MINE WASTE DUMP MANAGEMENT STUDY:

A PROGRESS REPORT

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BACKGROUND

STUDY FOR THE TECHNICAL AND RESEARCH COMMITTEE ON RECLAMATION,

FUNDED LARGELY BY THE CANADA-BRITISH COLUMBIA MINERAL DEVELOPMENT SUBSIDIARY AGREEMENT,

CONDUCTED BY: NORECOL ENVIRONMENTAL CONSULTANTS LTD

ASSISTANCE: WRIGHT ENGINEERS LIMITED
THURBER CONSULTANTS LIMITED
POLSTER ENVIRONMENTAL SERVICES
OBJECTIVES OF STUDY

- To develop criteria for waste dump management for future as well as past dumps.
- Evaluate the major engineering (materials handling, cost) stability and environmental factors important for consideration.
- Consider the need for and when resloping may be required.
OBJECTIVES OF THIS PRESENTATION

0 STUDY IS IN PROGRESS AND RESULTS ARE NOT COMPLETE

0 PRESENT INTERIM RESULTS FROM LITERATURE SURVEY, INTERVIEWS AND INDUSTRY QUESTIONNAIRE

0 PRESENT SOME INITIAL FINDINGS AND OBTAIN FEEDBACK FROM AUDIENCE
OVERVIEW OF PROBLEM

LEGISLATION: GENERAL REQUIREMENT FOR RECLAMATION UNDER

- **MINES RECLAMATION ACT (1969) 11(1)**

- **COAL MINES REGULATION ACT (1969) 8 (1)**

- **MEMPR GUIDELINE (1984)**

- "ALL WASTE DUMPS SHALL BE RECLAIMED IN ACCORDANCE WITH THE LAND USE OBJECTIVES"

- "WASTE DUMPS SHALL BE RECONTOURED SO THAT THE ANGLE OF REPOSE DOES NOT EXCEED 27 DEGREES, UNLESS PROVED THROUGH FIELD SCALE TRIALS THAT LAND USE AND PRODUCTIVITY OBJECTIVES CAN BE OTHERWISE ACHIEVED"

...CONT’D
COST:

- Resloping can be largest reclamation cost item

- Outstanding reclamation costs on active mining sites total millions of dollars - costs will be greatly affected by resloping decisions

...Cont'd
ENVIRONMENTAL

- BENEFITS DIFFICULT TO QUANTIFY
- MUCH VARIABILITY IN CONDITIONS FROM MINE TO MINE
- NEED TO PROVIDE GUIDELINES
  - REASONABLY SIMPLE FOR ADMINISTRATION, ETC
  - BUT, BY NATURE, CAN TEND TO BE: ARBITRARY AND INFLEXIBLE OR TOO VAGUE AND GENERAL
- EXTREMES ARE LESS DIFFICULT: E.G.
  - LIFE OR PROPERTY ENDANGERED
  - VERY HIGH VALUE SPAWNING STREAM
  - REMOTE AREAS WITH ONLY LOW WILDLIFE HABITAT VALUES
- IN BETWEEN CASES CAN BE PROBLEMATIC

INSTITUTIONAL

- TOO MANY INDIVIDUAL COMPANIES AND GOVT AGENCIES ACTING IN RELATIVE ISOLATION?
PROGRESS - WHAT HAS BEEN DONE?

0 LITERATURE SEARCH

CAN MET DATA BANK
30,000 SOURCES
>200 "POTENTIAL" REFERENCES
116 REVIEWED
28 DIRECTLY RELEVANT REFERENCES

OTHER SOURCES LIBRARIES INFORMATION ON HAND
(PROCEEDINGS, ETC)

