channel through the pit bottom as a replacement to the original river channel. Appropriate meanders and pools will be incorporated into the route.
- The Erith River will then be re-routed from the temporary channel in the McPherson Pit to the permanent route through the Mynheer Pit.

Revision C

Similarly, a temporary channel will be provided for Erith River to pass by the Val d'Or Pit. This channel will provide for natural flows and fish passage. Replacement fish habitat will be provided in the channel. A backfill bridge incorporated into the mining plan will provide for a permanent constructed river channel. This channel will provide the permanent route for the river and will include appropriate fish habitat additions. The end pit lakes will outlet into this channel and permit fish passage in/out of the lakes.

These changes will provide 'replacement' channels during mining and incorporate a permanent replacement channel in the reclamation profile for continued natural flow and fish passage. The original scheme resulted in a habitat loss of 67,485 m^2. The revised plan will provide a replacement stream channel as replacement to the entire river profile. The entire 67,485 m2 of habitat will be replaced by stream habitat.

3.1 ERT1

The proposed development in this area would result in a HADD of 5,834 m^2. Spawning activity in this reach of the river has been noted.

Revision D

ESRD SIR Appendix 86 suggested possible alternatives to the plan including eliminating a 500 m section of the Mynheer Pit.

Such changes would reduce HADD from 5,834 m^2 to 1,000 m^2.

This change requires elimination of approximately 500 strike length of Mynheer Pit. This would result in salvage of important spawning sites in ERT1.

3.2 ERT1A

Revision D would also eliminate the projected loss of 102 m^2 of habitat loss to bring the disturbance to 0 m^2.

4. Bacon Creek

The conceptual plan proposed was estimated to result approximately 2,777 m^2 of HADD with an additional potential loss of 10,000 m^2 from lost downstream flow.

Revision E

The revised mine plan will accommodate continued flow of Bacon Creek through the Project area. The eastern end of the Mynheer Pit will be modified to permit continued flow of Bacon Creek, bypassing the pit. The 'backfilled' dyke in Lake 5 (East) will be modified to accommodate a reconstructed stream to carry Bacon Creek across the mined pit to continue to the downstream channel.

The original scheme resulted in a habitat loss of 2,777 m^2 and a possible additional loss of 10,000 m^2 due to lost downstream flow. The revised plan preserves the habitat and flow route thus eliminating these losses.

5. Halpenny Creek

   Habitat changes in the Halpenny system were estimated at (7,601 + 2,239 + 219) 10,059 m^2.

Revision F

ESRD SIR Appendix 86 suggested limits in coal extraction that would eliminate direct habitat impacts in upper Halpenny Creek (HLT1 and HLT2). These changes would be justified to retain spawning habitat. This would require removing approximately 700 m of Mynheer Pit from the Project.

Implementation of these revisions would eliminate the loss of 10,059 m^2 of habitat.

6. Lendrum Creek

   The conceptual plan for development in the Lendrum Creek area was estimated to have an impact on HADD of (17,468 + 1923 + 22,161) 41,552 m^2.

   No revisions to the plan have yet been identified.

7. Lund Creek

   The conceptual plan for development in the Lund Creek area was estimated to have an impact on HADD of (11,026 + 0 + 2991 + 1091 + 2507 + 0) 17,615 m^2.

   No revisions to the plan have yet been identified.

8. Pembina East (Unnamed)

   The conceptual plan for development in the Pembina River East was estimated to have an impact on HADD of (154 + 5,236) 5,390 m^2.

   ESRD SIR Appendix 86 suggested a revision to the drainage plan that would result in PET1 being directed through Mynheer Pit into the Pembina River.

Revision G

Recent reviews of the East end of the Project are suggesting that an additional ‘buffer’ between development and the Pembina River valley may be of advantage. Should this concept be followed the east end of the Val d’Or pit would be shortened thus provided opportunity for PET to be rerouted around the end of the pit.

This revision would result in a reduction of HADD from 5,390 m^2 to 0 m^2.

9. Total Reduction

   Efforts to reduce impacts on watercourses have resulted in development modifications and changes to mining sequences that would result in reduction to watercourse impacts. These impact reductions directly reduce the HADD estimate for the overall Project.

   Table 1 provides the details of the changes so far identified and a summary (Table 2) is also provided highlighting the most notable modifications. Additional reductions will be the focus of future, ongoing planning.

The potential revisions lead to a reduced overall footprint, reduced footprint on sensitive habitat (habitat with high utilization/sensitivity rating), and increased amount of habitat that is reclaimed as stream channel as compared to lake habitat.

End Pit Lakes

CVRI had previously provided discussion regarding possible modification to end pit lake layout in order to provide improvements to lake design with respect to fisheries capabilities (see ESRD SIR122b).

1. Robb West

   Robb West (Val d'Or pits) can likely be developed in multiple phases so as to increase backfill quantity. A larger bridge could be provided separating two smaller lakes. This would lessen the water depth and corresponding fill times.

   1.1 Lake 1

   Potential modification to Lake 1 would provide some reduction in size and depth with lowering of the water level and increased backfill volume. Additional littoral areas would also be achieved.

   1.2 Lake 2

   The modifications noted would result in a smaller lake with reduced depth and increased littoral areas.

   The proposed 'watercourse' revised plan (see Revision A) would eliminate the 'flow through' of Bryan Creek although lake outlets to the creek could be achieved.

2. Robb Main

   2.1 Lake 3

   Revised mining sequence could provide additional in pit backfill and provide a smaller lake with reduced depth and greater littoral zones.

   2.2 Lake 4

   Revisions in the handling of Erith River would result in the elimination of Lake 4 and replacement with a constructed channel for permanent routing of Erith River.

   2.3 Lake 5

   Revised mining sequence could further reduce size and depth of Lake 5. Backfilled dykes which sub-divide the lake segments could be left as submerged areas to develop wetlands or developed as barrier ridges to accommodate constructed stream channels as inter-connection between the lake segments.

3. Robb Center

   Minor changes in the Robb Center area have been identified in order to reduce fish habitat loss. Flow of Bacon Creek through the project area and continued to the downstream route is now accommodated. Changes to mining in the upper Halpenny basin will accommodate continued flow of the upper tributaries.

3.1 Lake 6

The 'land bridge' between Lake 5 and 6 will be modified to accommodate a constructed channel for Bacon Creek.

3.2 Lake 7

This lake is narrow and shallow. Modifications to the reclaimed terrain will be considered to eliminate the lake in favor of wetlands.

4. Robb East

4.1 Lake 8

No revisions to the lake profile are currently contemplated.

4.2 Lake 9

No revisions to the lake profile are currently contemplated.

4.3 Lake 10

This lake is narrow and shallow. Modifications to the reclaimed terrain will be considered to eliminate the lake in favor of wetlands.

4.4 Lake 11

This lake is narrow and shallow. Modifications to the reclaimed terrain will be considered to eliminate the lake in favor of wetlands.

4.5 Lake 12

The mine plan for this area accommodates a single large and deep pit. Mine sequence may result in increased backfill opportunities which could lessen the depth of the lake and add greater littoral area.

Internal review of the mine plan in response to providing a greater buffer between development and the Pembina River indicates likely elimination of the eastern 'tip' of the proposed pit. This would accommodate rerouting of PET1 flow within a reconstructed channel.

Mine Plan

CVRI has introduced a variety of minor revisions to the proposed development plan in response to reducing impacts to watercourses and fish habitat. These modifications will result in changes to the mine development through elimination of small pit segments. The resulting loss of coal resource is balance by reduced environmental impact. In many instances site specific high value environmental values are being protected by the mine revisions.

The ‘mine changes’ resulting from the current Project changes are identified below:

1. Robb West

   1.1 Val D’Or Pit

   The western end of the Val D’Or pit will likely be subject to ‘end wall’ agreement between CVRI and Mancal. No significant modification of the pit layout of coal recovery is anticipated.

   1.2 Mynheer Pit

   A revision in the mine sequence will allow The Bryan Creek to be replaced with a constructed channel in the bottom of the Mynheer Pit.

   There is no change in the coal recovery volumes.

2. Robb Main

   2.1 Reclamation of the Mynheer Pit within the Erith River basin will be modified to provide a stream channel in place of the previous lake plan.

   No changes to the mine plan are anticipated.

3. Robb Center

   3.1 Mining in the Mynheer Seam within Robb Center will be modified to accommodate retaining existing tributaries of Erith River and Bacon and Halpenny Creeks.

   Portions of the dragline pits proposed for recovery of the Mynheer Seam will be eliminated in favor of avoidance of disturbance of important stream flows thus salvaging high value fish habitat and maintaining integrity of stream flow routes.

   In total approximately 1,200 m of seam strike length will be dropped from the plan. This length is comprised of several smaller segments distributed through the Bacon and Halpenny basin. CVRI estimates that approximately 400,000 RMT of coal resource would be left in place as a result of these changes.

4. Robb East

   4.1 The eastern most pit of the project is located within an over-thickened ‘pod’ of the Val d’Or Seam. Early drilling results suggest that the ‘pod’ is truncated west of the Pembina River. Various factors will also need consideration in determining the appropriate ‘buffer’ between the proposed pit and the Pembina River floodplain. CVRI anticipates modification of the eastern limit of this pit to increase the buffer zone.

   Such an increased buffer zone would support a bypass of the PET1 stream thus maintaining the fish habitat and flow values of the stream.

Summary

CVRI presents the alternatives identified above as desired modification to the proposed Project. While these revisions will result in minor changes to the overall Project impact CVRI believes that all the options provide positive contributions to the Project and result in reductions to magnitude and risk of environmental impacts. Therefore CVRI believes the overall EIA assessment for the proposed Project benefits from the updates proposed.

FIGURES

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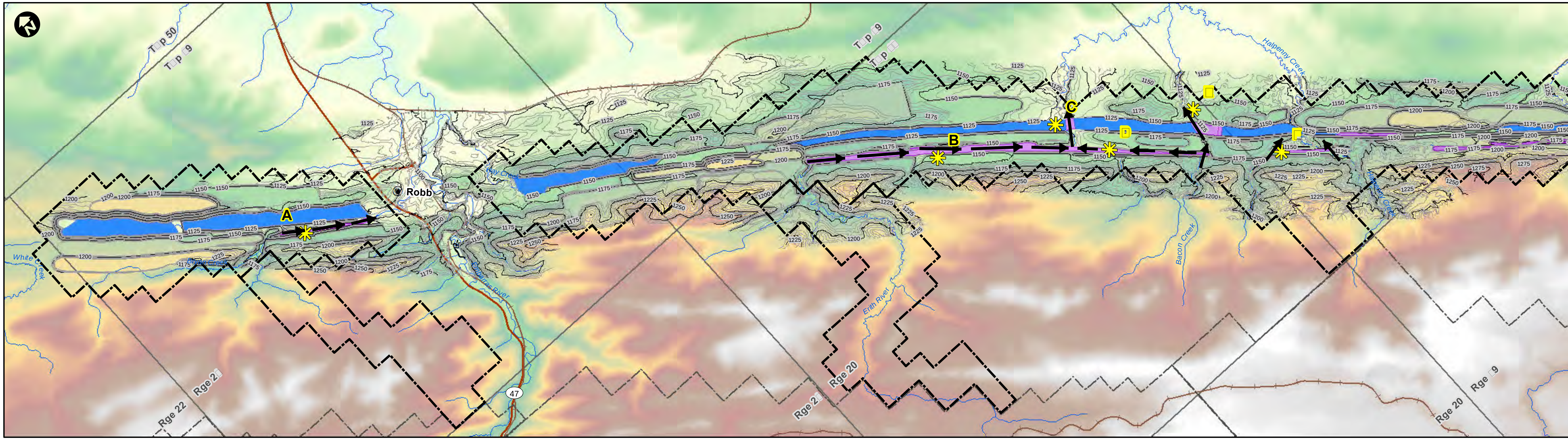

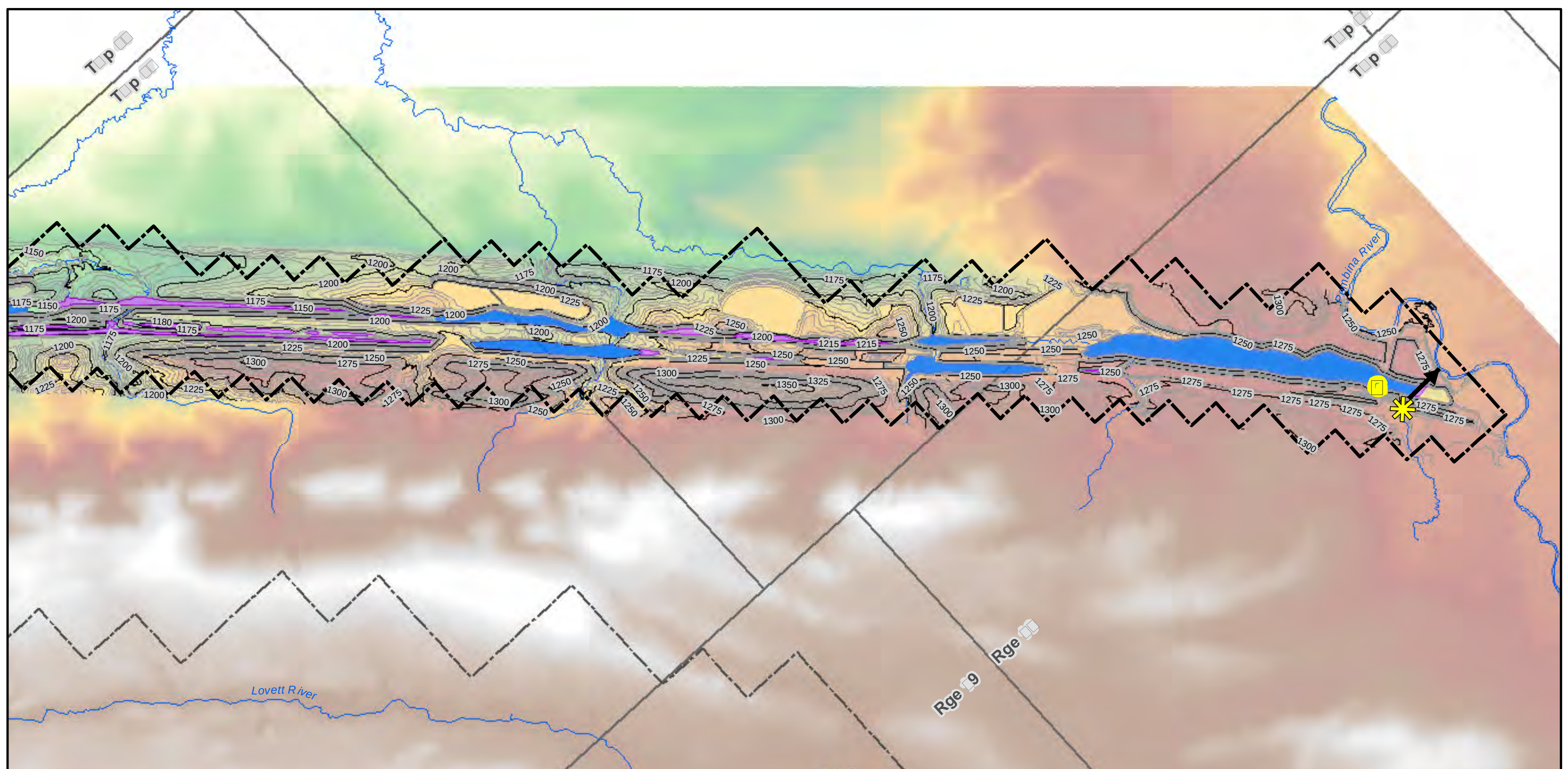

Legend

- Water Management Area
- Constructed Streams
- Contour (Interval 10m)
- Index Contour
- Reclaimed Lake
- Reclaimed Wetland
- Existing Mine Permit Boundary
- Proposed Robb Trend Mine Permit Boundary
- Paved Road
- Railway
- Permanent Watercourse

Topography (masl)
High : 1500
Low : 1050

0 1 2 4
Kilometres

PROJECT:
Coal Valley Mine
Robb Trend Project

TITLE:
Conceptual Reclaimed Landscape - Revisions

cvri

DRAWN: KD/JG
CHECKED: KP
DATE: Jun 17/13
PROJECT: 08-041
FIGURE:

REF: CVRI, Robb Trend Project Extents 2B.dwg, Feb 7, 2011.

