17

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

VOLUME I	SUMMARY
VOLUME II	GEOLOGY AND COAL QUALITY
VOLUME III	MINE PLANNING
VOLUME IV	MINE SUPPORT FACILITIES
VOLUME V	MINE RECLAMATION AND ENVIRONMENTAL PROTECTION
VOLUME VI	CAPITAL AND OPERATING COSTS
APPENDIX A	STUDY ON THE APPLICATION OF BUCKET WHEEL EXCAVATORS FOR THE EXPLOITATION OF THE HAT CREEK PROJECT
APPENDIX B	HAT CREEK COAL BENEFICIATION

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

APPENDIX B

HAT CREEK COAL BENEFICIATION

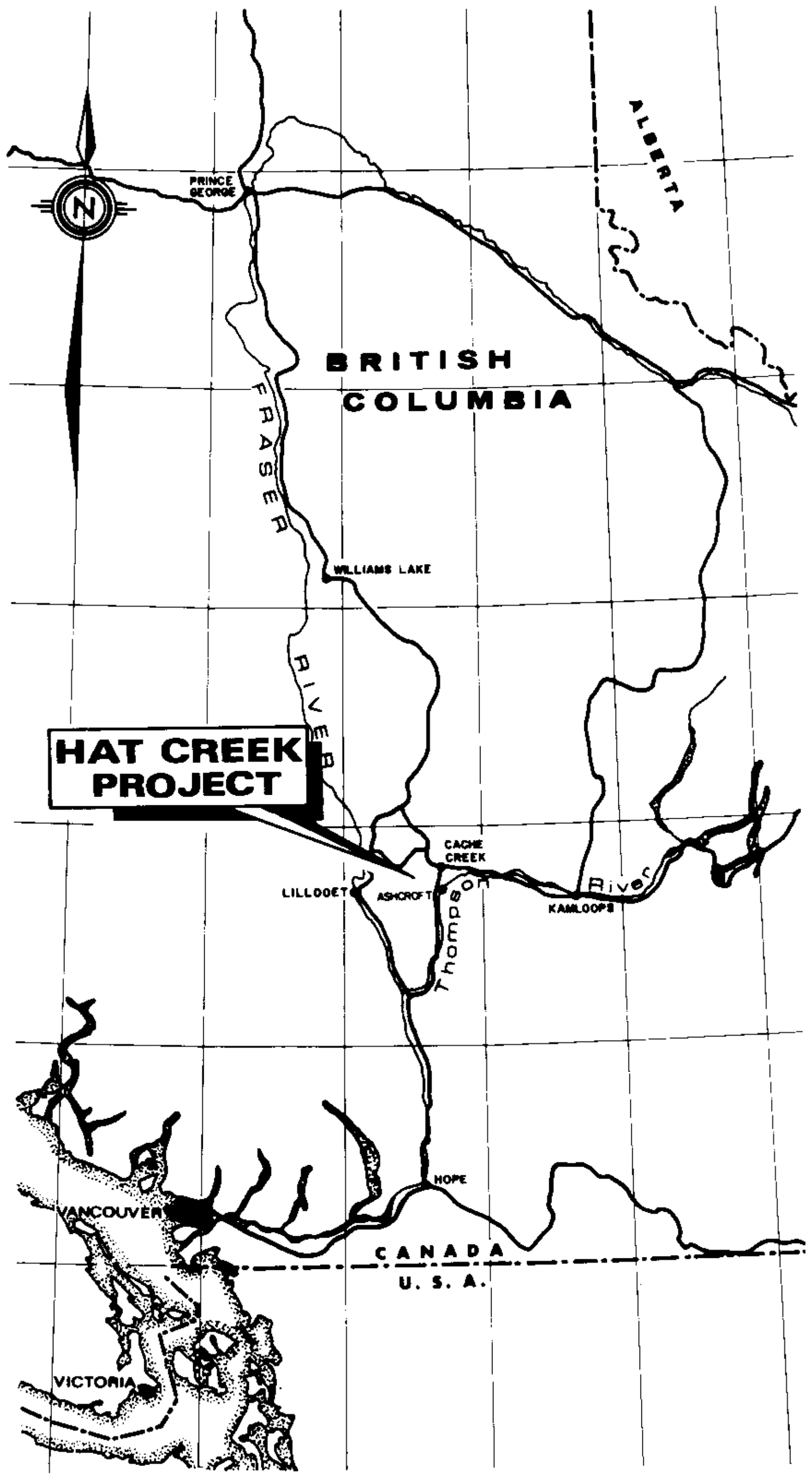
prepared for
British Columbia Hydro and Power Authority

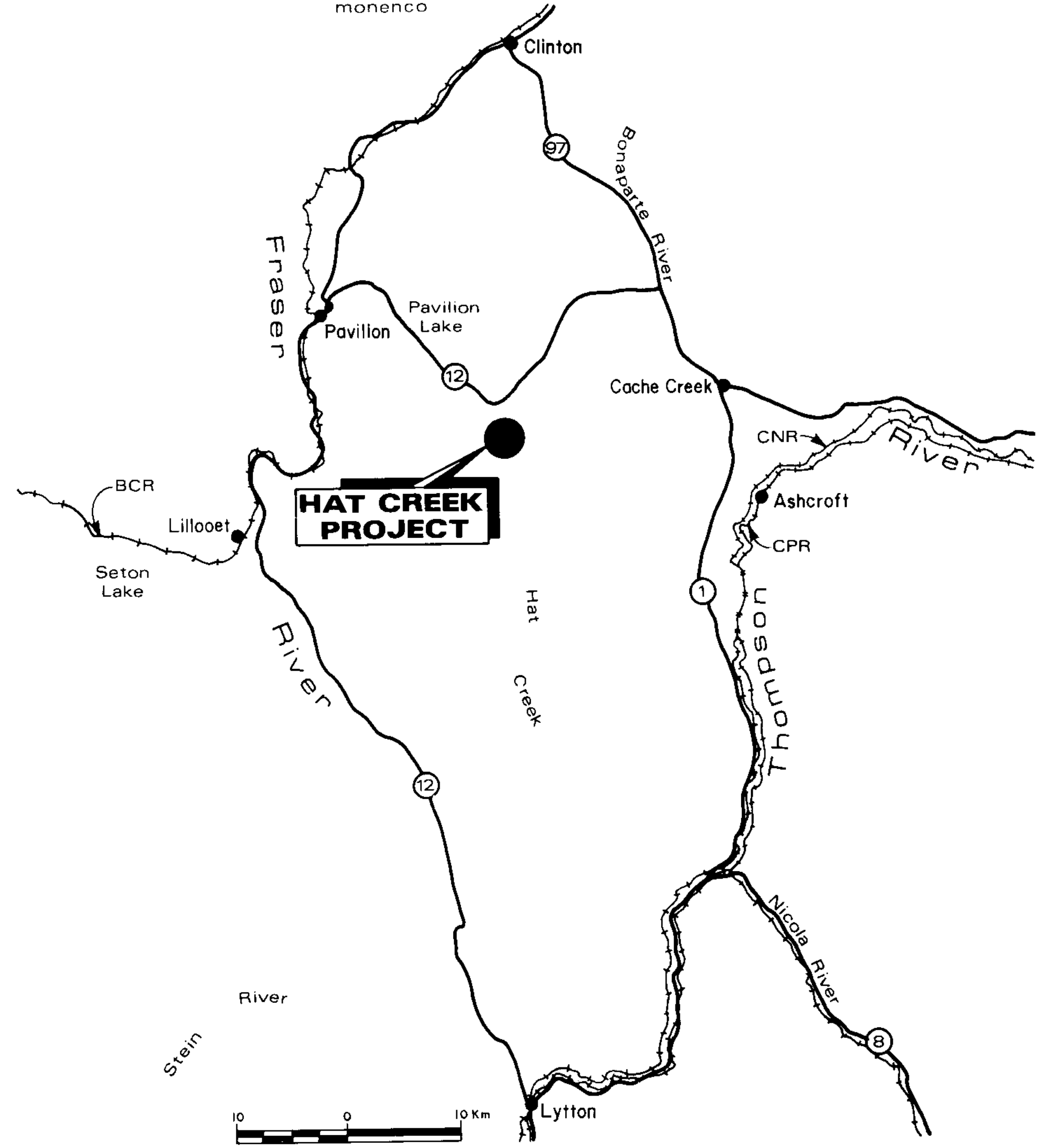
by

Simon-Carves of Canada Limited
Coal Preparation sub-consultants to the
Cominco-Monenco Joint Venture

1978

cominco-monenco joint venture





BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
PROJECT LOCATION

HAT CREEK
COAL BENEFICIATION

A Summary Report on
the Beneficiation Characteristics
of Hat Creek Coals
and the Potential Application
of Alternative Coal Preparation Plant Schemes
within the Requirements
of the Mining Feasibility Report

prepared for
British Columbia Hydro and Power Authority

by
Simon-Carves of Canada Limited
Coal Preparation Sub-Consultants

on behalf of

Cominco-Monenco Joint Venture

OCTOBER 1978

Simon-Carves of Canada Ltd.
2025 Sheppard Ave. East
Willowdale, Ontario M2J 1W2

SIMON-CARVES

APPENDIX B

HAT CREEK COAL BENEFICIATION

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (*continued*)

LIST OF TABLES

LIST OF FIGURES

SECTION 1

INTRODUCTION

1.1 BACKGROUND

Preliminary engineering studies related to the mining of Hat Creek coal for use in the generation of thermal power were undertaken for the British Columbia Hydro and Power Authority (BCHPA) between 1975 and 1977 by PD-NCB Consultants Limited (PD-NCB).

Conceptual studies of the thermal power station complex were undertaken by the Integ-Ebasco Joint Venture.

In 1976 BCHPA collected three samples. These were submitted to the Coal Science and Minerals Testing Division of Birtley Engineering (Canada) Limited (CSMT) for laboratory analyses and bulk wash tests. The three sets of raw and clean coal samples were used for a series of pilot-scale combustion tests by CANMET Energy Research Laboratories.

For the next stage of the investigations BCHPA invited proposals for preliminary engineering and final design for mining the No. 1 Deposit at Hat Creek to supply a 2000 MW generating station over a period of 35 years. Coal preparation facilities were included in the terms of reference of this invitation.

On 16 May, 1977, the Cominco-Monenco Joint Venture (C-MJV) was engaged for Phase I, Preliminary Engineering with Simon-Carves of Canada Limited (SCAN) as the nominated Coal Preparation Sub-consultant.

1.2 SCOPE OF REPORT

Throughout the studies SCAN representatives worked as a section of the C-MJV team, and were therefore subject to the Terms of Reference existing between BCHPA and C-MJV. The scope of work undertaken by SCAN was mutually arranged to make best use of the C-MJV and SCAN capabilities.

This report is specifically concerned with the design, costs and benefits of alternative coal cleaning plant schemes within the proposed Hat Creek mine complex. It is not concerned with that degree of coal quality control which can be achieved by mine planning, selective mining schemes or raw coal blending. Nor is it concerned with the techniques of coal handling, screening, crushing and blending which are necessary to form a complete scheme from mine to boiler plant. Contributions to these aspects of the study by SCAN are within the main C-MJV Report.

The overall purpose of these studies was to establish whether the inclusion of a beneficiation scheme would reduce the net cost of thermal power from the Hat Creek complex. The cost impact on the mine design is therefore reviewed in the C-MJV Report, and for the total Project by BCHPA.

1.3 BASIC DATA PROVIDED BY BCHPA

1. A Preliminary Fuel Specification, issue (2), dated 13 April 1977.

2. PD-NCB Reports Nos. 2 and 9.

3. 1976 CSMT "Report to B.C. Hydro and Power Authority on the Analysis and Beneficiation of Bulk Samples".

4. 1977 Bulk Sample Programme Results.

5. B.C. Hydro - Canmet Joint Research Project "Pilot Scale Preparation Studies with Hat Creek Coal" April 1978

1.4 ACKNOWLEDGEMENTS

We wish to acknowledge the assistance and co-operation of Mr. J.J. Fitzpatrick, Manager, Mining Department, BCHPA and members of his staff, particularly in the Bulk Sample Programme and 1977 Testwork.

The contributions to the study of Hat Creek coal beneficiation characteristics by Miss J. Picard, Manager, Western Research Laboratory, Department of Energy, Mines and Resources (EMR), and her staff are acknowledged as a major input to this report.

The assistance of the thermal dryer manufacturers and their clients in reviewing data and experience gained in drying and classifying low rank coals is also recognized and appreciated.

SECTION 2

SUMMARY

2.1 OBJECTIVES & RELATIONSHIP TO FUEL SPECIFICATIONS

The main objective of these coal beneficiation studies was to evaluate the contribution which a beneficiation plant might make to the production of an optimum power plant fuel from Open Pit Number 1.

The basis of boiler and power plant design was a Draft Fuel Specification with a "Normal Low Quality" coal (5900 Btu/lb) and a "Typical Quality" (6300 Btu/lb) for assessing boiler plant performance. These were in a range (5500 to 7300 Btu/lb at 20% moisture, equivalent to 6875 to 9125 Btu/lb on the dry basis) which, based on previous studies, assumed some of the lower grade coal in the deposit would be beneficiated to raise it to power plant quality.

Beneficiation to reduce ash content and raise the heating value was the prime consideration. Also assessed were the potential of beneficiation as a means of quality control, the effects on moisture content and coal handleability and the reduction of sulphur.

The coal beneficiation studies included conceptual design and costing of alternative beneficiation schemes. They were integrated into the mining feasibility studies programme and used the "Typical Quality" (6300 Btu/lb as received) as an initial target.

By March 1978 the studies indicated that a beneficiation plant was not financially attractive, and that the optimum power plant fuel should be achieved by planned selective mining and blending.

2.2 BENEFICIATION CHARACTERISTICS

221 TESTWORK OBJECTIVES

1. To extend the knowledge of coal washability characteristics and size consist data.

2. To obtain size consist data representative of "as mined" coal.

3. To examine the relationship between size consist and washability characteristics resulting from coal breakage and crushing. This was particularly necessary to validate the 1976 data which had not been obtained by normal mining methods.

4. To examine the breakdown of soft shale and clay materials in wet processing and evaluate the resultant tailings problems.

222 EVALUATION OF DATA

All Hat Creek coals examined have very difficult beneficiation characteristics:

(a) In addition to the normal shale partings and soft shale and clay partings in bands within the seams, there are also clay inclusions in the smallest of fissures of the coal. Thus, normal removal of free refuse leaves a relatively high ash product.

(b) The coarser size fractions contain coals of comparatively low ash, while the finer size fractions are all comparatively high in ash. This is the reverse of situations where conventional coal beneficiation techniques are most effective.

(c) Liberation of high ash fines by deliberate attrition prior to more conventional recovery of the clean coal product could result in a more useful degree of beneficiation. However, this would result in a formidable tailings dewatering and disposal problem.

Further evaluation of the data suggests that the deposit contains a single family of coals with a varying ash content due to the degree of high ash clay inclusions. It was therefore established that:-

1. There would be no benefits from cleaning the lower ash coals, which occur principally in the D Zone.

2. Even the most sophisticated beneficiation scheme could not, by itself, provide the required degree of quality control. A substantial degree of mine planning to produce determined ratios of D to A, B and C Zone coals at all times would be essential.

3. Any relatively useful degree of beneficiation of the higher ash coals would result in a relatively high loss of heating value to tailings and plant rejects. For example, halving the ash weight for a given heat input would result in loss of more than 10% of heating value.

4. Some 2.2% of the heating value of the resource is contained in the low grade coals. Recovery of a below average quality product, containing say, two thirds of this heating value, would be very expensive on the basis of present knowledge.

5. Total washing of the A, B and C Zone coals could effect a 20% reduction in sulphur content per unit calorific value of these coals, whilst the more practical partial washing would only achieve a reduction of 8%. Beneficiation would, therefore, not be the total answer to sulphur dioxide emission control.

6. A sophisticated facility for blending A, B and C Zone coals with D Zone coals would be necessary to achieve consistent product ash and sulphur contents.

7. Very large lagoons would be required to dispose of the tailings from wet cleaning. Lack of space and the environmental sensitivity of such lagoons suggest that mechanical dewatering must be used. A dewatering plant has therefore, been included in scheme costing, but it is regarded as at or

beyond current limits of technology.

8. Dry cleaning methods would not be effective on the very difficult Hat Creek coals.

2.3 BENEFICIATION SCHEMES

From the review of the beneficiation characteristics, preliminary mine plans and the potential of commercially available processes, six schemes were selected for further study. A conceptual flowsheet and preliminary layout drawings were produced for each scheme, together with budgetary capital and operating costs. Each scheme was drafted so that plant capacity could be adjusted to suit alternative raw coal input and/or product specifications within its process capability.

In this report, each scheme is reviewed on the common basis of providing a 1200 tonne per hour beneficiation plant. Table 2-1 below compares results and costs on the basis of treating the average mine product (calorific value 7327 Btu/lb, 36.3% ash dry basis) on the assumption that:

(a) all of the output from A, B and C Zones would be passed to the beneficiation plant

(b) the output from D Zone would by-pass the beneficiation plant and be blended into the final product.

The products obtained are also compared with the original Typical Fuel Specification.

Financial evaluation of these scheme capabilities and costs and their impact on the Mining and Power Plant studies has been undertaken by C-MJV and BCHPA.

TABLE 2-1

Summary of Beneficiation Schemes

Hat Creek Coal Beneficiation Report 1978

	Target Fuel Specification (BCHPA)	Raw Coal (C-MJV Mining Scheme)	Results and Costs of Processing C-MJV Raw Coal, A, B and C Zone coals (1000 MTPH) cleaned and blended with D Zone coal (741 MTPH) which does not need cleaning					
TREATMENT SCHEME			1	2	3	4	5	6
Coarse Coal (+13mm) Fine Coal (-13mm)			H.M. Bath W.O.C.	H.M. Bath None	Baum Jig None	None Dryer/ Classifier	W.O.C. W.O.C.	H.M. Bath Dryer/ Classifier
PRODUCT - Dry Basis Analysis								
Calorific Value, Btu/lb	7875	7327	9043	7882	7853	7683	9136	8333
% Ash	33.7	36.3	24.5	32.5	32.7	33.9	23.8	29.4
% Sulphur	0.45	0.48	0.39	0.47	0.47	0.45	0.39	0.43
lb Ash per 10^6 Btu	42.8	49.5	27.1	41.2	41.6	44.1	26.1	35.3
lb Sulphur per 10^6 Btu	0.57	0.66	0.43	0.60	0.60	0.59	0.43	0.52
- As Received Analysis								
Calorific Value, Btu/lb	6300	5495	6686	5891	5870	5796	6693	6266
% Ash	27.0	27.3	18.1	24.3	24.4	25.6	17.5	22.4
% Moisture	20.0	25.0	26.1	25.3	25.3	24.6	26.7	24.8
Yield % Weight (as received)	-	Base Case	75.0	91.1	90.5	91.0	73.0	82.1
Yield Btu %	-		91.2	97.6	96.6	96.0	88.9	93.6
Degree of Beneficiation	-		1.83	1.20	1.19	1.13	1.90	1.39
MTPH of Dewatered Tailings for Disposal		0	365	83	83	0	548	83
Capital Costs of Beneficiation and Tailings Plant $000,000's	-	0	32.7	19.2	16.0	6.3	*	25.5
Operating Costs for Total Average Product $ per tonne	-	0	1.10	0.45	0.38	0.24	*	0.76

* *Scheme 5, which is equivalent to the EMR Canmet proposal, has not been costed.* H.M. = Heavy Medium. W.O.C. = Water Only Cyclones.

2.4 CONCLUSION

The principal conclusion is that all Hat Creek samples show difficult beneficiation characteristics and thus there is no beneficiation process plant scheme which can be recommended for inclusion in the Hat Creek Project at this stage.

Further consideration of beneficiation should be pursued as operational experience is gained with respect to selective mining and actual production of low grade coals. Provision should be made in site layout plans for future beneficiation facilities.

SECTION 3

BENEFICIATION CHARACTERISTICS OF HAT CREEK COALS

3.1 GENERAL APPROACH

311 INTRODUCTION TO STUDY

Throughout the studies, Simon-Carves representatives worked, as a section of the Joint Venture Team, towards the total understanding of the coal deposit for its proposed utilization as feed to the Thermal Generating Plant. Thus this Report incorporates and interprets beneficiation studies initiated as part of the 1977 Bulk Sample Programme by the BCHPA.

This Report is specifically concerned with the advantages which might be realized by the incorporation into the total scheme of beneficiation plant processes.

The overall consideration is whether, by incorporating a beneficiation plant within the total scheme it is possible to present to the boiler plant a more acceptable fuel than could be achieved by blending raw coal. Against such advantages must be evaluated the beneficiation costs and the net utilization of the mine resources.

SCAN presented a number of interim reports on specific aspects and preliminary schemes during the period October 1977 to April 1978. These have now been finalized as supporting documents to this report.

312 DEFINITION OF TERMS

Keywords and phrases, which have particular meanings within coal preparation technology, used in this report are defined in the Glossary of Selected Terms: Section 7.2.

"Beneficiation" has been used throughout this study as representing a more meaningful definition of the objectives than the more frequently used terms "Coal Preparation" or "coal cleaning".

Because the prime interests have been the supply of heat to the boiler and ash disposal requirements, two terms have become common parlance during these studies, and are defined:-

(a) Btu (or Heating Value) Yield =

$$\% \text{ by weight yield of cleaning process} \times \frac{\text{Calorific Value of Cleaned Coal}}{\text{Calorific Value of Raw Coal}}$$

For example, if the % Btu Yield is 94%, then 6.38% more coal would have to be mined to provide the same total heat input to the generating plant.

(b) Degree of Beneficiation =

$$\frac{\% \text{ Ash Content of Raw Coal}}{\% \text{ Ash Content of Cleaned Coal}} \times \frac{\text{Calorific Value of Cleaned Coal}}{\text{Calorific Value of Raw Coal}}$$

A Degree of Beneficiation of 2 means that for a given heat input to the boiler plant the ash weight input is halved.

313 REVIEW OF EARLIER STUDIES

313.1 Requirement for Beneficiation

Analytical data from the geological drill cores had not indicated specific problems which would necessitate beneficiation. However, the variability of coal quality through the deposit showed that extensive product blending would be necessary.

The PD-NCB outline mining scheme envisaged a cut-off grade of 4350 Btu/lb (dry basis) which would supply a 7875 Btu/lb (dry basis) average fuel to the boiler plant without beneficiation. This was adopted as the target coal for boiler plant performance assessment and mine design in the current studies. The PD-NCB Report envisaged quality control by:

(a) separate stockpiling of all the low grade coal for possible future use.

(b) varying the cut-off grade according to the current performance.

(c) blending material from the low grade coal stockpile into the mine product when this is better than average quality.

313.2 1976 Beneficiation Testwork

Three bulk samples of Hat Creek coal were obtained by drilling a series of 36 inch diameter bucket auger holes. These three samples represented coals of different qualities: 5700, 7800 and 8700 Btu/lb (dry basis). A laboratory programme was drawn up and conducted by Coal Science and Minerals Testing at Calgary. The work was observed by representatives of PD-NCB and Integ-Ebasco, as well as BCHPA. It included size consist and washability tests, together with a test wash of each sample.

Standard washability test procedures were found to be inadequate, the problems resulted from the sub-bituminous nature of the coals and their clay content. CSMT modified procedures and obtained apparently acceptable results.

The normal washability test procedure is to perform the whole series of float and sink operations on one sample, thus obtaining all the required specific gravity fractions. The Hat Creek coal samples degraded rapidly in the handling, wetting and drying of this procedure. The modified procedure took nine (9) sub-samples,subjecting each to one float and sink operation, and then calculating the required data for the individual fractions.

The test wash operations proved to be very troublesome, especially on the high ash (low calorific value) sample which contained a significant quantity of clay. CSMT discussed the results and concluded that the Hat Creek coals would be difficult to wash both in terms of the washability characteristics and the associated clay tailings problem.

Simon-Carves review of this report focussed concern on the fact that the yields of clean coal and tailings from the test washes did not agree with those which could be predicted from the analyses.

313.3 Evaluation of Beneficiation

There was little detail consideration of the principle advantage of cleaning, namely the reduction in boiler plant ash load.

The washability data obtained was not interpreted into a conceptual coal beneficiation process plant flowsheet and design. Thus the PD-NCB and Integ-Ebasco overview studies could not evaluate beneficiation.

It was recognized that when practical mining plans were drawn up in subsequent studies beneficiation may be necessary to achieve acceptable qualities during periods of mine life.

The three samples of prepared coals from the CSMT test washes were used along with samples of the raw coals for pilot scale burn tests conducted in the research boiler at the Canadian Combustion Research Laboratory. The principle recommendations relative to beneficiation were that consideration should be given to washing material below 6000 Btu/lb (dry basis) and that blending of this material into the mine product should not be considered without further study of handling problems.

314 OBJECTIVES AND STUDY PLAN

The objectives of this 1977-78 beneficiation study were:-

1. To extend and interpret the coal size consist and washability data to be representative of full scale mining. This was necessary to validate the 1976 testwork which had used auger samples.

2. To examine the costs and benefits associated with alternative methods of upgrading the Hat Creek coals. Beneficiation was to be considered in relation to its effects on:-

(a) calorific value and ash content
(b) smoothing out variations in coal quality
(c) control of sulphur content
(d) product size distribution, moisture and handling characteristics
(e) ultimate disposal of ash constituents
(f) resource utilization

These effects were to be considered together with the overall impact of beneficiation on the design and operation of the mine and powerplant. From this, the "initial washplant decision", i.e. whether or not to recommend a mine scheme which included a beneficiation plant, would be made.

3. To obtain all data necessary for the selection, preliminary design and costing of a complete process plant scheme to the detail required for this Phase I, Preliminary Engineering Study.

