monenco consultants pacific ltd.
535 THURLOW STREET,
VANCOUVER, B.C. V6E 3L2
Telephone: (604) 687-0331 Telex: 04-53347

15 December 1976

Dolmage Campbell
1055 W. Hastings
Vancouver, B.C.

Reference: Hat Creek Thermal Plant
Hat Creek Diversion Study

Gentlemen: -

The draft report entitled "Hat Creek Diversion Study" prepared for the British Columbia Hydro & Power Authority is complete and is available for your examination in our office.

At this time publication of the draft is limited, therefore we have enclosed a xerox copy of the sections which overlap with your studies and would be pleased to receive your comments on the material presented in the report.

We trust that this is to your satisfaction.

Yours very truly,

D. R. Duguid, P. Eng.
Vice-President

JPC/mmck.

Encl.

cc R. Merer - Integ-Ebasco

TABLE OF CONTENTS

SUMMARY

The terms of reference were interpreted in essence to require examination of the Hat Creek Valley in the context of the proposed coal mine and thermal plant, and to consider all reasonable alternative ways to divert Hat Creek around the works taking into consideration the reliability, ease and cost of operation, capital cost, and environmental and social impact on the area. These schemes were to be listed, their merits and difficulties explained, and a recommendation made for the best scheme considering all factors. Mitigation and enhancement measures where appropriate were also to be suggested.

Diversion Schemes

A wide range of alternatives were considered for diversion around the Pit No. 1 area including those utilizing flow by gravity, by pumping and by upstream diversion out of the watershed. For conduits, consideration was given to canals, tunnels, flumes, pipes and chutes. A preliminary examination was made of utilization of Hat Creek flow for the plant water supply.

From these alternatives three were selected as practical and relatively more economic, all using a diversion route on the east side of the mine:

1. A Canal scheme whereby the creek would be diverted upstream of the pit perimeter at sufficient elevation to flow in a sidehill canal at El. 3200 along the edge of the mine excavation discharging into Harry Creek and thence returning to Hat Creek. Canal capacity would be 800 cfs.

2. A Tunnel scheme at El. 3150 which substitutes a lined tunnel conduit having an 800 cfs capacity for the centre reach of the canal, and carrying the creek flow well outside the pit perimeter discharging into Harry Creek.

3. A Pumping scheme which provides creek flow regulation by upstream storage reservoirs formed by earth fill dams, and pumps this flow using a 100 cfs

capacity pumping plant through a pipeline along the pit perimeter to Harry Creek. A diversion canal carries up to 40 cfs from the headwaters of Hat Creek out of the watershed into Oregon Jack Creek thus reducing the flow to be pumped or stored for the main diversion.

The above schemes were examined in more depth to permit preliminary detailed estimates to be made. Of these the canal scheme was judged by far the best. There was little to chose between the tunnel scheme and the pumping scheme as regards total cost, although the latter has a substantially greater impact on the community and environment than the other schemes, primarily due to the need for storage reservoirs.

The chief advantages of the canal scheme are (1) a cost of $6.9 million which is about half that of the other schemes, (2) a higher degree of reliability than the pumping scheme, together with low operating and maintenance costs. (3) a very low community and environmental impact. (4) simple rapid earthwork construction - relatively cost inflation proof in recent years.

The chief disadvantage is the possible requirement after 26 years to divert by a tunnel a short centre reach which infringes on the pit perimeter. This might not be required depending on possible pit perimeter and mine slope adjustments. The present worth of the tunnel is included in the cost estimate.

Environmentally the diversion schemes' principal impact is the alienation of land. There will also be some loss of fish production, the magnitude of which will vary with the final selection. Surface disturbances range from 55 acres in a tunnel concept, to 135 acres with a canal scheme and 375 acres for a pumped diversion. Community impact through the interuption of ranching operations will be significant only with the pumped diversion. Although the importance of incremental impact to the environment is recognized, the overall impact of the diversion is minor in relation to that which would be caused by the mine and project as a whole.

Table 6-1 provides a comparison and ranking of the three schemes with regard to engineering, cost and environmental considerations.

An arrangement for providing Hat Creek water for the thermal plant has also been examined on a preliminary basis and depending on the value of benefits which might result, such a scheme could prove viable and is deserving of further investigation. However the environmental and social impact is higher than for the other diversion schemes due to the need for more storage reservoir capacity.

It was not found practical for any of the diversions to pass the maximum probable flood around the pit. However all schemes meet the criterion that only flows greater than the 100 year flood would spill any water into the pit. The probability of such spill into the pit is about 1 in 3 and may be reduced by utilizing the reserve capacity built into the systems. It may be further reduced by adding storage or increasing diversion capacity but at additional cost.

1. The Hat Creek Valley

1.1 Topography, Geology and Soils

The Upper Hat Creek Valley (Fig. 2) lies from south to north roughly mid way between the Fraser River Valley to the west and the Thompson River Valley to the east. The north/south trending portion of the Hat Creek Valley bottom has an elevation between 2700 ft at the north end and 3800 ft at the south end, thus lying more than 2000 ft higher than the Fraser and Thompson Rivers to the west and east.

The No. 1 coal deposit lies at the north end of the valley over an area of about 1 square mile. The larger No. 2 deposit underlies about 4 miles of the valley to the south and both coal areas extend virtually from one side of the valley to the other.

Hat Creek is a small stream although subject to substantial flood flows, which follows a gentle and meandering course in the southern part of the valley where it runs over the No. 2 coal deposit. Towards the north end of the valley it is incised about 60 feet into the overburden before running over the No. 1 deposit and turning sharply to the east to join the Bonaparte River.

The rock formations in the Hat Creek area are of the Jurassic and Cretaceous period which have been extensively folded and faulted. These rocks are primarily volcanic and sedimentary, with granitic intrusions into the latter. Tertiary sediments overlay these rocks in some areas and in recent time there has been mantling of the bedrock by till, sands and gravels, with some clayey slide areas. The study area is almost entirely covered by overburden, with few bedrock outcrops.