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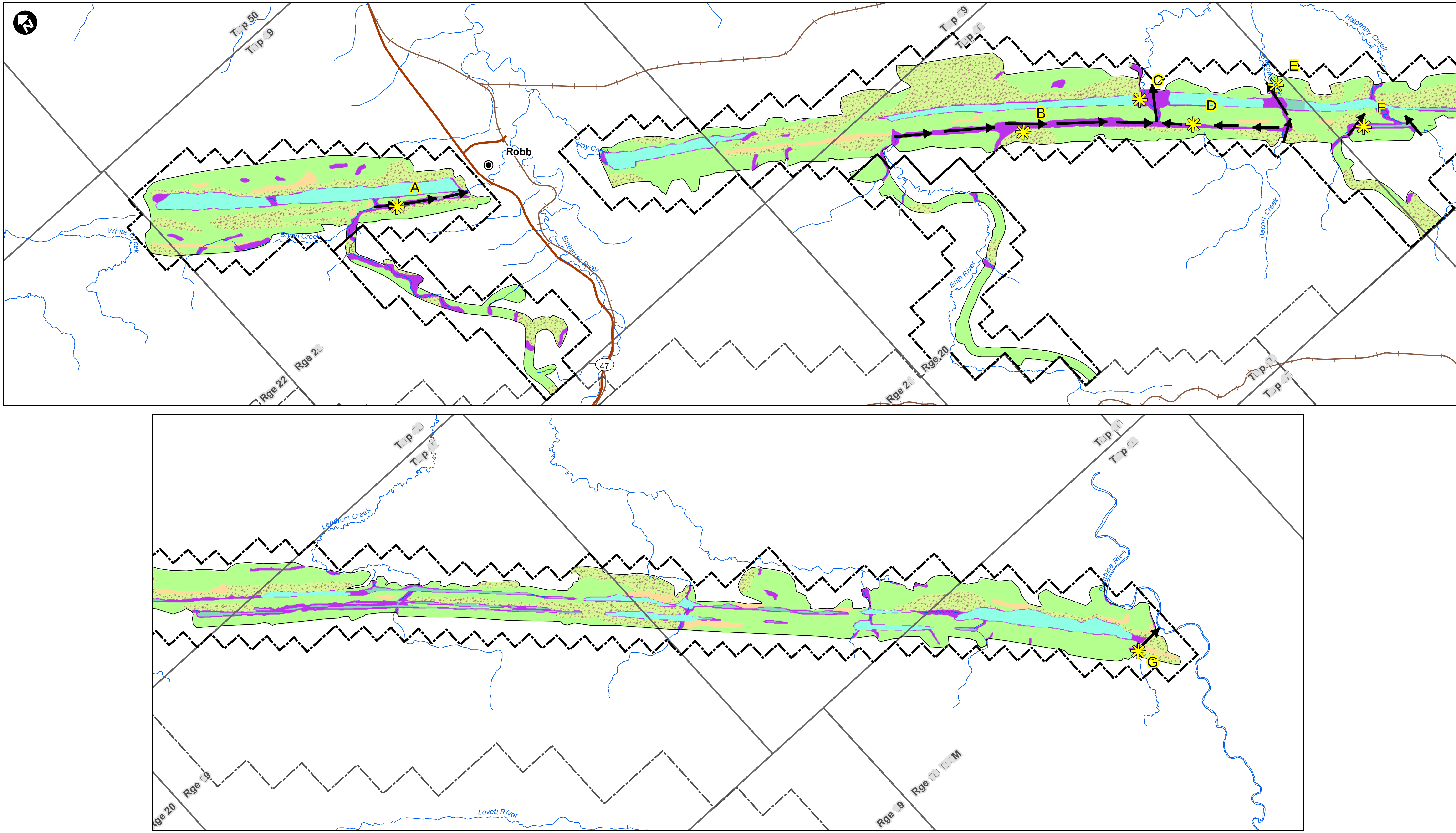
[Main Menu] [Search]



□egend

Water Management Area	Grassland	Proposed Robb Trend Mine Permit Boundary
Coniferous Forest	Riparian	Existing Mine Permit Boundary
Mixed Forest	Wetland	Paved Road
	Lake	Railway
		Permanent Watercourse

0 1 2 4
Kilometres

REF: CVRI, Robb Trend Project Extents 2B.dwg, Feb 7, 2011.

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PROJECT:
Coal Valley Mine
Robb Trend Project

cvri

TITLE:
Conceptual □nd □and □se Plan - Re□isions

DRAWN:	JG/KD
CHECKED:	KP
DATE:	Jun 17/13
PROJECT:	08-041

FIGURE: 2

TABLES

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Table 1 - Fish Habitat Impact Comparison

Mine Area	Basin	Waterbody	Sensitivity	Fish Habitat Impacted (m²) – Application: Reconstructed Channel	Application: Lake/Other	Application: Total Habitat Impacted	Level 1 Revision: Reconstructed Channel	Level 1 Revision: Lake/Other	Level 1 Revision: Fallow Channel	Level 1 Revision: Total Habitat Impacted	Level 2 Revision: Reconstructed Channel	Level 2 Revision: Lake/Other	Level 2 Revision: Fallow Channel	Level 2 Revision: Total Habitat Impacted	Comments
West	Bryan	Bryan Creek	Low		4,708	4,708	4,708			4,708	4,708			4,708	Bryan Creek was originally to be reclaimed as Lake 2, now is being reclaimed as reconstructed channel
			High		9,500	9,500	9,500			9,500	9,500			9,500	
			Low			TBD	2,625			2,625	2,625			2,625	Estimated habitat impacts on upper Bryan Creek, to be assessed in 2013. These impacts can be avoided by modifying western dump to not encroach on upper Bryan Creek
Main	Bacon	Bacon Creek	High		2,777	2,777	1,377	1,000		2,777	2,777			2,777	Bacon Creek was originally to be reclaimed as Lake 4/5, then as half reconstructed channel/half lake, now being reclaimed as all reconstructed channel
			High			10,000				10,000				-	Bacon Creek was originally being diverted into Lake 4/5 but now Bacon Creek flows will be maintained
	Erith	Erith River	High		67,485	67,485		67,485		67,485	67,485			67,485	Represents options of either reclaiming to lakes or reconsructing the Erith River
		ERT1	High		5,834	5,834	1,000			1,000	1,000			1,000	Only if 500m of the Mynheer Pit is not developed (leaving majority of ERT1 undisturbed). 400m upstream of confluence is still disturbed by the Val d'Or Pit and will be reclaimed as reconstructed channel
		ERT1A	Low		102	102				-				-	Only if 500m of the Mynheer Pit is not developed (leaving ERT1A undisturbed)
		ERT2	Low	406		406	406			406	406			406	
		ERT3	Low		7,751	7,751		7,751		7,751		7,751		7,751	
	Hay	Hay Creek	Low		1,804	1,804		2,325		2,325		2,325		2,325	Revised analysis
			Low			10,000			10,000	10,000			10,000	10,000	This represents habitat that will be lost due to downstream flows being diverted away from Hay Creek while filling Lake 3. Habitat will be assessed in 2013.
Centre	Halpenny	Halpenny Creek	Low		1,910	1,910		4,129		4,129		4,129		4,129	Reclaimed as Lake 6
			High		5,691	5,691	4,435			4,435	-			-	Only if 400m of the Mynheer Pit is not developed (leaving majority of Halpenny Creek undisturbed)
		HLT1	Mod		2,239	2,239		2,239		2,239		-		-	Only if 200m of the Mynheer Pit is not developed (leaving HLT1 undisturbed)
		HLT2	Low		219	219	219			219	-			-	Only if 150m of the Mynheer Pit is not developed (leaving HLT2 undisturbed)
	Lendrum	Lendrum Creek	Mod		17,468	17,468		17,468		17,468		17,468		17,468	
		LET1	Mod	982	941	1,923	1,600	1,682		3,282	1,600	1,682		3,282	Reclaimed as pond/channel
			Mod			5,000				5,000				5,000	This represents habitat that will be lost due to flows being diverted away from LET1 to LET3.
		LET3	High	12,021	10,140	22,161	6,595	1,364		7,959	6,595	1,364		7,959	Revised Analysis
East	Lund	Lund Creek	Mod		11,026	11,026	2,505	4,814		7,319	2,505	4,814		7,319	Lund Creek reclaimed as vegetation, reconstructed channel and lake
			Mod			TBD		5,300		5,300		5,300		5,300	Estimated impact on Lund Creek (from FMF 885 to confluence with LDT3), habitat to be assessed in 2013
			Mod			12,000				12,000				12,000	This represents habitat that will be lost due to downstream flows being diverted away from Lund Creek. Habitat will be assessed in 2013
		LDT1	Low	640	2,351	2,991	640	2,351		2,991	640	2,351		2,991	Revised analysis
		LDT1A	Low		1,091	1,091		1,091		1,091		1,091		1,091	
		LDT2	Low			TBD		209		209		209		209	No habitat impacts were identified in the Application but it now appears like there may be some minimal impacts
		LDT3	Low	507	2,000	2,507	1,800	2,031		3,831	1,800	2,031		3,831	Revised analysis
		LDT4	Low			TBD		113		113		113		113	No habitat impacts were identified in the Application but it now appears like there may be some minimal impacts
		LDT5	Low		154	154		154		154		154		154	
	Pembina	PET1	High		5,236	5,236	5,236			5,236	5,236			5,236	
Total		**Original Report**		**14,556**	**160,427**	**211,983**									
		Level 1 Revision					**42,646**	**121,506**		**201,552**					
		Level 2 Revision									**106,877**	**50,782**		**184,659**	

Legend

(light blue)	**Modified Development Plan**
(yellow)	**Revised Value**
(red)	**To Be Confirmed (2013)**

Table 2 - Fish Habitat Impact Comparison Summary

	Total Habitat Impacts	Total Habitat Reclaimed to Channel		Total Habitat Not Reclaimed to Channel		Total Impacts to High Sensitivity Habitat	Total Impacts to High Sensitivity Habitat Reclaimed to Channel		Flow-Through End Pit Lakes		Off-Channel End Pit Lakes	
									Total Habitat Available	Total Littoral Habitat	Total Habitat Available	Total Littoral Habitat
	(m^2)	(m^2)	%	(m^2)	%	(m^2)	(m^2)	%	(m^2)	(m^2)	(m^2)	(m^2)
Application	211,983	14,556	7	197,427	93	128,684	12,021	9	5,650,000	1,082,000	603,000	83,000
Level 1 Revision	201,552	42,646	21	158,906	79	118,392	28,143	24	3,374,000	678,000	2,168,000	309,000
Level 2 Revision	184,659	106,877	58	77,782	42	93,957	92,593	99	3,374,000	678,000	2,168,000	309,000

ESRD Appendix 31

OBSERVATIONS AT THE MERCOAL WETLAND

Main Menu Search

MILLENNIUM
EMS Solutions Ltd.

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Drawdown Adjacent to Mining Pits South Extension Wetlands in Coal Valley Area

Prepared for:
Coal Valley Resources Inc.
Coal Valley Mine

Prepared by:
Millennium EMS Solutions Ltd.
Suite 325, 1925 – 18th Avenue NE
Calgary, Alberta
T2E 7T8

May 2013
File # 10-156

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1.0 INTRODUCTION

Coal Valley Resources Inc. (CVRI) operates a number of coal mines in the vicinity of Robb, Alberta (Figure 1). Groundwater monitoring has been taking place for over thirty years in a network of observation wells located adjacent to the mines (Figure 2).

The anticipation of drawdown of groundwater levels impacting nearby peat lands and wetlands (and, potentially water courses) led to the installation of a monitoring system specifically at the South Extension Wetland (Wetland)(Figures 2 and 3).

The South Extension Wetland is a patterned open fen with no internal lawns. Patterned fens are characterized by an interlocking pattern of large open, wet hollows or pools of water (flarks) and drier wooded strings and margins (P) (Halsey and Vitt 1996). The strings are oriented perpendicular to the water flow, forming sinuous ribs within the gently sloping terrain (Halsey and Vitt 1996). The flarks are often dominated by graminoid species (sedges and wetland grasses) and mosses. The drier wooded strings are dominated by white spruce, shrubs, forbs, grasses and feather mosses.

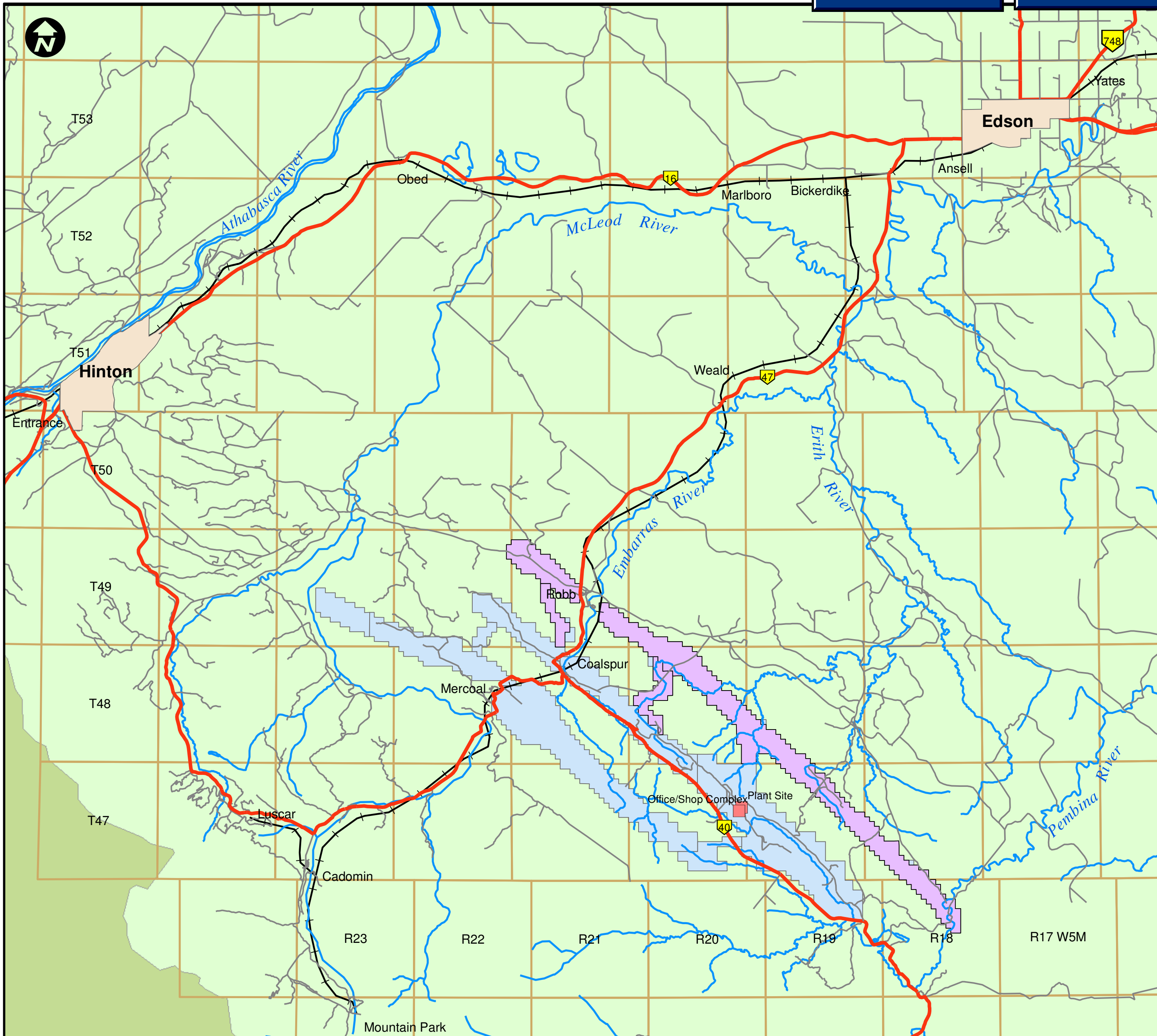
Ground cover within patterned fens can be quite diverse, depending on whether the fen is poor, moderate-rich, or extreme-rich. The South Extension Wetland is primarily a poor fen dominated by *Sphagnum* species within the flarks.