To achieve these objectives, the following plans were made at the commencement of the studies. (These included participation in the 1977 Bulk Sample Programme already arranged by BCHPA).

(a) Review literature, in particular, the CSMT Report and summarize the known coal characteristics.

(b) Computer Process the CSMT Washability Data to show the range of coal product qualities which could be obtained from the deposit. For this, it was assumed these samples were representative of the bulk of the deposit in basic characteristics.

(c) Provide for mine planning, product handling/blending and waste disposal purposes,preliminary estimates of yields and qualities which could be realized by beneficiation.

(d) Detail a Washability Testwork programme and work flowsheet for obtaining all practicable beneficiation data from the 1977 Bulk Sample Programme.

(e) Arrange and supervise this Washability Testwork Programme.

(f) Observe coal handling during mining, handling and test burn programmes, particularly the effects of clays present.

(g) Review proposed EMR Canmet Test Wash programme to permit correlation with 1977 Washability Tests.

(h) Review clay removal techniques.

(i) Review tailings disposal requirements, methods and possible lagoon sites.

(j) Review all commercially available beneficiation processes for applicability to Hat Creek coals, evaluating on the basis of 1976 and 1977 Testwork Data and provisional mine plans.

(k) Preliminary design and order of magnitude cost estimate of modular beneficiation plant scheme such that comparative costs could be developed for evaluation of alternative mine schemes.

(l) Preliminary design and order of magnitude cost estimate of alternative beneficiation plant schemes which merited consideration.

(m) Present alternative fuel product specifications.

(n) Select Beneficiation Scheme to be included in Mining Feasibility Report. Develop preliminary design and costs to requirements of this report. Integrate with raw coal handling and product blending schemes. Define ancillary service requirements.

Burn tests were conducted at Battle River power station near Forestburg, Alberta, during August 1977 on coal from Trench A which contained a significant amount of free clay. This test concluded that this relatively low quality Hat Creek coal did not present major coal handling problems, and pulverizers performed well. It was thus decided that removal of clays (item h above) was not to be considered separately from the overall question of reduction of ash content.

In March 1978 the "initial washplant decision" was that the mining scheme would not include a beneficiation plant at this stage, and therefore the more detailed design and cost estimate (item n above) was not required.

315 1977 TESTWORK PROGRAMME

In order to determine how Hat Creek coals would behave in various beneficiation processes the following testwork was performed:-

(a) Size Consist Tests related to the proposed mining and handling systems, and the size degradation characteristics under dry handling and wet washing conditions.

(b) Float and Sink Tests including associated analyses, otherwise called Washability Tests.

(c) Test Washing : to validate the above data and its interpretation in respect of selected processes, and to observe associated phenomena, e.g. effluent production.

The laboratory samples were obtained as part of the Bulk Sample Programme. They were separately mined and handled in order that exact correlation with coal zone structure could be obtained. Two samples (X & Y) were taken from Trench A, and one (Z) from Trench B. They were then passed through the Bradford Breaker which gave a raw coal of 150mm top size which was judged to be a realistic plant feed.

Sampling was supervised by representatives of Simon-Carves and the Laboratory Work was undertaken by Warnock-Hersey Professional Services Ltd. at Calgary. Dry and wet sizing in addition to the +¼" washability data was reported by Warnock-Hersey in November 1977.

The modified float and sink procedure developed by CSMT in 1976 was adopted. This time five representative splits were taken of each sub-sample for testing at individual specific gravities. The use of this procedure on more adequately sized samples gave good results.

Sulphur values were determined for all size and specific gravity fractions.

To investigate the breakdown of coal shale and clay materials under the conditions of wet processing (which had given anomalous results in the 1976 testwork) a new Wet Attrition Procedure was introduced. The equipment was manufactured to the recommendations of the Australian Standard, and advice was obtained from the Australian laboratories responsible for its development on the application to Hat Creek coals.

Some difficulties were experienced : these are discussed at some length in the February, 1978 Report. Figure 3-1 shows the laboratory work flowsheet as ultimately used.

The sample for the EMR Canmet Test Wash at the Edmonton Pilot Plant was taken from two sections immediately parallel to the X and Y samples. This has permitted direct correlation between the washability and size consist testwork, and the test wash results.

Table 3-1 summarizes the scope of the 1976 and 1977 Beneficiation Testwork. When the 1977 programme was drawn up Trench A was believed to be in a representative area of Zone A. Subsequent geological work has indicated this to be in Zone B. It is therefore, of concern that only one bulk sample (C) has been obtained of the Zone A coal, and this sample is of unusually low ash content for this Zone.

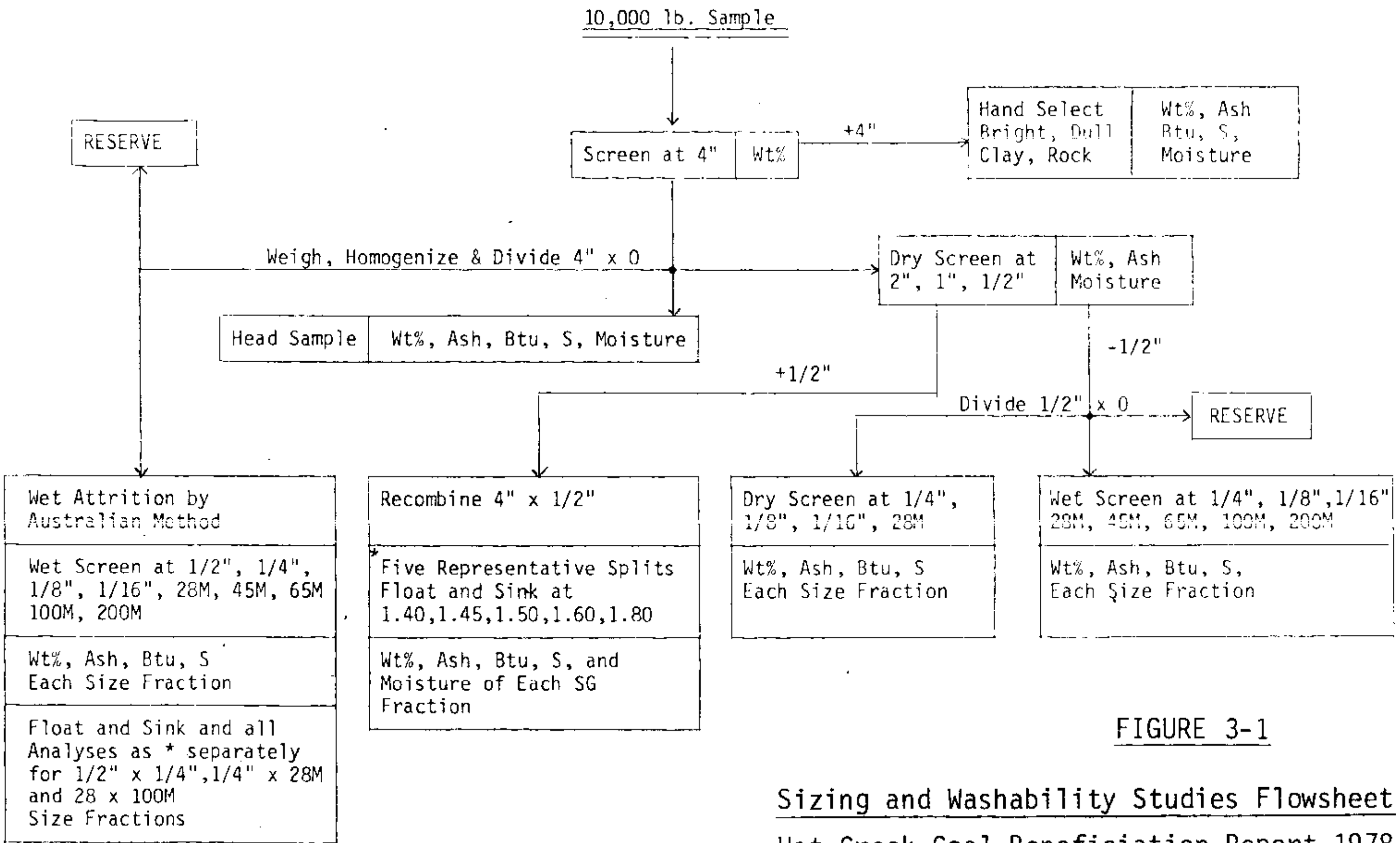


FIGURE 3-1

Sizing and Washability Studies Flowsheet

Hat Creek Coal Beneficiation Report 1978

TABLE 3-1
Summary of Beneficiation Testwork Samples
Hat Creek Coal Beneficiation Report 1978

Zone	B	B	A	B		D
Place				Trench A		Trench B
Sample	A	B	C	X	Y	Z
Year		1976		1977		1977
Method of Obtaining Sample		Auger		Backhoe		Front End Loader
				Bradford Breaker (essentially -4") at site		
Laboratory		CSMT		Warnock - Hersey		
Size Reduction		Crushing -2"		None for main tests		
				Wet Attrition Tests		
Test Washes		CSMT		EMR		none
Plant	HM Cyclones 3/4"x28M WO Cyclones 28 x 65M			WO Cyclones 3/8"x100M		
No. of Runs	1	1	1	8 (for combined) (X & Y sample)		
Effluent Studies		Toxicity		Flocculation		

3.2 SIZE CONSIST

321 SIGNIFICANCE OF SIZE CONSIST

Western Canadian coals are known to be highly friable. Size consist is the most critical data for coal beneficiation plant design.

Firstly, most beneficiation processes have a limited size range within which they are effective. A wrong estimate of size consist can therefore lead to overdesign of one part of a scheme, and severe overloading of another.

Secondly, beneficiation costs are inversely proportional to the particle size. Coarse coal cleaning is more efficient.

Size consist is also a critical factor in the coal quality for a boiler plant. A finer coal will hold more surface moisture, as a result, for example, of wet processing or adverse storage conditions. Thus, a finer coal is more difficult to handle on account of its moisture content as well as its actual particle size. The preferred mine product thus has a top size of 50mm to give good handleability characteristics, even though it has to be milled to below 0.075mm at the boiler.

Some coals liberate high ash material on crushing, and thus a higher degree of beneficiation can be obtained at a given yield value. However, washed coals of less than 20mm top size are very likely to give handleability problems. In the Hat Creek climate, this will include freezing.

Coal does not break in a totally unpredictable manner, for example the Rosin-Rammler equation has been used in this section of the study. However, the nature of the coal and its seam structure determine practical limits to particle sizing. Thus determination of the "as mined" raw coal size consist must be supplemented by investigation of how it will degrade either by voluntary crushing or involuntary particle breakage in various process operations.(see Section 7.4)

322 SIZE CONSIST OF RAW COAL

322.1 1976 Testwork

The 1976 Testwork was questionable since the samples were obtained by 3 ft. diameter augers. These were suspected of containing more fine coal than would be produced from full scale mining. The Wash Test results did not correlate with the data obtained by testing the crushed 3/4" x 0 feed. The -28mesh fines content of the total reconstituted product was in the range 21.4 to 39.9% compared with raw coal analyses in the range 2.7 to 19.4%. The associated clay material had broken down in wet processing. It was not possible to identify the degree to which this was affected by:-

(a) Method of obtaining samples
(b) Crushing of raw coal to -3/4"
(c) Attrition in the wet washing processes
(d) Feeding unacceptable clay material to washing process.

As a result of these factors, it was impossible to make any realistic estimates of raw coal or product size consist from this testwork.

322.2 1977 Bulk Sample Mining Programme

Careful attention was paid to the Trench A and B Mining Tests. As mined the coal was minus 300mm and upon subsequent handling and passage through the Bradford Breaker, became minus 200mm. The softer clay bands within the seams would probably preclude a substantially coarser "as mined" product from full scale mining operations and it would be normal practice to break in the mine at least to minus 300mm to facilitate subsequent handling.

Observations of the Bradford Breaker during the mining tests showed that the Trench A product contained between 15 and 20% +50mm and the Trench B product contained 10% +50mm. Two further important observations were made at this stage:-

Figure 3-2: Slope of the Rosin-Rammler size consist graphs similar to those reported in the 1976 Testwork.

Figure 3-3 Similar progression of higher ash contents in finer size fractions to the 1976 Testwork.

It was concluded that the 1976 Washability Test Data would probably be valid information for raw coal, after allowing for the change in size consist caused by the auger mining and subsequent crushing. This was confirmed : see paragraph 322.3.

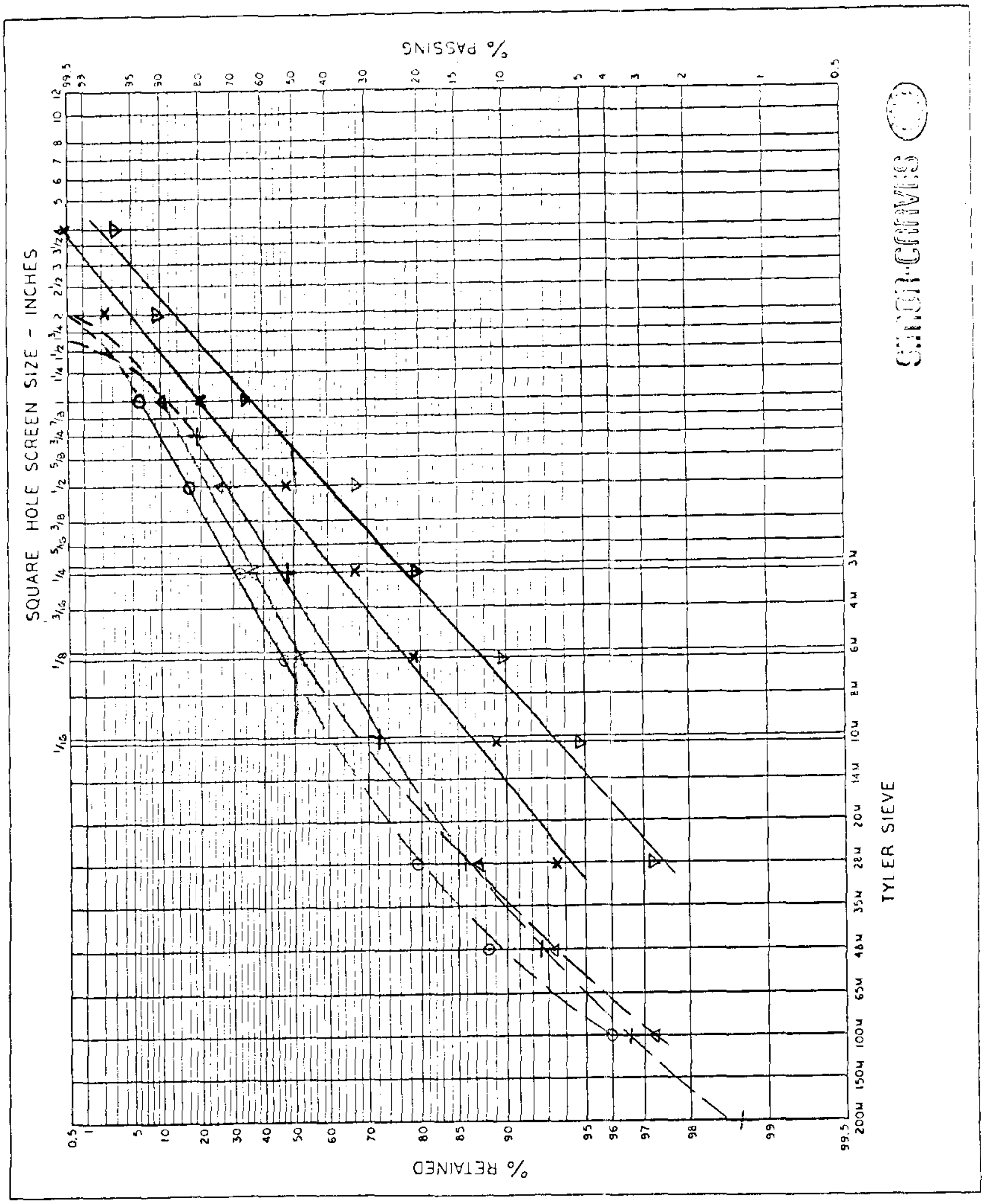
The X and Y samples from Trench A were taken after the main mining operation had been completed in order that they and the sample for the EMR Wash Test could be from immediately adjacent cuts. The report "Washability Testwork of 1977 Bulk Samples" shows only some 5% +50mm as compared with 15 to 20% reported above for normal operation. Limitations were observed in the Backhoe machine used, but since the sample had not been designed to be truly representative for the +50mm material, no change in method was made.

The size consist tests performed showed significant differences between dry and wet screening methods, and there is evidence of poor repeatability. Table 3-2 summarizes the size consist data. A wide range of values is observed in both the 1976 and 1977 testwork.

322.3 Predicted Raw Coal and Product Size Consist

All available raw coal size consist data has been plotted by the Rosin-Rammler method and used to obtain the anticipated average values given in Table 3-3.

The beneficiation schemes in Section 5 were designed to accept the wide variations in size consist observed. After allowing for breakage in raw coal handling and screening the average value for the basis of design and evaluation of alternative beneficiation schemes assumed that nominal screening at 13mm would give 50% by weight to coarse coal processing and 50% to fine coal processing.



⊙ _ _ _ _ _ _ _ C Sample 1976 Crushed -2", Dry Screened
△ _ _ _ _ _ _ A+B Samples 1976 Crushed -2", Dry Screened (Average)
-┼- _ _ _ _ _ _ X+Y Samples 1977 Undersize from Breaker 1-5/8" after transport, EMR, Wet Screened
✕ _ _ _ _ _ _ X+Y Samples 1977, Reconstituted after Breaker, Dry Screened (Average)
▽ _ _ _ _ _ _ _ Z Sample 1977, Reconstituted after Breaker, Dry Screened

FIGURE 3-2

Rosin-Rammler Graphs for Raw Coals

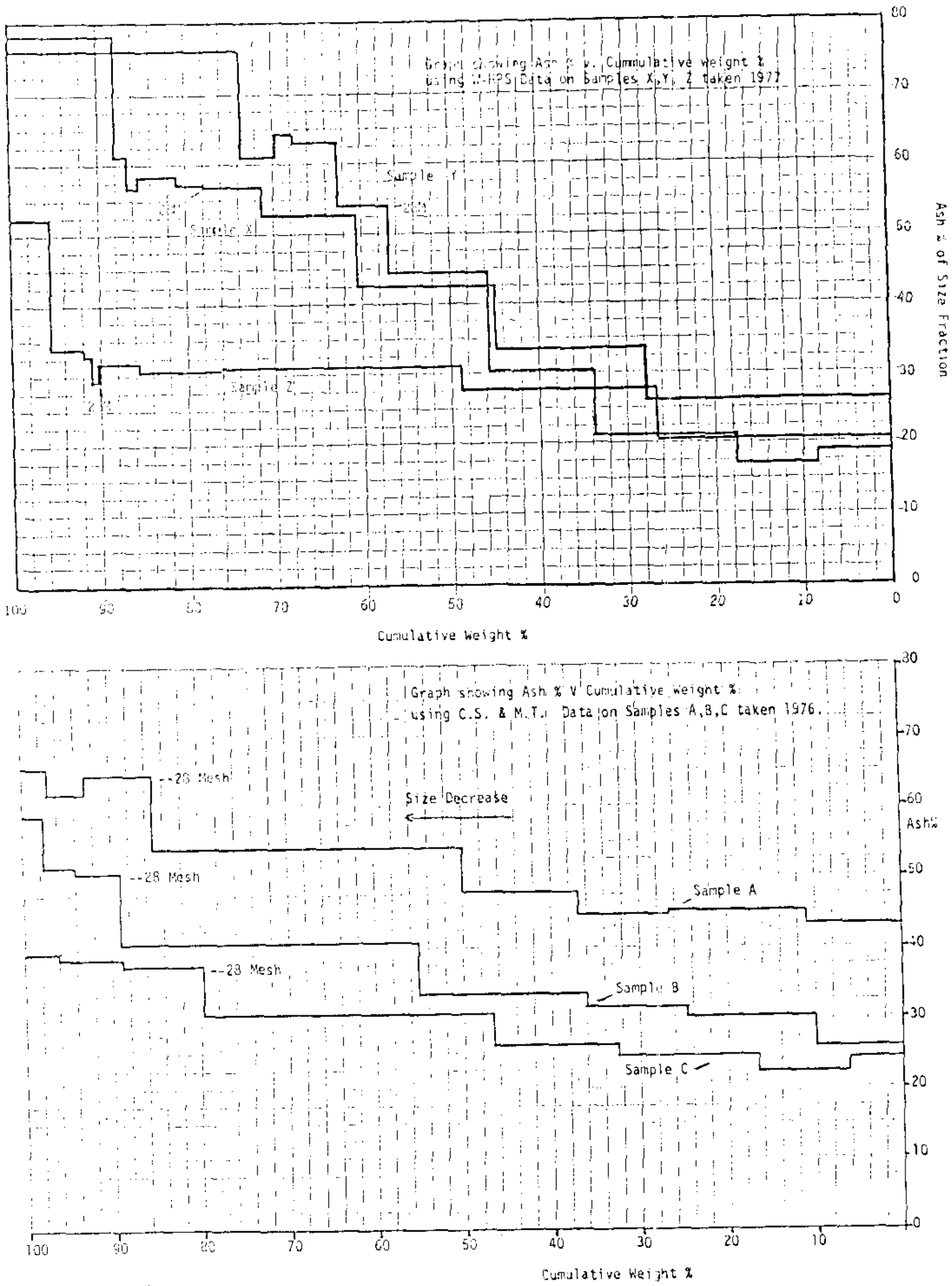


FIGURE 3-3

Size Consist and Ash Content

TABLE 3-2

Size Consist by Alternative Methods Compared With Reconstituted Products from Wash Tests
Hat Creek Coal Beneficiation Report 1978

Sample	(ALL FIGURES DRY BASIS) Test	Head Ash %	+1/4" Wt.%	+28mesh Wt.%	28mesh x 0 Wt.%	45mesh x 0 Wt.%	65mesh x 0 Wt.%	100mesh x 0 Wt.%
A	Wash Test	50.5	-	60.1	39.9		22.9	
	Dry Screening (2" x 0)	51.2	36.5	85.6	14.4	7.5		2.9
X + Y (Avg.)	Dry Screening (4" x 0)	43.4	66.6	93.5	6.5			
	Wet Screening (4" x 0)	43.4	59.1	78.1	21.9	20.8	18.0	15.3
	Wet Attrition (4" x 0)	44.9	31.4	67.2	32.8	28.2	23.4	22.0
X + Y at EMR	Dry Screening (1-5/8" x 0)	42.8	47.5	86.1	13.9	7.5		3.4
	Wet Screening (1-5/8" x 0)	42.4	44.8	79.0	21.0	15.3		11.3
	Wet Screening (3/8" x 0)	40.6	-	69.0	31.0			15.7
	Wash Test (3/8" x 0)	39.8	-	55.0	45.0	31.2		23.6
B	Wash Test (3/4" x 0)	34.6	-	78.6	21.4		8.5	
	Dry Screening (2" x 0)	36.3	36.5	88.8	11.2	6.0		2.5
C	Wash Test (3/4" x 0)	27.7	-	72.1	27.9		12.6	
	Dry Screening (2" x 0)	29.1	32.3	79.7	20.3	11.6		4.0
Z	Dry Screening (4" x 0)	27.7	79.8	97.3	2.7			
	Wet Screening (4" x 0)	27.7	82.5	87.2	12.8	11.6	9.3	7.0
	Wet Attrition (4" x 0)	28.7	48.9	90.1	9.9	8.7	8.1	8.0

TABLE 3-3

Size Consist of Raw Coal Before and After Crushing

	(1) Raw Coal from Mine Breaker	(2) Fresh Raw Coal Crushed to -50mm	(3) As Delivered to Thermal Plant	(4) After Storage
Effective top size (mm)	200	50	50	50
Size (mm)		% by weight		
+50mm	15	-	-	-
50 - 25	18	13	10	7
25 - 13	26	19	16	15
13 - 6	15	18	17	16
6 - 3	10	15	15	15
3 - 1.5	7	10	13	10
1.5 - 0.6	4	14	14	12
0.6 - 0	5	11	15	25
Total	100	100	100	100

These predicted average size consists have been obtained by consideration of the Rosin-Rammler graphs for all the 1976 and 1977 samples based on dry screening.

(1) Equivalent to feed to conventional beneficiation scheme

(2) Equivalent to feed to C-MJV product blending scheme, water only cyclone washery, etc.

(3) As above plus effects of blending, stockpiling and reclaim

(4) Estimate : as above but subjected to weathering/long term storage.

323 DEGRADATION BY WET ATTRITION

These results are also summarized in Table 3-2.

During the laboratory work, there were some doubts regarding the high fines contents determined for the X and Y samples by wet screening and by the wet attrition tests. Similarly there was a problem with the Z sample result which showed less -28mesh material after wet attrition than by the preceeding wet screening test. The source of these problems was the inadequacy of the wet screening equipment available. Thus a sufficient number of tests was not performed to establish repeatability.

However, the X and Y results now appear to be fully justified by the reconstituted products from the EMR Pilot Scale test washes, and comparison with the 1976 CSMT test washes. (This is discussed further in paragraph 332.2).

There is a significant increase in fines production as a result of breakdown in water. Visual observations during the wet attrition tests confirmed that this breakdown affected not only the obvious clay/shale bands, but that the apparently good coal was degraded by "leaching" clay from the fissures.

3.3 CLEANING

331 OBJECTIVES

331.1 General

In their March 1977 Draft Report No. 9, PD-NCB did not include any cleaning plant proposals, but concluded:-

"On balance, it is considered that cleaning is to be avoided if an acceptable boiler design can be produced to burn the untreated, but blended, coal.