The soils in the valley which vary in depth for a few feet to 500 ft or more, are of glacial origin and include till, clay, sand, gravel, and boulders. Till predominates in the area as ground moraine while there are alluvial fans of gravel at points along some of the tributary creek valleys. Gravels are also present in the Hat Creek flood plain. There are a number of mud flows in the area and one flow west of No. 1 Pit location is active. There are some areas of talus rock. The water table is high in the valley bottom but there is no evidence of substantial subsurface flows down the valley.

1.2 Climate and Hydrology

Hat Creek Valley lies in the south west interior of British Columbia on the western extremity of a "Dry Belt" which extends from Lytton through Ashcroft to Kamloops. Precipitation is light on the valley floor. The recorded mean being 12 inches per annum of which 5½ inches falls as snow. Most precipitation falls in the summer and winter months with spring and fall noticeably drier.

Winters are cold, while summers are warm with many hot days but cool and occasionally cold nights. The mean daily temperature recorded on the valley floor is 3.4° C. with a measured range between 36°C. in July and -41°C. in January. The mean frost free period is 50 days but has varied between 13 and 86 days duration.

Hat Creek flows north down the valley then east to its confluence with the Bonaparte River. There are two active hydrometric stations on the Creek, one near Upper Hat Creek, and one near Carquile. At Upper Hat Creek the mean recorded flow is 24.5 cfs, with a recorded daily maximum of 517 cfs and a minimum of 1 cfs. Annual streamflow is characterized by a 2-3 month duration spring flood which reaches a peak discharge in late May or early June. The bulk of the streamflow

2. Coal Mine & Thermal Plant

2.1 The Coal Deposits

The Upper Hat Creek coal reserves represent one of the largest known concentrated coal deposits in the world. The main coal layer is up to 1800 feet thick and the total reserves have an estimated potential of some 2.7 billion tons. Investigation of the deposits is still in progress. The main coal layer ranges in true width from 1,000 to 1,800 feet of which, approximately 30 per cent is made up of interbedded waste rock.

The coal reserves are separated by faulting into two main deposits. The No. 1 deposit lies at the north end of the valley and the No. 2 deposit some 2 miles to the south. The No. 1 deposit is currently being explored as an open pit source of feed for a 2000 MW thermal plant. It is possible that the No. 2 deposit could be developed at a later date for additional thermal plant capacity.

The No. 1 deposit has been considered for mining to alternative depths of 600 and 1,500 feet. Following geotechnical investigations Golder Brawner and Associates have recommended a preliminary design slope of 16 degrees on the pit walls. Because of these relatively flat slopes, the preferred plan is to mine to the 600 foot limit, although provision must be made in ultimate mine designs for mining to a deeper limit. The geographic location of the No. 1 deposit and ultimate outlines of the 600 foot and 1500 foot pits is shown on Figure 2. Coal in the No. 1 deposit to 600 feet is sufficient for 35 years of operation of the 2000 MW plant. Overburden depths varies from 50 to 700 feet across the area and some 850 million cubic yards of overburden and waste material must be disposed of outside the pit limits.

4.2 Alternative Diversion Schemes

4.21 Canal Scheme

A number of schemes were examined for diversion of Hat Creek regulated and unregulated, from the vicinity of Anderson and Ambusten Creeks into a gravity conduit, to follow the 3200 ft contour around the east side of the proposed Pit No. 1. From there, the shortest convenient route back to the natural stream bed downstream of the pit was down the steep "Harry Creek" valley.

The most economic scheme, and the one recommended as the best in this report, is shown on Figure 4.1. It is based on a lined canal of 800 cfs capacity, extending 23,000 ft. along the east flank of the valley from an intake structure on Hat Creek just downstream of the Anderson Creek confluence, and discharging down Harry Creek at elevation 3190 ft.

The intake structure is a rectangular concrete flume with provision for stoplog control, but is otherwise ungated. Adjacent to it is a concrete overflow spillway also with stoplog control, having a design discharge capacity of cfs. Peak flows in excess of 800 cfs could either be spilled or, by adjusting the spillway crest height, passed down the canal while infringing on some of the available free-board up to a maximum of 1150 cfs. The intake and spillway structures are part of a 50 ft high earthfill diversion dam.

The canal has 12 ft wide base and 2:1 side slopes rising to a vertical height of 12 ft. above the canal bottom. It is lined with an impervious, possibly bentonitic, stony material salvaged from the excavation of Pit No. 1 surficials. The lining is 2 ft. thick and may require gravel erosion protection depending on the available lining material. The necessity for the lining would, of course, be dependent on soil tests taken along the proposed alignment. With a base gradient of 0.05%, the design water depth at 800 cfs is 8.6 ft, leaving 3.4 ft as freeboard. Velocities range from less than 1.25 ft/sec. during the low winter flows to 3.2 ft/sec. at 800 cfs and 3.5 ft/sec. at 1150 cfs, all slightly less than the suggested non-silt/ non-scour velocities for each case.

The canal cross section is designed for balanced cut-and-fill and a 20 ft. wide service roadway is included on the up-hill side of the canal to serve as a buffer against material sloughing down the hill side directly into the canal. A ditch and culverts are used to direct runoff water into the canal. The downhill side berm is 30 ft. wide and could serve as an access roadway around the pit.

The canal crosses both Ambusten and Medicine Creek Valleys on pit waste material fills approximately 70 ft. high. Although the cost of two side hill ditches was included in the estimate for diversion of Ambusten and Medicine Creek flows into the main canal, the scheme could be modified as dictated by the presence of the waste material dump proposed for that location.

Hydraulic control and erosion protection is maintained at the canal exit by a simple concrete outlet structure of sufficient length to prevent canal lining scour by the accelerating canal velocity as the flow passes into the downstream chute section. A cutoff is included to prevent undercutting and stoplogs provided to allow canal depths to be increased in winter if necessary.

The 7500 ft. long chute down the Harry Creek Valley declines at a fairly constant 7%, and while it poses some design problems is not unique in application. Requiring hydraulic model studies, available design data suggest a lining of heavy rock with a median size of 27 in. which in conjunction with a suitable filter layer would be required to withstand velocities up to about 17 ft/sec when passing 800 cfs. For estimating purposes an allowance was included for a number of steel sheet piles to aid in the stability of the rock lining. A rock lined plunge pool is required at the confluence with Hat Creek for energy dissipation.