Previous assessment of drawdown adjacent to CVRI mine pits has been done approximately 10 km to the northwest at hydrogeological cross section 4,000 E (CVRI, 2012). This report demonstrated that:

- At a distance of 100 m from the operating pit declines of the water table were approximately 10 % of the 45 m depth of the pit.
- Water levels recovered to nearly pre-mining conditions in 4 to 9 months after mining ceased.

The purpose of this document is to provide a detailed assessment of the effects of pit dewatering on water levels in and beneath the South Extension Wetlands (Figure 3). These effects are assessed over the period of April 2006 through November, 2012.

Dewatering in mine pits in this area was accomplished with in-pit sumps. Dewatering wells in advance of mining were not used. Groundwater inflow can be adequately managed by in-pit sumps. After mining operations have moved far enough away, pumping of the in-pit sumps ceases and water levels are allowed to rise in the pit. Berms may be employed to prevent water from moving along the pit to the operating area.



Legend

- Proposed Mine Operations
- Existing Mine Operations
- Highway
- Minor Road
- Railway

0 5 10 20
Kilometres

PROJECT:

cvri

Coal Valley Mine
South Extension Wetland

MILLENNIUM
EMS Solutions Ltd.

TITLE:

Location Map

DRAWN:	PS/JDC
CHECKED:	DH
DATE:	Apr 30/13
PROJECT:	10-156B

FIGURE:
1

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Main Menu
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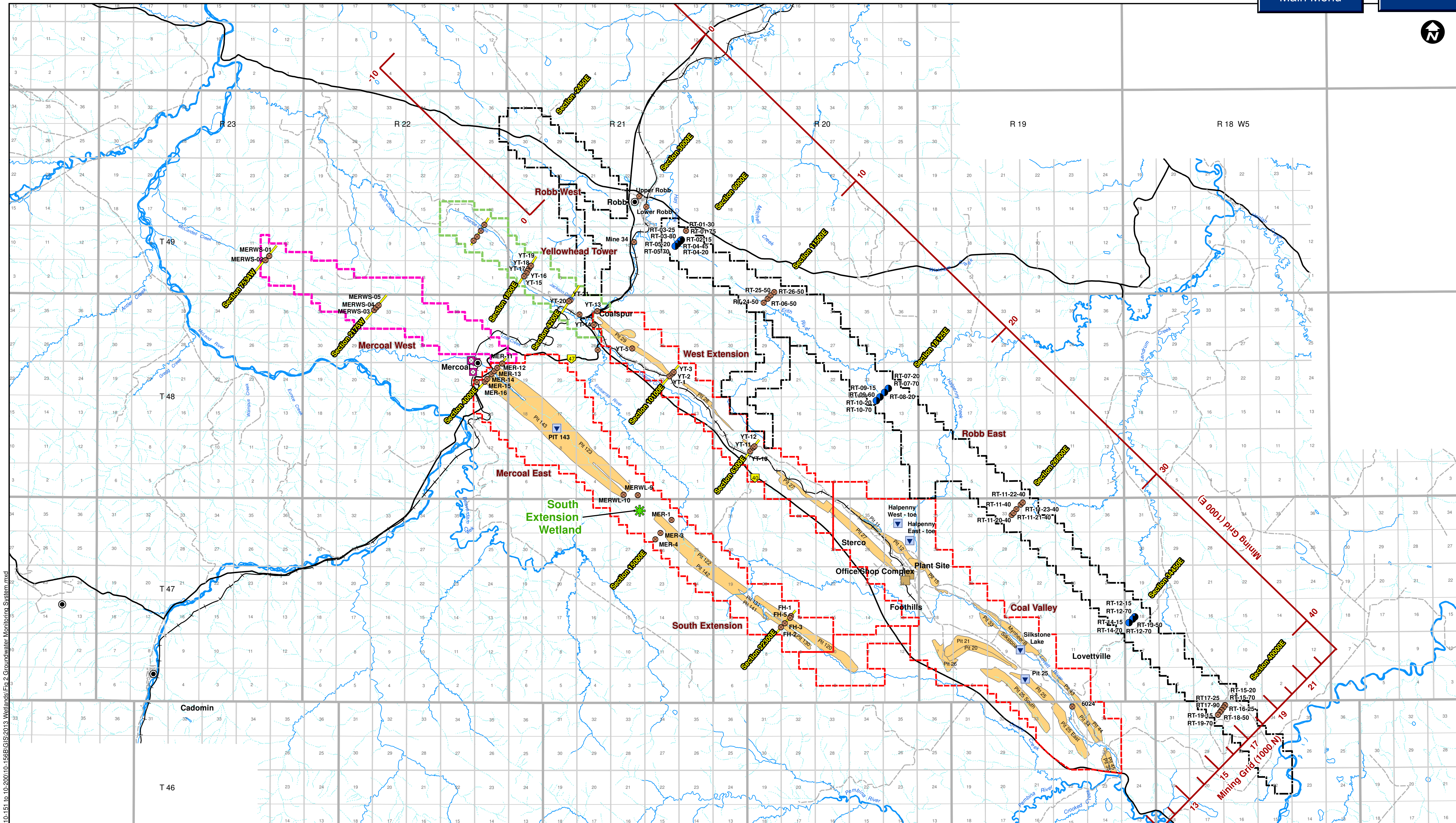

Legend

- Proposed Monitoring Well
- Existing Monitoring Well
- Surface Discharge Site
- Water Well
- Hydrogeological Section
- Robb Trend Mine Permit Boundary (Proposed)
- Mercoal West Mine Permit Boundary
- Yellowhead Tower Mine Permit Boundary
- Existing Coal Valley Mine Permit Boundary
- Mine Pit
- Coal Valley — Operational Mine Area
- Section 7534W — Monitor Well Section

0 1.25 2.5 5
Kilometres

PROJECT:
cvri
Coal Valley Mine
South Extension Wetland

MILLENNIUM
EMS Solutions Ltd.

TITLE:
Groundwater Monitoring System

DRAWN: SL/JDC	FIGURE:
CHECKED: DH	2
DATE: Apr 22/13	
PROJECT: 10-156B	

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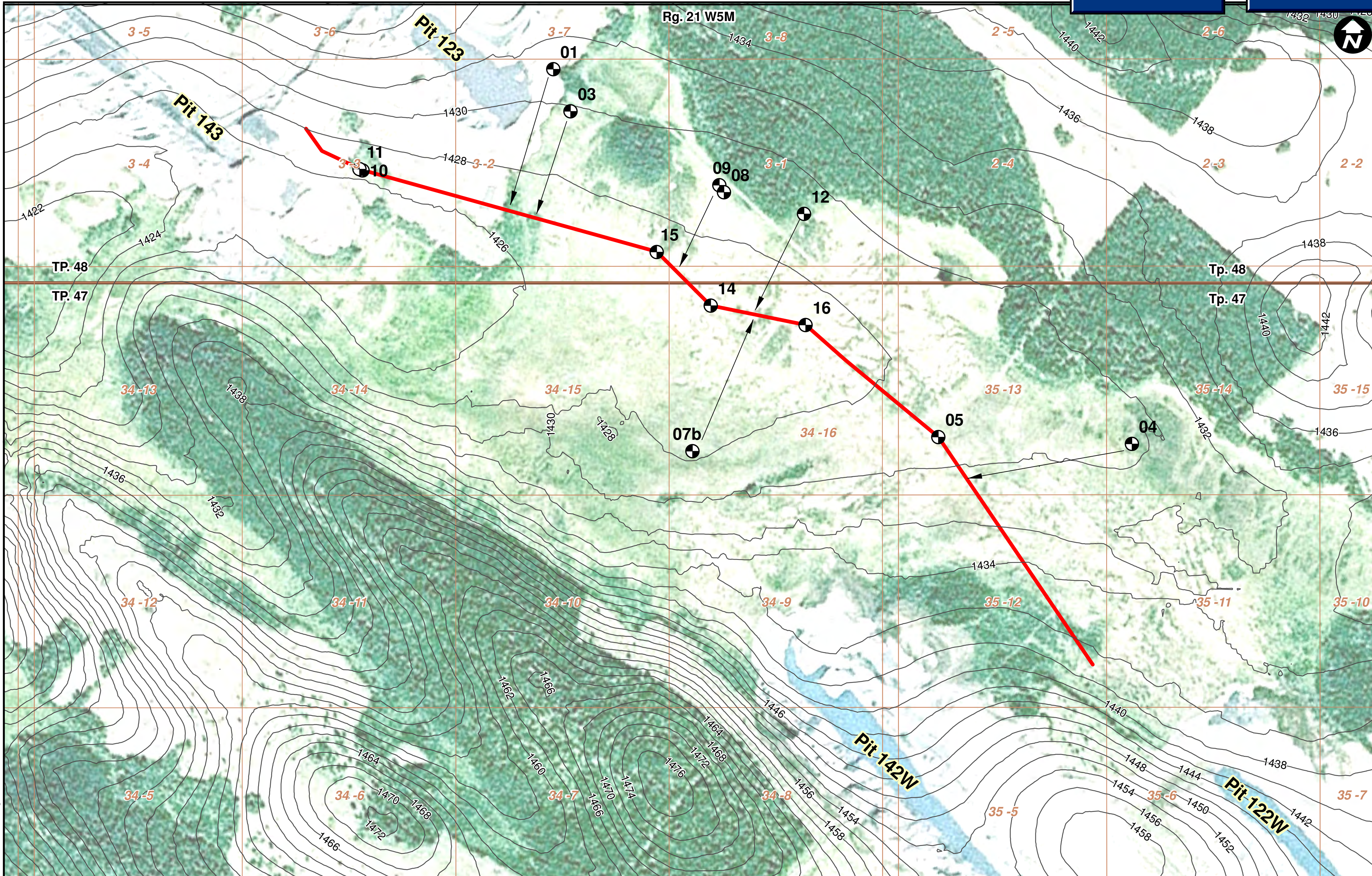


Document Path: K:\Active Client\CVRI\GIS\ME_wetland\Fig 3 Well Location in South Extension Wetlands.mxd

Legend

- Well Location
- Cross-Section Lline
- Contour (2m interval)

0 100 200 400
Meters

REF: Air Photo Date: Sept 07, 2011.

PROJECT:

cvri

Coal Valley Mine
South Extension Wetland

MILLENNIUM
EMS Solutions Ltd.

TITLE:

Well Locations in South Extension Wetland

DRAWN:	PS/JDC
CHECKED:	DH
DATE:	Apr 22/13
PROJECT:	10-156B

FIGURE:

3

Mine operations potentially affecting the Wetland can be described as follows:

- All mine pits were approximately 40 m deep in the vicinity of the Wetland. The drawdown of the water table at the location of a pit can therefore be assumed to be 40 m. Throughout the time frame described in the following bullets the maximum drawdown of the water table in the four mine pits located at the southeast and northwest ends of the Wetland was approximately 40 m.
- Mining in Pit 122W (Figure 3) advanced from the southeast. At approximately 400 m from the Wetland in November, 2005, Pit 122W temporarily stopped advancing and the operations were moved to Pit 142W. CVRI cannot determine if dewatering activities ceased in Pit 122W at this time.
  - Monitoring of water levels in the Wetland commenced in April 2006 (Appendix A).
- Mining in Pit 142W, as well as associated dewatering activities, commenced in November, 2005 and the pit progressed northwest until July, 2006. The Wetland lies along the north and northwest boundaries of Pit 142W. Dewatering activities ceased in Pit 142W in July, 2006.
- Mining operations moved back to Pit 122W in July, 2006 and continued until September 2006. The Wetland lies at the northwest end of Pit 122W. Dewatering of Pit 122W ceased in September, 2006.
- Mining operation moved to the southeast end of Pit 123, adjacent to the Wetland, in September, 2006 and progressed northwest away from the Wetland. Operations would have progressed sufficiently northwestward by January, 2007 that dewatering likely ceased at that time.
- Mining returned to the vicinity of the Wetland in approximately June 2009. Pit 143, progressing southeastward, came within approximately 500 m of the Wetlands at that time. In January, 2010 the southeast limit of Pit 143 was reached and mining, along with dewatering, ceased in this area.
- These pits are not yet reclaimed to the approved configuration. It may therefore be presumed that a decline of the water table at the pit remains to some extent. Figure 3 shows that water is present in each of the pits however the level of this water likely remains below pre-pit conditions.

2.0 OBSERVATIONS

There are 12 monitoring wells at 10 locations within the Wetlands (Figure 3). Many of these wells have been in place since 2006 and the remainder were installed in 2009. Water levels in these wells are presented in Appendix A. Construction diagrams and geological logs are presented in Appendix B. Most wells are completed in the peat deposits of the wetland however two are completed significantly below the base of the peat and reflect conditions in the underlying coal seams in the bedrock. Figure 4 presents a cross section through the Wetland showing the projected location of monitoring sites. This figure also shows the hydrographs of the individual observation wells as well as an approximate time frame for the pit activities described above.