Blending does not, of course, change the average quality, only the variance. Beneficiation (or cleaning) is concerned with improving the average quality to a desired value or range of values".

The reasoning behind this statement, which is commonly applied to mine mouth generating stations, is that most materials within and adjacent to coal seams have some heating value, therefore any beneficiation will involve some loss. Process plant beneficiation is however, generally more efficient than any selective mining.

The primary reason for cleaning many thermal coals is quality control: but in such overall economic evaluations there are two important factors which do not apply at Hat Creek, namely:-

(a) Beneficiation becomes economic as transport costs increase.

(b) Where available coal qualities have deteriorated it has been found economic to purchase beneficiated coals, rather than refurbish or downrate an existing generating plant.

The ultimate objective is the most economic overall operation.

331.2 Reduction of Ash Content

On a standard moisture basis there is a straight line correlation of ash content with calorific value for a specified coal. The regression for coals included in the present mine plans is:-

Dry Basis Calorific Value, Btu/lb = 12,580 - 144.6a
where a = % ash (dry basis)

Therefore, reduction in ash is synonymous with an increase in calorific value. (Note also paragraph 312).

One objective is to attain acceptable levels for these values. Acceptable must be defined in terms both of limiting values and those which give most economic overall operation. Beneficiation for Thermal Generation must be a reduction of ash content to an economically acceptable compromise level. This compromise involves the lowering of ash content sufficiently while minimizing the heat value lost to discard.

In overall economic appraisal of Hat Creek alternative schemes have to dispose of the same weight of ash. Only the proportions will vary between the following categories:-

(a) Mine Waste - Overburden & Major Partings
(b) Beneficiation Plant - Discard
(c) Beneficiation Plant - Tailings
(d) Boiler Plant - Bottom Ash
(e) Boiler Plant - Fly Ash

For example, simple cleaning to remove coarse shale particles may be economic since these are easier to dispose of than the equivalent weight of fly ash.

331.3 Moisture Content and Handleability

The majority of run of mine coals have a total moisture content only a few percentage points above their equilibrium moisture content. Exceptions to this occur where they are mined in water bearing strata or by hydraulic mining. Virtually all coal cleaning is done by wet processing. Although not strictly an objective, all considerations of coal cleaning must simultaneously evaluate the effects on product moisture content.

The calorific value of the power plant fuel is inversely proportional to the total moisture content. Also, wet beneficiation increases the surface moisture adversely affecting the handleability characteristics. Thermal drying to correct this increase is not economic unless long distance transport is involved.

The significance of size consist in relation to moisture content has been discussed in section 321. It can be simply deduced from this that increases in surface moisture content by wet cleaning (washing) can be negligeable if only coarse (say +13mm) coal is washed, but very significant if fines (say -6mm) are washed. For this reason the preferred product for many thermal generation schemes is "Part Washed Blended Smalls", i.e. only a coarse fraction is cleaned to obtain a product which has an acceptable compromise ratio of ash and surface moisture contents.

331.4 Quality Control

Run of mine coals are frequently of very variable quality. These variations may be in the coal quality itself (which is observed as a change in the coal washability) or in the proportions of partings and dilution contaminating the run of mine coal. Where the latter predominates,cleaning to remove the low heating value material effects a substantial degree of quality control.

331.5 Reduction of Specific Contaminants

Reduction of sulphur content is considered in section 3.4.

Reduction of other element concentrations is an objective in some situations, for example, where a high sodium content is found in associated waste materials. No specific requirements have been determined by the combustion studies of Hat Creek coals.

Removal of clay content was initially considered in this study.

332 WASHABILITY CHARACTERISTICS

332.1 Significance of Washability Data

A more detailed note on the significance and use of Washability Data is given in the Glossary, Section 7.3.

The float and sink analysis together with ash and other analyses of the specific gravity fractions, generally called Washability Data, determines the cleaning potential by gravimetric processes of a coal. It is used to calculate the theoretical yields and qualities, and those which can be achieved in practical process plants. It is essential, along with the size consist, in determining the coal beneficiation plant design.

332.2 Cleaning Potential

The evaluation of cleaning potential of a coal requires the simultaneous consideration of the size consist/ash content of size fractions and washability data/ash content of specific gravity fractions. The size samples of Hat Creek coals tested all show closely related overall characteristics:-

- (a) difficult coals to wash
- (b) better coal in the coarser size fractions
- (c) almost negligible quantities of 1.40 sp.gr. floats in the 28 x 100mesh size fraction
- (d) increased high gravity material content in the finer size fractions.

The washability characteristics could hardly be more difficult overall. Assuming that the requirement is for a simple process to remove the bulk of the higher ash material and thus maximize the yield, difficulty may be assessed on the basis of the quantity of material in the 1.60 to 1.80 specific gravity fractions. This gives a range from "moderately difficult" for some of the coarser coals to "exceedingly difficult" for some of the finer, dirtier raw coal fractions.

For each sample, the finer size fractions have a higher total ash content. It derives primarily from the fact that the associated shales and clays are softer than the coals. It is the reverse of the situation where the frequently employed "Part Washed Blended Smalls" scheme is most effective.

Secondly, the finer size fractions have more difficult washability characteristics. This alone identifies Hat Creek as unusual if not unique. This derives from the fact that in addition to the normal shale (and clay) partings, there are clays in even the most minute fissures of the coal particle structure. This has been found even in the cleaner coals (eg. D Zone).

The proportion of the ash content which occurs as a normal partings material is in fact unusually low.

A unique correlation has been obtained for these six sets of washability data. (This has been discussed in detail in the report on Beneficiation of Low Grade Coals). For example the washability curve for a specific size fraction (eg. 2" x 1") with a 35% ash content from one set was found to be essentially similar to that of the 35% ash content size fraction (eg. ¼" x 28mesh) of another set.

Thus variations in the raw coals are due to inclusions in the coal particles and not to variations in the partings content. Quality control by cleaning would thus be ineffective. This is consistent with the survey of the float and sink data from the geological drill cores undertaken by BCHPA which failed to find any correlation between the sinks content and raw coal ash content, either overall or within coal zones.

Table 3-4 shows the theoretical cleaning potential of the Hat Creek samples calculated from the washability and size consist data. The family relationship between the Hat Creek samples is evident from these results. For comparison, data is also given for two "typical" thermal coals with "normal" washability but similar size consist characteristics.

When using realistic cut points, a low degree of beneficiation is achieved, yet the levels of resource utilization achieved (i.e. % Btu yield) are also low: probably unacceptably low for a mine-mouth plant. Further note that the degree of beneficiation is lower for the cleaner raw coals.

TABLE 3-4

Theoretical Beneficiation Potential of Hat Creek Coals with Typical Coals Not Having Clay Inclusions

Hat Creek Coal Beneficiation Report 1978

	Hat Creek Coal Samples					Typical Sub-Bituminous Coal with Soft Shale and Clay Partings	Typical High Volatile Bituminous Coal with Firm Shale and No Clay
	A	X + Y	B	C	Z		
Raw Coal							
Calorific Value	5176	6304	7331	8372	8575	7800	9939
Ash Content	51.2	43.4	36.3	29.1	27.7	34.8	30.7
Product from Partial Washing (+13mm separated at 1.60 sp. gr. blended with -13mm untreated)							
Yield Wt. %	88.2	86.4	94.7	95.9	90.5	92.6	82.8
Calorific Value	5697	6998	7570	8627	9140	8007	11323
Ash Content %	47.6	38.6	34.7	27.3	23.8	33.0	21.0
Btu Yield %	97.1	95.9	97.8	98.8	96.5	95.1	94.3
Degree of Beneficiation	1.18	1.25	1.08	1.10	1.24	1.08	1.66
Product from Conventional Total Washing (+28mesh separated at 1.60 sp. gr., -28mesh rejected to tailings)							
Yield Wt. %	45.8	54.2	64.8	65.0	68.9	60.2	64.7
Calorific Value	8546	9485	9127	10035	9723	10698	13021
Ash Content %	27.9	21.4	23.9	17.6	19.8	10.5	9.2
Btu Yield %	80.1	81.6	80.7	77.9	78.1	82.6	84.8
Degree of Beneficiation	3.02	3.05	1.89	1.98	1.59	4.53	4.39
Product After Wet Attrition and Total Washing (+28mesh separated at 1.60 sp. gr., -28mesh rejected to tailings)							
Yield Wt. %		45.5			66.2		
Calorific Value		10129			10020		
Ash Content %		17.0			17.7		
Btu Yield		73.1			77.4		
Degree of Beneficiation		4.10			1.83		

NOTE:

1. These are theoretical results which do not take account of misplaced materials in processes. Due to the difficult washability characteristics of the Hat Creek coals results from practical plant schemes would be significantly poorer.
2. For the A, B and C samples, the untreated coal fraction is calculated as the ¼ x 0 material in the Partial Washing case to allow for the higher fines content resulting from the auger sampling method.

Cleaning may therefore, be worthwhile only for the poorer coals, say A, B and C Zones. The D Zone raw coals are, in fact, of similar quality to the cleaned coals from the other zones.

332.3 Modification by Crushing

Some coals "liberate ash" on crushing, because intermediate specific gravity fractions, termed "false middlings", release clean coal and shale particles. (Such coals are normally recognized by having less difficult washability characteristics in the finer size fractions. The reverse is the case for Hat Creek coals).

The 1976 CSMT testwork included three washability tests of each sample: at 4" x 0 (as obtained by auger mining), 2" x 0 (after crushing for main tests), and 3/4" x 0 (pilot samples for wash tests). There is no indication of a useful modification of the washability characteristics by comparison of these data sets.

The 1977 testwork by EMR included composite data of the delivered 1-5/8" x 0 sample, and of the 3/8" x 0 crushed feed to the test wash. Again there is a very significant lack of modification of the washability curves by this relatively fine crushing.

332.4 Modification by Wet Attrition

CSMT observed in 1976 that their test wash yield values were higher than the theoretical values as indicated by the float and sink analysis, and attributed this to particle breakdown liberating clays during the washing process. This was further investigated by the EMR Western Research Laboratory, and formed the basis for their 1977 Test Wash. The investigation of this phenomenon was the key feature of the 1977 beneficiation testwork as already discussed in paragraphs 315 and 323.

The washability characteristics of a given size fraction are not substantially changed by the wet attrition except for the reduction in the proportion of the high ash, (above 1.80 s.g fraction) of the coarser sizes. Taken overall, however, there is a significant change due to the liberation of the high ash clay materials. This increases the cleaning potential of the coal for example the X + Y data:

Samples X + Y	% Ash (d.b.)	Yield % Wt.
Raw Coal	43.4	100
After attrition and desliming at 28mesh	32.5	67.2
After subsequent washing at:		
1.60 sp.gr.	16.8	45.5
1.80 sp.gr.	22.1	54.0
(Theoretical values, no allowance for process errors)		

This is shown in more detail in Table 3-4. Against this must be evaluated the disadvantages of the finer size consist : it will be seen in the results summarized in Table 2-1 that the net yield of a given quality is not increased since the washing equipment efficiency at these finer sizes is lower. i.e. advantage cannot be taken of this liberation.

333 TEST WASH RESULTS

333.1 1976 CSMT Test Washes

Test Runs were conducted on three bulk samples A, B and C and were comprehensively reported. The primary objective of providing comparative samples for the EMR Canmet Burn Test was achieved. Results obtained are summarized in Table 3-5 below.

An Appendix gives data on the Analysis of Effluents from the above wash test programme, including bioassay tests which showed no damage to fish life.

Difficulties were encountered during test evaluation due to the absence of float and sink analysis of the products and the poor correlation of the results with raw coal washability data. However, the tests provided valuable information on the anticipated practical difficulties of washing Hat Creek coals, particularly with respect to the larger production of tailings than would be predicted by conventional interpretation of data.

333.2 1977 EMR Canmet Test Washes

Observations during the 1976 Tests indicated that a significant degree of beneficiation might be achieved by "washing" by wet extraction of dirt/clay fines rather than "wet gravimetric separation" of coal from shale/rock. This could be achieved by the process of attrition which occurs in a multi-stage washing cyclone plant, simultaneously with gravimetric separation.

A preliminary test together with examination of the 1976 data at the Western Research Laboratory of the EMR resulted in a joint BCHPA/EMR programme with the following objectives:-

> "Tests will be aimed at approximately 50% reduction of raw coal ash with minimum 90% recovery of Btu. Depending on raw coal quality as delivered we may... have to compromise one of the above...objectives... heat value recovery to take precedence provided that the clean coal could be kept at or below 25% ash. The objectives of flocculation studies will be to determine conditions for clay removal and disposal to allow maximum recovery and recirculation of process water to the wash plant.

This programme consisted of a number of test runs. An eighty ton sample was extracted from Trench A in two cuts from the strata immediately adjacent to the X and Y washability sample cuts. This was passed through the Bradford Breaker, and the 1-5/8" x 0 raw coal was further crushed to 3/8" x 0 to suit the EMR Pilot Plant.

Eight runs, each of approximately 10 tons, were performed together with appropriate samples and analyses.

Full float and sink analyses on feed and products were conducted on samples from one run. Samples of tailings were taken for flocculation trials, which are discussed later.

The results are summarized in Table 3-5.

They do not appear to meet the basic objective of halving the ash content with a Btu yield of not less than 90%. Data is presented to show that a plant designed specifically for Hat Creek coals could achieve this objective.

The results obtained agree closely with those predicted from the X + Y Washability Test Data, i.e. that incorporating the Wet Attrition Test results. This wash test has therefore demonstrated the usefulness of the wet attrition procedure. For example, wet screening showed only 15.3% -100mesh whilst the wet attrition test showed 22.0%. The reconstituted raw coal from Test Run 7 (the only one fully analyzed) showed 23.6% -100mesh. (See Table 3-2) Similarly, the composite washability curves from the wet attrition test are more similar to those of the re-constituted raw coal.

The EMR Report contains a comprehensive review of the properties of this Hat Creek sample and its behaviour in a washing plant circuit. It is fully supported by relevant analyses. A materials balance and flow diagram are given for a 1500 TPH scheme.

The product moisture contents achieved are a cause for concern. The clean coal after centrifuging has a surface moisture content of over 9% and would therefore, have difficult handleability characteristics. The pilot plant used a 10mm x 0 feed. The full scale plant proposed in EMR's Material Balance diagram would accept a 40mm x 0 feed. It included additional equipment to improve recovery of fine coal, and they predict a surface moisture content of under 7% (which may be acceptable).

TABLE 3-5

Summary of Test Wash Results

Hat Creek Coal Beneficiation Report 1978

	Raw Coal	Clean Coal	Discard	Tailings
Sample A (1976 - CSMT)				
%Wt.	100.0	51.2	25.9	22.9
%Ash (d.b.)	50.5	33.3	74.3	60.3
CV (d.b.)	5700	7952	2320	4290
%S	1.07	1.08		
% Moisture	21.1	32.4		
% Btu Yield =		73.0		
Degree of Beneficiation		2.11		
Sample B (1976 - CSMT)				
%Wt.	100.0	65.9	25.6	8.5
%Ash (d.b.)	34.6	21.9	72.5	47.8
CV (d.b.)	7793	9527	2513	6020
%S	0.94	0.67		
% Moisture	19.8	39.7		
% Btu Yield =		79.7		
Degree of Beneficiation		1.93		
Sample C (1976 - CSMT)				
%Wt.	100.0	76.9	10.5	12.6
%Ash (d.b.)	27.7	19.9	70.0	36.1
CV (d.b.)	8765	9897	2914	7600
%S	0.60	0.72		
% Moisture	19.5	32.1		
% Btu Yield =		86.2		
Degree of Beneficiation		1.57		
Sample X + Y (1977 - EMR - Average of 8 runs)				
%Wt.	100.0	57.5	23.6	18.9
%Ash (d.b.)	40.6	23.9	62.9	63.6
CV (d.b.)	6438	8753	3365	3268
%S				
% Moisture	23.4	29.6	39.0	
% Btu Yield =		78.2		
Degree of Beneficiation		2.31		

The coarse discard with some 20% surface moisture would be extremely difficult in disposal systems. Again allowance must be made for the coarser size consist. The proposed scheme materials balance predicts just under 10% surface moisture which would be acceptable. However, this is achieved at the expense of producing some 60% of the (dry basis) total discard as tailings.

The tailings cake moisture content is not reported: the pilot plant was not equipped for handling this product from the Hat Creek coals. The tailings flocculated well in the subsequent flocculant evaluation and operation with an essentially closed water circuit is envisaged. However, the compaction of the tailings was very poor: 20% solids in thickener underflow is forecast (30% is often a safe design figure, and 40% or more can frequently be achieved). This indicates that subsequent dewatering will be very difficult.

334 LOW GRADE COALS

No washability data has been obtained for the low grade coals, i.e. material between 3000 and 4000 Btu/lb calorific value. As part of the mining plan some 16 million tons would be extracted and separately stockpiled for other uses: they represent some 2.2% of the heating value of the resource.

The potential for cleaning coals between 2000 and 5000 Btu/lb was estimated in the report "Beneficiation of Low Grade Coals". Projections of the washability curves were made on the basis of the deposit containing a family of coals : the correlations obtained were good.

These considerations confirmed that the potential value of the material of less than 3000 Btu/lb is very low. The cut-off grade for waste was therefore set at 3000 Btu/lb.

It is estimated that from the 16 million tons of low grade coal, a theoretical yield of 7.2 million tons of washed coal could be produced of a 6000 Btu/lb quality. If blended with the proposed 7327 Btu/lb fuel, this would reduce average quality to 7300 Btu/lb. This could be corrected if necessary by washing some material above 4000 Btu/lb quality.

The practical problems of cleaning this coal could be formidable. Allowing for the need to maximize on the effects of wet attrition to achieve this cleaning, and for misplaced material in the washing processes, a reasonable estimate is that 6.0 million tons (dry basis) of tailings would be produced in recovering 6.0 million tons of usable coal.

The proposed mining plant will produce significant quantities of this material in years 4 to 15. The subject must, therefore, be actively investigated in the initial production period. A pilot plant on site would be essential to establish any cleaning plant designs.

3.4 REDUCTION OF SULPHUR CONTENT

341 SIGNIFICANCE OF SULPHUR CONTENT

Power plants must minimize emissions of sulphur dioxide. If the coal used has a high sulphur content it is necessary to employ flue gas desulphurization. This process is stated to be costly and troublesome.

Acceptable sulphur dioxide emission levels are often specified in terms of weight (lb) of sulphur dioxide per unit heating value (10^6 Btu) of the boiler plant fuel.

The Hat Creek raw coals are of low total sulphur content. (Average zone values corresponding to present mine plans are:-

A : 0.70%, B : 0.67%, C_1 : 0.48%, C_2 : 0.43%, D : 0.31%)

In view of the low heating value, particularly of the A Zone coals, it is necessary to assess sulphur content in terms of lb. of sulphur per 10^6 Btu.

342 SULPHUR REDUCTION POTENTIAL

The primary purpose of cleaning is normally to reduce ash content and increase calorific value. However, in some cases, cleaning specifically to reduce sulphur dioxide emissions can be a viable process. Note that even if the % sulphur content is not reduced, the increase in unit heating value by cleaning gives a net benefit. The sulphur beneficiation characteristics of Hat Creek coals have therefore been investigated.

Considerable work has been done by the U.S. Bureau of Mines on the potential for sulphur reduction of low rank coals by washing processes. This work has drawn attention to the possibility of significant sulphur reduction by crushing some raw coals prior to washing, and the advantages of cleaning such coals to a greater degree than necessary solely on the basis of ash content control. For other coals, the desired degree of cleaning would give totally unacceptable resource utilization.

Sulphur is present in the Hat Creek coals in all three possible forms:

Organic	0.35%(dry basis)
Pyritic	0.13%(dry basis)
Salts, eg. gypsum (calcium sulphate)	0.01%(dry basis)

Only pyritic material is high in specific gravity, so it is the only sulphur form which can be directly removed by cleaning processes. Organic sulphur is part of the coal substance, although predominately associated with the intermediate specific gravity fractions (1.45 - 1.65 range). Since these fractions contain a very high proportion of the heating value of Hat Creek coals, their rejection to reduce sulphur would be unacceptable. Washing does leach out salts into the washwater.

342.1 1976 Test Washes

The 1976 washability tests by CSMT did not include determination of the specific gravity increment sulphur values. Raw coal and clean coal product sulphur contents, were however, determined as part of the test washes, which are summarized in Table 3-6.

From samples A and B, the beneficiation in terms of lb. sulphur per 10^6 Btu in the product is significant. C sample would not require washing for ash reduction.

342.2 1977 Testwork

The 1977 washability tests included sulphur determinations from which the theoretical potential has been calculated as summarized in Table 3-6.

The sample used for the EMR test washes was equal proportions of X and Y. Their results agree closely with the above predictions:

> "A 25% dry basis ash product (9200 Btu/lb) can be produced from 40% dry basis ash material (6290 Btu/lb) with a Btu yield of 86%. A reduction of 20 to 25% lb sulphur dioxide per million Btu can be achieved".

TABLE 3-6

Summary of Sulphur Beneficiation Potential

Hat Creek Coal Beneficiation Report 1978

	1976 Test Washes			1977 Washability Data		
SAMPLE (All figures on dry basis)	A	B	C	X	Y	Z
Raw Coal:						
Btu/lb	5700	7793	8765	6301	6456	8800
% Ash	50.5	34.6	27.7	43.4	42.3	26.9
% sulphur	1.07	0.94	0.60	1.38	0.87	0.31
lb sulphur/10^6 Btu	1.88	1.21	0.68	2.19	1.35	0.35
Clean Coal Product:						
Weight % Yield	51.2	65.9	76.9	59.2	57.2	85.4
Btu/lb	8122	9421	9827	9030	9713	9190
Btu % Yield	73.0	79.7	86.2	84.8	86.1	89.2
% Ash	32.4	22.7	20.3	23.9	19.0	24.3
% sulphur	1.08	0.67	0.72	1.48	1.09	0.27
lb sulphur/10^6 Btu	1.33	0.71	0.73	1.64	1.12	0.29

For samples X and Y, the decrease in lb sulphur per 10^6 Btu is significant. The Z sample would not require washing for ash content.

Examination of the various size fractions has shown that the potential liberation of pyritic and organic sulphur by crushing the coal prior to washing is negligible.

On the basis of the very limited data, we have estimated that total washing could give a 20% reduction in the lb sulphur per 10^6 Btu for the A, B and C zone coals. Partial washing would effect only an 8% reduction.

The D zone coal is low in sulphur as well as ash content. There are therefore, no benefits to be obtained by cleaning D zone coal. The sulphur contents emphasize the advantages of planned mining and blending ratios for the A+B+C : D coals.

Beneficiation therefore does not appear to offer a total answer to any demands for sulphur dioxide emission controls when burning Hat Creek coals.

3.5 VALIDITY OF BENEFICIATION STUDIES

The present studies are based on six full sets of Washability Data and four pilot plant Test Washes. The areas from which the coals for these tests could be obtained were relatviely limited. Due to the nature of the deposit, it is not possible to take fully representative samples of the in situ coal. These limitations together with the following facts must be considered in the assessment of beneficiation potential:-

(a) For an integrated mine/power plant complex, it is normal practice to design the boiler to burn the as mined coal. Beneficiation has to be an operating or economic necessity to be justified in most cases.

(b) The six sets of data cover the range 25 to 50% ash which normally would be considered for beneficiation. Although this represents a wide range of washability data, the predictions all indicate a low Btu yield and a poor degree of beneficiation (see Table 3-4). Thus, justification of beneficiation costs is very unlikely.

(c) There is no indication that coals from other areas of the deposit will be more amenable to beneficiation. This is confirmed by limited float and sink analyses from the drill cores.

The above mentioned data indicates that this coal deposit has uniquely difficult beneficiation characteristics. As the mine develops the following situations may evolve:-

(a) Coals from some areas may be more amenable to beneficiation. A reduction in power plant operating costs could then be evaluated.

(b) Difficulties in segregation of major partings from coal bands. This could require revision of mining techniques, rather than a beneficiation plant.

(c) Inability of the blending system to handle run of mine variability.

(d) More useful beneficiation of lower grade coal than projected from present data. Further investigation of intensive wet attrition methods should be considered.

SECTION 4

BENEFICIATION PROCESSES AND ANCILLARY OPERATIONS

4.1 CLEANING PROCESSES

411 WET GRAVIMETRIC PROCESSES

A summary of the wet cleaning processes is as follows and outline of descriptions of these processes are contained in Section 5.1 of the Simon-Carves Alternative Beneficiation Report.

Process	Possible Size Range Cleaned	Relative Accuracy
Heavy Medium Bath	500mm x 6mm	very accurate
Heavy Medium Cyclone	50mm x 0.5mm	accurate
Baum Jig	150mm x 0.5mm	less accurate
Concentrating Tables	10mm x 0.25mm	less accurate
Water Only Washing Cyclone (large)	40mm x 0.5mm	less accurate
Water Only Washing Cyclone (small)	6mm x 0.1mm	less accurate

There are two basic groups of gravimetric wet cleaning processes: Dense Medium and Water Medium. Differences in accuracy between alternative water medium processes for a specific size range are relatively small and depend on factors such as plant loading rate. On selection between Dense Medium or Water Medium Processes, the final selection would be on the basis of practical plant and/or cost factors related to the specific duty.

Appendix II of the Simon-Carves Alternative Beneficiation Report sets out the large volume of detailed predictions of performance of the alternative washing processes. To keep this work to a reasonable level, the size ranges used for each of the several processes were selected to provide the basis of anticipated plant schemes. For example, direct comparison is not available between Baum Jigs and Water Only Washing Cyclones for some specific size ranges.

The difficult washability characteristics of the Hat Creek coals emphasize the differences in washing efficiency of the various processes. Practical Degrees of Beneficiation are therefore, significantly less than theoretical values.