With the canal alignment established along the 3200 ft. elevation contour, it is evident that realignment of the canal would be necessary shortly after development of Pit No. 1 to Stage 6, noted in the PD-NCB report to be in the year 2005. Although a few different alternatives may be considered such as pumping or shifting the canal laterally into a deep cut in the steepening eastern side hill, the cost of a 4800 ft. long tunnel was estimated and a sum equal to its present worth included in the estimate for comparative purposes.

The area to the southwest of Pit No. 1, containing Finney and Aleece Lakes, would be drained via a 30 cfs ditch to Anderson Creek for diversion into the canal. Drainage from the remaining area in the valley bottom below the diversion ditch and up to the canal on the east valley slope would be retained behind a 30 ft. high earthfill barrier dam located at the Stage 8 intercept, where it would be pumped up to the canal with a 2 cfs capacity pump.

In developing the recommended canal scheme, a number of variations and alternatives were examined and discarded on the basis of economics. The graph of Figure 4.11 summarizes some of these findings, indicating the comparative cost of a unit length of canal, flume and pipeline for a range of conduit capacities. Also shown is the cost of storage curve required for the range of conduit capacities in order to accommodate the 100 year return period flood.

If about the same length as the canal, the flume and gravity pipes can be quickly eliminated on a cost basis. Other schemes such as the inverted gravity siphon running down and then out of the mine, while shorter than the canal, are not attractive as long as the expanding mine operation dictates periodic relocation of the conduit. Also evident from the graph is the higher cost of a smaller diversion pipe with pumphouse, which was confirmed by complete cost estimates of 50 and 100 cfs capacity pumping systems.

As attention concentrated on the canal scheme, a curve of the cost of a unit length of canal vs. the cost per foot of dam height for increasing head was developed. On this basis an initially conceived 130 ft. high dam across Hat Creek near Ambusten Creek was replaced by the present 50 ft. diversion dam downstream of Anderson Creek.

A range of canal sizes with matching storage facilities was investigated, leading finally to the selection of the 800 cfs capacity canal. However, an estimate for a 300 cfs canal scheme with a 70 ft high storage dam at Site 2 is included in the Appendix as it represents the smallest canal capacity that is practical to consider. This is in view of the fact the drainage area between the Site 2 dam and the canal intake would produce about one quarter of the 100 year return period flood, or about 240 cfs peak. This peak which cannot be stored, would have to pass directly down the canal. Adding a minimum of 60 cfs outflow for the Site 2 dam to this base flow increases the required capacity to 300 cfs.

Buried concrete pipe siphons to facilitate the canal crossings of Ambusten and Medicine Creeks were investigated but were discarded due to their high cost.

It should be noted that the elevation of the canal could be varied within limits in optimizing the design of this scheme. The higher the alignment, the further it lies from the Stage 6 intercept. However the higher it is on the steepening talus slope, the closer it would be to the waste dump in the Medicine Creek Valley area, and the higher the canal intake dam would become.

4.22 Pumping Scheme

Pumping schemes with peak design capacities ranging from 30 to 100 cfs were investigated and as shown in the graph of Fig. 4.11 have all proved to be considerable more expensive than the canal scheme. The graph indicates that the least expensive pumping scheme would be that having higher capacity and so the 100 cfs capacity was selected and is described below.

This scheme utilizes a 100 cfs capacity pumping plant in conjunction with a 100 ft high dam at Site 1, providing an intake forebay and storage reservoir, Fig. 4.2.

The pipeline from the pumphouse would be a buried 42 inch diameter steel or concrete pipe, about 20,000 feet long, skirting around the Stage 8 intercept of Pit 1, then along to Harry Creek. The flow could then be discharged down the rock lined Harry Creek Chute back to the Hat Creek channel.

Additional regulating storage is provided by a 71 ft high dam at Site 2.

The scheme envisaged utilizes the 40 cfs capacity Oregon Jack Creek diversion described in section 4.12 in order to eliminate the necessity of a dam at Site 3. This more than compensates for the cost of the Oregon Jack diversion.

A 40 ft high dam to collect flow at the Pit rim is also necessary and a pumping plant with a higher capacity (7.5 cfs) than for the other schemes.

The cost estimate for Site 2 dam is based on material borrowed locally, within its projected reservoir area and from its spillway excavation. For Site 1 dam, material would come from the Pit 1 surficials, with a credit applied equal to the estimated cost of excavating and hauling the waste material to one of the dump areas.

The site 2 Dam includes a concrete pipe outflow structure, and a simple earth cut spillway canal in the East side embankment.

As the Site 1 Dam is the largest and that closest to the pit, considerable attention is needed to ensure that it is both stable and does not materially increase the subsurface flow to the mine. An impervious core and a 70 ft deep slurry trench have been included in the cost estimates.

Included at Site 1 would be an overflow rocklined earth cut spillway through the west embankment, but has no outlet works, as it has been chosen over the "pit rim" dam site for the intake of the main pumping plant. This location as compared with a pit rim forebay saves more by pumping against a lower head despite having a longer pipeline.

A small pumphouse with a capacity of about 7.5 cfs is required at the pit rim site to pump either directly into the main pipeline or back into the Site 1 forebay, to accommodate inflow downstream of Site 1 and the southern section of the east valley slope traversed by the diversion pipeline. A spillway is required in the "pit rim" dam leading towards Pit No. 1. The spillway channel would require some measure of protection upstream of where mine surficials excavation had cut through down to bedrock in order to prevent serious back erosion should the spillway ever have to be used. Once on bedrock, spillage would be allowed to cascade freely down the pit slopes to the bottom.

4.23 Tunnel Scheme

In the assessment of the tunnel scheme three alternative alignments were considered.

1) To the west of the pit.
2) Directly beneath the pit.
3) To the east of the pit.

The first was discounted as it involved the longest tunnel route and offered no other advantages.

The second alternative would involve the construction of two deep vertical shafts upstream and downstream of the pit and the construction of a tunnel between them. This tunnel could be at a depth below which mining might be considered impractical and would involve a fully lined tunnel in coal excavated probably in very wet and difficult conditions. Conflict with full development of the No. 1 deposit is a negative aspect of this scheme, however feasibility would be enhanced if the pit access ramp were not located in the bottom of the existing creek. In this case the ramp could be constructed without major diversion of the creek initially, and a tunnel could be excavated from the bottom of the pit to intercept a vertical shaft upstream of the pit perimeter. The conduit on the downstream side of the pit would follow the conveyor incline to the surface and then be directed back to the creek bed.