... CONT'D
QUESTIONNAIRES TO INDUSTRY

- 30 SENT

11 RESPONSES TO DATE
(EXPECT SOME MORE TO COME)

SOME VALUABLE DESCRIPTIVE DATA (SEE TABLE FOR EXAMPLE)
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>% rock &gt; 10 cm</td>
<td>41%</td>
<td>31%</td>
<td>2 - 95%</td>
</tr>
<tr>
<td>% hard durable rock</td>
<td>56%</td>
<td>34%</td>
<td>0 - 100%</td>
</tr>
<tr>
<td>Stack Angle (degrees)</td>
<td>36°</td>
<td>2.5°</td>
<td>26° - 37°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(always 37° for coal)</td>
</tr>
<tr>
<td>Acid Producing</td>
<td>19%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(% of &quot;yes&quot; responses)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Metals</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(% of &quot;yes&quot; responses)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Range</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------</td>
<td>--------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Overall Height (m)</td>
<td>108m</td>
<td>86m</td>
<td>10 to 300m</td>
</tr>
<tr>
<td>Terrace Ht. (m)</td>
<td>28m</td>
<td>15m</td>
<td>10 to 58m</td>
</tr>
<tr>
<td>(when present)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terrace Width (m)</td>
<td>39m</td>
<td>16m</td>
<td>14 to 60m (2 mines no</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>terrace width)</td>
</tr>
<tr>
<td>Slope Face Length (m)</td>
<td>74m</td>
<td>51m</td>
<td></td>
</tr>
<tr>
<td>Av. as built dump slope (degrees)</td>
<td>28°</td>
<td>8°</td>
<td></td>
</tr>
<tr>
<td>Surface erosion (% yes)</td>
<td>25%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stability problem</td>
<td>10%</td>
<td>-</td>
<td>-</td>
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</tbody>
</table>
WASTE DUMP CLASSIFICATION

- 5 CONFIGURATIONS

- USEFUL FOR COST ANALYSIS

- MAY ALSO BE APPLIED TO OTHER CONSIDERATIONS

- EXAMPLES (FIGS, 1 - 5)

COST ANALYSIS

- FRAMEWORK DEVELOPED

- NEEDS SOME REFINEMENTS

- NEED GOOD INPUT DATA FOR COSTS AND VALUES!

- SEE EXAMPLE
CONCLUSIONS (INTERIM)

0 IN GENERAL, CRITERIA ARE WIDELY DOCUMENTED IN LITERATURE; NEED TO KNOW HOW TO WEIGHT VARIOUS CRITERIA IN VARIOUS SITUATIONS AND NEED A FRAME WORK FOR GUIDING DECISION MAKING

0 END LAND USE AND COSTS ARE COMMONLY THE MOST IMPORTANT CRITERIA IN DETERMINING WHETHER OR NOT AREAS SHOULD BE RESLOPED

0 SHOULD NOT LOOK AT WASTE DUMPS IN ISOLATION – CONSIDER LAND USE AND PRODUCTIVITY IN PERSPECTIVE OF THE TOTAL MINE AREA

0 ANY ONE, RIGID, BLANKET RULE SUCH AS - ALL DUMPS MUST BE SLOPED TO 26 DEGREES - MAY NOT BE JUSTIFIABLE

0 WASTE DUMP CLASSIFICATION AND COST ANALYSIS METHODS MAY BE USEFUL AIDS FOR RECLAMATION DECISION MAKING

0 RESLOPING CONSIDERATIONS REQUIRE ENGINEERING, COST AND GEOTECHNICAL CONSIDERATIONS AS WELL AS ENVIRONMENTAL
I. Valley Bottom / Internal Pit Operation

• PIT AND WASTE DUMPS ESTABLISHED ON FLAT LAND
• DEVELOPMENT OF PIT RIMS
• HAULS BECOME MORE ADVERSE AS OPERATIONS MATURE
• DUMP CAN BE TERRACED ECONOMICALLY TO CREATE FLATTER ANGLES

EXAMPLE: COMINCO'S VALLEY COPPER OPERATION
2. Mountain Bench / Daylighted Pit Operation

- OREBODY ON SIDE OF MOUNTAIN, SLOPE GRADIENTS 20 DEGREES APPROX.
- OREBODY SHALLOW AND IT'S PLUNGE PARALLEL TO SLOPE OF GROUND
- MOST OF BENCH DAYLIGHTED
- HAULAGE OF WASTE FLAT TO DUMP
- NECESSITY FOR MAINTAINANCE OF HAULAGE BERMS RESULTS IN DUMP FACE SLOPES 16-23 DEGREES

EXAMPLE: ABANDONED DUMPS OF CRAIGMONT MINES
3. Mountain Bench/Internal Pit Operation

- SITUATION OF OREBODY EXCLUDES POSSIBILITY OF DAY-LIGHTING THE BENCHES
- PIT RIM ESTABLISHED EARLY
- WASTE HAUL IS ADVERSE TO PIT RIM THEN FLAT TO DUMP
- DUMP BERM ADVANCED BY END DUMPING, CREATING A 37 DEGREE SLOPE FROM DUMP CREST TO TOE
- TOO EXPENSIVE TO CONSTRUCT AT FLATTER ANGLES