For +13mm coals at a 95% Btu yield, typical values are:

Theoretical	-	2.0
Heavy Medium Bath	-	1.85
Baum Jig	-	1.75
Dry Cleaning	-	1.60 (see below)

Similarly, for 13 x 0.5mm coals at a 90% Btu yield, typical values are:

Theoretical	-	2.0
Heavy Medium Cyclone	-	1.8
Baum Jig/ Water Cyclones (two stage)	-	1.65

The Heavy Medium Bath is potentially the most useful process. Degradation of coal would be minimal due to its short time in the wet circuit. The bath design would have to take account of the presence of clays, as recommended by Griffiths. See Scheme 1.

The Baum Jig is frequently used for thermal plant fuels. However, degradation within the jig could preclude its use for washing Hat Creek coals without substantial testwork. See Scheme 3.

The CSMT Test Wash indicated problems due to clay particles coating the magnetite medium in the Heavy Medium Cyclone Circuit, and this process has been eliminated for this reason.

Water Only Washing Cyclones, which are now being successfully applied to several fine size consist western Canadian coals, are recognized as potentially the least troublesome process for the -13mm coals should they require washing. However, the operation of a commercial scale pilot plant to finalize design criteria for ancillary operations would be necessary. See Scheme 1.

Initial interpretation of Washability Data (eg. 1976 Testwork) indicated that Water Only Washing Cyclones would not be viable for the +13mm coals. In addition to excessive yield error, crushing the feed -40mm would be necessary thereby increasing product moisture. However, this has been considered further to take account of the modification of washability characteristics by wet attrition : see paragraph 332.4. Scheme 5, based on the EMR Canmet Wash Test shows results comparable with Scheme 1.

412 DRY CLEANING PROCESSES

Since Dry Cleaning does not produce a tailings, there would be a substantial advantage in its use for Hat Creek coals.

Air Tables, which went out of general use in the 1950's, require closely sized raw feed, eg. 50 x 25, 25 x 12, 12 x 6mm fractions, and are of small unit capacity. The plants are very complex in mechanical handling.

Air Jigs are being developed for 50 x 2mm coals, and may be an acceptable alternative for scalping out high gravity shale from thermal coal qualities.

All dry cleaning machines become inoperable on damp feeds and generally the degree of wetting necessary to meet current dust control requirements is unacceptable to the cleaning unit.

Efficiency is substantially less than that of wet cleaning as indicated by the degree of beneficiation tabulated in paragraph 411.

413 CLEANING BY DIFFERENTIAL CRUSHING

The Bradford Breaker is frequently used to reject hard shale whilst simultaneously breaking softer coal prior to processing. An experimental Breaker was installed at Hat Creek as part of the 1977 Bulk Sample Programme and the breaking characteristics tested. It was anticipated that wet clays would agglomerate and pass out as rejects. In fact all clays observed as separate bands were dry and broke very readily, concentrating the high ash clays in the -13mm size fractions. The Hat Creek coals are in fact harder than the associated shales.

The non-agglomerating characteristics of the Hat Creek clays also indicates that the Siebra crusher, used in the brown coal industry in Germany, would not be effective in segregating clays.

414 CLEANING BY FINES EXTRACTION

Since finer coal particles at Hat Creek are higher in ash content, and the quantity of fines is higher in dirtier coals, partial cleaning could be achieved by extracting fines.

414.1 Dry Screening

This is only practicable above 13mm with conventional screens or 6mm with special, eg. heated deck, screens. This is considered in detail in the report on Beneficiation of Low Grade Coals. The calorific value of the screen underflow would be too great for this method to be acceptable other than for the low grade coals.

414.2 Desliming

Desliming the higher ash raw coals at 0.5mm by sieve bends or 0.2mm by hydrocyclones would be an effective means of beneficiation (see para. 332.4), particularly if the raw coal were subjected to wet attrition. However, it would cause as great a tailings problem as a full wet cleaning process, and is considered only as part of such schemes.

414.3 Dry Size Classification

Dry extraction by dedusters of -0.5mm fines would not remove a sufficiently high proportion of the fines for it to be considered as a cleaning method.

The drying of -13mm coals and subsequent fines classification has been investigated as an alternative beneficiation scheme. Although the degree of cleaning is low, its overall benefit to product quality derives from the simultaneous redcution of ash and moisture: see Schemes 4 and 6.

415 CLAY EXTRACTION AND WET ATTRITION

At the commencement of the studies, the extraction of clays was recognized as a possible requirement to avoid problmes in the pulverizers at the Boiler Plant. Available methods were reviewed noting these were based on requirements to facilitate operation of conventional washing plants.

(a) Bradford Breaker as per Centralia.

(b) Simple washing may be effective for removal of clay fines adhering to coarser coal particles, as described above under desliming (para. 414.2). This would be supplemented by additional high pressure water sprays on the desliming screen.

(c) Tumbling Scrubbers are used where clays require more than water forces to effect their release. They consist essentially of a drum with lifters. Rate of tumbling, and water flows are adjusted, together with addition of steel tumbling media to break up clays but not coal. Tumbling is followed by desliming.

Practical observations during the mining and test wash programmes have shown that soft shale and clay will degrade in wet processing.

During the Wet Attrition Tests as part of the 1977 Washability Studies, it was observed also that all the coals degraded on tumbling in water giving effluent with very finely divided clay. The coal was "attacked" by water and clays contained within coal fissures "leached out".

Consequently, size consist and washability characteristics after wet attrition are substantially modified. This confirms that a process scheme which allows for this wet attrition would achieve a greater degree of beneficiation (for a given yield) than could be predicted from conventional data.

The EMR Canmet Wash Test's pumping/cyclone circuits effect substantial attrition and liberation. It has been shown that Water Only Cyclones could be used to provide an equivalent degree of cleaning to processes normally considered "more efficient".

A process scheme has been outlined based on these findings. However, doubts remain regarding the practicability of handling the large volumes of difficult tailings produced. A commercial scale pilot plant operation would be necessary prior to a major plant scheme. See Scheme 5.

416 MISCELLANEOUS CLEANING PROCESSES

Froth flotation would not be applicable to the -0.5mm fines due to the low rank of the Hat Creek coals.

Oil agglomeration is still at the development stage. Like froth flotation, it is dependent on surface properties identified with coal rank, but Australian research is giving encouraging results. We have summarized the current position for BCHPA. Reagent costs are too high for an on site thermal plant scheme and the tailings problem is no less than when using other fine coal washing processes.

4.2 DRYING

Mechancial dewatering of all washed coal products is taken as read.

Thermal drying has been investigated as an alternative means of beneficiation due to the high equilibrium moisture content of the coal.

The Roto-Louvre is the only method which can effectively remove equilibrium moisture, but its use is not economic when compared with designing the boiler plant to accept higher moisture coals.

The Fluidized Bed Dryer would reduce the surface moisture to permit effective extraction of the high ash fines, and an alternative beneficiation scheme has been costed based on this concept: Scheme 4. Performance data from a facility specifically designed to optimize on classification out of the dry fines was used to evaluate this process.

The assistance of Thermal Dryer plant manufacturers in this section of study is acknowledged.

4.3 MATERIALS HANDLING

431 BACKGROUND

As an introduction to the discussion of ancillary operations, it is necessary to identify the criteria which have governed proposed designs.

Philosophy regarding treatment of Hat Creek coals suggests that if a beneficiation plant is installed, then it will be required for partial or total treatment of the A, B and C Zone coals only. On average these represent over fifty percent of the total run of mine coal production.

Partial treatment may be of either coarser or finer coals. Note that in the run of mine coal handling, screening and crushing system, the Joint Venture have allowed for screening at a nominal 13mm. This size could be adjusted to give approximately equal feed rates to the coarse and fine coal treatment units.

432 RAW COAL HANDLING AND SCREENING

Peak production from the mine will be 3000 MTPH and maximum daily production has been assumed at 40,000 Tonnes represented by 20 operating hours at an average production of 2000 MTPH.

The average quantity of coal considered for beneficiation is 16,000 MTPD and maximum production rate of these A, B and C Zone coals is assumed as 2000 MTPH sized 200mm x 0.

Various alternate routings for these A, B and C Zone coals on arrival at the central Screening and Crushing Plant, are as follows:-

(a) Total Production is processed through the Screening and Crushing facility and delivered to the Product Blending System

(b) Total Production of 200mm x 0 raw coal by-passes the Screening and Crushing facility and is delivered to the stockpiling facility prior to beneficiation.

(c) The 200mmx 13mm portion of the production is delivered to the raw coal stockpiling facility for beneficiation and the 13mm x 0 portion is delivered to the Product Blending System. (Or vice-versa if the Dryer/Classifier Scheme is chosen).

From low grade coal production, the 13mm x 0 may be passed to the discard disposal conveyors.

433 RAW COAL STOCKPILING

Fluctuations in output rates makes it essential that raw coal be stockpiled to provide constant feed to the beneficiation plant. Stockpiling facilities required prior to the beneficiation plant must be designed to handle the variations between mine production and feed to the plant and not be considered as long term storage. It can be assumed that a beneficiation plant to handle up to 24,000 MTPD will employ the parameters of 20 operating hours at a constant feed of 1200 MTPH (3 x 400 MTPH Modules).

Given the design parameters of maximum mine production at 2000 MTPH the minimum storage requirements are 8,000 Tonnes. However, if 2 x 400 MTPH Modules were operational, the stockpile capacity required would be 12,000 Tonnes. Allowing for 50% extra, 18,000 Tonnes of storage capability would be provided prior to the beneficiation plant.

The design of stockpiling facilities is dependent upon the type of beneficiation plant that is selected but in event the plant is modular then reclaim facilities must be designed to allow for feeds to the separate modules.

434 PRODUCT BLENDING

Responsibility for the Product Blending Scheme is with C-MJV. Simon-Carves participated in preliminary discussions of the requirements. Blending of D coals with A, B and C Zone coals, whether beneficiated or not, will be particularly necessary for sulphur control.

435 SOLID DISCARD DISPOSAL

Operating conditions producing the greatest discard volume will be where total washing of low grade raw coals is applied. Each 100 MTPH of low grade coal feed will produce approximately 42 MTPH of discard with a surface moisture content of 11.6%.

A conventional total washing operation, eg. Scheme 1, would produce 25 MTPH of washery discard per 100 MTPH of raw coal feed with a surface moisture content estiamted at 7.7%. The Scheme 5, based on the EMR Canmet Water Only Cyclone proposal would produce a 10.0% surface moisture content discard.

This discard will be routed to the overland conveyors for ultimate disposal at either Houth Meadows or Medicine Creek, as designed by C-MJV.

Special facilities would be required for handling the dried fines from Scheme 4.

TABLE 4-1

Summary of Water Clarification and Tailings Dewatering Methods

Hat Creek Coal Beneficiation Report 1978

METHOD	COSTS	ADVANTAGES	DISADVANTAGES	CONCLUSIONS
1. Lagoon Clarification	Very High civil costs	Flocculants may not be req'd	Very Large lagoon required Environmentally sensitive	Hat Creek material not amenable to this process
2. Conventional Flocculation/ Thickeners				Necessary as initial step in disposal
3. Super Flocculat'n/ Deep Cone Thickeners	High	Thick Sludge	High Flocculant Costs	Hat Creek material not amenable to this process
4. Incorporation in Product	Low	Simple Disposal	High Ash Sludge giving very poor handling	Unacceptable to Boilers
5. Lagoon Disposal	High civil costs	Sequential Re-use	Large lagoons required Environmentally sensitive	Hat Creek material not amenable to this process
6. Filter Presses	Very High	High Cake Solids no flocculants	Batch process Labour intensive	Too expensive in capital
7. Tube Presses	Very High	Continuous process	In development stage	Unacceptable
8. Solid Bowl Centrifuges	High	Continuous process. In use on similar materials	High maintenance Very high flocculant costs	Only practical means available

compaction reported in the EMR Flocculation Testwork shows that the machines would be used at the limit of present experience. Larger scale washing tests coupled with pilot plant centrifuge tests on the sludges will be necessary before any wet beneficiation scheme could be proposed.

(b) All experience to date indicates that an Emergency back-up must be provided. For the tailings quantities at Hat Creek this would be a substantial lagoon. We have included in our costs for pumping schemes to be used in conjunction with this lagoon.

444 TAILINGS DEWATERING PLANT

The requirements are calculated on EMR Testwork data:

Thickener Solids Loading Rate : 0.106 tons per sq. ft. per day
Thickener Solids Underflow : 20% solids, weight/weight basis

This scheme has been detailed in Simon-Carves' Preliminary Report on Design of Alternative Equipment for Tailings Disposal, and the enclosed drawings:

Figure 4-1 Flowsheet of Thickeners and Solid Bowl Centrifuges
Figure 4-2 Layout of Solid Bowl Centrifuge Plant

These drawings were based on the requirements for a provisional washery scheme not incorporated in this Report. The actual requirements in terms of thickener sizes and numbers of centrifuges vary with the individual washery schemes and are detailed in the appropriate paragraphs of Section 5.

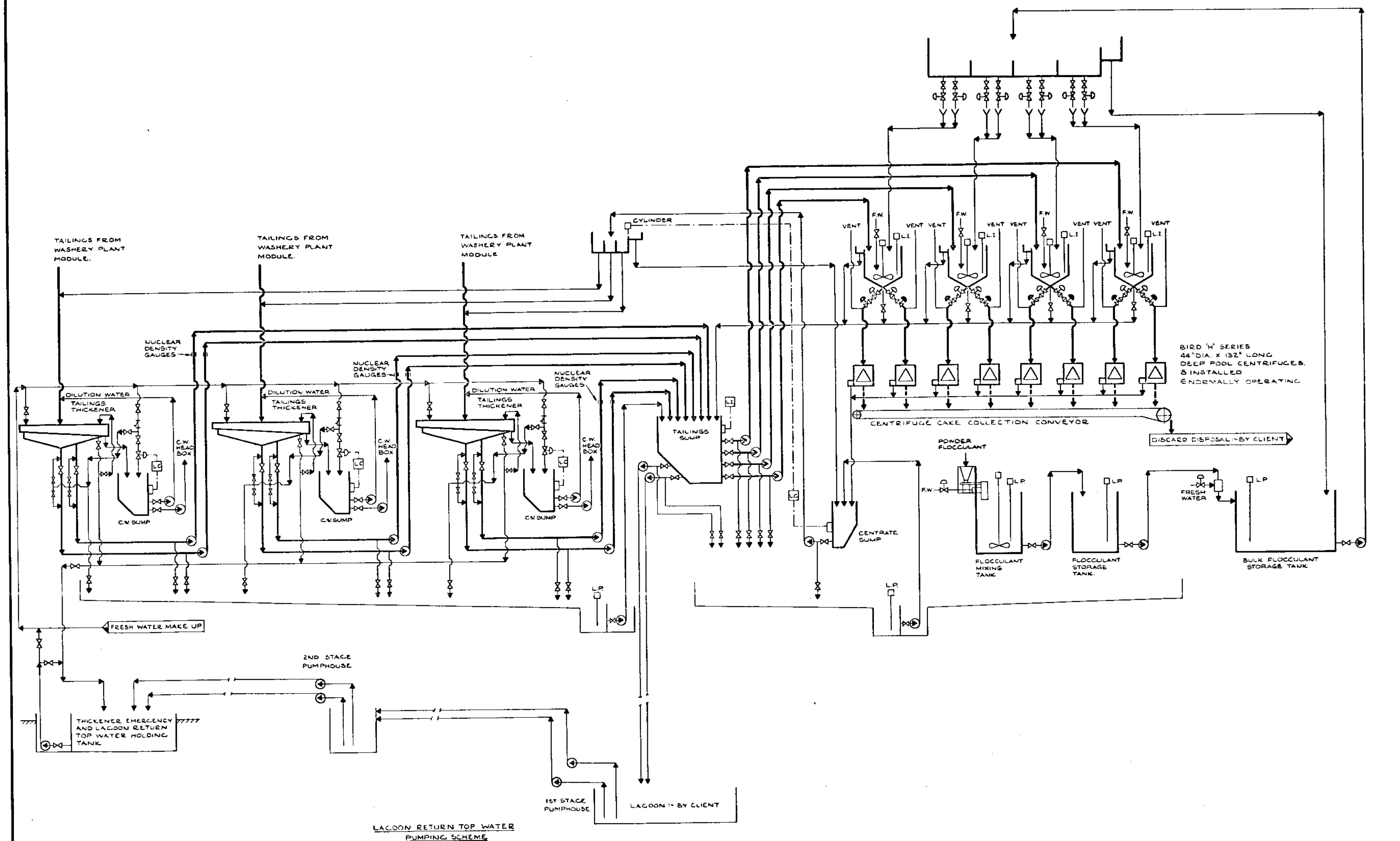
The tailings in the washwater flow will be dosed with the normal clarifier flocculants within the washery modules and will flow to the conventional thickener/clarifiers. The overflow of clarified water will be returned to the washery circuit, together with any required make-up water.

The thickener underflow will be pumped to buffer tanks. Each pipeline will incorporate a nuclear density gauge to monitor sludge consistency and facilitate balancing of solids load withdrawl from the thickeners.

In the stirred buffer tanks the "high grade" flocculant solution will be added. The conditioned slurry would gravitate to the Bird "H" Series Deep Pool Solid Bowl Centrifuges via automatic feed valves controlled by the centrifuge discharge torque drive mechanism.

The main purpose of the "high grade" flocculant is to hold the ulrrafines in the centrifuge cake despite the high centrifugal classifying forces. The centrate is recirculated via the thickeners.

The cake would be discharged to a belt conveyor for disposal. (Note that this cake is not of an adequate consistency for conveying any distance without being mixed with lump discard. It cannot be bunkered).



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA.
WILLIAM CORSE
NON-RESIDENTS LICENCE (EXPIRY DATE 8 JAN 1979)

REV.	DESCRIPTION	BY	DATE	CHK.
2	ISSUED WITH FINAL REPORT	K.B.	OCT 23/78	
1	DRAFT FOR FINAL REPORT	C.W.	MAY	

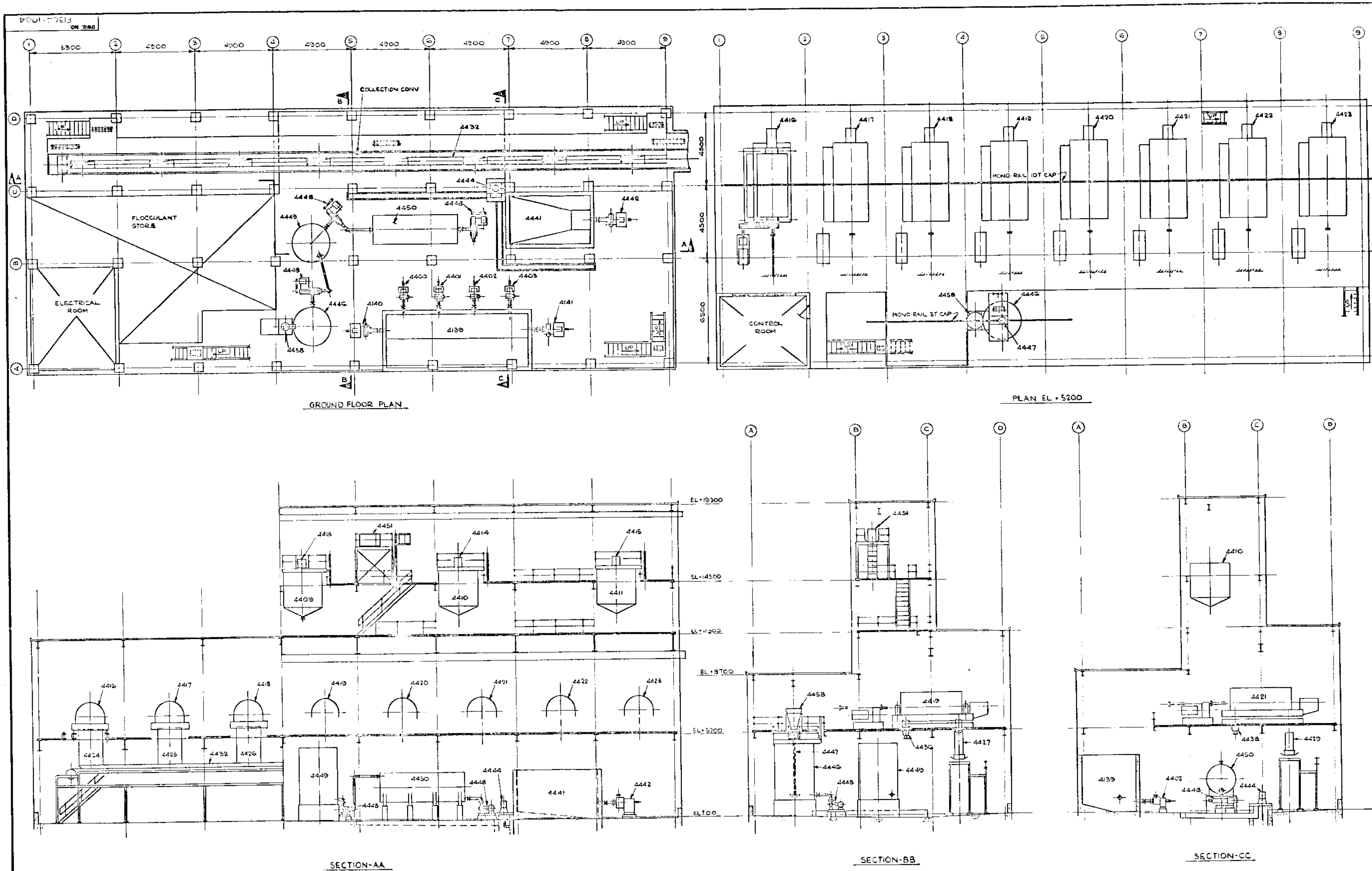
BRITISH COLUMBIA HYDRO & POWER AUTHORITY, HAT CREEK PROJECT, BRITISH COLUMBIA, CANADA. TAILINGS DEWATERING SCHEME.

SIMON-CARVES

DWG. TITLE: FLOWSHEET FOR THICKENERS AND TAILINGS DISPOSAL SCHEME (SOLID BOWL CENTRIFUGES)

DESIGNED D.V.W. · DRAWN K.C.L. · CHECKED S.C.B. · PROJ. MGR. S.C.B.

REPORT FIGURE NUMBER 4-1 · SCAN DRAWING NUMBER F1304-0005 · SHEET 1 OF 1 · REV. 2



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA
WILLIAM CORSE
NON-RESIDENTS LICENCE (EXPIRY DATE 8 JAN 1979)

REV	DESCRIPTION	BY	DATE	CHK
2	ISSUED WITH FINAL REPORT	K.S.		
1	DRAFT FOR FINAL REPORT	KGL	MAY 31 78	

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT, BRITISH COLUMBIA, CANADA.
2400 M.T.P.H MODULAR COAL WASHERY.

PHOTOGRAPHIC SCALE — MILLIMETRES 5 & 10 DIV./INCH

DESIGNED	D.V.W.		SCALE 1:75	PROJ. MGR.	S.C.B.
DRAWN	KGL	MAY 31 78		PROJ. DES.	
CHECKED	S.C.B.			D.O. MGR.	

SIMON-CARVES

AREA:
CATEGORY:
DWG. TITLE: SOLID BOWL CENTRIFUGE - LAYOUT.

REPORT FIGURE NUMBER	SCAN DRAWING NUMBER	REV.
4 - 2	F1304-1004	2

4.5 WATER REQUIREMENTS

Make-up water requirements are shown for the alternative schemes on the Materials Balance Diagrams in Section 5.

The EMR Canmet Test Wash Report states that there was a rapid build-up of dissolved solids, particularly the sulphate ion. The latter reached 2440 parts per million and was increasing. This would necessitate the use of high grade sulphate resisting cement in the washery constructions and possible special sulphate resisting linings. Also, during these short runs, various crystalline forms of sulphate were observed in the water circuits. A special investigation of this problem would be needed prior to any washery design.

This report also notes that ultra-fines solids are likely to build up in the circuit, for example, by loss of ultra-fines from the tailings centrifuges due to their classifying effect.

The make-up water requirements could therefore, be several times greater to maintain satisfactory in-plant conditions.

SECTION 5

BENEFICIATION SCHEMES AND COST ESTIMATES

5.1 BASIS OF DESIGN

The required output of the Mine Complex was originally set out in the BCHPA Memo of July 11, 1977:-

For the maximum capacity factor period, 1989-1998, product production requirement of:

(a) 10,894,000 MTPY at 5,500 Btu/lb

(b) 10,119,000 MTPY at 5,900 Btu/lb

(c) 9,272,000 MTPY at 6,300 Btu/lb

(These values assumed as "as delivered" coal moisture of 20%).

If it is accepted that only coals from A, B and C Zones warrant beneficiation, then we have a raw coal input to the Beneficiation Plant for the years 6 - 10 of:-

7,941,000 MTPY

Taking the operating hours as defined in the Project Criteria Manual, the capacity required is:-

$$\frac{7,941,000}{365 \times 24} = 906 \text{ MTPH}$$

A nominal capacity of 1000 MTPH has been selected, which demands an average availability of 90.6%.

Original considerations for washing all coals called for a 2000 MTPH nominal capacity, and the Modular Coal Washery was designed on the basis of 5 operating modules each of 400 MTPH capacity plus a complete standby module. For the present, therefore, three of these modules would be considered, two or three being operational as needed. (Note that the 906/1000 MTPH value given above is the average requirement over the 5 year period. A 1200 MTPH installation will allow reasonable flexibility in the shorter term).

The philosophy of the coal washery design is discussed in Simon-Carves' Summary Report on Preliminary Design and Costing of a Modular Washery, October 1977.