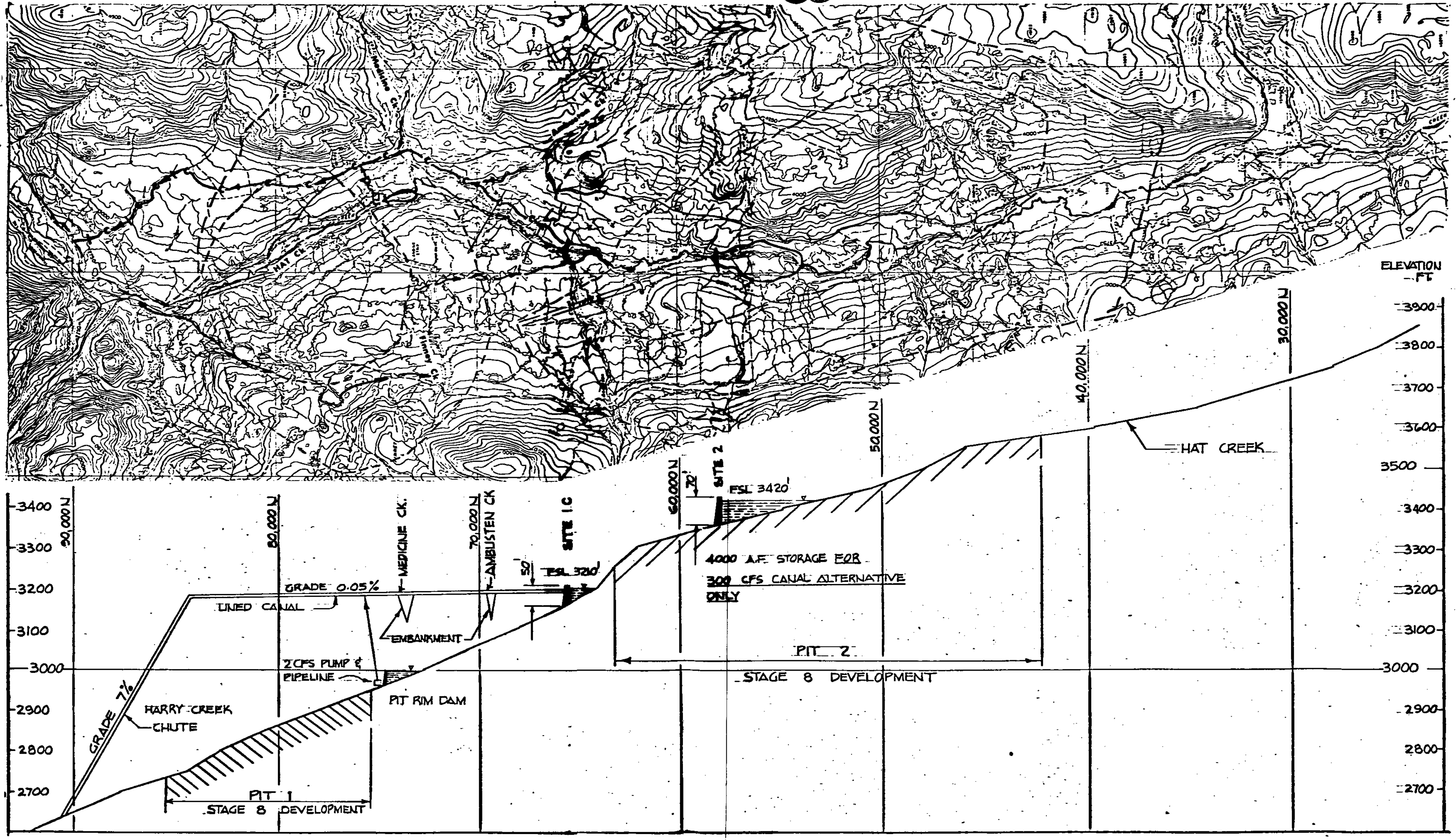
The third alternative alignment to the east of the pit was selected as best since it is feasible to construct a tunnel clear of Stage 9 at this location.

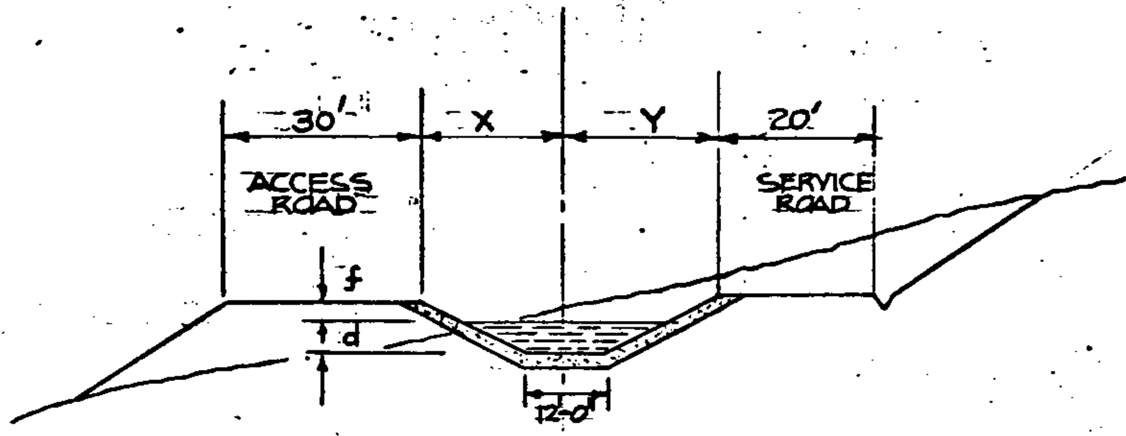
The selected tunnel scheme is shown on Figure 4.3 and consists of:

1) An 800 cfs capacity canal intake on Hat Creek just downstream of Anderson Creek.
2) An 800 cfs capacity canal which conveys water to a tunnel portal in the Medicine Creek Valley.
3) A 10 ft. diameter circular tunnel 12,500 ft long. excavated by soft ground tunnelling methods and fully lined.
4) A rock lined discharge chute down Harry Creek to Hat Creek.