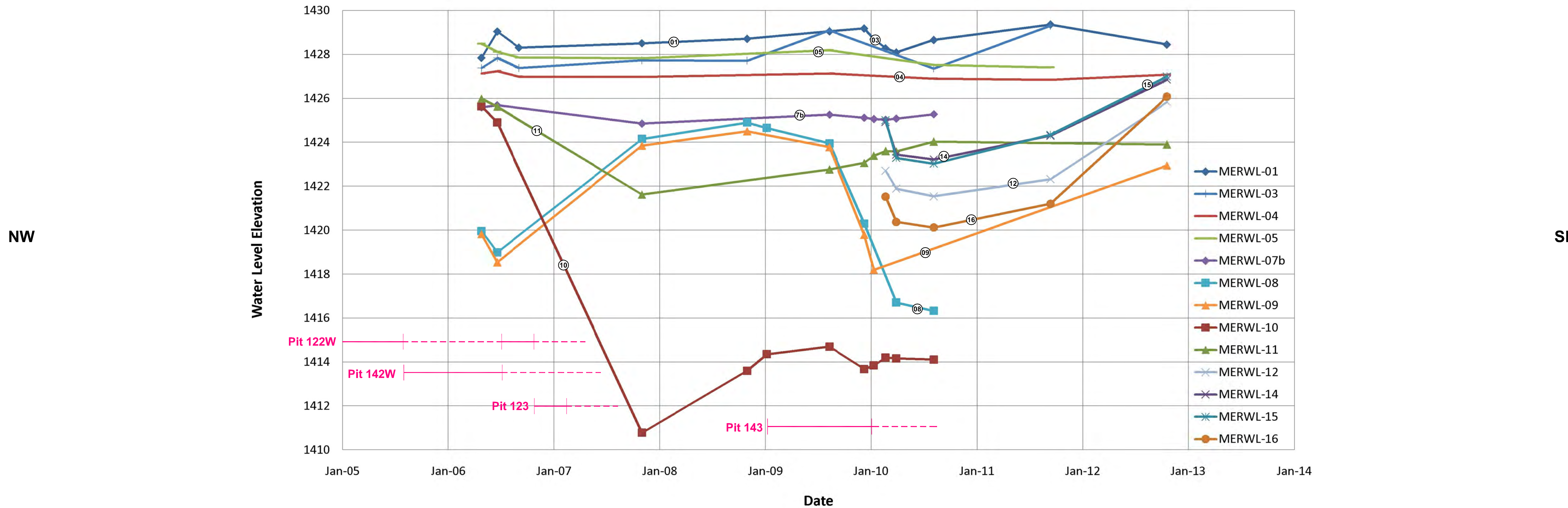
The borehole logs in Appendix B reveal the following geological sequence from surface to depth:

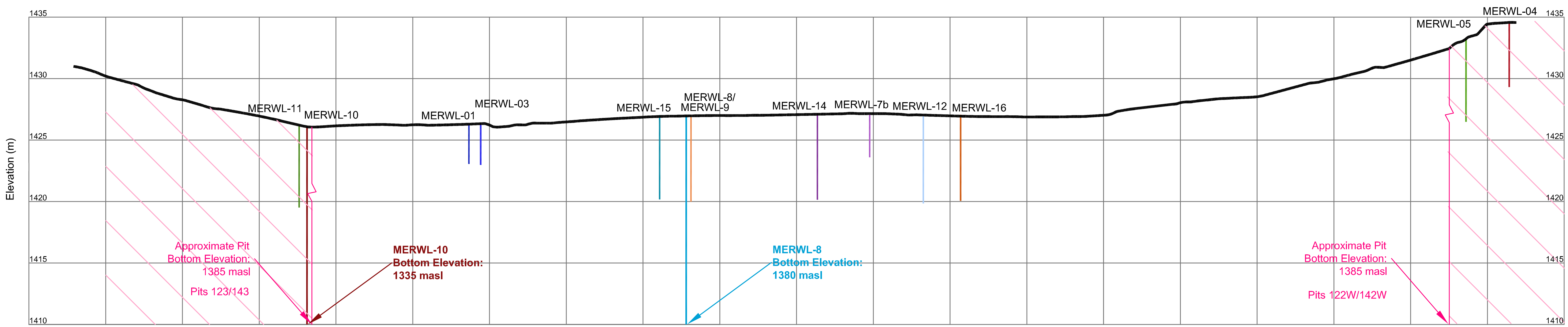
- Peat – observed up to 6.5 m in thickness.
- Clay or glacial till – highly plastic – observed to be approximately 4 m thick and present in all boreholes.
- Paskapoo and Coalspur Formations (bedrock).

The following sections discuss specific conditions at each of the monitoring sites. Table 1 provides a number of characteristics of the individual monitoring wells. The three "level change" intervals were chosen to approximately coincide with pit activities as follows:

- 2006-08: The period when mining first approached the Wetland through the completion of both southeast pits as well as pit 123.
- 2008-10: The period when mining was away from the Wetland toward the northwest and subsequently returned I pit 143.
- 2010-12: The period when mining was no longer active near the Wetland.

Search Main Menu





Legend

Pit within 500 of Wetland

Pit Inactive

0 50 100 200m

Scale 1 : 5 000
Vertical Exaggeration x16

PROJECT:

cvri

Coal Valley Mine
South Extension Wetland

MILLENNIUM
EMS Solutions Ltd.

TITLE:

Hydrograph and Cross-Section

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DATE: Apr 30/13		
PROJECT: 10-156B		

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REF: CVRI, 2012

Table 1 Characteristics of Wetland Monitoring Wells.

Monitoring Well Name (MERWL)	Former Name	Depth (m)	Soil Type	Distance from nearest pit (m)	Level Change (m) 2006-08	Level Change (m) 2008-10	Level Change (m) 2010-12
01	A835-03	3	clay	50	nil	nil	nil
03	A835-05	3	peat	75	nil	nil	nil
04	A835-06	6	peat/clay	625	nil	nil	nil
05	A835-07	6	peat	500	nil	nil	nil
07b	A835-10	2	peat	400	nil	nil	nr
08 (Nest with 09)	ValD'Or#1	46	coal	400	-2+/+6	-6	nr
09 (nest with 08)	Val D'Or#2	8	clay	400	2+/+6	-5	+5
10 (nest with 11)	Mynheer #1	89	coal	250	-15	+5	nr
11 (nest with 10)	Mynheer #2	8	clay	250	-4	+2	nil
12	A2010-01	7	Clay till	550	nr	nr	-1/+4
14	A2010-03	8	Gravel/clay till	500	nr	nr	-2/+4
15	A2010-04	8	Clay till	350	nr	nr	-2/+4
16	A2010-05	8	Clay till	600	nr	nr	-2/+6

Key; nr= no record; nil= no significant change

The surface of the peat in the Wetland varies from 1426 to 1430 m asl at the various monitoring sites. The depth to water below land surface can therefore be seen to be in the range of 0 to 3 m (Figure 4) for MERWL 01, 03, 04, 05 and 7b throughout the period of record.

2.1 MERWL 01

MERWL 01 is completed in clay immediately beneath 0.3 m of peat. The well is immediately southeast of Pit 123. Water levels in this well have not changed significantly between 2006 and 2012.

2.2 MERWL 03

MERWL 03 is completed in peat. Approximately 3 m of peat is present at this location. The well is approximately 75 m southeast of Pit 123. Water levels in this well have not changed significantly between 2006 and 2012.

2.3 MERWL 04

MERWL 04 is completed at the peat – clay contact. The peat at this location is approximately 5.5 m thick. The well is approximately 625 m from Pits 122W or 142W. Water levels have not changed significantly between 2006 and 2012.

2.4 MERWL 05

MERWL 05 is completed at 6 m depth in peat. The thickness of the peat at this location is 6.5 m. The well is approximately 500 m from Pit 142W. Water levels have not changed significantly between 2006 and 2012.

2.5 MERWL 07b

MERWL 07b is completed at a depth of 2 m in peat. The thickness of the peat is approximately 2 m at this location. The well is approximately 400 m northwest of Pit 142W. Water levels have not changed significantly between 2006 and 2010.

2.6 MERWL 08 and 09

These adjacent wells are completed at depths of 8 and 46 m between Pits 143 and 123. MERWL 08 is completed in the clay underlying the peat while MERWL 9 is completed in the Val D'Or coal seam in the Coalspur Formation.

Water levels in both wells declined approximately 1 m in mid-2006 and subsequently rose 6 m to January 2009. This reflects the end of operations in Pit 122 and the cessation of dewatering in that pit. The decline after January 2009 reflects the approach of operations in Pit 143 at that time. The data after January 2010 for these two wells is a bit sparse however drawdown likely ceased in mid-2010 when Pit 143 ceased operations and water level in MERWL 09 (the shallow well) , and likely MERWL 08 as well, rose by 6 m to 2012.

2.7 MERWL 10 and 11

These adjacent wells are completed at depths of 8 and 89 m between Pits 143 and 123. MERWL 10 is completed in the clay underlying the peat while MERWL 11 is completed in the Mynheer coal seam in the Coalspur Formation.

Water levels in the shallow MERWL 11 declined by 4 m between 2006 and 2008, rose by 2 m between 2008 and 2010 and have remained stable between 2010 and 2012. This likely reflects the effects of operations at Pits 122W and 142W and the lack of any influence from the more northwesterly pits 123 and 143.

Water levels in the coal at 89 m depth declined 15 m between 2006 and 2008 likely reflecting operations at the southeasterly pits. Water levels rose several metres in the 2008 to 2010 period and appeared to stabilize into 2010.

2.8 MERWL 12

MERWL 12 is completed at a depth of 6 to 7 m in clay till. The thickness of the peat is approximately 5 m at this location. The well is approximately 550 m northwest of Pit 142W.

Water levels declined approximately 1 m in early 2010 and have risen 4 m in 2011 and 2012. The 1 m decline in water level in early 2010 is similar to that occurring at MERWL 08, also completed in the till underlying the peat, at that time.

2.9 MERWL 14

MERWL 12 is completed at a depth of 7 to 8 m in gravel and clay till. The thickness of the peat is approximately 4 m at this location and is underlain by 1 m of gravel. The well is approximately 500 m north of Pit 142W.

Water levels declined approximately 2 m in early 2010 and have risen 4 m in 2011 and 2012. The 2 m decline in water level in early 2010 is similar to that occurring at MERWL 08, also completed in the till underlying the peat, at that time.

2.10 MERWL 15

MERWL 15 is completed at a depth of 7 to 8 m in clay till. The thickness of the peat is approximately 5 m at this location. The well is approximately 350 m northwest of Pit 123.

Water levels declined approximately 2 m in early 2010 and have risen 4 m in 2011 and 2012. The 2 m decline in water level in early 2010 is similar to that occurring at MERWL 08, also completed in the till underlying the peat, at that time.

2.11 MERWL 16

MERWL 16 is completed at a depth of 7 to 8 m in clay till. The thickness of the peat is approximately 5 m at this location. The well is approximately 600 m north of Pit 142W.

Water levels declined approximately 2 m in early 2010 and have risen 6 m in 2011 and 2012. The 2 m decline in water level in early 2010 is similar to that occurring at MERWL 08, also completed in the till underlying the peat, at that time.

3.0 SUMMARY AND CONCLUSIONS

Geological conditions in the area are important to the formation and preservation of the Wetland. At the time of formation of the Wetland, the presence of clay or clay till deposits of presumably low hydraulic conductivity in the depression under the Wetlands resulted in moist conditions that favored vegetative growth and inhibited decay due to the presence of standing water. Currently, these same conditions buffer the Wetland against the temporary effects of drawdown of hydraulic head in the underlying mineral soils caused by mining operations.

The water level information collected at the Wetlands conclusively shows that:

- There is downward flow of groundwater out of the Wetland under non-mining conditions.
  - This is indicated by downward hydraulic gradients from the wells completed in peat (MERWL 01, 03, 04, 07a) and those completed significantly greater depth (MERWL 08, 09, 10, 11).
  - Due to the presence of clay under the Wetland and the presumed low hydraulic conductivity of that clay, the amount of downward flow of groundwater out of the Wetland was low.
- Adjacent mine pits resulted in drawdown of water levels in the bedrock that extended beneath the Wetland.
  - This occurred at MERWL 09 and 10.
  - These drawdowns occurred at depths of 46 and 89 m respectively in the bedrock – they do not reflect conditions in water table in the overlying peat.
- This drawdown even extended, to some degree, to the glacial deposits below the Wetlands.
  - This may have occurred prior to the period of record in MERWL 12, 14, 15 and 16.
  - This occurred at MERWL 09 but not at MERWL 11.
  - This phenomenon is therefore not ubiquitous throughout the Wetland.
- In spite of this drawdown in the mineral deposits below the Wetland, the water table in the peat of the Wetlands was not lowered regardless of proximity to the mine pit.

- This is shown in MERWL 01, 03, 04, 05 and 07b.
- The water table in the peat remained approximately at the surface and virtually unchanged throughout the period of 2006 through 2012.

Thus, although the natural downward hydraulic gradient was increased by mining activities, the downward flow of water from the Wetland did not increase sufficiently to cause any measureable change in the water table within the peat deposits.

This information demonstrates that a drawdown of hydraulic head of as much as 40 m produced no demonstrable impact on the Wetland. This lack of impact occurred despite the fact that pits were present on two ends of the 1,500 metre-long Wetland and that the lowering of the water level in the pits has been present since 2006.

4.0 REFERENCES

CVRI (2012): Application under the Canadian Environmental Assessment Act ("CEAA") for the Coal Valley Resources Inc. Robb Trend Project - Consultant's Report #3, Appendix D-1; April 11. Submitted to ESRD, ERCB and CEAA.

Halsey, L.A., and D.H. Vitt. 1996. Alberta Wetland Inventory Standards 2.0. Alberta Sustainable Resource Development, Edmonton, AB, Canada.

APPENDIX A: WATER LEVELS IN SOUTH EXTENSION WETLANDS

MILLENNIUM
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Piezometer Name>	MERWL-01	MERWL-03	MERWL-04	MERWL-05	MERWL-07b	MERWL-08	MERWL-09
Former Name>	A835-03	A835-05	A835-06	A835-07	A835-10	PIEZ#1VALD	PIEZ#2VALD
Piezometer Open Interval (m)>	1.4--2.6	1.3--2.8	4.7--6.2	4.5--6		39.6--46.6	4.9--7.9
Date	**WATER LEVEL ELEVATION (m)**						
28-Apr-06	1427.85	1427.38	1427.13	1428.49	1425.59	1419.96	1419.82
22-Jun-06	1429.04	1427.84	1427.24	1428.12	1425.69	1418.99	1418.53
6-Sep-06	1428.31	1427.38	1426.99	1427.86			
6-Nov-07	1428.51	1427.73	1426.98	1427.82	1424.85	1424.15	1423.85
5-Nov-08	1428.71	1427.71				1424.90	1424.50
12-Jan-09						1424.65	
17-Aug-09	1429.05	1429.09	1427.13	1428.19	1425.26	1423.95	1423.78
17-Dec-09	1429.18				1425.12	1420.29	1419.79
19-Jan-10	1428.70				1425.06		1418.20
1-Mar-10	1428.28				1425.03		
7-Apr-10	1428.10				1425.08	1416.71	
15-Aug-10	1428.66	1427.36	1426.90	1427.52	1425.28	1416.33	
24-Sep-11	1429.36	1429.30	1426.85	1427.41			
2-Nov-12	1428.45		1427.08				1422.94

Piezometer Name>	MERWL-10	MERWL-11	MERWL-12	MERWL-14	MERWL-15	MERWL-16
Former Name>	PIEZ#1MYN	PIEZ#2MYN	A2010-01	A2010- 03	A2010-04	A2010-05
Piezometer Open Interval (m)>	82.6--89	5--8.1	6-7.5	6.1-7.6	6.9-8.4	6.9-8.4
Date	WATER LEVEL ELEVATION (m)					
28-Apr-06	1425.64	1425.99				
22-Jun-06	1424.90	1425.62				
6-Sep-06						
6-Nov-07	1410.78	1421.62				
5-Nov-08	1413.60					
12-Jan-09	1414.35					
17-Aug-09	1414.70	1422.76				
17-Dec-09	1413.68	1423.06				
19-Jan-10	1413.84	1423.39				
1-Mar-10	1414.20	1423.60	1422.70	1424.93	1425.01	1421.52
7-Apr-10	1414.16	1423.58	1421.89	1423.44	1423.29	1420.38
15-Aug-10	1414.11	1424.03	1421.54	1423.22	1423.03	1420.12
24-Sep-11			1422.32	1424.30	1424.34	1421.20
2-Nov-12	frozen	1423.9	1425.84	1426.86	1427.00	1426.08

APPENDIX B: GEOLOGICAL LOGS AND MONITORING WELL COMPLETIONS

Main Menu | Search

Project No: 05-171

Borehole No: Merwl - 08 (Piezo #1 Valdor)

Drill Method: Rotary

Client: Coal Valley Resources Inc.