The prime intention is to allow for maintenance within a 7 day week, 24 hour day operating schedule. For a developing situation it also allows additional capacity to be added at a later stage.

Consideration of the Raw Coal Size Consist, (para. 332.3) and the substantial advantages of partial washing, led to incorporating Raw Coal Screening at a nominal 13mm. This would give a nominal 50% to Coarse Coal treatment and 50% to Fine Coal treatment. The process equipment selected means that this nominal screening size could be adjusted in the range 25mm to 6mm without the need to re-design or re-cost the Schemes for Budget purposes.

Six possible Schemes are evaluated on a common basis in this Report, whereas the Interim Reports used various bases. These are supported by Materials Balance diagrams based on:-

(a) Mine Plan Data.

(b) To correspond with the Basis of Design, this takes 1000 MTPH of Run of Mine Coal from Zones A + B + C, and 741 MTPH of Run of Mine Coal from Zone D.

(c) Screening the 1000 MTPH of Beneficiation Plant feed at a nominal 13mm to give 500 MTPH to any fine coal treatment.

(d) Computer predictions of process yields for the X and Y samples using "After Wet Attrition" data for the -13mm material and for all material in Scheme 5.

In all cases the D Zone coal is blended back without any beneficiation.

The schemes evaluated are:-

(1) Total Washing: Heavy Medium Bath + Water Only Cyclones (Modular Washery)

(2) Partial Washing: Heavy Medium Bath (Coarse Coal Sections of Modular Washery)

(3) Partial Washing: Baum Jig (for coarse coal only)

(4) Dryer/Classifier Scheme

(5) Total Washing: Water Only Cyclone Washery (equivalent to EMR Canmet proposal)

(6) Total Beneficiation: (2) + (4)

For a summary of these Schemes see Table 2-1. Outline descriptions and costs follow in Section 5.2.

5.2 ALTERNATIVE SCHEMES

521 TOTAL WASHING : HEAVY MEDIUM BATH AND WATER ONLY CYCLONES (MODULAR WASHERY)

521.1 Scheme Capability

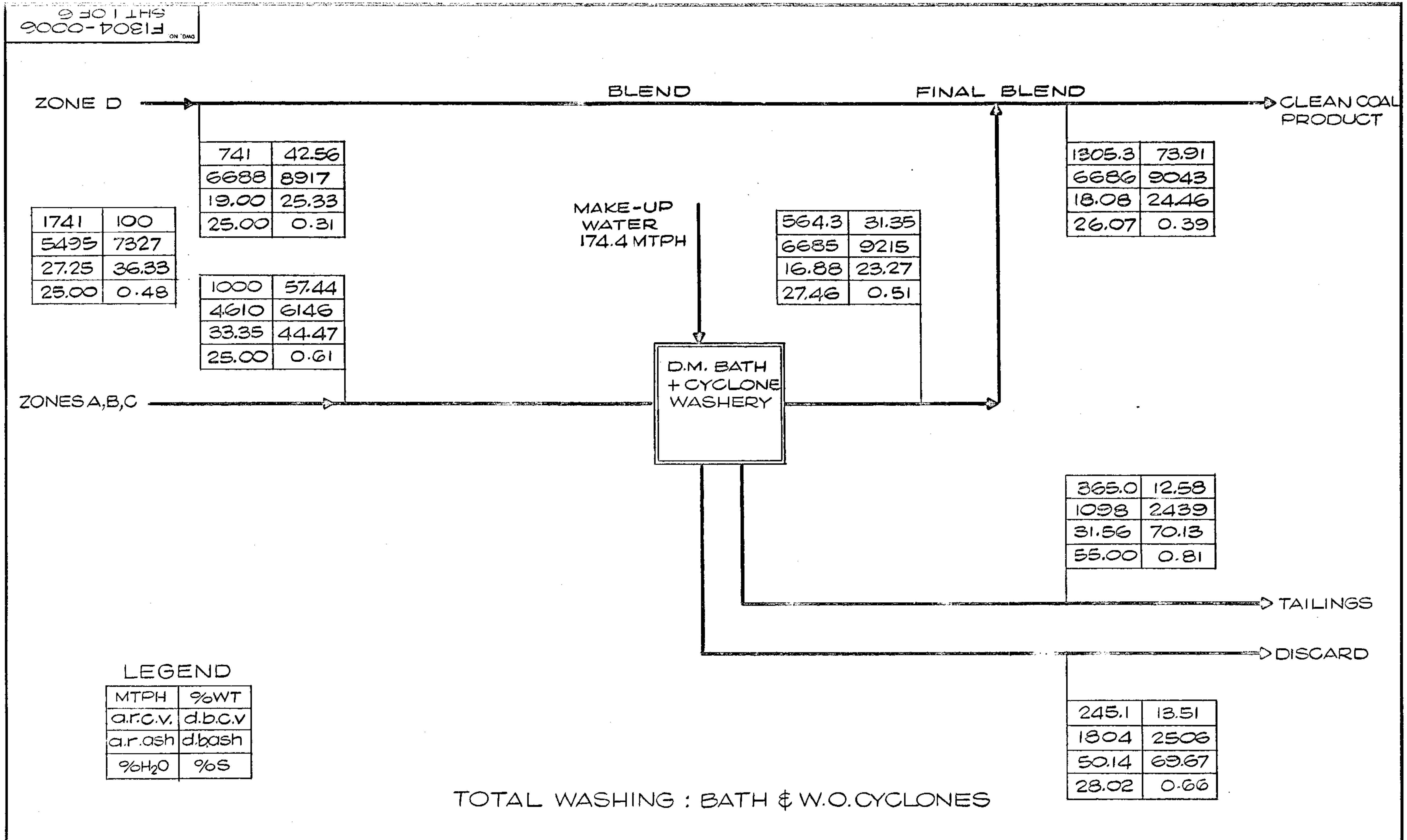
This is summarized on the Materials Balance Diagram - Figure 5-1-1.

The average feed to the plant would be 1000 MTPH of Zone A, B and C coals with an ash content of 33.35% at 25% moisture, equivalent to a calorific value of 4610 Btu/lb, as received basis.

The washing processes would yield 564.3 MTPH of product at 16.88% ash, 27.46% moisture, equivalent to a calorific value of 6685 Btu/lb, as received basis, i.e. the washery scheme would achieve a Degree of Beneficiation of 2.86 at a 81.8% Btu yield.

There would be 365.0 MTPH of tailings after mechancial dewatering to a 45% solids content cake. There would be 245.1 MTPH of solid discard.

The 564.3 MTPH clean coal from the washery would be blended with the 741 MTPH of Zone D coals, to give a clean coal product of 18.08% ash at 26.07% moisture, equivalent to a calorific value of 6686 Btu/lb, as received basis, i.e. overall, the scheme would achieve a Degree of Beneficiation of 1.83 at a 91.2% Btu yield.



REV.	DESCRIPTION	BY	DATE	CHK
2	ISSUED WITH FINAL REPORT SULPHUR VALUES ADDED	KS	OCT 20/78	
1	DRAFT FOR FINAL REPORT	TG	MAY 31/78	

B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
BRITISH COLUMBIA, CANADA

DESIGNED: PVT
DRAWN: T.G.
CHECKED: SG

SIMON-CARVES

DWG. TITLE: MATERIALS BALANCE
D.M. BATH & W.O. CYCLONES WASHERY

REPORT FIGURE NUMBER 5-1-1

F1304-0006 SHT 1 OF 6

REV. 2

521.2 Modular Design

This scheme will consist of a number of (tentatively 3) identical Modules each rated for a nominal 400 MTPH capacity. Each Module would be fed from the Raw Coal Handling System by a separate Raw Coal Feed Conveyor; thus each Module could be independently set to optimize the product yield from its particular raw coal feed. This allows for each Module to be taken out of service in turn for maintenance.

The modules would be constructed to work with a common set of product conveyors:

(a) Coarse Clean Coal Conveyor

(b) Fine Clean Coal Conveyor

(c) Fine Untreated Coal Conveyor

(d) Discard Conveyor

The three coal product conveyors have been included for two reasons: firstly to facilitate separate product stockpiling if required, and secondly to give flexibility in product blending without complicating the modular plant layout.

Each module would consist of:

(a) Raw Coal Screening Section

(b) Coarse Coal Washing Section

(c) Fine Coal Washing Section

The design as a series of independent modules facilitates the stagewise development of the plant, and will greatly simplify the initial commissioning and on-going operator training programme.

521.3 Description of Scheme

A detailed description of the scheme and its operation is given in the Modular Coal Washery Report. The scheme is outlined on the attached drawings:

Fig. 5-1-2 Flowsheet for Coarse Coal (Heavy Medium Bath) Section
Fig. 5-1-3 Flowsheet for Fine Coal (Water Only Cyclone) Section
Fig. 5-1-4 Washery Layout

521.4 Thickener and Tailings Disposal Requirements

These have been calculated for EACH 400 MTPH module as:

ONE 52.5m diameter thickener
FOUR Bird "H" Series Centrifuges together with all supporting facilities

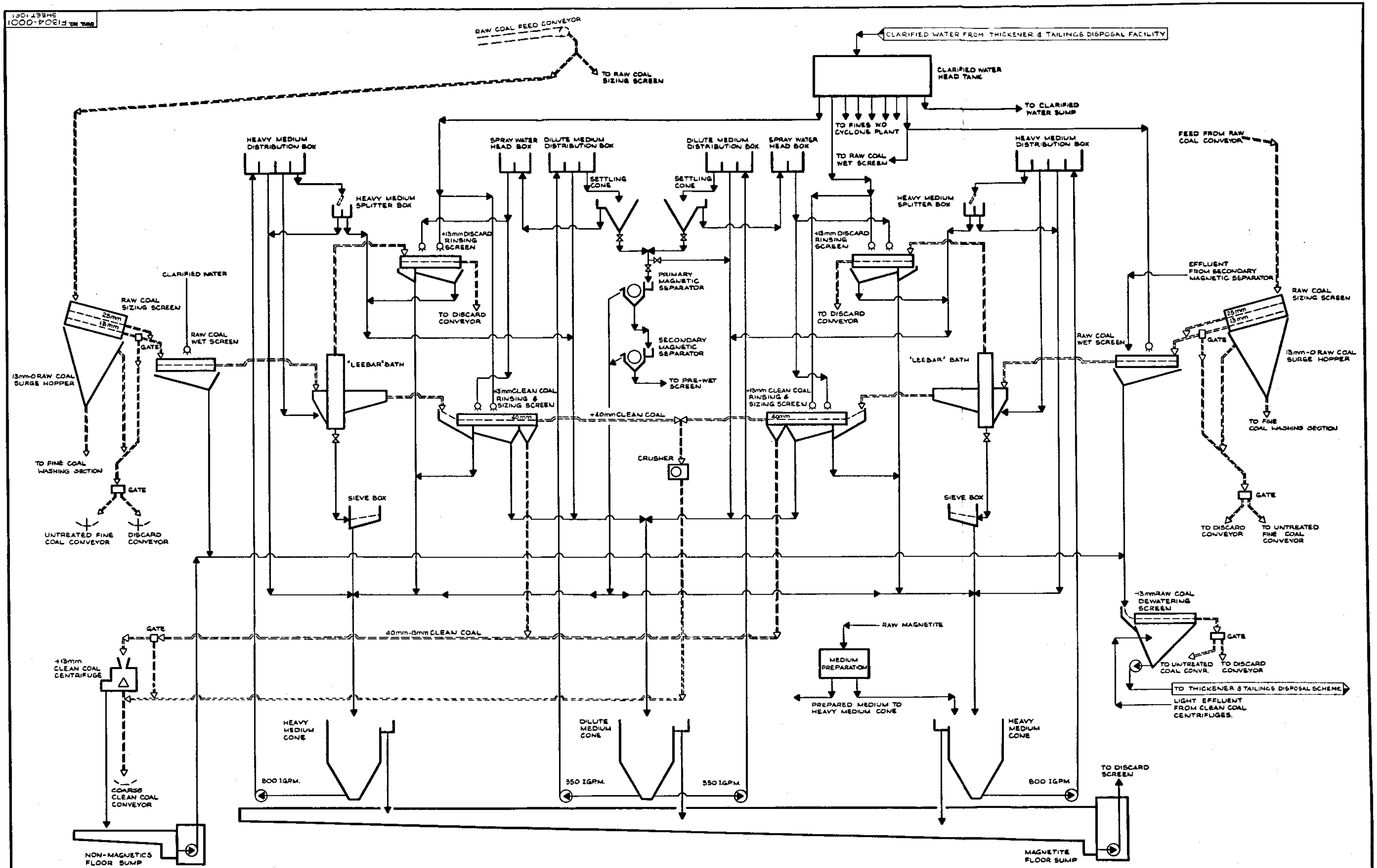
Thus, in total there would be three thickeners and twelve tailings centrifuges installed.

The average annual output of tailings cake would be 2,161,128 tonnes,or 1,630,670 cubic metres. Alternatively, if the tailings were allowed to compact in a lagoon to the solids content of 40% by weight, the residual annual volume would be 1,900,000 cubic metres after the top water had been returned to the washery circuit.

521.5 Capital Costs

Coal Preparation Plant

End Modules (2)	9,554,894	
Interior Module (1)	4,530,712	
Common Items	980,520	
Thickeners (3x52.5m)	6,288,000	
Engineering	4,568,000	25,922,926



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA.
WILLIAM CORSE
NON-RESIDENT LICENCE (EXPIRY DATE 8 JAN 1979)

REV.	DESCRIPTION	BY	DATE	CHK.
3	ISSUED WITH FINAL REPORT	K.S.	OCT 24/78	
2	DRAFT FOR FINAL REPORT	C.W.	31 MAY 78	
1	ISSUED WITH INTERIM REPORT		OCT 14/77	—
P	PRELIMINARY	K.S.	SEP 28/77	

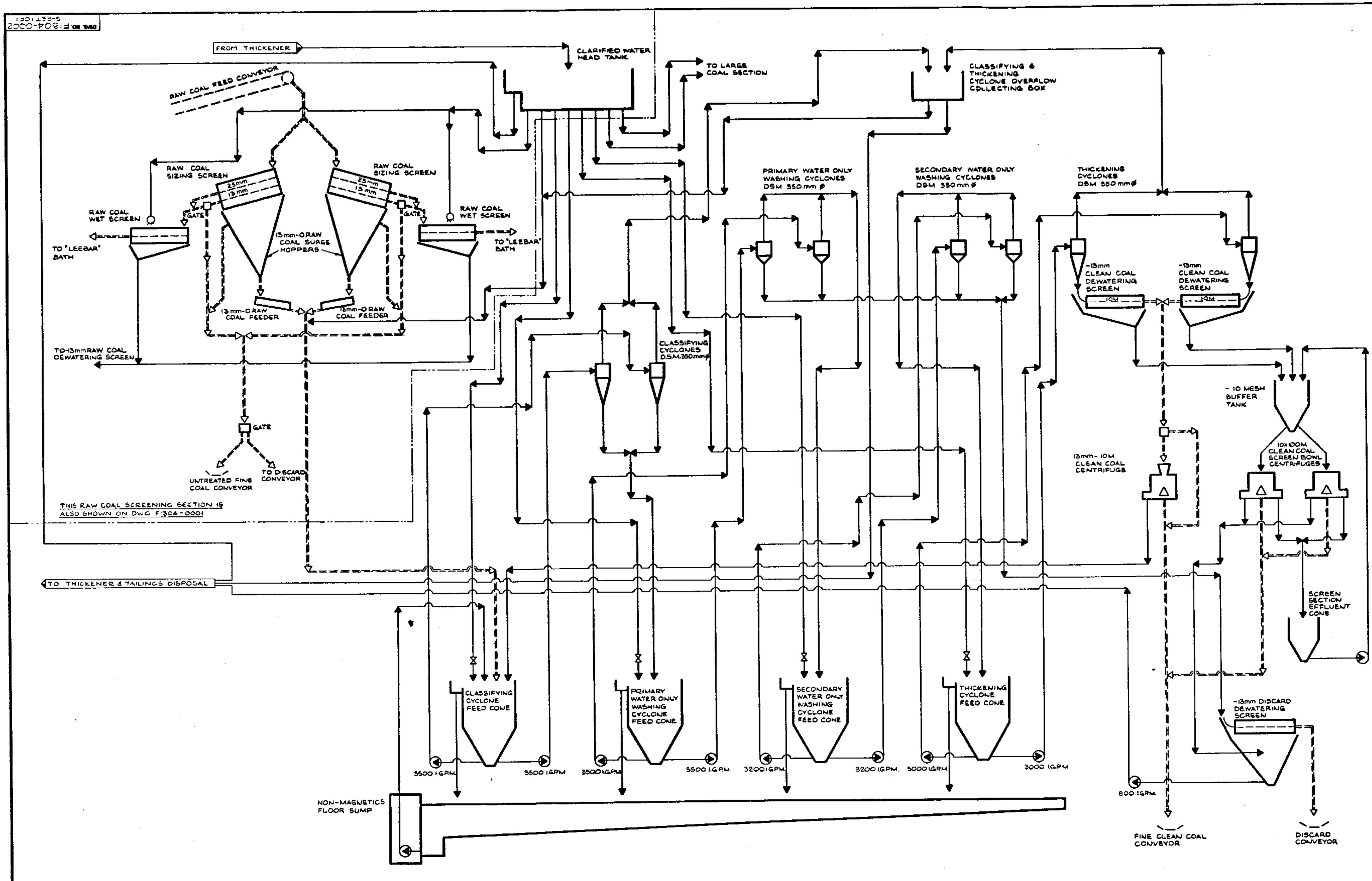
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT, BRITISH COLUMBIA, CANADA
2400 M.T.P.H. MODULAR COAL WASHERY.

SIMON-CARVES

DWG. TITLE: FLOWSHEET FOR COARSE COAL H.M. SECTION (1 MODULE)

DESIGNED	D.V.W.		SCALE	PROJ. MGR.	S.C.B.
DRAWN	K.S.	SEP 28/77	N.T.S.	PROJ. DES.	
CHECKED	S.C.B.			D.D. MGR.	

REPORT FIGURE NUMBER	SCAN DRAWING NUMBER	REV.
5-1-2	F1304-0001 SHEET 1 OF 1	3



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA.
WILLIAM CORSE
NON-RESIDENTS LICENCE (EXPIRY DATE 8 JAN 1979)

REV.	DESCRIPTION	BY	DATE	CHK.
3	ISSUED WITH FINAL REPORT	K.S.	OCT 25/78	
2	DRAFT FOR FINAL REPORT	C.W.	MAY	
1	ISSUED WITH INTERIM REPORT		OCT 14/77	—
P	PRELIMINARY	K.S.	SEP 29/77	

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT, BRITISH COLUMBIA, CANADA
2400 M.T.P.H. MODULAR COAL WASHERY

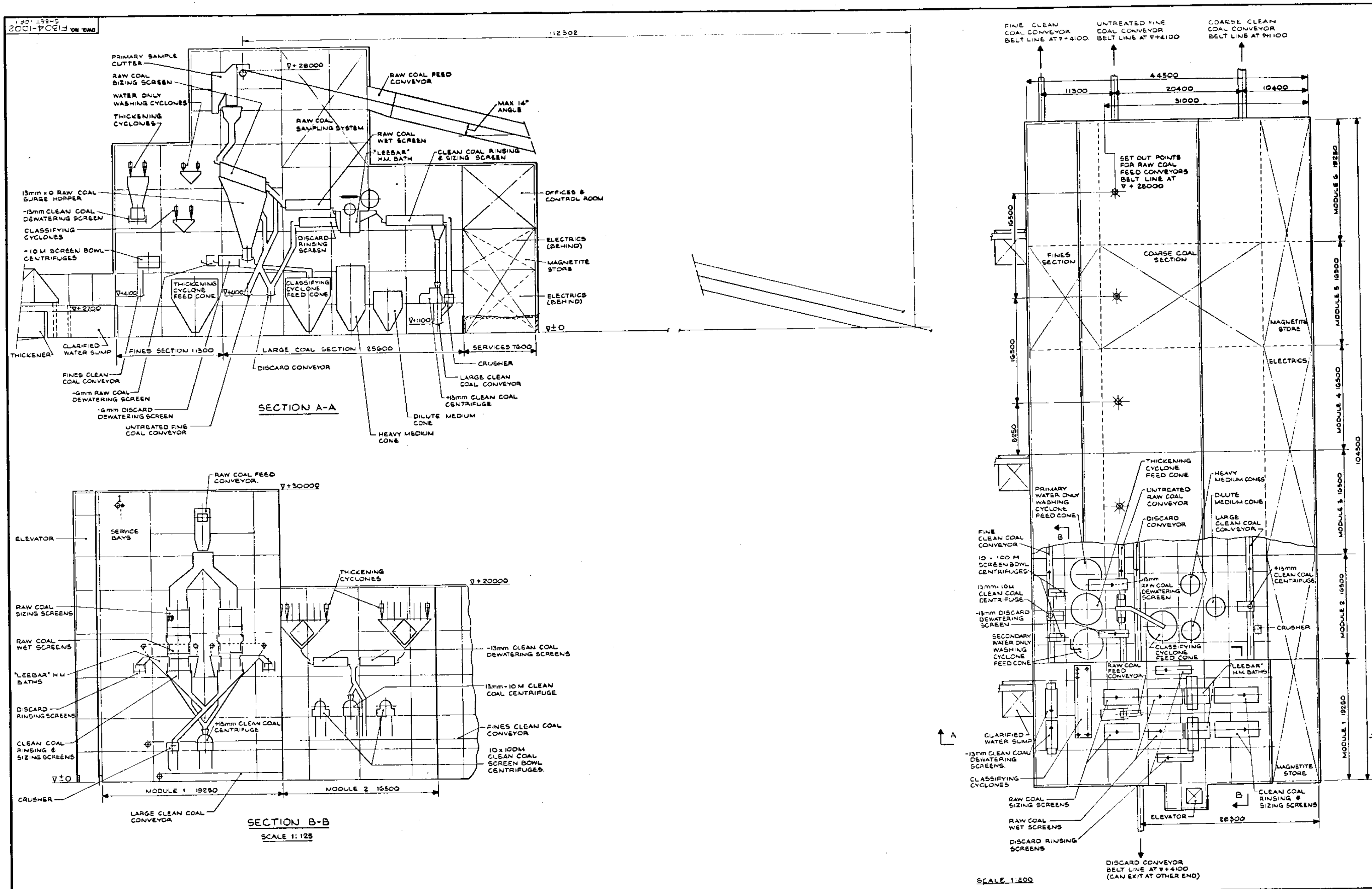
PHOTOGRAPHIC SCALE — MILLIMETRES 5 & 10 DIV./INCH

DESIGNED: D.V.W. — DRAWN: K.S. SEP 29/77 — CHECKED: S.C.B.
SCALE: N.T.S.
PROJ. MGR.: S.C.B. — PROJ. DES. — D.O. MGR.

SIMON-CARVES

AREA: — CATEGORY:
DWG. TITLE: FLOWSHEET FOR FINE COAL SECTION (1 MODULE)

REPORT FIGURE NUMBER: 5-1-3
SCAN DRAWING NUMBER: F1304-0002 SHEET 1 OF 1
REV. 3



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA.
WILLIAM CORSE
NON-RESIDENTS LICENCE (EXPIRY DATE 8 JAN 1979)

REV.	DESCRIPTION	BY	DATE	CHK.
3	ISSUED WITH FINAL REPORT	K.S	OCT 28/78	
2	DRAFT FOR FINAL REPORT	C.W	31 MAY 78	
1	"ISSUED WITH INTERIM REPORT"		OCT 14/77	–
P	PRELIMINARY	K.S.		

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT, BRITISH COLUMBIA, CANADA
2400 M.T.P.H. MODULAR COAL WASHERY

DESIGNED D.V.W. — DRAWN K.S — CHECKED S.C.B. — SCALE AS NOTED — PROJ. MGR. S.C.B.

SIMON-CARVES

DWG. TITLE: MODULALAR COAL WASHERY LAYOUT.