The main disadvantage of the tunnel scheme is the necessity for costly tunnelling methods, and uncertain rock conditions. The tunnel alignment lies outside the area of intense geological investigation, however data interpolated from work done, indicates that the tunnel will intercept the Coldwater sediment series and may traverse a section of the Cache Creek group of volcanic and mixed sedimentary rocks. Both these rock formations are variable and indications are at this stage that soft ground tunnelling cannot be avoided. In addition there is a substantial section of overburden tunnel.

For a tunnel excavated in this way the minimum tunnel size is determined by the excavation method, therefore a tunnel of 10 ft. diameter is large enough to facilitate construction but easily able to accommodate the design peak flow of 800 cfs without any flood regulation. Furthermore the tunnel would have a reserve capacity available when operating under flood surcharge. A pit rim dam and pumphouse similar to that for the canal scheme is required.





CANAL DIMENSIONS

CAPACITY (cfs)	800	300
X ft	30	22
Y ft	36	27
f ft	3.4	2.7
d ft	8.6	5.3

legend

- LINED CANAL
- BURIED PIPELINE
- LINED TUNNEL
- ROCK LINED CHUTE
- DIVERSION DITCH
- PUMPHOUSE
- DAM

PLAN SCALE 1:50,000

FIGURE 4-1

CANAL SCHEME

monenco consultants pacific ltd.

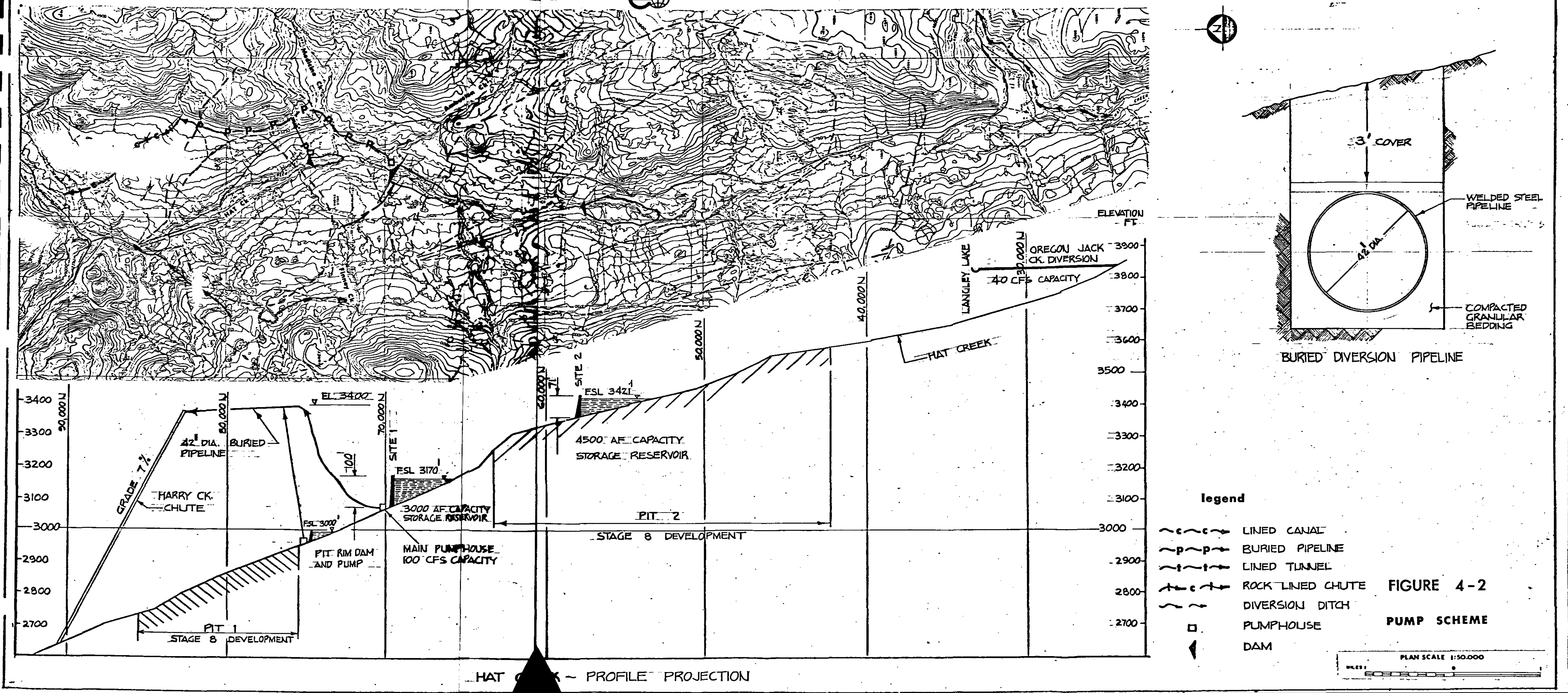


FIGURE 4-2

PUMP SCHEME

monenco consultants pacific ltd.