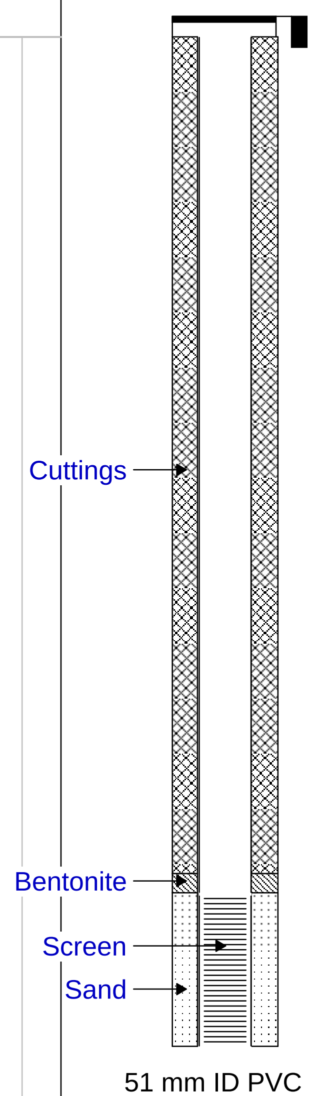
Location:

MILLENNIUM
EMS Solutions Ltd.

Depth (m)	Subsurface Profile – Description	Sample – Sample Point (m)
	Ground Surface	
0.0	***Muskeg***	
	Clay with Gravel	
10.0	***Sandstone***	
20.0		
30.0		
	Coal	
	Sandstone	
	Coal	
40.0		
	End of Borehole	
50.0		

VOC Concentration
PPM: 100, 200, 300, 400
%LEL: 10, 30, 50, 70, 90

Well Completion Details



Logged By: CVRI

Entered By: SC

Drill Date: March, 2006

Millennium □MS Solutions □td□
□□□□ - 9□ Street
□dmonton□AB T□□ □V□

Main Menu | Search

Project No: 05-171

Borehole No: Merwl - 09 (Piezo #2 Valdor)

Drill Method: Rotary

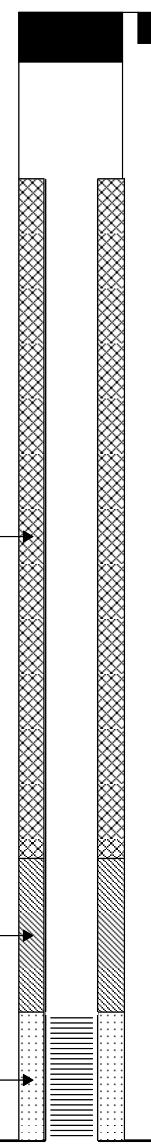
Client: Coal Valley Resources Inc.

Location:

APEC:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	× ppm × 100 200 300 400 ▼ % LEL ▼ 10 30 50 70 90	
	Ground Surface			
0.0				
1.0				
2.0				
3.0				
4.0				
5.0				



Logged By: CVRI

Entered By: SC

Drill Date: March, 2006

Millennium □MS Solutions □td□
□□□□ - 9□ Street
□dmonton□AB T□□ □V□

Main Menu | **Search**

Project No: 05-171

Borehole No: Merwl - 09 (Piezo #2 Valdor)

Drill Method: Rotary

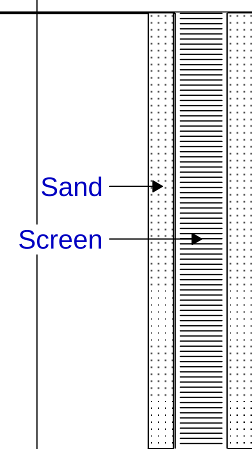
Client: Coal Valley Resources Inc.

Location:

APEC:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile		**Sample**	VOC Concentration ppm (× 100, 200, 300, 400) / % LEL (▼ 10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
6.0				
7.0				
8.0				
9.0	End of Borehole			
10.0				
11.0				
12.0				



51mm ID PVC

Logged By: CVRI

Entered By: SC

Drill Date: March, 2006

Millennium □MS Solutions □td□
□□□□ - 9□ Street
□dmonton□AB T□□ □V□

Main Menu | Search

Project No: 05-171

Borehole No: Merwl - 10 (Piezo #1 Myher)

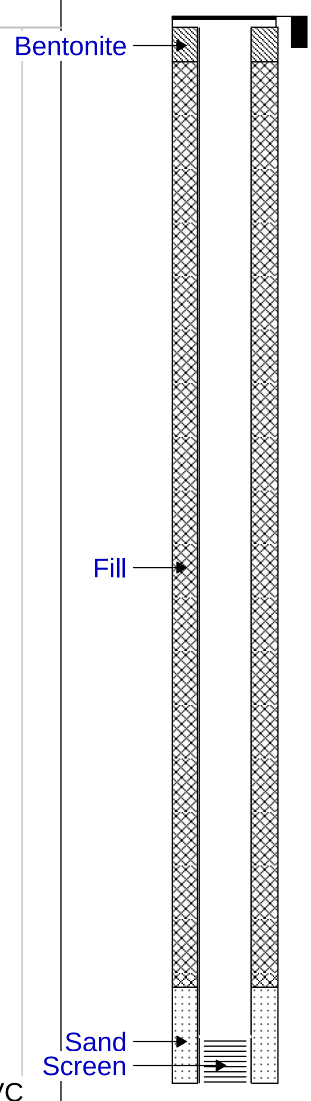
Drill Method: Rotary

Client: Coal Valley Resources Inc.

Location:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile		Sample		
Depth (m)	Description	Sample Point (m)	VOC Concentration PPM (100, 200, 300, 400); %LEL (10, 30, 50, 70, 90)	Well Completion Details
	Ground Surface			
0.0	***Muskeg***			
	Clay and Boulders			
10.0	***Sandstone***			
20.0				
30.0				
40.0				
50.0				
60.0				
70.0				
80.0	***Coal***			
90.0	End of Borehole			



Logged By: CVRI

Entered By: SC

Drill Date: March, 2006

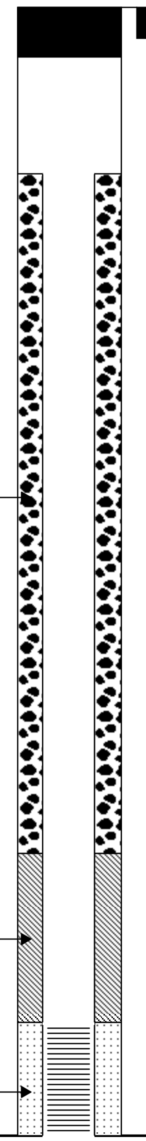
Millennium □MS Solutions □td□
□□□□ - 9□ Street
□dmonton□AB T□□ □V□

Main Menu | Search

Project No: 05-171
Borehole No: Merwl - 11 (Piezo #2 Myher)
Drill Method: Rotary
Client: Coal Valley Resources Inc.
Location:
APEC:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (× 100, 200, 300, 400 ×) / % LEL (▼ 10, 30, 50, 70, 90 ▼)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
1.0				
2.0				
3.0				
4.0				
5.0				



Logged By: CVRI

Entered By: SC

Drill Date: March, 2006

Millennium □MS Solutions □td□
□□□□ - 9□ Street
□dmonton□AB T□□ □V□

Main Menu | Search

Project No: 05-171

Borehole No: Merwl - 11 (Piezo #2 Myher)

Drill Method: Rotary

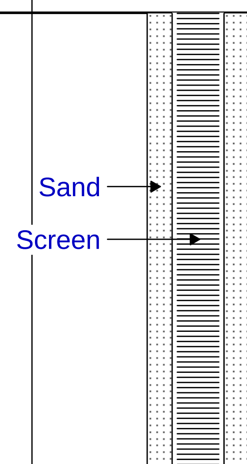
Client: Coal Valley Resources Inc.

Location:

APEC:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile		**Sample**	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
6.0				
7.0				
8.0				
9.0	End of Borehole			
10.0				
11.0				
12.0				



51mm ID PVC

Logged By: CVRI

Entered By: SC

Drill Date: March, 2006

Millennium □MS Solutions □td□
□□□□ - 9□ Street
□dmonton□AB T□□ □V□

M□R□ □0□

TESTHOLE TH-A835-03
COAL VALLEY RESOURCES INC.
COAL VALLEY MINE
2006

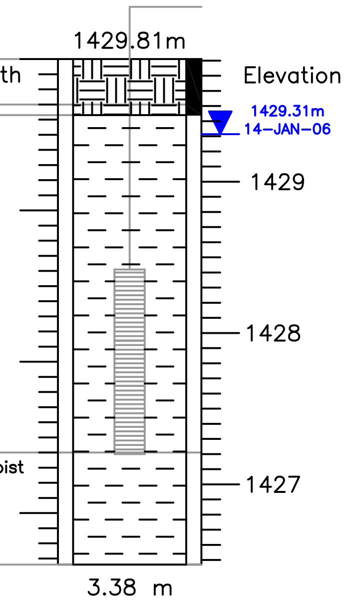
4961.47 N 12621.43 E
MINE GRID

PEAT: reddish brown, hard, frozen

PEAT: reddish brown, oxidized, soft, wet

CLAY: grey, unoxidized, soft, high plasticity, wet

CLAY: some sand, trace rocks, grey, unox., firm, med. plasticity, moist



LIMITATIONS

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

FOR PIEZOMETER INSTALLATION DETAILS SEE DWG: PS-A835-03

COAL VALLEY RESOURCES INC.

MDH ENGINEERED SOLUTIONS

SUPERVISOR:	R. OSICKI, M.Sc., E.I.T.	**DRILL OPERATOR:**	R. OSICKI, M.Sc., E.I.T.	**APPROVED BY:**	A. KARVONEN, P.Eng., P.Geo.
DATE DRILLED:	12-JAN-06	**CONTRACTOR:**	MDH	**DRAWN BY:**	H. DE SOUZA
LOGGED BY:	R. OSICKI, M.Sc., E.I.T.	**TYPE OF DRILL RIG:**	ARGO (GSRPSUVA)	**PROJECT No.**	A835-280205
GEOLOGY BY:	R. OSICKI, M.Sc., E.I.T.	**ABANDONMENT:**	STANDPIPE PIEZOMETER	**DATE:** 09-MAR-06	**SCALE:** 1:50

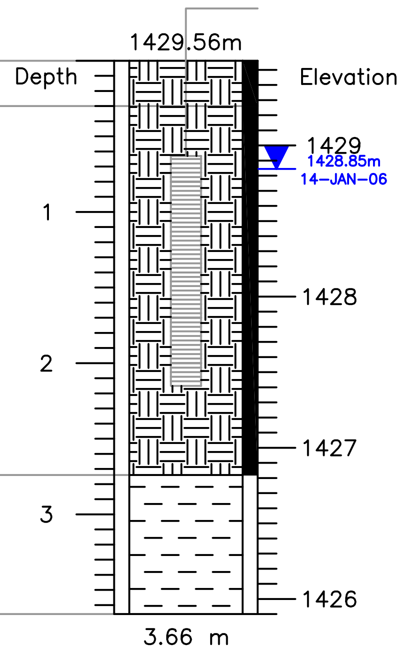
ACADDWG:\Logan\Projects\Luscar\Coal Valley\A835-280205 2006 Piezometer Installation\Testholes\TH-A835-03

M□R□ □03

TESTHOLE TH-A835-05
COAL VALLEY RESOURCES INC.
COAL VALLEY MINE
2006

4927.67 N 12700.73 E
MINE GRID

PEAT: reddish brown, hard, frozen	
PEAT: reddish brown, oxidized, soft, wet	
CLAY: bluish-grey, unox., soft, high plasticity, wet, sticky	



LIMITATIONS

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

FOR PIEZOMETER INSTALLATION DETAILS SEE DWG: PS-A835-05

COAL VALLEY RESOURCES INC.

MDH ENGINEERED SOLUTIONS

SUPERVISOR:	R. OSICKI, M.Sc., E.I.T.	**DRILL OPERATOR:**	R. OSICKI, M.Sc., E.I.T.	**APPROVED BY:**	A. KARVONEN, P.Eng., P.Geo.
DATE DRILLED:	13-JAN-06	**CONTRACTOR:**	MDH	**DRAWN BY:**	H. DE SOUZA
LOGGED BY:	R. OSICKI, M.Sc., E.I.T.	**TYPE OF DRILL RIG:**	ARGO (GSRPSUVA)	**PROJECT No.**	A835-280205
GEOLOGY BY:	R. OSICKI, M.Sc., E.I.T.	**ABANDONMENT:**	STANDPIPE PIEZOMETER	**DATE:** 16-MAR-06	**SCALE:** 1:50

ACADDWG:\Logan\Projects\Luscar\Coal Valley\A835-280205 2006 Piezometer Installation\Testholes\TH-A835-05

M□R□ □0□

TESTHOLE TH-A835-06
COAL VALLEY RESOURCES INC.
COAL VALLEY MINE
2006

5216.55 N 13898.32 E

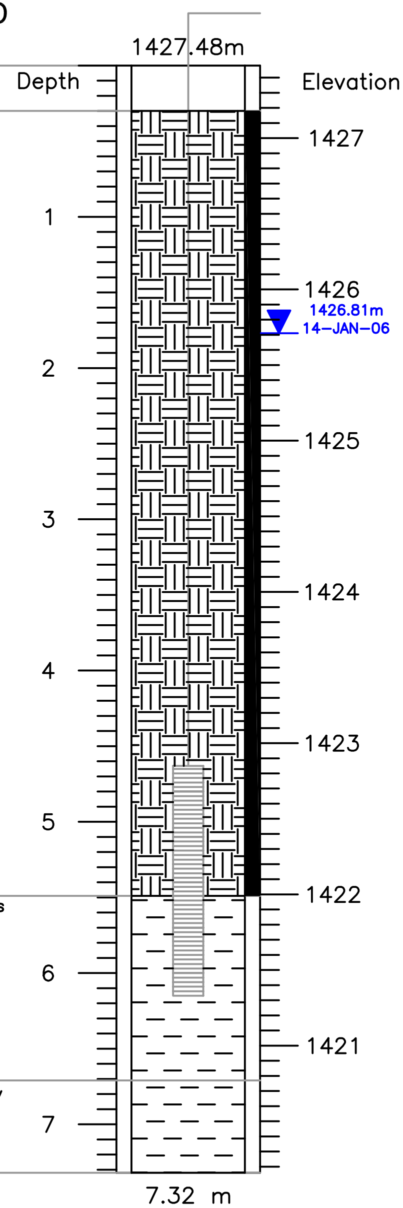
MINE GRID

ICE / WATER

PEAT: reddish brown, oxidized, soft, wet

CLAY: dark grey, unoxidized, soft, high plasticity, wet, organics

CLAY: trace coarse sand, grey, unoxidized, firm, high plasticity



LIMITATIONS

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

FOR PIEZOMETER INSTALLATION DETAILS SEE DWG: PS-A835-06

COAL VALLEY RESOURCES INC.