REPORT FIGURE NUMBER 5-1-4 — SCAN DRAWING NUMBER F1304-1002 SHEET 1 OF 1 — REV. 3

Tailings Dewatering Plant

Centrifuge Plant (12 units)	4,720,000	
Emergency/Pumping	1,376,790	
Engineering	655,500	6,752,290
SIMON-CARVES TOTAL		32,675,216

Allow for Raw Coal Stockpile

Feed and Product Conveyors

Construction of Tailings Emergency Lagoon

Water Supply

521.6 Operating Costs per Annum

Coal Preparation Plant

Power	614,286	
Heating	115,714	
Magnetite	113,978	
Flocculants	202,552	
Spares	528,470	
Labour	3,010,082	4,585,082

Tailings Dewatering Plant

Power	131,745	
Heating	46,286	
Flocculants	2,490,840	
Spares	315,332	
Labour	901,620	3,885,823
		8,470,905

Operating Cost per tonne of Coal Preparation Plant Output

$$= \frac{8,470,905}{3,341,163} = \$2.535$$

Operating Cost per tonne of Total Product

$$= \frac{8,470,905}{7,728,549} = \$1.096$$

522 PARTIAL WASHING USING HEAVY MEDIUM BATH

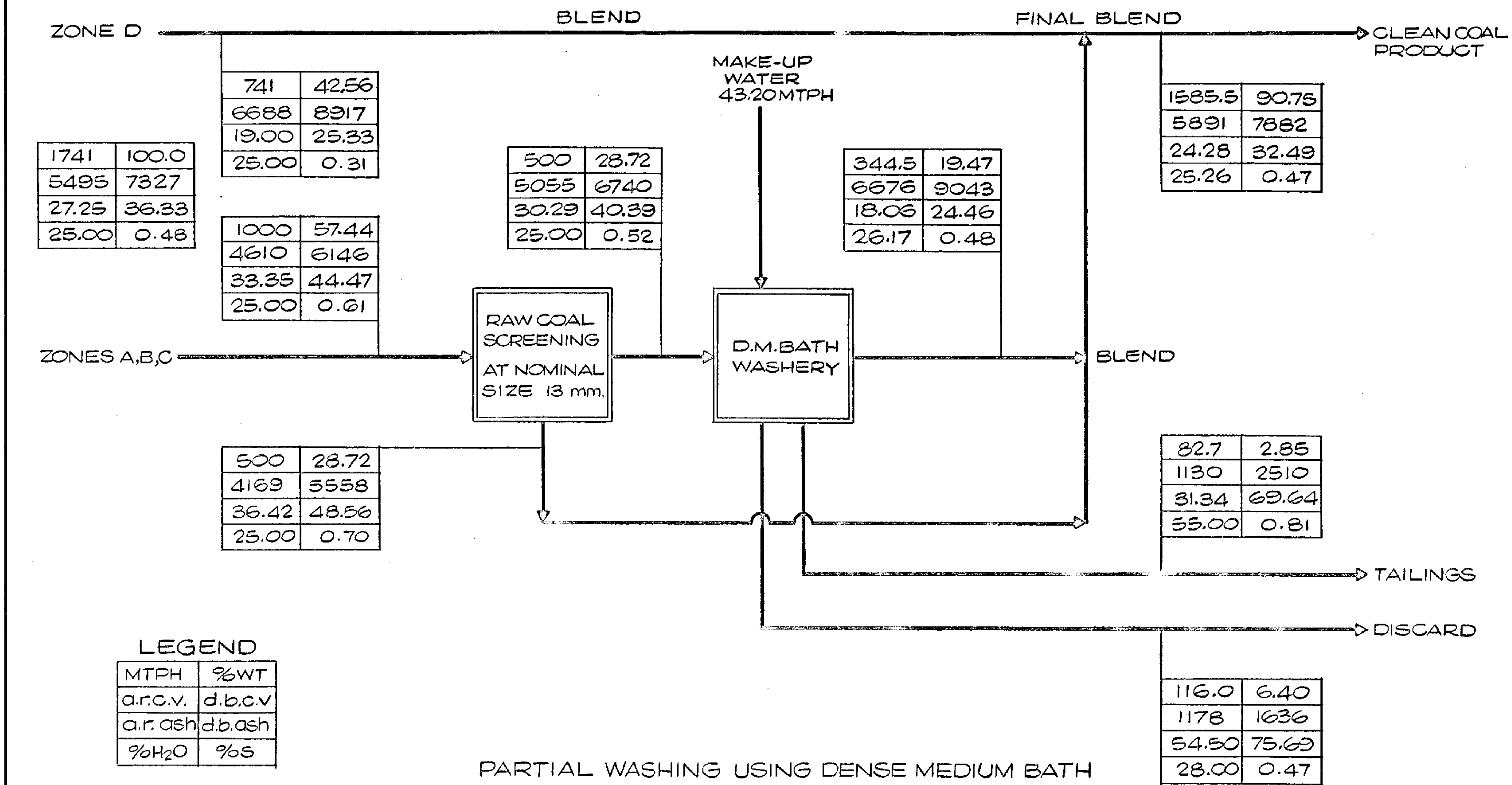
522.1 Scheme Capability

This is summarized on the Material Balance Diagram : Figure 5-2-1, which follows the same pattern as that for the previous scheme.

The average feed to the plant would be 1000 MTPH of Zone A, B and C coals. The raw coal would be screened at a nominal 13mm so as to feed 500 MTPH of coarser coal to the Dense Medium Bath Washery (Note that the screen overflow is cleaner than the screen underflow). The washery would achieve a 2.21 degree of beneficiation at a 91.0% Btu yield.

There would be tailings resulting from misplaced material in the dry screening operationand breakdown of coal in the washing process. This is estimated at 82.7 MTPH after mechancial dewatering to a 45% solids cake.

The 344.5 MTPH of cleaned coal would be blended with the 500 MTPH of screen underflow and finally with the 741 MTPH of Zone D coals, to give a "Part Washed Blended Smalls" product of 24.28% ash at 25.26% moisture equivalent to a calorific value of 5891 Btu/lb, as received basis, i.e. overall the scheme would achieve a degree of beneficiation of 1.20 at a 97.6% Btu yield.



REV.	DESCRIPTION	BY	DATE	CHK.
2	ISSUED WITH FINAL REPORT SULPHUR VALUES ADDED	KS	OCT. 20/76	
1	DRAFT FOR FINAL REPORT	TG	MAY 31/76	

B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
BRITISH COLUMBIA, CANADA

SIMON-CARVES

DWG. TITLE: MATERIALS BALANCE PARTIAL WASHING USING D.M. BATH

DESIGNED: P.V.T
DRAWN: T.G.
CHECKED: S.G.B.

REPORT FIGURE NUMBER: 5-2-1

SCAN DRAWING NUMBER: F1304-0006 SHT 2 OF 6

REV.: 2

SHEET SIZE I.S.O. A3

522.2 Modular Design

This scheme will consist of three identical Modules each rated at a nominal 400 MTPH. Developed from Scheme 1, the partial washing scheme consists of the Raw Coal Screening Section and Coarse Coal Washing Section. The Automatic Ash Monitor within the Raw Coal Screening Section will be used to determine the "mode" in which the Module is to operate.

Reference to the flowsheet and Washery Arragnement Drawing should be made to visualize the practical arrangement of automatically operated gates and overflow chutes by which this is achieved. The Conveyors will run the length of the Plant receiving products from all Modules.

There are three "modes", the sequence for increasing ash content raw coal with a greater degree of beneficiation requirement being:

(a) Coarse Coal Washing (+25mm)

Only +25mm Raw Coal being passed to the Dense Medium Baths for Washing. All 25mm x 0 Raw Coal would overflow the Fine Coal Surge Hopper to the Untreated Fine Coal Conveyor.

(b) Coarse Coal Washing (+13mm)

The +25mm x 13mm Raw Coal being passed together to the Dense Medium Baths for washing. All 13mm x 0 Raw Coal would overflow the Fine Coal Surge Hopper to the Untreated Fine Coal Conveyor.

(c) Low Grade Coal Washing (Optional Feature)

The module would be set as above except that 13mm x 0 Raw Coal would be diverted to the Discard Conveyor. Clean Coal would be recovered from the +13mm Raw Coal only.

522.3 Description of Scheme

The scheme would be exactly as the Modular Coal Washery, except that the Water Only Cyclone sections would be omitted.

522.4 Thickener and Tailings Disposal Requirements

The requirement to work in conjunction with THREE x 400 MTPH Modules is:-

ONE 42.5m Diameter Thickener

FOUR Bird "H" Series Centrifuges complete with all supporting facilities.

(Note that this is equivalent to the 3 x 125 ft. diameter thickeners and 8 centrifuges envisaged for the 6 module plant in the Interim Report on Alternative Equipment for Tailings Disposal).

The average annual output of tailings cake would be 489,658 tonnes, or 370,363 cubic metres.

Alternatively, if the tailings were allowed to settle in a lagoon to the solids content of 40% by weight, the residual annual volume would be 430,000 cubic metres after the top water has been returned to the plant.

522.5 Capital Costs

Coal Preparation Plant		
End Module (2)	6,022,680	
Interior Module (1)	2,848,344	
Common Items	980,520	
Thickeners (1 x 42.5m)	1,428,770	
Engineering	4,568,800	15,849,114

Tailings Disposal

Centrifuge Plant (4 units)	2,202,666	
Emergency/Pumping	688,395	
Engineering	437,000	3,328,061
SIMON-CARVES TOTAL		19,177,175

Note: Allow for:

Raw Coal Stockpile, Feed and Product Conveyors.
Construction of Tailings Emergency Lagoon.
Water Supply

522.6 Operating Costs per Annum

Coal Preparation Plant

Power	320,213	
Heating	115,714	
Magnetite	113,978	
Flocculants	44,517	
Spares	284,927	
Labour	2,122,256	3,001,605

Tailings Disposal

Power	43,915	
Heating	15,429	
Flocculants	564,300	
Spares	105,111	
Labour	447,636	1,176,391
Plant Total		4,177,996

Per tonne of Coal Preparation Plant Output

$$= \frac{4,177,996}{2,039,750} = \$2,048$$

Per tonne of Boiler Plant Feed

$$= \frac{4,177,996}{9,387,585} = \$0.445$$

523 PARTIAL WASHING USING BAUM JIG WASHERY

523.1 Scheme Capability

This is summarized on the Material Balance Diagram: Figure 5-3-1. Essentially, the scheme is the same as the previous scheme for Partial Washing, Baum Jigs being substituted for Dense Medium Baths for washing the nominal +13mm raw coal. The washery would achieve a somewhat lower efficiency : a degree of beneficiation of 2.13 at an 87.2% Btu yield.

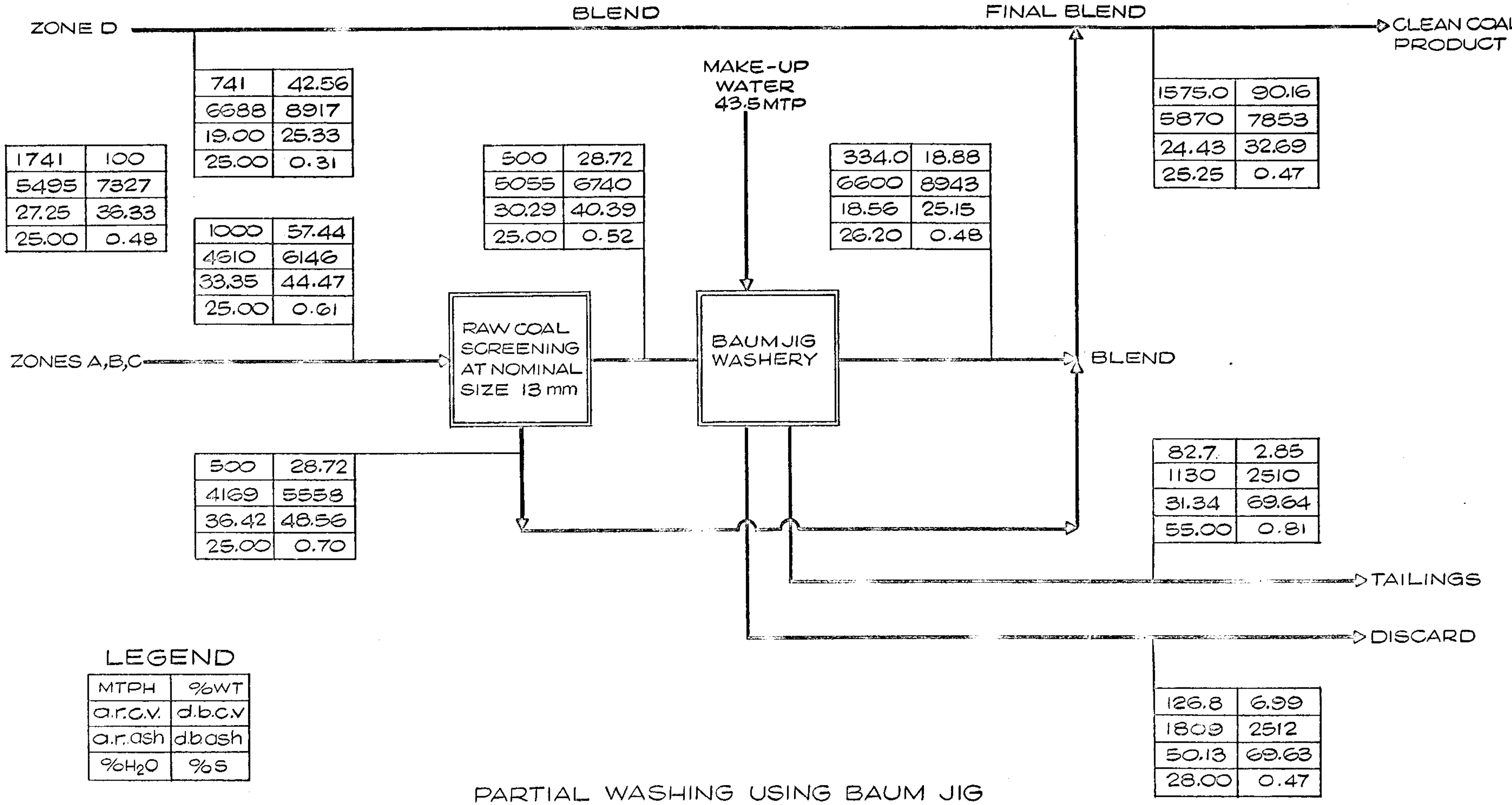
For the purpose of this exercise, it has been assumed that the tailings production would be as for the Dense Medium Bath scheme. In practice, there might be somewhat larger yield of tailings.

The "Part Washed Blended Smalls" product would have a calorific value of 5870 Btu/lb, as received basis. The overall degree of beneficiation would be 1.19 at a 96.6% Btu yield. Thus, the baum jig, washing in fact only 28.7% of the raw coal, gives an overall 1.0% lower yield than the dense medium bath.

523.2 Modular Design

This scheme was developed after the decision by the Cominco-Monenco Joint Venture that screening out of the -13mm raw coal should be done as part of the Run of Mine coal handling and crushing facility. Any washery plant would receive a nominal +13mm feed via a Raw Coal Stockpile. (C-MJV drawing 400-005).

DWG. NO. F1304-0006 SHT 3 OF 6



PARTIAL WASHING USING BAUM JIG

REV.	DESCRIPTION	BY	DATE	CHK
2	ISSUED WITH FINAL REPORT SULPHUR VALUES ADDED	K.S.	OCT 20/76	
1	DRAFT FOR FINAL REPORT	TG	MAY 31/76	

B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
BRITISH COLUMBIA, CANADA

DESIGNED: P.V.T.
DRAWN: T.G.
CHECKED: S.C.P.
SCALE
PROJ. MGR.
PROJ. DES.
D. O. MGR.

SIMON-CARVES

AREA: CATEGORY:
DWG. TITLE: MATERIAL BALANCE PARTIAL WASHING USING BAUM JIG

REPORT FIGURE NUMBER 5-3-1
SCAN DRAWING NUMBER F1304-0006 SHT 3 OF 6
REV. 2

SHEET SIZE I.S.O. A3

The plant is designed on a modular basis with a nominal 400 MTPH unit capacity. However dry screening out of the -13mm material would require a washery feed rate of 240 MTPH. (This is the 50% over nominal 13mm = 200 MTPH + allowance for misplaced -13mm material of 40 MTPH = 240 MTPH). One major advantage of a Baum Jig system is that it can accept a 150mm x 0 feed. Only 150 x 0.5mm particles would be cleaned and there would be substantial problems with the high -0.5mm fines content. The plant layout therefore includes a Desliming System to facilitate removal of the finer coal from the washery circuit.

Each module would be fed from the Raw Coal Handling system by a separate raw coal feed conveyor.

Each module performs the following duties:-

(a) Raw Coal Desliming
(b) Coal Washing
(c) Clean Coal Classifying

The modules would be constructed to work with three common product conveyors:-

(a) Coarse Clean Coal
(b) Fine Clean Coal
(c) Discard

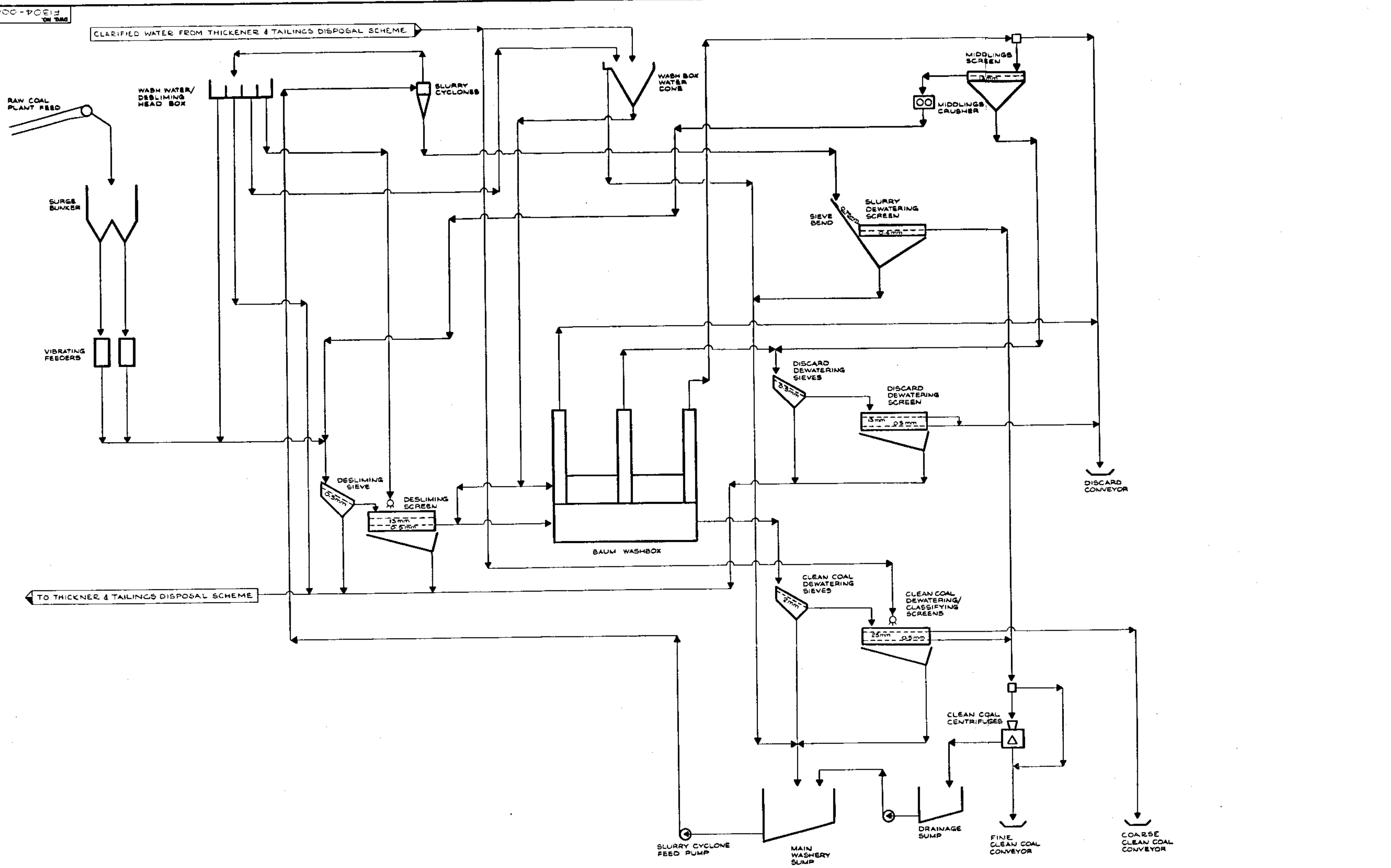
It would be possible for these conveyors to run in either direction.

523.3 Description of Scheme

A detailed description of the process scheme is given in the report - Preliminary Design and Costing of a Baum Washery. The scheme is outlined on the attached drawings:
Fig. 5-3-2 Flowsheet for Baum Washery
Fig. 5-3-3 Baum Washery Layout

523.4 Thickener and Tailings Disposal Requirements

These are the same as for the previous scheme, set out in paragraph 522.3.



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA.
WILLIAM CORGE
NON-RESIDENTS LICENCE (EXPIRY DATE 8 JAN 1979)

REV.	DESCRIPTION	BY	DATE	CHK.
2	ISSUED WITH FINAL REPORT	K.S.	OCT 25/78	
1	DRAFT FOR FINAL REPORT	CW	31 MAY 78	

BRITISH COLUMBIA HYDRO & POWER AUTHORITY
HAT CREEK PROJECT, BRITISH COLUMBIA, CANADA.
MODULAR BAUM COAL WASHERY

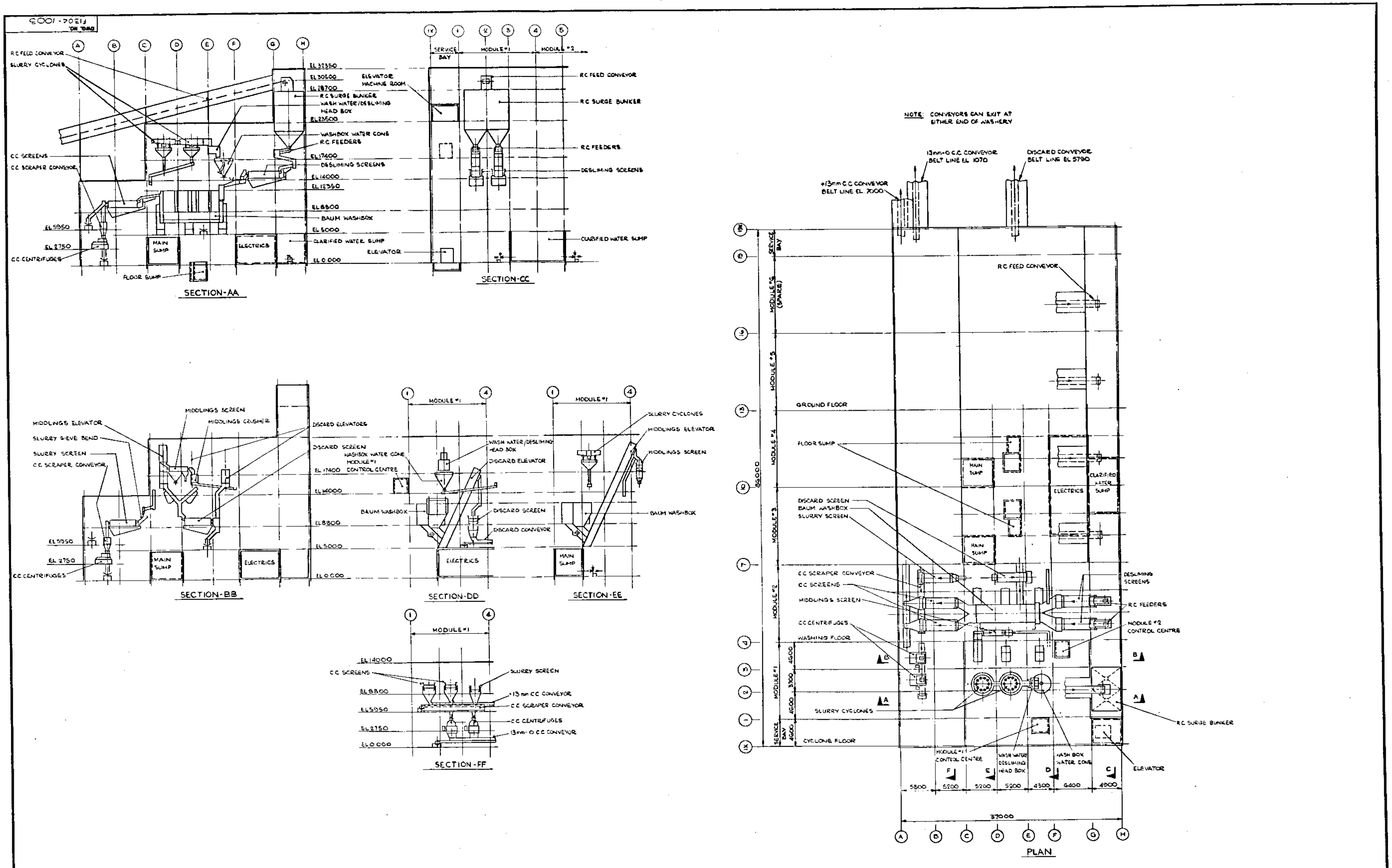
PHOTOGRAPHIC SCALE — MILLIMETRES 8 & 10 DIV./INCH

DESIGNED: D V W — CHECKED: S. C. B. — PROJ. MGR.: S. C. B.

SIMON-CARVES

DWG. TITLE: FLOWSHEET FOR BAUM WASHERY (ONE MODULE)

REPORT FIGURE NUMBER	SCAN DRAWING NUMBER	REV.
5-3-2	F1304-0004 SHEET 1 OF 1	2



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA.
WILLIAM CORSE
NON-RESIDENTS LICENCE (EXPIRY DATE 6 JAN 1979)

REV.	DESCRIPTION	BY	DATE	CHK.
2	ISSUED WITH FINAL REPORT	K.G.	OCT 23/78	
1	DRAFT FOR FINAL REPORT	C.W.	31 MAY 78	
P	PRELIMINARY	KGL	FEB 27/78	

BRITISH COLUMBIA HYDRO & POWER AUTHORITY
HAT CREEK PROJECT, BRITISH COLUMBIA, CANADA.
MODULAR BAUM JIG WASHERY.

PHOTOGRAPHIC SCALE — MILLIMETRES 8 & 10 DIV./INCH

DESIGNED	D.V.W.		SCALE	PROJ. MGR.	S.C.B.
DRAWN	KGL	FEB 27/78	1:200	PROJ. DES.	
CHECKED	S.C.B.			D.D. MGR.	

SIMON-CARVES

AREA: CATEGORY:
DWG. TITLE: MODULAR BAUM WASHERY LAYOUT.

REPORT FIGURE NUMBER	SCAN DRAWING NUMBER	REV.
5-3-3	F1304-1003 SHEET 1 OF 1	2

523.5 Capital Costs

Baum Washery

1st Module including Common Items	2,928,362	
Modules 2 and 3	5,026,894	
Thickener 1 x 42.5m	1,428,770	
Engineering	3,330,000	12,714,026
Tailings Disposal (as 522.5)		3,328,061
SIMON-CARVES TOTAL		16,042,087

Allow, as in paragraph 522.5 for ancillary items.

