

# Tunneling and Bridging to Success: Innovative Forest Road Design and Construction in Rugged Terrain on British Columbia's West Coast

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**ABSTRACT** - The CW300 road at Phillips Arm, on British Columbia's rugged west coast, is an example of a challenging new road that was built using thinking and methods that try to live up to the high standards of forest road design and construction demanded by today's regulatory and environmentally-conscious climate. To successfully complete this project, an experienced team, able to identify all issues and work together to find solutions, was first assembled. A considerable amount of time was spent on location surveys and terrain stability field assessments so that the best possible road alignment could be defined. Once the optimum route was established, detailed site surveys, a geometric road design, and a metre-by-metre geotechnical prescription was used to produce road construction plans. Finally, very specific plans and innovative solutions were developed for two special sites where a major bridge was needed to cross a precipitous, ice-avalanche-prone creek channel, and an adit was excavated to allow the road to be turned through a narrow switchback located on a steep sidehill.

**Keywords:** forest road construction, terrain analysis

On the west coast of British Columbia, road building operations in the forest industry must deal with some of the most difficult terrain in North America. Rugged, glacially-carved valleys, steep slopes, difficult rock covered with variable amounts of potentially unstable surficial material, and high annual precipitation, combine to produce major challenges for designers and builders of resource roads.

The challenge is really threefold: complying with a plethora of provincial and federal regulations, satisfying public demands for environmentally sound logging practices, and building roads within the fiscal constraints imposed by a globally-competitive industry.

In Canada, most regulation of the forest industry is the responsibility of the individual provincial government. In British Columbia, this is mainly done through the Forest Practices Code and Regulations legislation, which was adopted in 1995.

The Forest Practices Code and Regulations has language that both spells out the basic principles which must be followed, and also contains specific requirements that must be complied with. For example, before a forest road can be built and used, it must comply with no less than 25 provisions in the Forest Practices Code and over 200 specific requirements found in the Road Regulations. In addition, it must comply with the Water Act and other provincial legislation, as well as federal regulations, such as the Fisheries Act.

However, the Forest Practices Code and Road Regulations are arguably only a reflection of the high environmental standards that the public is demanding of the forest industry. Not just the public, but customers that buy the wood products as well. The public certainly do not want forest operations to initiate landslides, or cause sedimentation that would affect water quality. They also do not want practices that degrade fish habitat, affect wildlife, and, in some cases, cause visual impacts.

But in addition to the regulatory, environmental and political constraints, there are also the financial ones. It is sometimes easy to forget that a forest road is only a costly means to an end, a way of accessing timber that is becoming increasingly scarce and difficult to reach.

Given all these factors, it is easy to understand why there is a strong need to engage in careful planning so that roads can still be used and efficiently built to access timber, despite the physical constraints that may be present.

The CW300 road at Phillips Arm in coastal British Columbia is a good example of a modern resource road built using the type of planning and high standards demanded of the forest industry today. This road is located in the aptly named Clearwater Valley, about 220 km northwest of Vancouver, B.C. on the coastal mainland east of Vancouver Island. The area is part of Weyerhaeuser's Phillips Arm operation, a large timber supply area managed out of the Stillwater Timberlands divisional office in Powell River, B.C.



Figure 1: location of the CW300 road in coastal British Columbia, about 220 km north of Vancouver, B.C.

To appreciate the complexities of building roads in this terrain, one must first have a basic understanding of the geomorphology and geology involved.

The Clearwater River is located in a typical U-shaped, glacially-carved valley which connects with the larger Phillips River valley. The Clearwater River is a side valley to the main Phillips River valley, which ultimately flows into the Strait of Georgia at Phillips Arm. Shore Creek in turn is a smaller side valley to the Clearwater Valley.

All of these valleys have one thing in common: they were once filled with rivers of ice that ran out to the sea. But there was much less ice present in the side valleys and so the smaller glaciers were not able to carve out as much rock as a glacier in the adjacent main valley. When the ice eventually melted away, a prominent rock step was left at every point where a side valley connects to the main valley.

This then is the essential problem in the Clearwater Valley: there is a 500 metre step between the main valley and the timber that is to be accessed in the hanging Shore Creek valley.

The first attempt to build a road up into the Shore Creek valley was made in 1994 using a direct route that angled up the steep sidehill from the Clearwater Valley. But this heading ended in failure because the road had to be fully benched into the hillside to provide bearing support for heavy equipment, which left steep surficial material resting on bedrock above the road unsupported. When this upper material became saturated with water during a period of wet weather, a slide involving several thousand cubic metres of material abruptly cascaded down, burying the road heading. Fortunately, the road construction supervisor was aware of the potential problem and had pulled out the equipment when heavy rains started falling just prior to the slide releasing. But the slide proved that the road could not be safely built at this location, and so this heading was abandoned.



Figure 2: overview of the main Clearwater River valley and the Shore Creek side valley on the far right. The initial road heading is visible in the left center of the picture.