MDH ENGINEERED SOLUTIONS

SUPERVISOR:	R. OSICKI, M.Sc., E.I.T.	**DRILL OPERATOR:**	R. OSICKI, M.Sc., E.I.T.	**APPROVED BY:**	A. KARVONEN, P.Eng., P.Geo.
DATE DRILLED:	13-JAN-06	**CONTRACTOR:**	MDH	**DRAWN BY:**	H. DE SOUZA
LOGGED BY:	R. OSICKI, M.Sc., E.I.T.	**TYPE OF DRILL RIG:**	ARGO (GSRPSUVA)	**PROJECT No.**	A835-280205
GEOLOGY BY:	R. OSICKI, M.Sc., E.I.T.	**ABANDONMENT:**	STANDPIPE PIEZOMETER	**DATE:** 16-MAR-06	**SCALE:** 1:50

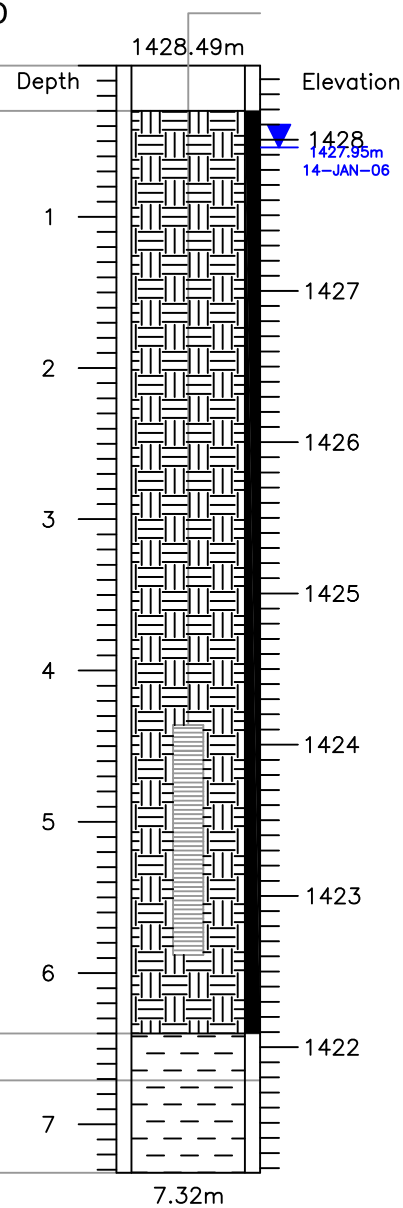
ACADDWG:\Logan\Projects\Luscar\Coal Valley\A835-280205 2006 Piezometer Installation\Testholes\TH-A835-06

M□R□ □05

TESTHOLE TH-A835-07
COAL VALLEY RESOURCES INC.
COAL VALLEY MINE
2006

4970.14 N 13627.58 E
MINE GRID

Description
ICE / WATER
PEAT: reddish brown, oxidized, soft, wet
CLAY: grey, unoxidized, soft, high plasticity, wet
CLAY: bluish-grey, unoxidized, soft-firm, high plasticity, moist



LIMITATIONS

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

FOR PIEZOMETER INSTALLATION DETAILS SEE DWG: PS-A835-07

COAL VALLEY RESOURCES INC.

MDH ENGINEERED SOLUTIONS

SUPERVISOR:	R. OSICKI, M.Sc., E.I.T.	DRILL OPERATOR:	R. OSICKI, M.Sc., E.I.T.	APPROVED BY:	A. KARVONEN, P.Eng., P.Geo.
DATE DRILLED:	13-JAN-06	CONTRACTOR:	MDH	DRAWN BY:	H. DE SOUZA
LOGGED BY:	R. OSICKI, M.Sc., E.I.T.	TYPE OF DRILL RIG:	ARGO (GSRPSUVA)	PROJECT No.	A835-280205
GEOLOGY BY:	R. OSICKI, M.Sc., E.I.T.	ABANDONMENT:	STANDPIPE PIEZOMETER	DATE: 16-MAR-06	SCALE: 1:50

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M□R□ □0□b

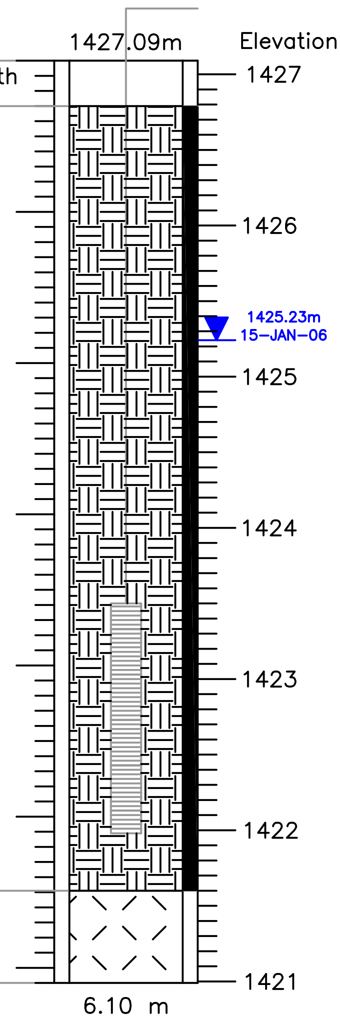
TESTHOLE TH-A835-10
COAL VALLEY RESOURCES INC.
COAL VALLEY MINE
2006

4628.30 N 13313.56 E
MINE GRID

ICE / WATER

PEAT: reddish brown, oxidized, soft, wet

TILL: clay, trace gravel, grey, unoxdized, soft, high plasticity, wet



LIMITATIONS

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

FOR PIEZOMETER INSTALLATION DETAILS SEE DWG: PS–A835–10

COAL VALLEY RESOURCES INC.

MDH ENGINEERED SOLUTIONS

SUPERVISOR:	R. OSICKI, M.Sc., E.I.T.	**DRILL OPERATOR:**	R. OSICKI, M.Sc., E.I.T.	**APPROVED BY:**	A. KARVONEN, P.Eng., P.Geo.
DATE DRILLED:	14–JAN–06	**CONTRACTOR:**	MDH	**DRAWN BY:**	H. DE SOUZA / P. BIRNIE
LOGGED BY:	R. OSICKI, M.Sc., E.I.T.	**TYPE OF DRILL RIG:**	ARGO (GSRPSUVA)	**PROJECT No.**	A835–280205
GEOLOGY BY:	R. OSICKI, M.Sc., E.I.T.	**ABANDONMENT:**	STANDPIPE PIEZOMETER	**DATE:** 16–MAR–06	**SCALE:** 1:50

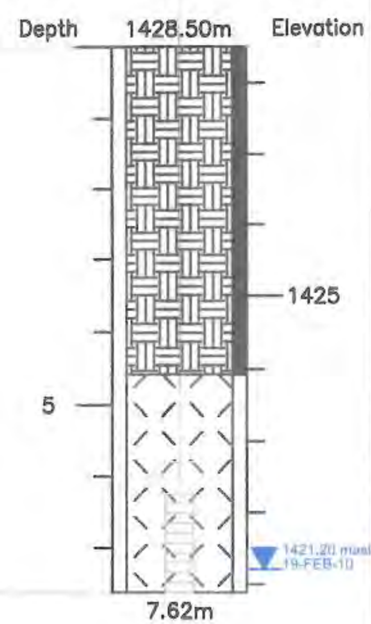
ACADDWG:\Logan\Projects\Luscar\Coal Valley\A835–280205 2006 Piezometer Installation\Testholes\TH–A835–10

BOREHOLE A2010-01
COAL VALLEY RESOURCES INC.
PIT #123 EAST
2010

5096.4 N 13151.7 E

PEAT: fibrious, highly degraded organic matter, dark brown, wet to saturated (Muskeg deposit)

TILL: sandy, silty, clayey, firm to stiff, grey, some wet sand pockets, moist to wet



NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates are in Coal Valley mine system

LIMITATION

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

FOR PIEZOMETER INFORMATION SEE DWG: PS–A2010–01.dwg

CLIENT: KEH & Associates Ltd.	PRODUCED BY: MDH ENGINEERED SOLUTIONS

SUPERVISOR: A. SMORSCHOK, P.Geol.	CONTRACTOR: ALL SERVICE DRILLING INC.	APPROVED BY: M. COHEN, P.Geol., MBA
LOGGED BY: A. ACO, B.Sc., Geol.I.T.	OPERATOR: T. ASSETS	DRAWN BY: C. SCHMIDT
GEOLOGY BY: A. SMORSCHOK, P.Geol.	TYPE OF DRILL RIG: ACKER SOIL–MAX	PROJECT No. A2010–1250009
DATE DRILLED: 19–FEB–10	ABANDONMENT: PIEZOMETER	SCALE: 1:100 / DATE: 12–MAR–10

ACADDWG:\\P:\Hebil, Keith\A2010–1250009 Piezometer Installation\2. Drafting\1. Boreholes\BH–A2010–01.dwg

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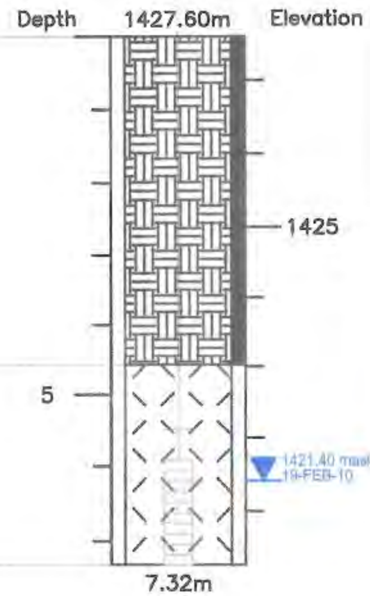
BOREHOLE A2010-02
COAL VALLEY RESOURCES INC.
PIT #123 EAST
2010

4948.4 N 13146.1 E

PEAT: fibrious, highly degraded organic matter, dark brown, wet to saturated (Muskeg deposit)

TILL: sandy, silty, clayey, firm to stiff, grey, some wet sand pockets, moist to wet



NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates are in Coal Valley mine system

FOR PIEZOMETER INFORMATION SEE DWG: PS-A2010-02.dwg

LIMITATION

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

CLIENT	PRODUCED BY
KEH & Associates Ltd.	MDH ENGINEERED SOLUTIONS

SUPERVISOR: A. SMORSCHOK, P.Geol.	CONTRACTOR: ALL SERVICE DRILLING INC.	APPROVED BY: M. COHEN, P.Geol., MBA
LOGGED BY: A. ACO, B.Sc., Geol.I.T.	OPERATOR: T. ASSETS	DRAWN BY: C. SCHMIDT
GEOLOGY BY: A. SMORSCHOK, P.Geol.	TYPE OF DRILL RIG: ACKER SOIL-MAX	PROJECT No. A2010-1250009
DATE DRILLED: 19-FEB-10	ABANDONMENT: PIEZOMETER	SCALE: 1:100 — DATE: 12-MAR-10

ACADDWG: \\P:\Hebil, Keith\A2010-1250009 Piezometer Installation\2. Drafting\1. Boreholes\BH-A2010-02.dwg

BOREHOLE A2010-03
COAL VALLEY RESOURCES INC.
PIT #123 EAST
2010

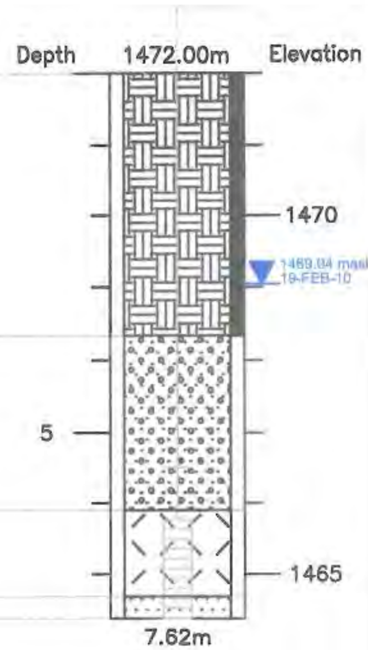
4848.1 N 13146.1 E

PEAT: fibrious, highly degraded organic matter, dark brown, wet to saturated (Muskeg deposit)

Gravel and SAND, clayey, saturated

TILL: sandy, silty, clayey, firm to stiff, grey, some wet sand pockets, moist to wet

SAND STONE weak, weathered



NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates are in Coal Valley mine system

FOR PIEZOMETER INFORMATION SEE DWG: PS-A2010-03.dwg

LIMITATION

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

CLIENT	PRODUCED BY
KEH & Associates Ltd.	MDH ENGINEERED SOLUTIONS

SUPERVISOR: A. SMORSCHOK, P.Geol.	CONTRACTOR: ALL SERVICE DRILLING INC.	APPROVED BY: M. COHEN, P.Geol., MBA
LOGGED BY: A. ACO, B.Sc., Geol.I.T.	OPERATOR: T. ASSETS	DRAWN BY: C. SCHMIDT
GEOLOGY BY: A. SMORSCHOK, P.Geol.	TYPE OF DRILL RIG: ACKER SOIL-MAX	PROJECT No. A2010-1250009
DATE DRILLED: 18-FEB-10	ABANDONMENT: PIEZOMETER	SCALE: 1:100 / DATE: 12-MAR-10

ACADDWG:\\P:\Hebil, Keith\A2010-1250009 Piezometer Installation\2. Drafting\1. Boreholes\BH-A2010-03.dwg

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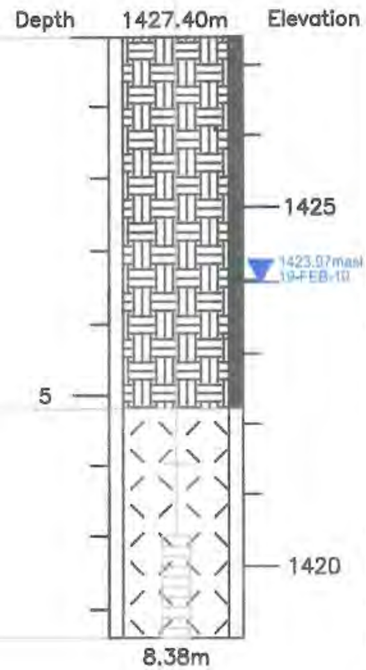
BOREHOLE A2010-04
COAL VALLEY RESOURCES INC.
PIT #123 EAST
2010

4850.2 N 13002.5 E

Depth	Description
0 – 5	PEAT, fibrious, highly degraded organic matter, dark brown, wet to saturated (Muskeg deposit)
5 – 8.38	TILL: sandy, silty, clayey, firm to stiff, grey, some wet sand pockets, moist to wet



NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates are in Coal Valley mine system

FOR PIEZOMETER INFORMATION SEE DWG: PS–A2010–04.dwg

LIMITATION

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

CLIENT: KEH & Associates Ltd.