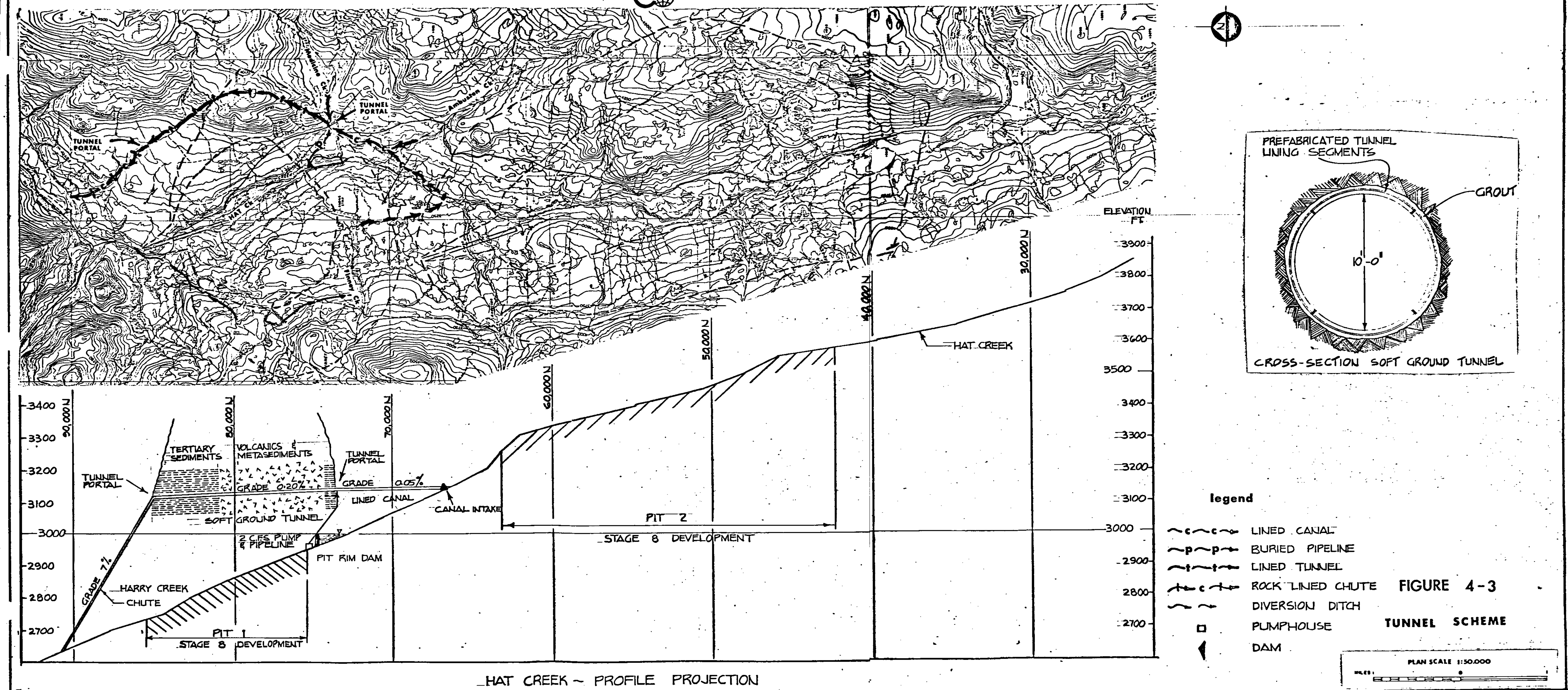


FIGURE 4-3

TUNNEL SCHEME

6. Comparison and Ranking of Diversion Schemes

Table 6.1 contains a summary of the costs, advantages and disadvantages, and ranking of the three basic schemes. The canal scheme is apparently the best by a considerable margin, primarily on the basis of low cost, \$6.9 million which is estimated at about half the cost of the next lowest cost alternative - the pumping scheme \$14.5 million. The tunnel scheme cost is almost the same, \$14.6 million. A comparison of the schemes will be made by describing the pros and cons of the canal alternative and then comparing the other schemes with it.

The Canal Scheme - is a simple arrangement with a high degree of reliability and low operating and maintenance costs. It does not require storage reservoirs with the attendant flooding of parts of the cultivated valley bottom. Construction is simple and should be completed in one year. Earthworks which comprise a major part of the scheme have proved to be relatively inflation proof over the last decade as compared with tunnelling, concrete and equipment prices. The layout calls for no structures within the Stage 8 intercept of the No. 2 pit. It is further compatible with Pit No. 2 development as it does not require replacement of storage located in the Pit No. 2 area which must later be abandoned.

A significant benefit is that is does not require any construction in the middle or south end of the valley, thus allowing the ranching community to continue undisturbed in that area for the 30 years or more during which mining may be restricted to Pit No. 1.

Another advantage of the arrangement is that it picks up the flows from the small creeks draining the hillside to the east of the mine. It has somewhat more capability in handling short peak flows by infringement of dyke freeboard and could have its capacity increased by heightening of the dyke if this proved necessary for any reason.

The flows down lower Hat Creek remain essentially unchanged except for extreme flood conditions where water will flow into the pit. The probability of such a spill is of the order of 1 in 100 years or about 1 chance in 3 of one spill during the life of the mine. This could be reduced by addition of storage, or increasing canal capacity.

On the negative side, with Pit No. 1 slopes as presently envisaged, the canal infringes slightly on the surface intercept of Stage 7, and unless some adjustment of pit boundaries or slopes is possible in that area, it would be necessary after 26 years to divert the canal flow for a short distance outside the final pit perimeter perhaps by tunnel and at substantial cost. In effect the canal is a staged scheme unless the pit perimeter can be adjusted. The present worth of the future rerouting is of course included in the total estimated cost of this scheme. Another negative factor is the problem of providing erosion protection against high spill discharges down Harry Creek. The rock protection proposed is near the limit of present practice, and further investigation might dictate a more costly method. A potential difficulty may exist in ensuring a watertight and stable canal in some areas, but this should not prove insurmountable.

<u>The Tunnel Scheme</u> - by comparison has most of the advantages of the canal scheme but at about double the cost. It has the additional merit of being driven outside the ultimate Pit No. 1 excavation and so not requiring later rerouting. At the same time the cost advantages of staging are not obtained. It is also least obtrusive and has minimum environmental impact.

There are some negative aspects to the tunnel scheme over and above the high cost. Chief of these results from the relatively unfavourable geology requiring soft ground tunnelling, some incompetent rock formations, a requirement for lining, and uncertainties and difficulties which result from these conditions. A higher than normal contingency is required particularly as recent underground labour contracts have led to rapid escalation of costs.

The Pumping scheme - has relatively few advantages. The chief of these is that there need to no infringement on the pit perimeter. It is also capable of being later increased in capacity. The problem of spill down Harry Creek is less, since flows are reduced by regulation.

On the negative side are many factors, high cost, lower reliability (being subject to mechanical and electrical breakdown), conflict with Pit No. 2 development, and also a high dam at Site No. 1 where foundation conditions are likely to be poor and seepage into the pit may be difficult to reduce. The scheme has also more impact on the valley community and environment with two reservoirs and the Oregon Jack Creek diversion. The latter may however provide some benefits in a joint diversion irrigation project.