Setbacks are not uncommon when dealing with such complex projects in the rugged Coast mountains of British Columbia. To deal with this reality required managing the work at Phillips arm using a four fold strategy:

1. assembling an experienced team of engineers, foresters, technicians, and contractors who could apply their specific skills to an issue, but could then work together as a team and collectively decide on the best course of action.
2. encouraging brainstorming- conversations for possibilities- to generate ideas. Equally important is to ensure that all ideas, whether right or wrong, ultimately accepted or not, are valued and considered by the team.
3. investing enough time on field work and quality engineering. This starts by recognizing the three L's of road design: location, location, location; that is, taking the time to identify all possible routes, field checking every possibility, and then completing detailed assessments and producing detailed site plans to ensure that a proposed route is feasible.
4. working through setbacks and dealing with unforeseen problems. This requires having a focus on finding the best possible solution to a problem, and accepting the fact that plans may need to change if new and better information becomes available, or if errors are made.

Once all the assessments were completed, one route stood out- but it wasn't going to be easy. It involved using the top of a truncated debris cone at the base of a snow avalanche and debris flow gully to provide a location for a switchback, and therefore avoid the unstable ground along the initial route. But the switchback would require a lot of room- which simply wasn't there, and would require building a massive rock retaining wall. At this point, an innovative solution was devised to solve the room problem- instead of turning a truck around a normal semi-circular switchback, it was proposed to have a truck roll ahead to a stop, turn hard and back into a slot, and then turn forward again in the opposite direction and continue downhill- the classic railroad-type switchback of yesteryear.

Once the switchback problem was solved, a detailed terrain stability field assessment of the rest of the road was completed. Detailed terrain stability field assessments involve doing a metre by metre assessment of the terrain along a proposed route. The assessment involves establishing what kind of ground the road will go through- will it be bedrock or some kind of surficial material? If it is surficial material, what kind is it- glacial till, glaciofluvial gravel, or colluvium, and what are its properties? What are the terrain attributes- how steep is the slope, how much weathering has occurred, what is the slope aspect and curvature, how much water is present?

This assessment of terrain has two very practical purposes: first, it is meant to help establish that a road can be safely built, and second, it provides specific measures, such as benching and endhauling requirements, to help ensure that the road is built with sufficient bearing capacity to support the expected load of equipment and minimize the risk of failures, but still at optimum cost.

Normally, the geotechnical evaluation of a proposed resource road is not done as formally as might be done for a new highway. For example, rarely is any test drilling done to establish soil properties. Only in special cases are slope stability programs, such as LISA or XSTABL, used to help establish safety factors. Instead, the forest industry in B.C. relies heavily on engineers and geoscientists- qualified registered professionals, as they are referred to in the Forest Practices Code- to use their training in rock and soil mechanics, mass wastage, terrain analysis, and groundwater and surface hydrology to provide accurate assessments. But in

order to ensure that roads are safely built, are cost effective, and minimize environmental impacts, this training must also be supplemented with considerable experience, and an ability to work with all members of the road design and construction team.

The detailed terrain stability field assessment identified one area of particularly unstable rock where considerable blasting and scaling would be needed to provide a safe road alignment. To ensure a thorough analysis, two rock scaling and blasting experts were brought in to assess this area and estimate how much it would cost to remove the offending rock. When their assessment was complete, the news was not good- yes, it could be done, but at a cost of about \$150,000, and without any real assurance that the unstable rock could be fully removed. Furthermore, blasting and scaling would generate a considerable amount of waste rock, which would cover a large area of productive forest land on the slope below.

These problems and costs justified another assessment- and so for the third time, another attempt was made to find another route. Now the earlier location surveys really paid off because they allowed all the knowledge already gained of the area to be applied to new situations. A third route was found, but also required building a switchback on a steep sidehill- although this time there was no convenient slot to provide enough room for even a railroad-type switchback. Instead, a hole, or adit, had to be blasted into the rock face to provide the necessary gallery to allow a fully loaded logging truck to back up and turn down the hill.



Figure. 3: adit and the railroad-style switchback at the CW 300 road at Phillips Arm. Trucks come down the upper road, back into the adit, and then turn sharply and continue down the lower road at far right. The adit is fully grouted and bolted to minimize rockfall.

Table 1: adit statistics

Length	Width	Volume	4 m Bolts	Shotcrete	Cost
17.5 m	8.0 m	3520 m <sup>3</sup>	>200	60 m <sup>3</sup>	\$490,200

The adit solved the problem of turning the trucks through the switchback, but this road location also required crossing the lower portion of Shore Creek. Ordinarily, this would involve a simple bridge- but again, there was a major problem.