PRODUCED BY: MDH ENGINEERED SOLUTIONS

SUPERVISOR: A. SMORSCHOK, P.Geol.	CONTRACTOR: ALL SERVICE DRILLING INC.	APPROVED BY: M. COHEN, P.Geol., MBA
LOGGED BY: A. ACO, B.Sc., Geol.I.T.	OPERATOR: T. ASSETS	DRAWN BY: C. SCHMIDT
GEOLOGY BY: A. SMORSCHOK, P.Geol.	TYPE OF DRILL RIG: ACKER SOIL–MAX	PROJECT No. A2010–1250009
DATE DRILLED: 19–FEB–10	ABANDONMENT: PIEZOMETER	SCALE: 1:100 — DATE: 12–MAR–10

ACADDWG: \\P:\Hebil, Keith\A2010–1250009 Piezometer Installation\2. Drafting\1. Boreholes\BH–A2010–04.dwg

Main Menu Search

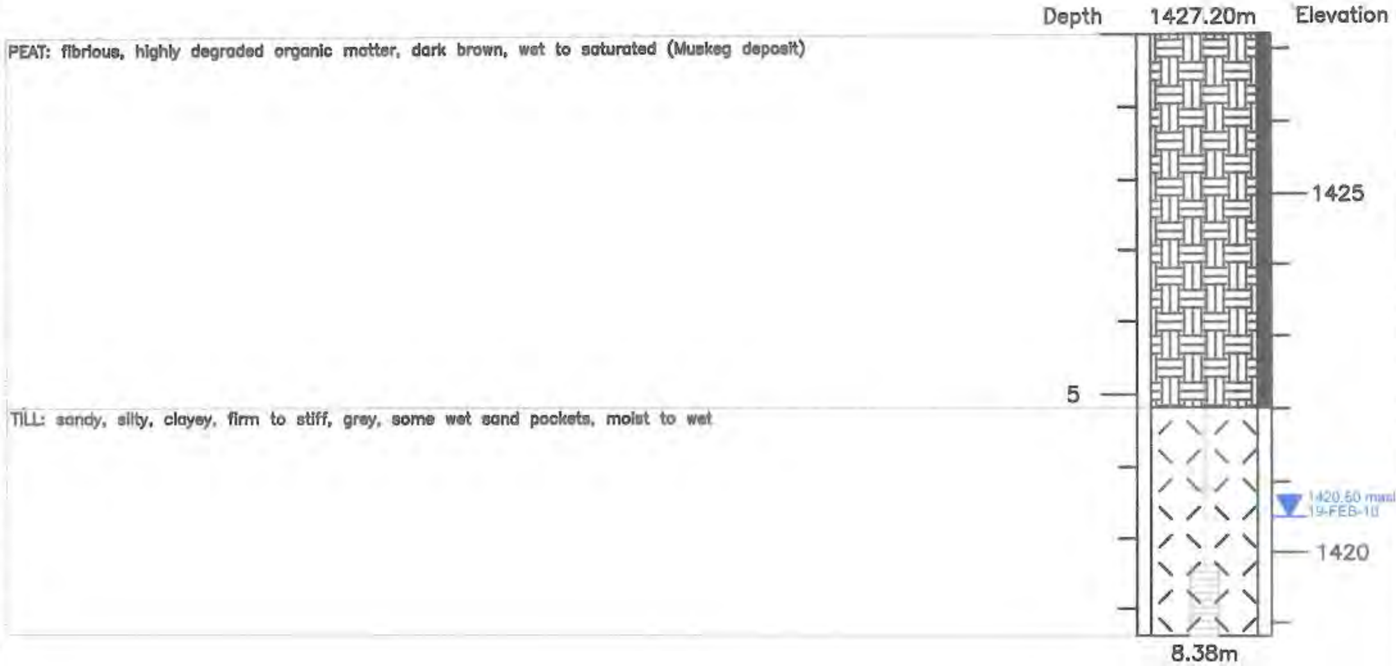
BOREHOLE A2010-05

COAL VALLEY RESOURCES INC.

PIT #123 EAST

2010

4947.5 N 13300.4 E



NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates are in Coal Valley mine system

FOR PIEZOMETER INFORMATION SEE DWG: PS–A2010–05.dwg

LIMITATION

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

CLIENT: KEH & Associates Ltd.	PRODUCED BY: MDH ENGINEERED SOLUTIONS	
SUPERVISOR: A. SMORSCHOK, P.Geol.	CONTRACTOR: ALL SERVICE DRILLING INC.	APPROVED BY: M. COHEN, P.Geol., MBA
LOGGED BY: A. ACO, B.Sc., Geol.I.T.	OPERATOR: T. ASSETS	DRAWN BY: C. SCHMIDT
GEOLOGY BY: A. SMORSCHOK, P.Geol.	TYPE OF DRILL RIG: ACKER SOIL–MAX	PROJECT No. A2010–1250009
DATE DRILLED: 18–FEB–10	ABANDONMENT: PIEZOMETER	SCALE: 1:100 DATE: 12–MAR–10

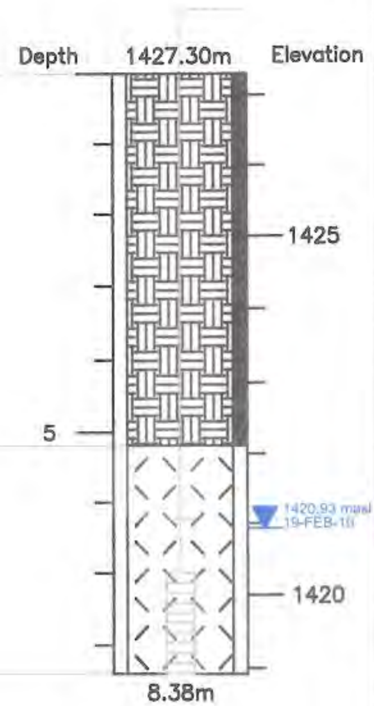
ACADDWG: \\P:\Hebil, Keith\A2010–1250009 Piezometer Installation\2. Drafting\1. Boreholes\BH–A2010–05.dwg

BOREHOLE A2010-06
COAL VALLEY RESOURCES INC.
PIT #123 EAST
2010

4952.3 N 13400.1 E

PEAT: fibrious, highly degraded organic matter, dark brown, wet to saturated (Muskeg deposit)

TILL: sandy, silty, clayey, firm to stiff, grey, some gravel and wet sand pockets, wet



NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates are in Coal Valley mine system

FOR PIEZOMETER INFORMATION SEE DWG: PS–A2010–06.dwg

LIMITATION

This drill log is a summary of the conditions estimated by the field personnel at the specific location at the time of drilling. The conditions and properties described above will vary between locations and may vary with time.

CLIENT: KEH & Associates Ltd.

PRODUCED BY: MDH ENGINEERED SOLUTIONS

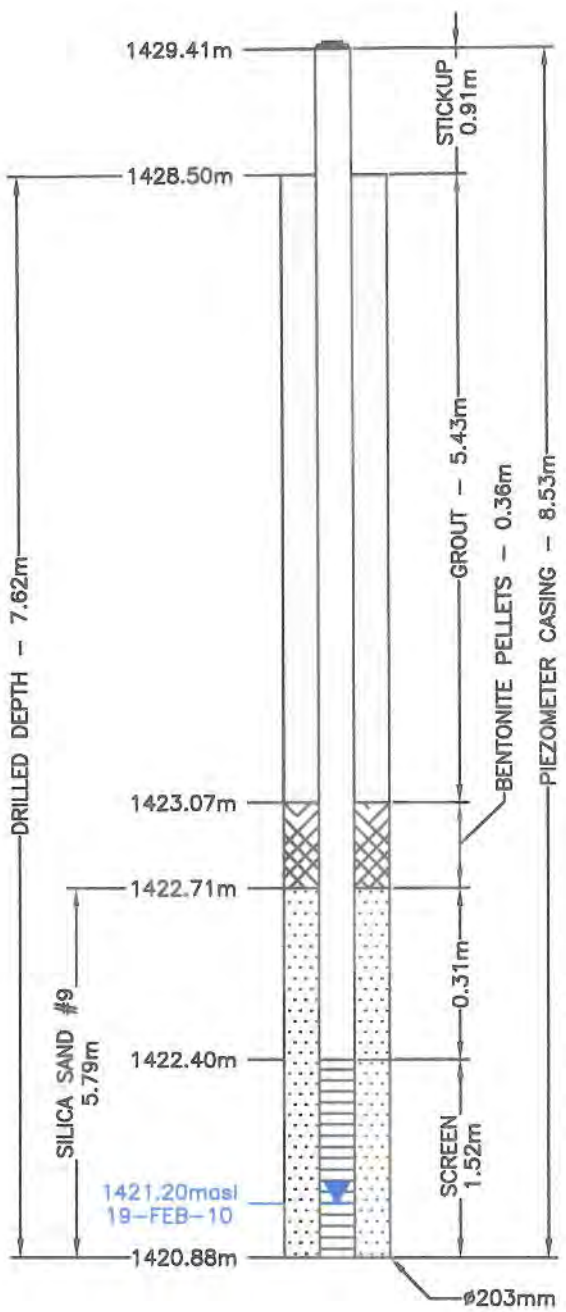
SUPERVISOR: A. SMORSCHOK, P.Geol.	CONTRACTOR: ALL SERVICE DRILLING INC.	APPROVED BY: M. COHEN, P.Geol., MBA
LOGGED BY: A. ACO, B.Sc., Geol.I.T.	OPERATOR: T. ASSETS	DRAWN BY: C. SCHMIDT
GEOLOGY BY: A. SMORSCHOK, P.Geol.	TYPE OF DRILL RIG: ACKER SOIL–MAX	PROJECT No. A2010–1250009
DATE DRILLED: 18–FEB–10	ABANDONMENT: PIEZOMETER	SCALE: 1:100 / DATE: 12–MAR–10

ACADDWG:\\P:\Hebil, Keith\A2010–1250009 Piezometer Installation\2. Drafting\1. Boreholes\BH–A2010–06.dwg

Main Menu | Search

PIEZOMETER A2010-01
COAL VALLEY RESOURCES INC
PIT #123 EAST
2010

5096.4 N 13151.7 E



GROUT SPECIFICATIONS:
- bentonite chips

FILTER PACK SEAL SPECIFICATIONS:
- bentonite pellets

FILTER PACK SPECIFICATIONS:
- silica sand #9

SCREEN SPECIFICATIONS:
- 10 slot PVC

CASING SPECIFICATIONS:
- PVC

CASING PROTECTOR SPECIFICATIONS:
- 5 foot tall slip on

NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates in Coal Valley system

All depths are expressed in metres above or below natural ground surface, unless otherwise indicated. All elevations are expressed in metres above sea level.

SUPERVISOR:	A. SMORSCHOK, P.Geol.
CONTRACTOR:	ALL SERVICE DRILLING INC.
OPERATOR:	T. ASSETS
TYPE OF DRILL RIG:	ACKER SOIL-MAX
DATE INSTALLED:	19-FEB-10

CLIENT: KEH & Associates Ltd.

PRODUCED BY: MDH ENGINEERED SOLUTIONS

APPROVED BY: M. COHEN, P.Geol., MBA

DRAWN BY: C. SCHMIDT

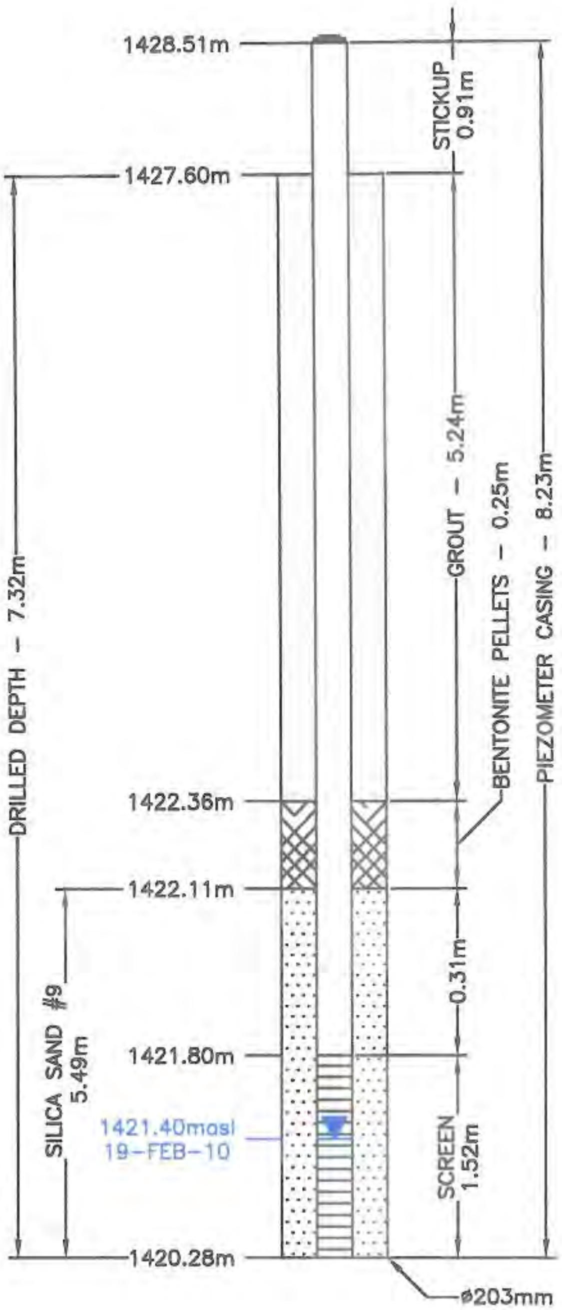
PROJECT No. A2010-1250009

SCALE: NOT TO SCALE | DATE: 12-MAR-10

ACADDWG:\\P:\Hebil, Keith\A2010-1250009 Piezometer Installation\2. Drafting\1. Boreholes\PS-A2010-01.dwg

PIEZOMETER A2010-02
COAL VALLEY RESOURCES INC
PIT #123 EAST
2010

4948.4 N 13146.1 E



GROUT SPECIFICATIONS:
– bentonite chips

FILTER PACK SEAL SPECIFICATIONS:
– bentonite pellets

FILTER PACK SPECIFICATIONS:
– silica sand #9

SCREEN SPECIFICATIONS:
– 10 slot PVC

CASING SPECIFICATIONS:
– PVC

CASING PROTECTOR SPECIFICATIONS:
– 5 foot tall slip on

NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates in Coal Valley system

All depths are expressed in metres above or below natural ground surface, unless otherwise indicated. All elevations are expressed in metres above sea level.