523.6 Operating Costs per Annum

Baum Washery

Power	137,724	
Heating	86,786	
Flocculants	44,517	
Spares	178,800	
Labour	1,877,852	2,325,679
Tailings Disposal (as 522.6)		1,176,070
		3,502,070

Per tonne of Coal Preparation Plant Output

$$= \frac{3,502,070}{2,039,750} = \$1.717$$

Per tonne of Boiler Plant Feed

$$= \frac{3,502,070}{9,325,416} = \$0.376$$

524 FINES DRYER - CLASSIFIER SCHEME

524.1 Scheme Capability

The prime attraction of this scheme is the absence of any tailings and the production of a lower surface moisture product. It will therefore, assume a much greater significance if the surface moisture of the raw coals are higher than currently anticipated.

The capability is summarized onthe Materials Balance Diagram Figure 5-4-1. The Zone A, B and C raw coals would be screened at a nominal 13mm. 500 MTPH of minus 13mm raw coal would be fed to the dryer-classifier unit. This would evaporate 18.4 MTPH of water and extract 137.9 MTPH of nominal minus 0.5mm fines. These fines, having an average ash content of 50.49% at 20.0% moisture, equivalent to a calorific value of 2763 Btu/lb, as received basis, would be discarded.

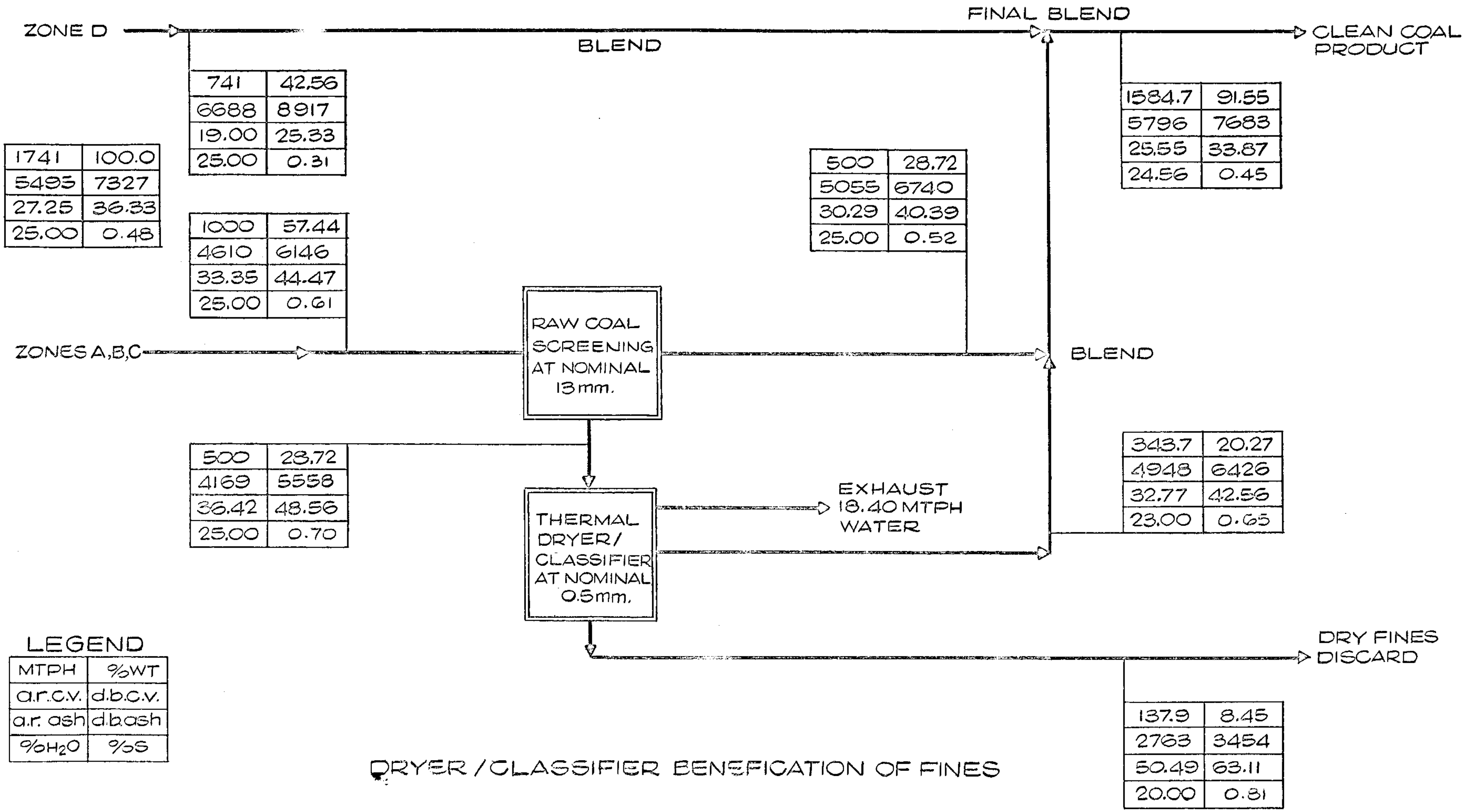
The dried coal (13mm x 0.5mm) would be blended back with the +13mm A, B and C coals and the 741 MTPH of Zone D raw coal.

The dryer-classifier unit would achieve a degree of beneficiation of 1.32 at an 81.6% Btu yield. (This latter figure does not include for the fuel used in the dryer).

524.2 Basis of Design

This proposal has been based on the drying and size classification of nominal 13mm x 0 raw coal from Zones A, B and C at a rate of 500 MTPH. This would be extracted by the C-MJV Screening Plant, Drawing CMV 400-005 and fed via a Stockpile.

The Basis of Design assumes that the air dried moisture content of this material is 20.0%. An evaporative capacity of 32.0 MTPH has been allowed to permit variations in feed moisture. The actual duty, based on the 25.0% Total Moisture currently anticipated for the Raw Coal to a dryer product at 23.0% is 18.40 MTPH evaporation.



REV.	DESCRIPTION	BY	DATE	CHK
2	ISSUED WITH FINAL REPORT SULPHUR VALUES ADDED	KS	OCT 20/7-	
1	DRAFT FOR FINAL REPORT	TG	MAY 31/7-	

B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
BRITISH COLUMBIA, CANADA

DESIGNED: P.V.T. DRAWN: T.G. CHECKED: S.G.R.

SIMON-CARVES

DWG. TITLE: MATERIALS BALANCE DRYER/CLASSIFIER SCHEME

REPORT FIGURE NUMBER: 5-4-1

SCAN DRAWING NUMBER: F1304-0006 SHT 4 OF 6

REV. 2

SHEET SIZE I.S.O. A3

Note the system objective is to permit efficient extraction of fines and not drying. Products dried to less than 3.0% moisture give dusting problems.

This scheme is tentatively proposed to evaluate potential capability and costs of this alternative on the same basis as the other schemes.

Further work on the feasibility of this system would be necessary. A potential problem exists with the clay fines "drying onto" the coraser material rather than liberating readily at -0.5mm. This has been proven possible for better coals by the commercial unit constructed by Heyl and Patterson. Note that partition factors obtained from Heyl and Patterson have been applied to the Wet Screen analysis. It is probable that clay liberation occurred inthis operation, therefore the results shown on the Materials Balance Diagram are optimistic.

524.3 Description and Scope of Scheme

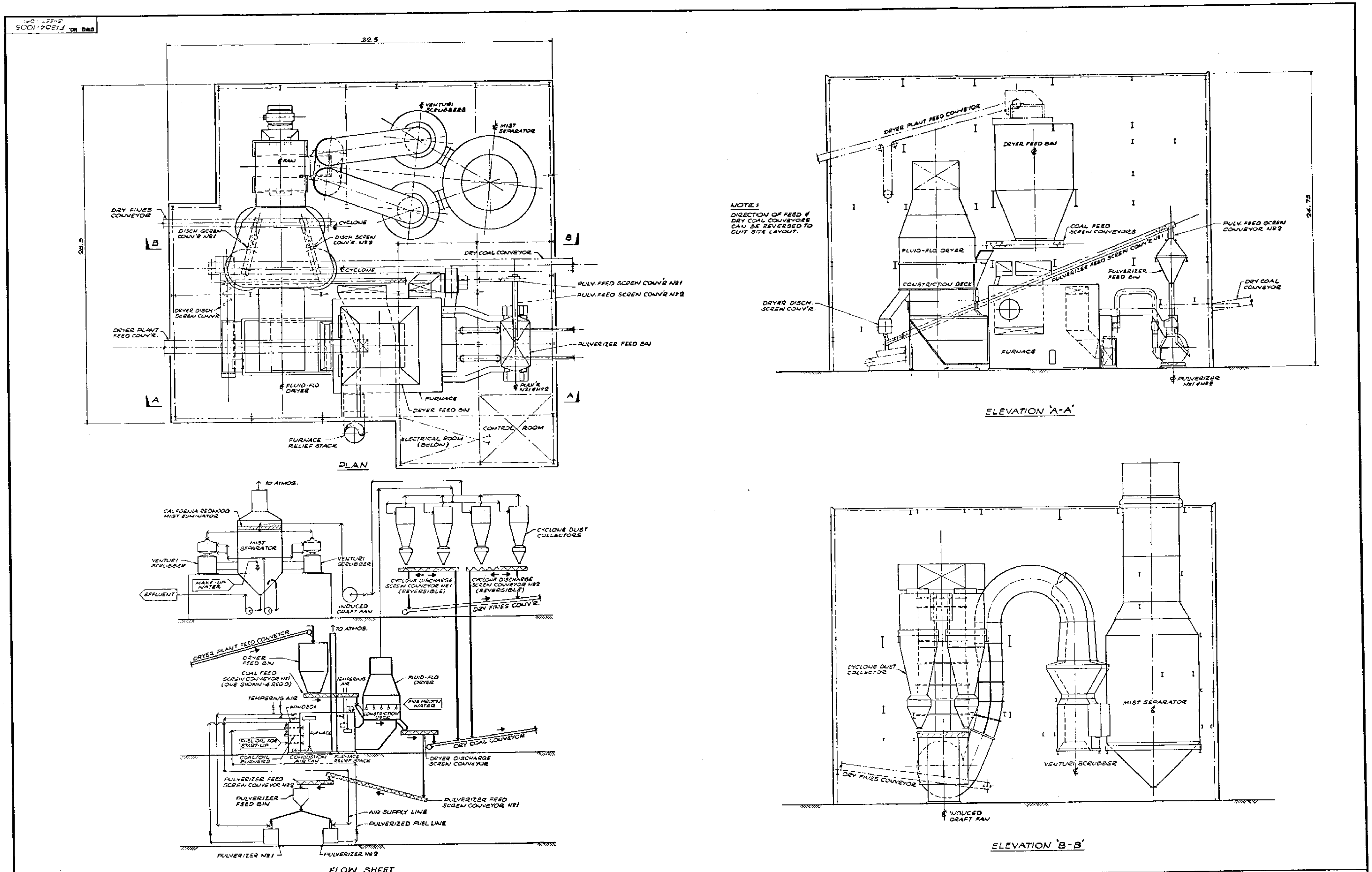
The General Layout and Process Flowsheet is shown on the attached Drawing Figure 5-4-2.

The design and cost estimate is based on one FMC Model 12' x 18' Fluid Flow Dryer System. All auxilliary equipment such as combustion, forced and induced draft fans, coal fired air heater, #2 fuel oil start up system, oil storage tank, dust collection equipment, ductwork, material feed bin, screw feeders, air locks, complete process controls, atomizing instrumentation and control air, and scrubber recycle pump system with level controls are included.

More detailed descriptions of the units are given in the correspondence received from the dryer manufacturers.

524.4 Effluent and Discard Disposal Requirements

There are no tailings from the dryer. The quantity of effluent from the scrubbers has not been determined at this stage, however, it is assumed that this will be handled by the general site facilities. Special facilities would be needed to handle very dry dust/discard fines to the mine discard conveying system.



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA
WILLIAM CORSE
NON-RESIDENTS LICENCE (EXPIRY DATE 8 JAN 1979)

REV.	DESCRIPTION	BY	DATE	CHK.
2	ISSUED WITH FINAL REPORT	K.S.	OCT. 23/78	
1	DRAFT FOR FINAL REPORT.	D.N.	31 MAY 78	

B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
BRITISH COLUMBIA, CANADA

PHOTOGRAPHIC SCALE — MILLIMETRES 5 & 10 DIV./INCH

DESIGNED	D.V.W.		SCALE	PROJ. MGR.	S.C.R.
DRAWN	D.N.	JUNE 7/78	N.T.S.	PROJ. DES.	
CHECKED	S.C.B.			D.O. MGR.	

THIS DRAWING IS CONFIDENTIAL AND IS THE PROPERTY OF SIMON-CARVES OF CANADA LTD. IT MUST NOT BE DISCLOSED TO A THIRD PARTY, COPIED OR LENT WITHOUT THE WRITTEN CONSENT OF SIMON-CARVES OF CANADA LTD.

SIMON-CARVES

AREA:
CATEGORY:
DWG. TITLE: THERMAL DRYER / CLASSIFIER

REPORT FIGURE NUMBER	SCAN DRAWING NUMBER	REV.
5-4-2	F1304-1005 SHEET 1 OF 1	2

524.5 Capital Costs

6,252,000
Total FMC scheme cost.

Allow for Raw Coal Screening, Feed and Product Conveyors and Stockpiles

524.6 Operating Costs per Annum

Power	348,645	
Fuel: Coal at $10.00 per tonne; Oil for start-up	130,357	
Labour	1,180,500	
Spares	241,400	2,232,855

Per tonne of Plant Output

$$= \frac{2,232,855}{2,035,013} = \$1.097$$

Per tonne of Boiler Plant Feed

$$= \frac{2,232,855}{9,382,848} = \$0.238$$

525 TOTAL WASHING: WATER ONLY CYCLONES

This scheme is equivalent to the EMR Canmet Scheme Proposal. A brief outline and materials balance diagrams for a 1500 MTPH plant based on wash results is included in their Report of April, 1978. A conceptual scheme and cost estimate was not prepared for this proposal.

Based on the above Report, and the interpretation of the X and Y sample washability data (after Wet Attrition), a provisional Mass Balance Diagram Figure 5-5-1 is included on the same 1000 MTPH basis as the other schemes described in this section.

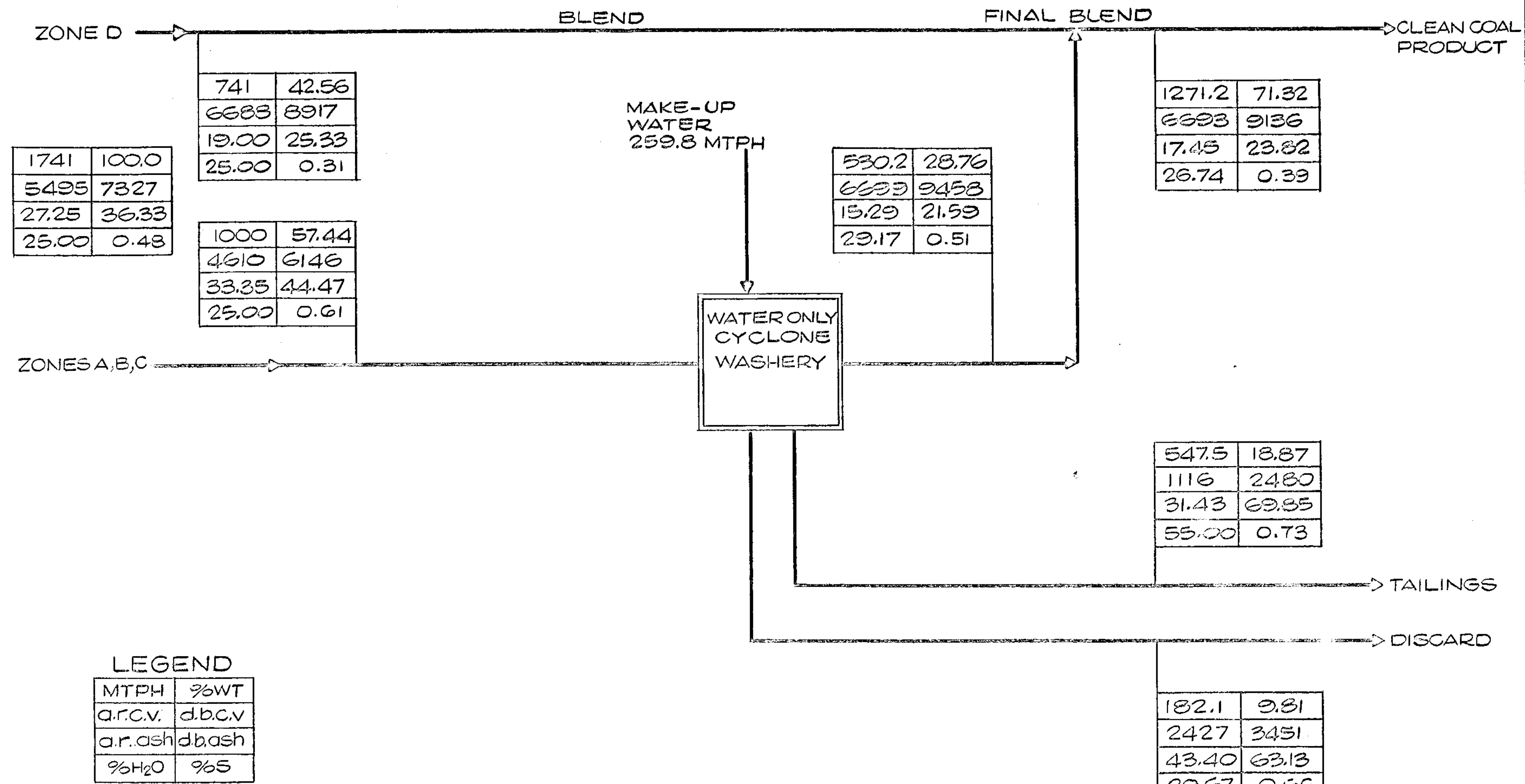
Note that a similar degree of beneficiation to the more conventional Total Washing Scheme 1 would be obtained. The clean coal yield is predicted as marginally lower. The washery plant costs would be significantly lower. However, the tailings problem is substantially increased, viz - two thirds (2/3) of the discard (on a dry solids basis) would be tailings. For EACH 400 MTPH Washery Module, if calculated on the same basis as the earlier scheme, the requirement would be for:-

- ONE 56m diameter Thickener
- SIX Bird "H" Series Centrifuges together with all supporting facilities.

To achieve the same result as the conventional Scheme 1, the tailings quantities are increased by 50% over the conventional scheme as detailed in paragraph 521.4.

526 TOTAL BENEFICIATION: HEAVY MEDIUM BATH AND FINES DRYER-CLASSIFIER SCHEME

Partial Washing by the Heavy Medium Bath, Scheme 2, and the Fines Dryer Classifier, Scheme 4, each have their advantages. These are related to the degree of beneficiation achieved relative to the tailings production.



TOTAL WASHING : W.O. CYCLONES

REV.	DESCRIPTION	BY	DATE	CHK
2	ISSUED WITH FINAL REPORT SULPHUR VALUES ADDED	KS	OCT 20/7	
1	DRAFT FOR FINAL REPORT	TG	MAY 31/7	

B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
BRITISH COLUMBIA, CANADA

DESIGNED P.V.T
DRAWN T.G
CHECKED S.C.B

SIMON-CARVES

DWG. TITLE: MATERIALS BALANCE W.O. CYCLONE WASHERY

REPORT FIGURE NUMBER 5-5-1

F1304-0006 SHT 5 OF 6

REV. 2

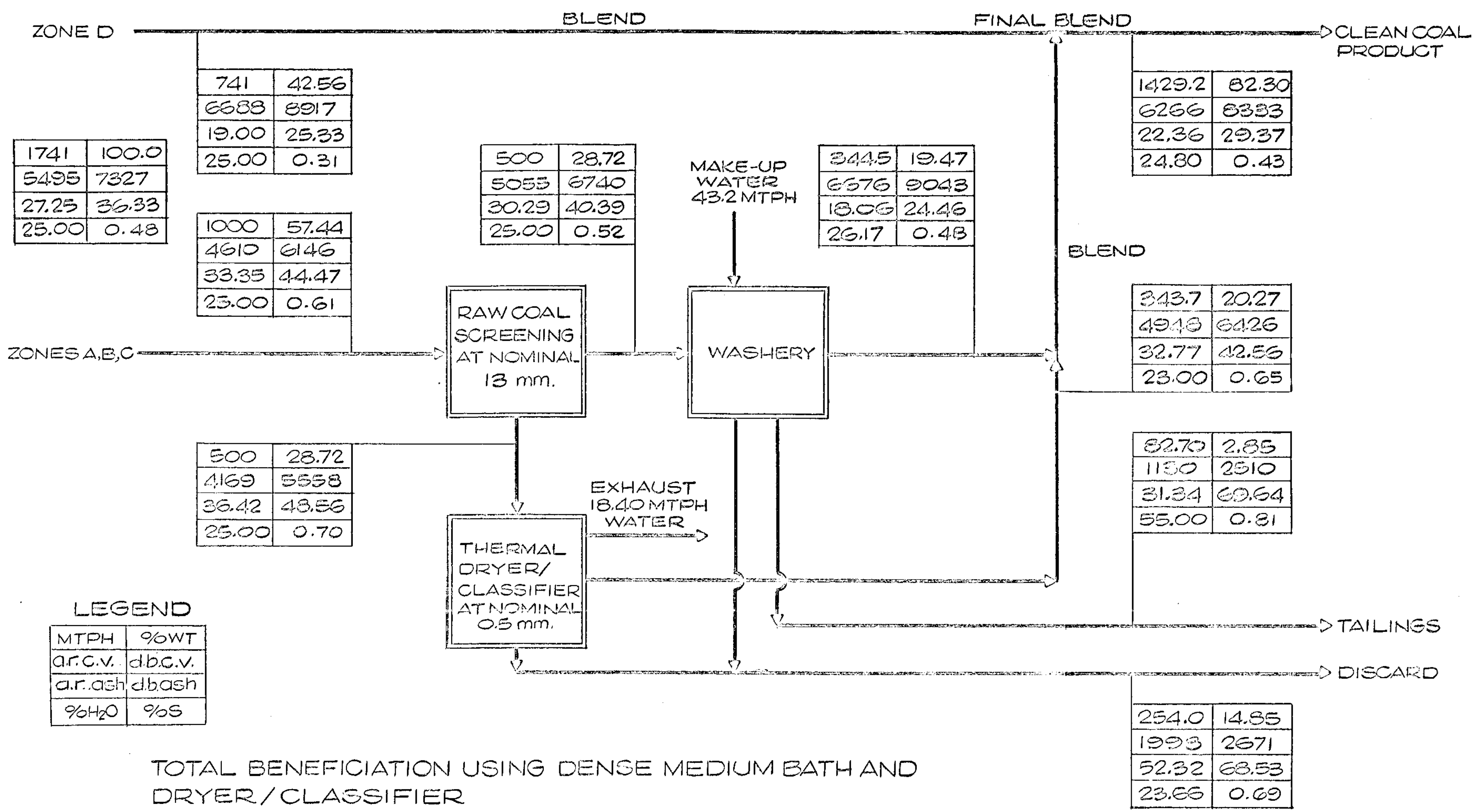
SHEET SIZE I.S.O. A3

Therefore, a composite of these two schemes has been outlined. This is shown as the Materials Balance Figure 5-6-1.

Note that this combined scheme achieves an average product of 6,266 Btu/lb on an as received basis*, together with a manageable tailings problem.

Costs are obtained by adding together those from paragraphs 522.5 and 524.5.

* The significance of this scheme is that it gives the closest overall product quality to the "Typical Quality" which was the starting point for the present studies.



TOTAL BENEFICIATION USING DENSE MEDIUM BATH AND DRYER/CLASSIFIER

REV.	DESCRIPTION	BY	DATE	CHK
2	ISSUED WITH FINAL REPORT SULPHUR VALUES ADDED	K.S.	OCT 20/78	
1	DRAFT FOR FINAL REPORT	TG	MAY 31/78	

B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
BRITISH COLUMBIA, CANADA

DESIGNED: R.V.T.
DRAWN: T.G.
CHECKED: S.G.L.