In summary the canal scheme is clearly and by a large margin the preferred arrangement based on present knowledge and assumptions. The pumping and tunnel alternatives are assessed as being very close in cost, with some enginering and environmental factors favouring one, and some favouring the other. It is apparent that within the scope of this study and the limits of accuracy of the estimates, and without the benefit of further investigation such as drilling for the tunnel, it is not possible to select from these two schemes a second best to the favoured canal arrangement. It could be assumed however, that if tunnel investigations revealed favourable conditions, the tunnel scheme might be preferable on the basis of lower environmental impact and increased reliability.

External or Indirect Costs

In Table 6.1 it will be noted that costs due to "external" or indirect losses such as fisheries, wildlife or recreation have not been included. Estimates of such losses could be seen as useful in two regards. First they might assist in more fully costing the various alternatives for comparative purposes; and second, they might provide a basis for establishing compensation for such losses.

In the case of the Hat Creek Valley it is clear that any such values would be very small, and hence would have little or no bearing on the choice of the preferred alternative, given the magnitude of diversion costs. Indeed the least costly alternative would probably also entail the smallest "external" cost, so any such calculation would only serve to reinforce the existing ranking.

An exercise aimed at evaluating "external" losses would thus serve primarily as a basis for establishing compensation for the losses. Such an evaluation would have to take account of the fact that all of the land seriously affected by the diversions is either privately owned or leased and devoted to agriculture and in the absence of the project will remain so. Hence it is unrealistic to anticipate that it would be intensively used to support wildlife or outdoor recreation and calculate losses of that nature. And since any costs of compensation arising from impairment for agricultural use have already been included in the cost estimates as necessary payment for land, the only "external" loss which can realistically be considered is the loss of stream fishing. The existence of such a loss is recognized, but it is felt that it would be minor for all three schemes, and particularly insignificant in the case of the preferred scheme.

For the above reasons we do not feel that an evaluation of "external" or indirect costs associated with the various diversion alternatives is either necessary or justified.

TABLE 6 - 1

SUMMARY AND RANKING OF DIVERSION SCHEMES

Scheme		Engineering and Operating Considerations	Capital and Operating Cost (PV 35 years)	Environmental Comment	Ranking: Economic and Technical	Ranking: Environment	Ranking: Combin
Canal (800 cfs) (Capacity)	+	High reliability, low maintenance good flood reserve capacity. Picks up east pit area surface flows. Earth works have low escalation. Minimum conflict with Pit 2 development	$6.9 million	Minimal disruption to aquatic ecosystem; relatively minor length of stream removed from production; Upper Hat Creek unaffected. Small area of lands disturbed classed as low capability for agriculture.	1	1	1
	-	May infringe pit perimeter after 26 years. Possible problems in Harry Creek chute, canal leakage					
Tunnel (800 cfs) (Capacity)	+	Most unobtrusive. High reliability. Good flood reserve capacity. No pit perimeter conflict. No conflict with Pit 2 development Minimum seepage into pit	$14.6 million	Insignificant disturbance of lands. Minimal disruption to aquatic ecosystems; relatively minor length of stream removed from production. Water and lands of Upper Hat Creek unaffected.	2	1	2
	-	Difficult construction-high cost contingency. Possible problem Harry Creek chute. Adverse geology. No staging benefits.					
Pumping (100 cfs) (Capacity)	+	No Pit perimeter infringement	$14.5 million	Reservoirs in Upper Hat Creek increase disruption to aquatic ecosystem; can be minimized by maintaining full supply over summer. Significant alienation of lands having moderate to good capability for agriculture. Potential benefits to agriculture by supply of irrigation water.	2	2	3
	-	Large reservoir at pit perimeter may increase mine seepage. Insufficient storage when capacity on Pit 2 area abandoned. Less than max. reliability and operating simplicity					

Note: In all three alternatives storage reservoir may be added to improve stream regulation, reduce conduit capacity or reduce probability of spill into pit; but at substantial cost increase.

Appendix C

General Hydrogeology of Upper Hat Creek

Geology

The bedrock geology of the Upper Hat Creek catchment has been described by Duffell and McTaggart (1952). Knowledge of the bedrock geology in the valley floor has been advanced by recent coalfield exploratory drilling documented by Dolmage, Campbell and Associates (1975) and Church (1975).

The coal, which has been divided into four discrete zones by Dolmage, Campbell and Associates (1975), is contained within a sedimentary sequence of tertiary age called the coldwater beds. These sedimentary rocks include siltstones, claystones and tuff bands above the coal, and sandstones, conglomerates and siltstones below.

These sedimentary rocks rest on the floor of a valley whose slopes and ridges are composed of older, more resistant volcanic and crystalline rocks. A thick sequence of crystalline limestone know as the marble canyon formation, stands as the Marble Range to the north and the Cornwall Hills to the east. Meta sediments including greenstone, chert, argillite, quartzite, and limestone outcrop to the northeast of the project area, and an intrusive complex of quartz diorite rises as Mt. Martley to the west. Flat lying volcanic flows of the Spences Bridge group define the southwestern valley wall. A sequence of volcanics rocks including lahars, dacite, basalt, rhyolite, and trachyte lavas overlie the coldwater beds and some of the older valley wall rocks in the lower portions of the catchment to the west, south and in a small area to the east.

The quaternary geology of the project area has been interpreted by Ryder (1976) through field mapping and the application of aerial photography in inaccessible regions. At least two ice advances during the pleistocene are evident. The most recent advance occurred in an easterly direction leaving deposits of clay rich drift covering the valley floor to average depth of

51 meters according to Church (1975).

Ryder (1976) has interpreted the drift as primarily morainic ranging from hummocky to undulating west of Upper Hat Creek and hummocky to undulating to only a veneer to the east, with the easternbench dominantly mantled with bouldery moraine. Drift mantling the highlands is apparently largely till.

Alluvial fans have been mapped at isolated locations on the valley floor and adjacent to the floodplain. The modern floodplain is narrow with associated alluvium shallow or essentially non existant.

A large mudflow has been mapped below the 3400 foot contour extending from Medicine Creek to beyond Harry Creek, however recent drilling and detailed interpretation no longer supports this concept.