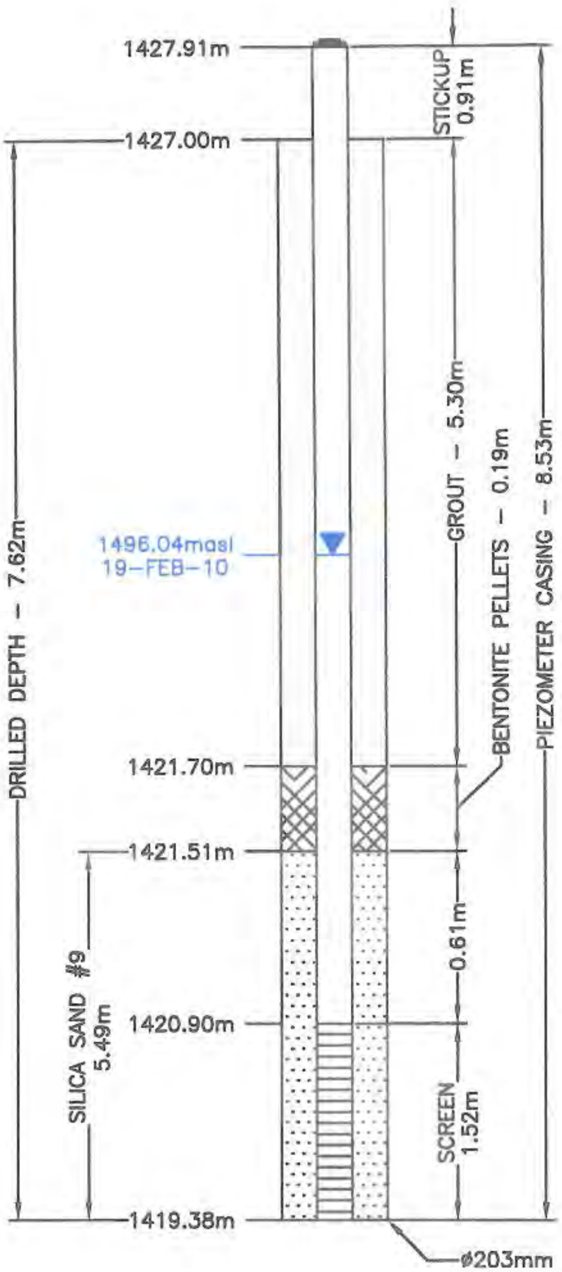
SUPERVISOR:	A. SMORSCHOK, P.Geol.
CONTRACTOR:	ALL SERVICE DRILLING INC.
OPERATOR:	T. ASSETS
TYPE OF DRILL RIG:	ACKER SOIL-MAX
DATE INSTALLED:	19-FEB-10

CLIENT	KEH & Associates Ltd.
PRODUCED BY	MDH ENGINEERED SOLUTIONS
APPROVED BY:	M. COHEN, P.Geol., MBA
DRAWN BY:	C. SCHMIDT
PROJECT No.	A2010-1250009
SCALE:	NOT TO SCALE
DATE:	12-MAR-10

ACADDWG: \\P:\Hebil, Keith\A2010-1250009 Piezometer Installation\2. Drafting\1. Boreholes\PS-A2010-02.dwg

PIEZOMETER A2010-03
COAL VALLEY RESOURCES INC
PIT #123 EAST
2010

4848.1 N 13146.1 E



GROUT SPECIFICATIONS:
- bentonite chips

FILTER PACK SEAL SPECIFICATIONS:
- bentonite pellets

FILTER PACK SPECIFICATIONS:
- silica sand #9

SCREEN SPECIFICATIONS:
- 10 slot PVC

CASING SPECIFICATIONS:
- PVC

CASING PROTECTOR SPECIFICATIONS:
- 5 foot tall slip on

NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates in Coal Valley system

CLIENT	KEH & Associates Ltd.
PRODUCED BY	MDH ENGINEERED SOLUTIONS
APPROVED BY:	M. COHEN, P.Geol., MBA
DRAWN BY:	C. SCHMIDT
PROJECT No.	A2010-1250009
SCALE:	NOT TO SCALE
DATE:	12-MAR-10

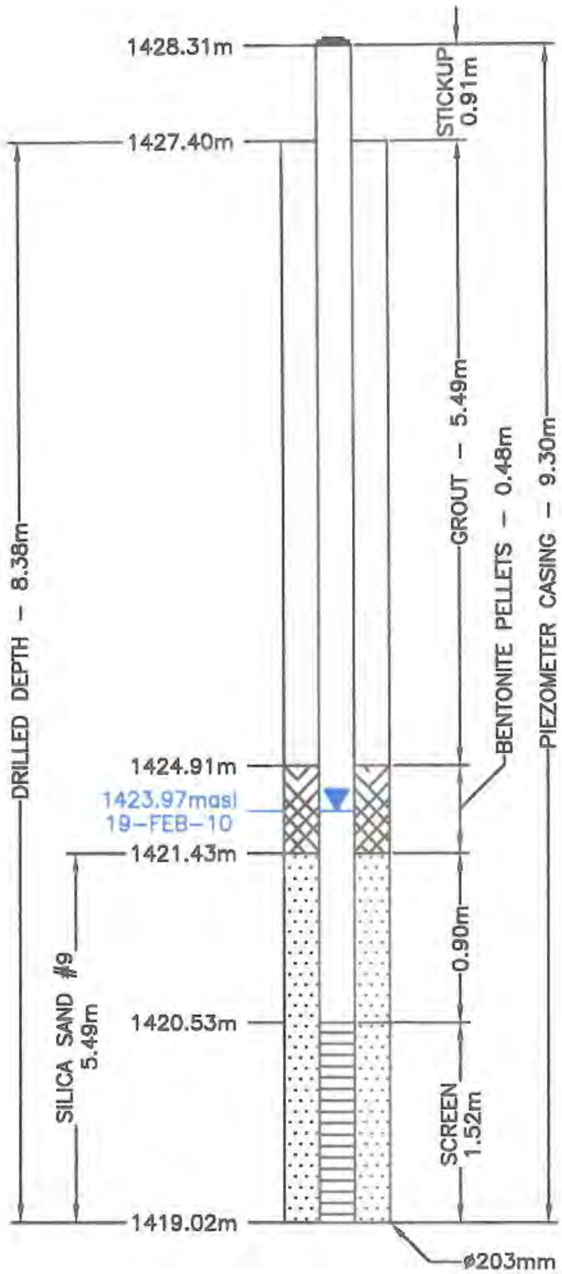
All depths are expressed in metres above or below natural ground surface, unless otherwise indicated. All elevations are expressed in metres above sea level.

SUPERVISOR:	A. SMORSCHOK, P.Geol.
CONTRACTOR:	ALL SERVICE DRILLING INC.
OPERATOR:	T. ASSETS
TYPE OF DRILL RIG:	ACKER SOIL-MAX
DATE INSTALLED:	18-FEB-10

ACADDWG: \\P:\Hebil, Keith\A2010-1250009 Piezometer Installation\2. Drafting\1. Boreholes\PS-A2010-03.dwg

PIEZOMETER A2010-04
COAL VALLEY RESOURCES INC
PIT #123 EAST
2010

4850.2 N 13002.5 E



GROUT SPECIFICATIONS:
- bentonite chips

FILTER PACK SEAL SPECIFICATIONS:
- bentonite pellets

FILTER PACK SPECIFICATIONS:
- silica sand #9

SCREEN SPECIFICATIONS:
- 10 slot PVC

CASING SPECIFICATIONS:
- PVC

CASING PROTECTOR SPECIFICATIONS:
- 5 foot tall slip on

NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates in Coal Valley system

CLIENT
KEH & Associates Ltd.

PRODUCED BY
MDH ENGINEERED SOLUTIONS

All depths are expressed in metres above or below natural ground surface, unless otherwise indicated. All elevations are expressed in metres above sea level.

SUPERVISOR:	A. SMORSCHOK, P.Geol.
CONTRACTOR:	ALL SERVICE DRILLING INC.
OPERATOR:	T. ASSETS
TYPE OF DRILL RIG:	ACKER SOIL-MAX
DATE INSTALLED:	19-FEB-10

APPROVED BY:	M. COHEN, P.Geol., MBA
DRAWN BY:	C. SCHMIDT
PROJECT No.	A2010-1250009
SCALE: NOT TO SCALE	DATE: 12-MAR-10

ACADDWG:\\P:\Hebil, Keith\A2010-1250009 Piezometer Installation\2. Drafting\1. Boreholes\PS-A2010-04.dwg

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PIEZOMETER A2010-05
COAL VALLEY RESOURCES INC
PIT #123 EAST
2010

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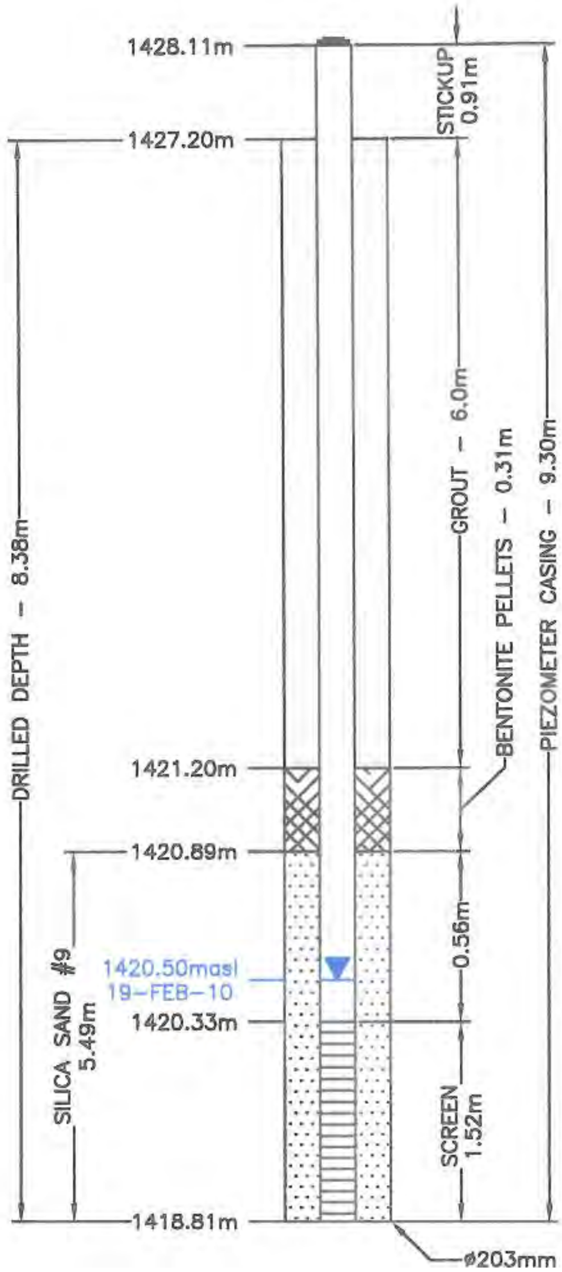

GROUT SPECIFICATIONS:
– bentonite chips

FILTER PACK SEAL SPECIFICATIONS:
– bentonite pellets

FILTER PACK SPECIFICATIONS:
– silica sand #9

SCREEN SPECIFICATIONS:
– 10 slot PVC

CASING SPECIFICATIONS:
– PVC

CASING PROTECTOR SPECIFICATIONS:
– 5 foot tall slip on

NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates in Coal Valley system

All depths are expressed in metres above or below natural ground surface, unless otherwise indicated. All elevations are expressed in metres above sea level.

CLIENT	KEH & Associates Ltd.
PRODUCED BY	MDH ENGINEERED SOLUTIONS
SUPERVISOR:	A. SMORSCHOK, P.Geol.
CONTRACTOR:	ALL SERVICE DRILLING INC.
OPERATOR:	T. ASSETS
TYPE OF DRILL RIG:	ACKER SOIL–MAX
DATE INSTALLED:	18–FEB–10
APPROVED BY:	M. COHEN, P.Geol., MBA
DRAWN BY:	C. SCHMIDT
PROJECT No.	A2010–1250009
SCALE:	NOT TO SCALE
DATE:	12–MAR–10

ACADDWG: \\P:\Hebil, Keith\A2010–1250009 Piezometer Installation\2. Drafting\1. Boreholes\PS–A2010–05.dwg

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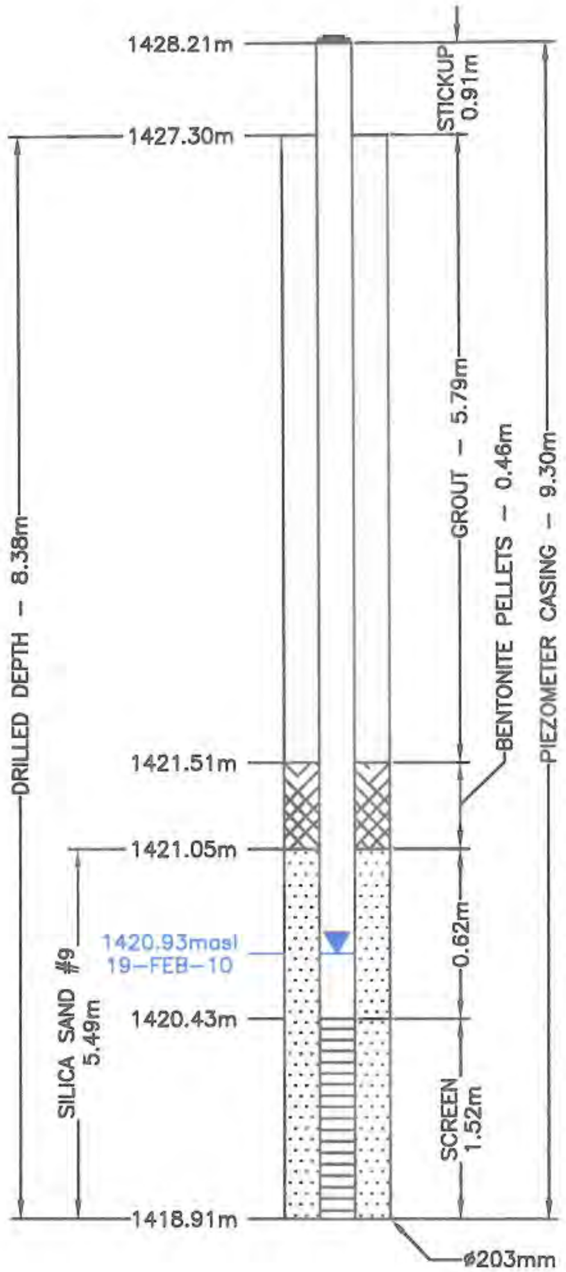
PIEZOMETER A2010-06
COAL VALLEY RESOURCES INC
PIT #123 EAST
2010

4952.3 N 13400.1 E



GROUT SPECIFICATIONS:
– bentonite chips

FILTER PACK SEAL SPECIFICATIONS:
– bentonite pellets

FILTER PACK SPECIFICATIONS:
– silica sand #9

SCREEN SPECIFICATIONS:
– 10 slot PVC

CASING SPECIFICATIONS:
– PVC

CASING PROTECTOR SPECIFICATIONS:
– 5 foot tall slip on

NOTES: 1. Survey done by Coal Valley Resources Inc.
2. All coordinates in Coal Valley system

All depths are expressed in metres above or below natural ground surface, unless otherwise indicated. All elevations are expressed in metres above sea level.

		CLIENT	KEH & Associates Ltd.
		PRODUCED BY	MDH ENGINEERED SOLUTIONS
SUPERVISOR:	A. SMORSCHOK, P.Geol.		
CONTRACTOR:	ALL SERVICE DRILLING INC.	APPROVED BY:	M. COHEN, P.Geol., MBA
OPERATOR:	T. ASSETS	DRAWN BY:	C. SCHMIDT
TYPE OF DRILL RIG:	ACKER SOIL–MAX	PROJECT No.	A2010–1250009
DATE INSTALLED:	18–FEB–10	SCALE:	NOT TO SCALE — DATE: 12–MAR–10

ACADDWG: \\P:\Hebil, Keith\A2010–1250009 Piezometer Installation\2. Drafting\1. Boreholes\PS–A2010–06.dwg

APPENDIX C: AUTHENTICATION

AUTHENTICATION

Form: MEMS-APEGA-BS

The Engineering, Geosciences Professions Act (the Act) of Alberta requires that engineering, geological or geophysical work be authenticated by the application of:

- The professional seal or stamp of the individual member responsible for preparing the work; **and**
- The corporate permit number or stamp of the company employing the responsible individual member.

This section identifies those portions of this report that fall under the Act and will be authenticated in compliance with the Act.

The report entitled "Drawdown Adjacent to Mining Pits South Extension Wetlands In Coal Valley Area" dated May, 2013 meets the definition of geology within the Act and are authenticated with APEGA Permit to Practice Number P07002 and the professional stamp applied below:

Millennium EMS Solutions Ltd. provides the same level of quality assurance to our clients throughout this report.