*EXAMPLE: GIBRALTER MINES*
4. Mountainous Terrain/Daylighted Pit Operation

- HIGH ON MOUNTAIN SIDES ( > 37 DEGREES, > 100 M)
- SHALLOW OREBODY ENABLING DAYLIGHTED BENCHES
- NEED CONSIDERABLE WASTE DUMPAGE TO ESTABLISH A CONTINUOUS SLOPE BACK FROM VALLEY FLOOR TO DUMP ELEVATION
- HIGH TENDENCY FOR CREEP IN UNSTABLE WASTES (E.G. OVERBURDENS) WHICH SPILL ACROSS VALLEY FLOOR
- THUS, POSSIBLE NEED FOR TOE DYKES OR OTHER MEANS OF CONTAINMENT
- UPON ESTABLISHMENT OF DUMP BERM, DUMPS MAY BE BUILT AT A REDUCED SLOPE ANGLE

EXAMPLE: FORDING COAL (EAST KOOTENAYS)
5. Terraced Slopes

- IDENTICAL TO NO.4, ONLY BENCHES NOT DAYLIGHTED
- SINGLE DUMP ELEVATION AT PIT RIM
- SHALLOW OREBODY, NEED CONSIDERABLE WASTE DUMPAGE TO ESTABLISH A CONTINUOUS SLOPE AND UNSTABLE WASTES TEND TO CREEP
- TOO EXPENSIVE TO CONSTRUCT DUMP SLOPE AT FLATTER ANGLE
- POST-OPERATIONAL RESLOPING (ONCE DUMP INACTIVE)
- CONTAINMENT MAY BE PROVIDED BY TOE DYKES

EXAMPLE: BETHLEHEM MINES
VARIABLES CONSIDERED IN COST ANALYSIS

• SLOPE ANGLE, CONTINUOUS OR TERRACED
• RESLOPING COST ($/m³ MOVED)
• REVEGETATION COST
• CONSTRUCTION COST (INCREMENTAL $/HA DUE TO $/+ HAULED DURING CONSTRUCTION OF DUMP TO INITIAL 27°) NOT USED IN EXAMPLE
• DUMP HEIGHT
• GROUND SLOPE
• SLOPE LENGTH
• TOE LAND
• RESLOPE VOLUME (VOL. MOVED IN RESLOPING PER METRE LATERAL DUMP TO DISTANCE)
• REHANDLE (APPROX. % OF ABOVE THAT MUST BE REHANDED IN RESLOPING THE DUMP)
• LAND VALUES
  ORIGINAL ASSESSED VALUE OR END USE OF LAND OCCUPIED BY DUMP
  RECLAIMED VALUE OR POTENTIAL LAND USE OF RESLOPED DUMP SURFACE
• NOTE
  (COST AND LAND VALUE DATA USED IN EXAMPLES ARE ORDER OF MAGNITUDE ESTIMATES)
### EXAMPLE

**COST ANALYSIS OF MINE WASTE DUMP RESLOPING** *($/HA)*

<table>
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<tr>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>RESLOPING</td>
<td>-246</td>
<td>-1218</td>
<td>-1218</td>
<td>-947</td>
<td>-947</td>
</tr>
<tr>
<td>TOE COVER</td>
<td>-38</td>
<td>-227</td>
<td>-227</td>
<td>-104</td>
<td>-104</td>
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<tr>
<td>RECLAMATION</td>
<td>-3000</td>
<td>-3000</td>
<td>-3000</td>
<td>-3000</td>
<td>-3000</td>
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<tr>
<td>TOTAL COST</td>
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<td>-4445</td>
<td>-4445</td>
<td>-4051</td>
<td>-4051</td>
</tr>
<tr>
<td>RECLAIMED LAND VALUE</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td>NET VALUE</td>
<td>-784</td>
<td>-1945</td>
<td>-1945</td>
<td>-1551</td>
<td>-1551</td>
</tr>
</tbody>
</table>

**ASSUMPTIONS**

- DUMP HEIGHT = 50 m
- ORIGINAL LAND VALUE = WILDLIFE @ $500/HA
- RECLAIMED LAND VALUE = FORESTRY @ $2500/HA
- POST OPERATION, CONTINUOUS RESLOPE RECLAMATION DUMPS ORIGINALLY BUILT BY END DUMPING @ 37º
- RESLOPE ANGLE = 27º