Hydraulic Characteristic of Major Units

Golder Associates have conducted tests to determine the hydraulic characteristics of water bearing formations in the vicinity of Pit No. 1. This work has established that the claystones, siltstones, sandstones and conglomerates of the coldwater formation are largely impermeable. Although the sub-bituminous coals are significantly more permeable with fracture flow permeabilities of 10^{-4} CM/SEC, overlying, and interbedded siltstones, claystones, and bentonitic tuff bands will significantly limit vertical recharge. Furthermore, the coals grade into carbonaceous sediments toward the margins from the central basin. Hence, the coals appear to be isolated from significant recharge and limited drafts are expected to result in formation dewatering.

A vessicular basalt lava flow within the Kamloops group demonstrated a falling head permeability of 3×10^{-4} CM/SEC in a relatively highly fractured zone between 83 and 94 feet below the surface. Rapid facies changes however, were evident in this formation and it is expected that fracture permeability is local and related to block faulting.

Duffell and McTaggart found the blue-grey limestone of the Marble Canyon member of the Cache Creek group to attain a width of about 7 miles at Blue Earth Lake. It dominates the eastern flank of the Upper Hat Creek basin to Medicine Creek. North of this point it is covered by lava flows and sedimentary sequences of the Kamloops group. The limestone is massive crystalline, and a minimum of 1,000 feet thick in exposed sections. Nevertheless, Church (1975) indicates that the formation has been extensively faulted near the valley floor. It may also be significant that some of the more important tributaries to Hat Creek arise from this unit. Anderson Creek rises from the contact of the Spences Bridge group with an isolated island of marble canyon limestone at Chipuin Mountain, whereas Medicine Creek rises from the base of this unit to the east. Blue Earth Creek, Langley Lake and Ambusten Creek rise from approximately 1,500 feet below the local maximum relief of the limestone formation. It is probable that this formation contributes a significant proportion of the baseflow in the Upper Hat Creek.

Groundwater flow within the limestone, however, will be limited to the secondary permeability afforded by fractures and solution cavities. Hence, recession of streamflow after the freshet delivery is rather dramatic with flows dropping an order of magnitude. Baseflow does, however, continue throughout the year.

The dioritic intrusive at Mount Martley is a crystalline stock. Permeability will be limited to shallow jointing. The Spences Bridge group is largely lavas and pyroclastics with lithology showing great variation over short distances. Rocks of this group are typically poorly permeable. They are relatively flat lying and are drained to Hat Creek via short steep ephemeral runoff channels. These rocks may be somewhat faulted where they rest against the dioritic intrusion and the Chipuin Mountain limestone and hence contribute some flow to Anderson Creek.

Ryder (1976) describes the till sheets within the major valleys as consisting of hard, compact, silty diamicton containing rounded cobbles and pebbles. Reworked pebble gravels have been identified in some locations within the morainic tills. Air-flushed rotary drilling in the overburden conducted by Golder Associates, has indicated that although these gravel lenses are relatively permeable they are of limited extent and quickly dewatered.

Isolated patches of porous materials on the surface of the valley floor till sheet have been mapped at gravelly alluvial fans. Some of these are found within the shallow discontinuous floodplain alluvium. Others are found on benches above the mainstream but almost all are associated with tributary streams. Ryder (1976) has mapped gravelley alluvial fans on the left bank (western bench) incised by the Colley, Yet, Pocock, Phil, McCormick and Anderson Creeks. Two such fans are found on the right bank, both on Medicine Creek.

A small mudflow is evident below a steep outcrop upgradient from Finney Lake. In addition, aerial photos also reveal a mudflow at the mouth of Finney Creek.

Mudflows and fans have both been developed from stream reworked drift deposits. The texture of both fluvial and mudflow pan materials becomes finer down-fan. Spring freshet flooding of these deposits may render them unstable. This may be a particular hazard in this area because the variety soils are rich with clays having unusual swelling properties. Church (1976) suggests that the clay is bentonite developed from volcanic ash, bands of which are evident in the glacial deposits.

Drift cover overlying the bedrock controlled ridges has not been differentiated in termsof texture although most areas are probably till with a fine textured matrix. Some more porous materials may provide higher permeabilities over small areas. The drift is generally found to exceed 2 meters in thickness on the ridges but bedrock is exposed in many isolated areas. Substantial exposures of bare rock are found along the fault controlled Langley Lake Valley and Blue Earth Creek. A broad exposure of dioritic rocks is also found along the steep slopes below Mount Martley.

General Groundwater Flow System

Based on static water level data developed through the vicinity of Pit No. 1 by Golder Associates it is evident that the subsurface flow in a general way, subparallels the pattern of surface drainage. Within the Upper Hat Creek Basin groundwater recharge will be severely limited by the general lack of permeability of surficial materials and relatively high slopes. Deposits of permeable overburden, if isolated to the extent suggested by the available mapping would provide only very limited detention storage. It is apparent that precipitation percolating through shallow drift or directly through the weathered bedrock surface in the upland areas particularly in the Cornwall Hills provides the bulk of the recharge to groundwater. Analysis of baseflow recession revealed that water released from groundwater storage at a rate of less than 0.1 inch per month.

Analysis of groundwater obtained during pump testing in the vicinity of Pit No. 1 showed it to be very low in minerals suggesting local circulation. It is of the calcium magnesium bicarbonate type.

There is no evidence to suggest that there exists a formation of either consolidated or unconsolidated materials within the valley of Upper Hat Creek which is continuous over a significant distance and sufficiently permeable to result in a significant discharge of groundwater.

Nevertheless, it it known that the pre-glacial channel eroded the bedrock to a depth of 400 feet below the current valley floor immediately east of the modern channel. Continuous alluvium from a pre-glacial stream or a glacial meltwater channel could provide a subterranean conduit for a substantial flow.

Ryder (1976) recognized a meltwater channel in the valley of Langley Lake. It is apparent that this channel allowed meltwater to drain through a predecessor of Oregon Jack Creek while ice damming occurred on Upper Hat Creek. There is insufficient data to determine the extent to which the porous alluvial materials associated with this channel extend along Hat Creek.

Project Interactions

Severe flooding of tributary streams which is likely to occur during the snowmelt period following a winter of heavy accumulation could render gravel or mudflow fans unstable. Slides in these areas are closely related to the moisture of clay rich soil materials. It may be necessary to modify tributary courses to avoid mass movement in critical areas.