The only feasible location for a bridge was at the base of a major waterfall which has high flood flows and periodically freezes over in winter. When the ice melts, large masses of ice cascade off the rock slabs, and there was a concern that this could damage the bridge. In order to find the specific best location for the bridge and so minimize the ice avalanche problems, a careful assessment of how the ice cascades down the channel was done using the evidence provided by damaged tree trunks on both sides of the channel. When this assessment was completed, the pattern of ice movement down the face could be defined, and the bridge could then be located in one of the troughs where cascading ice was least likely to be a problem. Then, in order to provide an additional assurance of safety, the bridge was located as far out and up from the water as possible, and a steel barrier plate was placed in between the bridge columns to help ensure that cascading ice would not score a direct blow on any one support column.



Figure 4: overview of the Shore Creek bridge at the base of the waterfall. In winter, ice avalanches are a major problem at this location and the bridge needed to be designed to avoid being damaged by both high water flows and cascading ice.

Now finally, the challenge of trying to build a road into the Shore Creek valley was solved. It required building a unique switchback, blasting an adit, and installing a bridge at the base of a large waterfall that not only has large volumes of water, but also periodically freezes and causes large ice avalanches to cascade down the channel. It involved investing a lot of effort in brainstorming to find opportunities for possibilities, to allow the free flow of ideas, so that the best possible and often unique solution for a particular problem could be found.

In summary, the CW 300 road into the Shore Creek valley is a testimony to the determination and ingenuity of the logging industry on the West Coast of Canada, and to the modern breed of

road builders who are willing to invest a lot of thought, time, effort and money into making sure that their roads meet the demanding standards of an environmentally-conscious public and an increasingly competitive world market.

Table 2: CW 300 Construction Costs

Road construction	Endhauling	Shore Creek Bridge	Adit	TOTAL
\$140,753	\$576,451	\$227,901	\$490,390	\$1,435,495

Table 3: Summary of CW 300 road construction timetable

### Original CW 1000 Route

Summer, 1992	Engineering layout of CW 1000 route from station 5100, Clearwater Main (Macmillan Bloedel staff)
September, 1992	Geotechnical review by Gordon Butt (Madrone Consultants)
July, 1993	Terrain condition and road construction plan review by Gordon Butt, Glynnis Horel (Macmillan Bloedel), and Glen Griffith (Ministry of Forests)
Summer, 1994	Road approved by Ministry of Forests, construction starts.
October 1, 1994	Major slide (>5000 m <sup>3</sup> ) suspends construction.
October,	Geotechnical and seismic analysis to determine feasibility of using an geogrid reinforced engineered fill. Negative results.
November, 1994	
February, 1995	Report concludes that the road cannot be built at the original location.

### CW1000 Gully Switchback Route

April, 1995	Review of alternative routes by Richard Mardis, Mike Dunn, (Macmillan Bloedel) and Frank Baumann (Baumann Engineering); selection of route that switches back in an avalanche/ debris flow gully.
June, 1995	Review of proposed new route by Frank Baumann and Terry Rollerson (Ministry of Forests)
March, 1995	Terrain stability field assessment confirms feasibility of new route, but warns of rockfall hazard.
September, 1997	Re-traverse of road location and production of detailed site plans by Glen Beaton (Stonecraft Engineering).
October /	Detailed assessment of rockfall hazard area by Frank Baumann,
November, 1997	Glen Beaton, and Mike Whittaker (Canada Shotcrete and Gunnite).
October, 1997	Identification of railroad switchback concept "this may be a dumb idea" by Dave Gatenby (Macmillan Bloedel). Adit concept proposed by Lyle McMurdo to extend back end of switchback.
January, 1998	Second geotechnical report and submission of road permit application to Ministry of Forests.

### CW300 Railroad Switchback and Adit Road

February, 1998	Identification of third possible route to avoid rockfall hazard.
March/April, 1998	Layout of CW300 road location, and production of detailed site plans for difficult sections, including the adit area and the Shore Creek bridge.
April 15, 1998	New geotechnical report for new location.

April 23, 1998	New road permit application submitted to Ministry of Forests
May 14, 1998	Shore Creek bridge approved by Ministry of Forests
May 21, 1998	Road permit approved.
May 29, 1998	Construction starts on the CW 300 road at the site of an old deactivated road.

### **CW300 Construction**

May 29 to June 28, 1998	Re-construction of the CW 300 road to 682 metres
June 3 to 23, 1998	Shore Creek bridge camp-side abutments built.
June 6 to July 2, 1998	Surespan Construction installs the Shore Creek bridge.
July 3 to 28, 1998	Wood-side cribs and endfills on the Shore Creek bridge constructed.
July 22 to August 29, 1998	Road construction from 845 m to 1200 m
August 10 to 29, 1998	Construction of switchback, initial cleaning of adit area.
August 31 to November 20	Work on adit face, start of construction of upper road.

### **CW300 Adit and Upper Road Construction**

May 9, 1999	Commencement of adit drilling, completion of upper road.
June 15, 1999	Adit complete, including installation of bolts, shotcrete and protective screeing.
June 19, 1999	First load of timber comes down the CW 300 road out of the Shore Creek valley.