SIMON-CARVES

DWG. TITLE: MATERIALS BALANCE D.M.BATH + DRYER/CLASSIFIER

REPORT FIGURE NUMBER: 5-6-1

F1304-0006 SHT. 6 OF 6

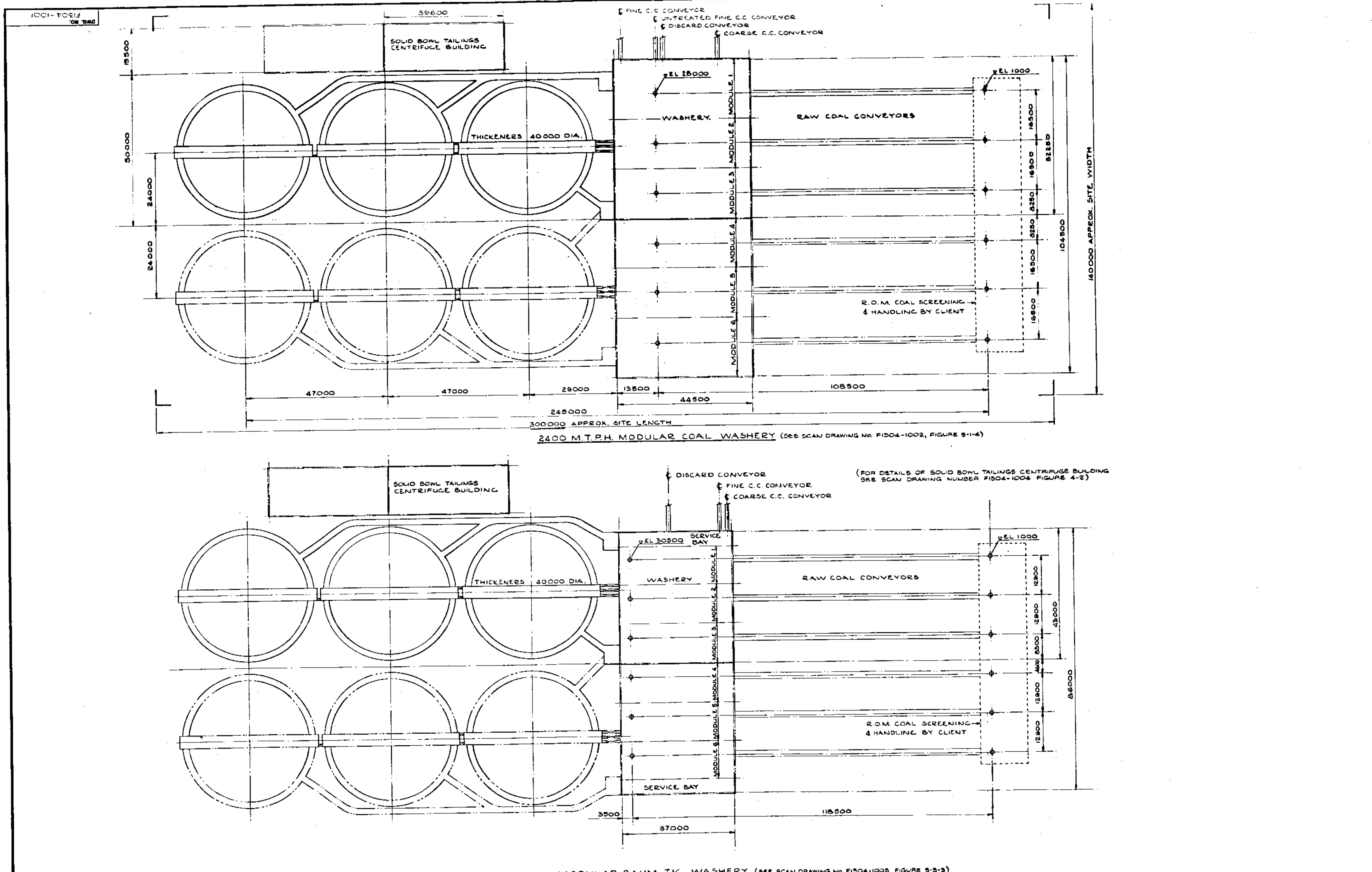
REV. 2

SHEET SIZE I.S.O. A3

5.3 SPACE REQUIREMENTS

Assuming a flat level site, we have outlined space requirements on Figure 5-7-1. This shows up to six modules of dense medium bath and water cyclone washery (schemes 1 and 2) or baum jig washery (scheme 3), together with their associated feed conveyors, thickeners and tailings dewatering plant.

It may be used in conjunction with Figure 5-4-2 to estimate the total space requirements for schemes 4 and 6.



THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF THE PROVINCE OF BRITISH COLUMBIA.
WILLIAM CORSE
NON-RESIDENTS LICENCE (EXPIRY DATE 8 JAN. 1978)

REV.	DESCRIPTION	BY	DATE	CHK.
2	ISSUED WITH FINAL REPORT	K.S.		
1	DRAFT FOR FINAL REPORT	C.W.		

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY,
HAT CREEK PROJECT,
BRITISH COLUMBIA, CANADA.

SIMON-CARVES

DWG. TITLE: SITE PLAN FOR ALTERNATE WASHERY SCHEMES

DESIGNED D.V.W. DRAWN C.W. CHECKED S.C.B. SCALE 1:400

REPORT FIGURE NUMBER	SCAN DRAWING NUMBER	REV.
5-7-1	F1304-1001 SHEET 1 OF 1	2

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

1. The Hat Creek coals examined all have difficult beneficiation characteristics.

2. The washability characteristics range from moderately difficult to very difficult when considered in relation to the simple cleaning normally required for thermal plant fuels.

3. The coals are associated with relatively soft shales and clays, and thus the wet processing methods normally employed would give rise to formidable tailings dewatering and disposal problems.

4. The lower ash coals, i.e. D Zone, are equally difficult and would not in any event, warrant cleaning.

5. The six full sets of washability data suggest that the deposit consists of a "single family" of coals with varying degrees of clay inclusions.

6. The clay inclusions are within even the most minute fissures of the coal particles and account for the high ash contents and difficult washability characteristics.

7. These minute clay inclusions absorb moisture and cause the coal to degrade in wet processing.

8. Deliberate wet attrition can release these clays and facilitate cleaning. The resultant product size consists: washed coal, discard and tailings would all present problems. However, further study of this process offers the best potential for effective beneficiation of lower grade coals.

9. The soft shales and clays means that the finer size fractions are of higher ash content. This is the reverse of the situation where the normal cleaning processes are most effective.

10. The variations in raw coal quality are such that sophisticated mine planning and product blending facilities are essential. The use of beneficiation processes would not substantially alter these requirements.

11. There is no established full scale operation handling similar tailings within restrictions likely to be acceptable at Hat Creek. No definitive proposals can be made without substantial pilot plant work.

12. Dry cleaning would not be effective due to the washability characteristics, quite apart from the probable moisture problems.

13. Drying of the finer coal and classification out of the high ash fines gives a low degree of beneficiation compared to the net loss of heating value. This method is recommended for further investigation, particularly if raw coal surface moisture content proves higher than currently predicted.

14. Due to the poor washability characteristics any significant degree of cleaning would necessitate mining of a relatively large additional quantity of raw coal to maintain the same net heating value output. This cost may be greater than the beneficiation costs.

15. Raw coal handling and boiler plant pulverizer problems were not encountered in the test programme. There is thus no specific requirement for clay removal.

16. The wet attrition test procedure has enabled prediction of results which correlate with test washes. The use of this procedure in conjunction with large diameter drill cores is recommended for future investigations at Hat Creek.

17. Some 6% of the planned mine output is currently classified as low grade coal. This will contain only 2% of the extracted heating value : the lack of definitive proposals for this material is therefore unlikely to affect project viability.

18. Estimates of the beneficiation characteristics of this low grade coal suggest that its beneficiation will present severe problems and the resultant product yield will be of dubious quality. Further testwork, including a pilot plant, is recommended using as mined low grade material in the early years of operation, since the bulk of material will be extracted in years 4 - 10.

19. Plans for further drill core surveys should include washability tests from areas and zones which are not represented by the six major samples taken. This is necessary to validate these studies, which are based on the theory of a family of coals. Of particular value will be samples from the low grade coal and shale-out zones.

SECTION 7

GLOSSARY

7.1 BIBLIOGRAPHY

Australian Standard, 1977. Float and Sink Testing of Hard Coal AS#1661-1977.

B.C. Hydro and Power Authority 1977. Proposed Mine Planning Parameters, BCHPA Memo File 1301.4-2.

________________ 1977. Boiler Fuel Specifications, BCHPA Thermal Engineering Department, April 13, 1977.

BCHPA/C-MJV/SCAN/MBB, 1977-8. Boiler Fuel Specifications Minutes of Meetings of Working Party, Mech. Services Personnel, November 15, 1977, MBB Letter November 28, 1977, December 12, 1977, January 17, 1978, February 10, 1978, March 3, 1978.

BCHPA 1977 Test Program, 1977. Sieve Analysis of Coal Passed Through Bradford Breaker, July 28, 1977.

________________ 1977. Analyses from Burn Test Samples, Chemical and Geological Laboratories Ltd., June 24, 1977.

________________ 1977. Preliminary Observations on Burn Tests, MBB Memo, August 19, 1977.

Beninger, B.L., Tucker, P.V., Lilleker, W.H., 1978. Computer Predictions of Coal Cleaning Performance, Paper to CIM 80th A.G.M. April, 1978.

Birtley Engineering (Canada) Ltd., 1976. Analysis and Beneficiation of Bulk Samples "A","B" and"C" from the Hat Creek Deposit, CSMT Division, August 13, 1976.

________________ 1976. Hat Creek Project, Notes on Visit to Calgary and Vancouver with Reference to the Preparation of Hat Creek Coals by J.H. Griffiths, and Secondment to PD-NCB by G. Armstrong.

Butcher, S.G., editor, 1977. Various Papers on Coal Drying and Classification, September 6, 1977.

Campbell, D.D., Jory, L.T., Saunders, C.R., 1977. Geology of the Hat Creek Coal Deposits, Dolmage Campbell and Associates, June 1977.

Canadian Standards Association. Requirements for Sulphate Resisting Cement.

____________________ 1977. File Note, July 15, 1977.

Cominco-Monenco Joint Venture, 1977. Criteria Used for the Preliminary Engineering Design of the Hat Creek Mine.

____________________ 1978. Effects of Cut-Offs on Quality of Remaining Coal, File Note Revision, January 3, 1978.

____________________ 1978. Values Calculated from 4000 Bt Cut-Off Grade Without Dilution, File Note Revision, April 28, 1978.

EMR CANMET, 1977. Energy Research Laboratories Report ERL 77/96(TR), Pilot Scale Combustion Studies with Hat Creek Coal, October, 1977.

____________________ 1978. Energy Research Laboratories Report ERP/ERL 78, Pilot Scale Preparation Studies with Hat Creek Coal, B.C. Hydro - Canmet Joint Research Project, April, 1978.

EMR Western Research Laboratory, 1977. Correspondence between EMR Edmonton and B.C. Hydro, January 31, 1977 to June 1, 1977.

Fawcett, D.A.,1977. Coal Crushing and Stockpiling, BCHPA 1977 Test Program, December 9, 1977.

____________________ 1977. Drop Tests, BCHPA 1977 Test Program, November 17, 1977.

____________________ 1977. Excavations, BCHPA 1977 Test Program, December 6, 1977.

____________________ 1977. Spontaneous Combustion Tests BCHPA 1977 Test Program, December 9, 1977.

FMC, 1978. Feasibility Study/Budget Proposal, April 25, 1978.

_________________ 1978. Proposal for Pilot Scale Investigation, February 13, 1978.

Heyl and Patterson Inc., 1978. Report on Bird Coal Air Classifier, 1962 with letter April 12, 1978.

Hodgson, S., 1977. Regression Curve Equations C-MJV File Note, December 13, 1977.

Integ-Ebasco, 1976. Interim Report on Hat Creek Coal, July, 1976.

____________________ Power Plant Conceptual Design,
____

LePage, A., Pollard, F., 1976. Methods for Providing Reliable Data for Coal Preparation Plant Design, Paper to 7th International Coal Preparation Congress, 1976.

PD-NCB Consultants Ltd., 1976. Report No. 2, Preliminary Report on Hat Creek Open Pit No. 1, March, 1976.

_________________________ 1977. Report No. 9 (Draft), Revised Report on Hat Creek Open Pit No. 1, March, 1977.

Simon-Carves of Canada Ltd., 1977. Observations on Production of Test Burn Samples, SCAN Memo, June 17, 1977.

_________________________ 1977. Memo from S.G. Butcher to J.J. Fitzpatrick, BCHPA, July 6, 1977.

_________________________ 1977. Hat Creek 1977 Washability Test Programme, August 2, 1977.

_________________________ 1977. Beneficiation Yields for Hat Creek Coals, August 19, 1977. (Graph)

_________________________ 1977. Blending and Stockpiling Requirements, September 19, 1977.

______________________ 1977. Summary Report on Preliminary Design and Costing of a Modular Coal Washery, October, 1977.

______________________ 1977. Hat Creek Washability Test Procedure Revised Procedure for Attrition Test and Subsequent Analyses, November 24, 1977.

______________________ 1977. Draft Report on the Potential Application of Alternative Processes for the Beneficiation of Hat Creek Coals, December 1977.

______________________ 1978. Block Flowsheets for Basic Alternatives, January 17, 1978.

______________________ 1978. Draft Report on Preliminary Design of Alternative Equipment for Tailings Disposal, January 1978.

______________________ 1978. Report on Visit to Grand Forks, N. Dakota and FMC/Commonwealth Edison Offices by S.G. Butcher, January 19,20, 1978.

______________________ 1978. Sulphur Beneficiation, Summary Memos, February 8, 1978 and May 4, 1978.

______________________ 1978. Coal Beneficiation by Spherical Agglomeration, Review of Current Literature, March 9, 1978.

______________________ 1978. Summary Report on Preliminary Design and Costing of a Baum Washery Scheme, March 1978.

______________________ 1978. Beneficiation of Low Grade Coals, March, 1978.

Simon-Hartley (UK) Ltd., 1978. Private Communication to S.G. Butcher from Industrial Effluents Division, 1978.

Stamicarbon Bv (division of Dutch State Mines), 1977. Private Communication to S.G. Butcher, May, 1977.

Warnock-Hersey Professional Services Ltd., 1977. Size Analysis and Conventional Washability Data of plus ¼" Material, Washability Testwork of 1977 Bulk Samples, November 4, 1977.

_______________________________ 1977. Washability Data of Minus ½" Material After Wet Attrition, Washability Testwork of 1977 Bulk Samples, December 20, 1977.

7.2 GLOSSARY OF SELECTED TERMS

Ash Balance - see Materials Balance

Btu Yield (or Heating Value Yield) -

$$\frac{\text{Calorific Value of Product}}{\text{Calorific Value of Raw Coal}} \times \frac{\text{Wt. Yield of Product}}{\text{Calorific Value of Raw Coal}}$$

Calorific Value - note that all values quoted are Gross Calorific Value (HHV).

Cut Point - the density corresponding to 50 percent recovery as read from a Partition Curve (see below). Also known as Partition Density and density of separation

Degradation - term applied to the breakage of coal caused by weathering and/or handling

Degree of Beneficiation -

$$\frac{\text{lb ash per } 10^6 \text{ Btu in Raw Coal}}{\text{lb ash per } 10^6 \text{ Btu in Cleaned Coal}}, \text{ or}$$

$$= \frac{\text{\% Ash Content of Raw Coal}}{\text{\% Ash Content of Cleaned Coal}} \times \frac{\text{Calorific Value of Cleaned Coal}}{\text{Calorific Value of Raw Coal}}$$

Discard - material extracted by cleaning plant and sent to refuse disposal

Friable - the tendency toward breakage on handling - an indication of the strength of coal

Materials Balance - logical application of the law of conservation of matter. A balance must be obtained for all the coal quality analyses, including ash, moisture, sulphur and calorific value.

Middlings - see Section 7.3

Misplaced Material	- the percentage of a feed which reports to the wrong product (by comparison to a theoretically perfect separation). May be applied to cleaning or sizing processes
Near-Gravity Material	- material within $\pm$ 0.10 specific gravity of the cut-point. (see Section 7.3)
Partition Curve	- Indicates for each small specific gravity fraction the percentage of that fraction which reports to floats product in an actual cleaning process. It is therefore a representation of the process capability which is independent of the coal being treated. Also known as Distribution Curve or Tromp Error Curve.
Raw Coal	- coal which has received no cleaning - but may have been affected by crushing, handling, blending
Reject	- high gravity material separated by a cleaning unit
Run of Mine Coal	- coal as produced from the mine mouth (It may have received limited top-size control to facilitate conveying, but no other treatment)
Scalping	- removing coarse top-size lumps or coarse high gravity material to protect subsequent processes
Tailings	- the nominally minus 28mesh/100mesh fine reject from a wet beneficiation process. This is normally flocculated and removed by a clarifier to form a thick sludge which may be filtered or centrifuged: fine high ash material which cannot be recovered by screening processes
Yield Error	- the difference between the yield of clean coal product actually obtained by a cleaning process and that which can be theoretically obtained at the same product ash content

7.3 SIGNIFICANCE AND USE OF WASHABILITY DATA

The float and sink analysis is conducted by introducing the coal sample into liquids of different specific gravity, usually within the range 1.30 - 1.90, weighing and analyzing the sink and float products for each gravity separation. Separate tests are done for each size fraction, these fractions being selected to correspond primarily with the size ranges which may be treated by alternative processes.

This testwork thus gives the theoretical yield and quality which may be obtained by gravimetric separation at these specific gravities. The results are traditionally expressed as "Washability Curves", each of which should be a smooth curve, and from which intermediate values can be readily estimated. In this study, the curves have been "drawn", interpolated and extended by established computer programmes.

Practical application of gravimetric separation processes can then be simulated by applying their known Partition Curves to this data : by manual calculations, graphical representations, or, as in this study, by the computer programmes.

The higher the specific gravity of a fraction, the higher its ash content. Thus, separation at a given specific gravity means that all particles less than say 30% ash will be classed as clean coal product and all particles of more than 30% ash as reject.

A raw coal which has "good" or "easy" washability characteristics has a high proportion of particles of either less than say 1.40 specific gravity and more than say 2.0, and very few particles in the intermediate specific gravity fractions. Any specific gravity cut-point between these values will achieve a low ash clean coal, and high ash reject.

A raw coal which has "poor" or "difficult" washability characteristics has a high proportion of particles in the intermediate specific gravity fractions. In this case the cut-point would have to be at a lower value to achieve the required clean coal ash content. The yield would be low, and a valuable proportion of the raw coal heat content would be discarded as a lower ash reject.

The significance of this has been brought out in this study in terms which are more readily related to the proposed utilization as a thermal fuel, eg. the degree of beneficiation at a given percentage Btu yield.

Another aspect of this data is significant in the selection and design of the coal preparation processes. Dry cleaning (or air cleaning) and water medium processes achieve specific gravity separations by virtue of interactions between the particles. These forces are strong between say pieces of good coal (specific gravity 1.30) and competent shales (specific gravity 2.60), and it is "easy" to achieve an effective separation of such raw coals. Where a high proportion of the material is within ± 0.1 of the required specific gravity cut-point, these forces are correspondingly lower and the separation is "difficult".

Quite apart from the problems of maintaining stable operation, and thus achieving product consistency when the coal washability is "difficult", the crowding of the process unit with these near gravity particles reduces its effective throughput rating. This is significant even in the dense medium processes.

To maximize yield it is frequently possible to "liberate ash" by crushing the intermediate specific gravity fractions. For example, the coarser coal will be subjected to two separations known as three product washing: producing cleaned coal, reject (i.e. shale), and "middlings".

If the "middlings" consist of intergrown pieces of coal and shale, these will separate on crushing and are termed "false middlings". On reprocessing in the small coal cleaning unit, more clean coal yield may be obtained.

If the "middlings" is coal with high ash material so intimately bound in the coal structure that they do not separate on crushing they are termed "true middlings". Hat Creek coals have a very high proportion of "true middlings". The clay in the minute fissures of these Hat Creek "true middlings" is however, liberated by attrition in wet processing as discussed in the body of the report.

Difficulty of Cleaning, with particular reference to the capability of water medium processes has been defined:-

Percentage of Feed to process within ± 0.1 specific gravity of required cut-point	Ease of Separation
0 - 7	Simple
7 - 10	Moderately Difficult
10 - 15	Difficult
15 - 20	Very Difficult
20 - 25	Exceedingly Difficult
Above 25	Formidable

7.4 USE OF ROSIN-RAMMLER EQUATION

The breakage of coal in mining, handling, crushing, pulverizing and processing is not a haphazard event in the sense that the size distribution is entirely unpredictable. The most widely utilized law is that formulated by Rosin and Rammler, which can be represented :

$$\log \log \frac{1}{R} = n \log X + k$$

where:

R = percentage of powder resting on a sieve having an aperture of X

and n & k are constants which are characteristics of specific coal sample and the nature of breakage it has received.

This complex formula can be applied graphically by use of a special logarithmic paper, a sample of which is given as Figure 7-1. (This particular form has been drawn up for use with standard screen and sieve sizes used in the Hat Creek study).

Line A represents a typical run of mine coal sample with a top-size somewhat over 12 inches. The size consist is 45% coarser than 1 inch, 50% 1 inch x 28mesh, and 5% finer than 28mesh. If the Rosin-Rammler equation applies such that n remains a constant during subsequent breakage then lines B and C may be projected. For example, B could represent a 6" x 0 washery feed : note that the quantity of coal finer than 28mesh has increased to 10%.

In practice deviations from the straight line are common, but may often be identified as tails to the anticipated set of parallel lines.

Many coal seams have, because of the cleats in the coal seam structure, a tendency to break more readily to a natural grain size, and less readily to finer sizes. Thus tail D indicates natural breakage around 1/16 inch,as a result of which crushing the raw coal may not cause such a significant increase in 65mesh x 0 particles.

Soft shales and clays breakdown readily in water to very fine "slimes". A raw coal which contains such materials will therefore give excessive fines as a result of wet processing, such that the effective size consist in the plant is represented by line B with tail E.

By a combination of good crushing and screening practice is is possible to avoid degradation of correctly sized particles: for example, by passing only the +2" material to the crusher a 2" x 0 total product could be obtained with a size consist represented by line B with tail F rather than line C. If the characteristic of tail D also applies, the total line F through B to tail D, will have the appearance of a line of steeper slope.

Values of n in the range 0.6 to 0.9 are frequently reported for raw coals, from 0.8 to 1.1 for crushed screened coals, and generally over 1.0 for pulverized coals.

A value of n near unity is also reported for some coals immediately on extraction at a coal face. Random forces of handling, storage, processing and weathering thus tend to reduce the value of n. Hence it is necessary to perform coal preparation testwork on raw coals after handling to simulate the likely mining conditions, rather than on freshly cut pillar or box cut samples. Similarly, whilst a raw coal crushing scheme may give a product of size consist represented by line F through B, the coal is likely to degrade in processing or storage towards line C, i.e. the natural line with a top size of 2".

In the case of uncleaned Hat Creek Coals the clay can be expected to degrade by absorption of moisture and give unusual curves of the form F through B to E.

Practical observations of a coal are often of value in predicting likely size consist data. For example in Trench A it was observed that the soft shale/clay partings were at various intervals, seldom greater than 12 inches. Thus, even if very gentle blasting or large mining equipment is employed, it would be unrealistic to anticipate a top size of more than 12 inches after normal handling to the mine mouth.

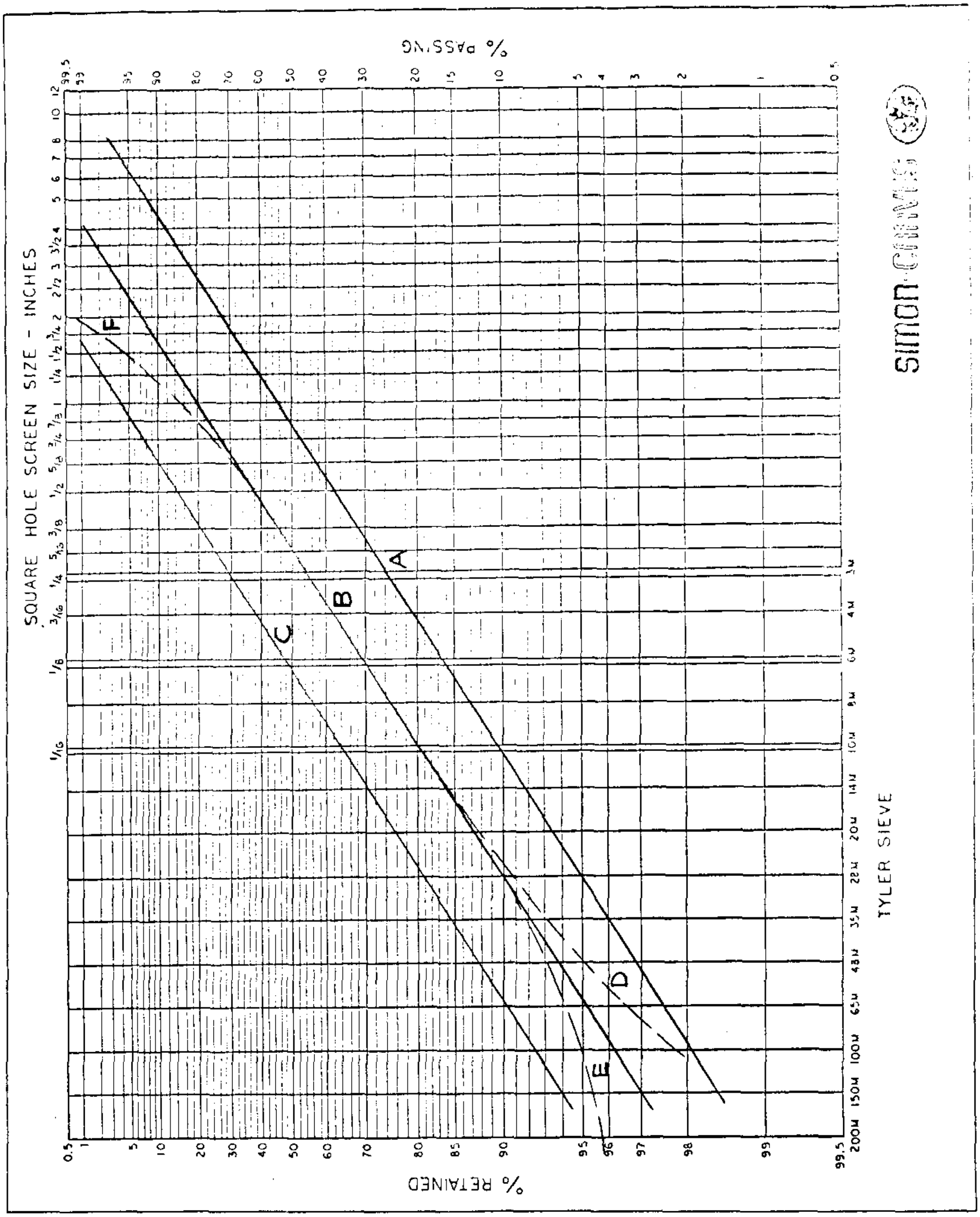


FIGURE 7-1

Forms of Typical Rosin-Rammler Graphs