Appendix 1. Field identification of soils

Describing soils

Soil classification systems are based mainly on particle size, and these usually fall into three main groups: coarse-grained soils, fine-grained soils, and organic soils.

Coarse-grained soils

These contain particle sizes that are large enough to be visible to the naked eye. They include gravels and sands and are generally referred to as cohesionless, or non-cohesive, soils. Strictly defined, coarse-grained soils have more than 50% of the dry weight larger than particle size 0.060 mm (Table A1.1).

Fine-grained soils

These contain particle sizes that are not visible to the naked eye. They are identified primarily on the basis of their behaviour in a number of simple indicator tests. They include silts and clays, the latter of which are generally referred to as cohesive soils. The term “cohesive” indicates stickiness in soils. Strictly defined, fine-grained soils are soils having more than 50% of the dry weight smaller than particle size 0.060 mm (Table A1.1).

Organic soils

These soils have a high (80%) natural organic content.

These three main groups are further divided into a series of subgroups, each determined by particle size divisions within the major groups.

In addition to particle size identification, soil classification also includes a description of such properties as “consistency” of a cohesive soil and “density” of a non-cohesive soil in its natural undisturbed state in the field. For example, consistency is a term that is used to describe the degree of firmness of cohesive soil and is indicated by such descriptive terms as soft, firm, or hard. In practice, the term is used only in reference to the condition of the cohesive fine-grained soils such as clayey silts, silty clays, and clays (i.e., those that are markedly affected by changes in moisture content). The term is not usually applied to coarse-grained soils such as sands and gravels or to non-cohesive silts.

As a cohesive soil changes consistency, its engineering properties change also. The strength of a soil varies considerably with consistency. A clay at a low moisture content and in a hard condition is obviously stronger than the same clay at a high moisture content and in a soft condition. Thus, classifying a clay by particle size alone is insufficient for engineering purposes. The classification should also take the consistency into account.

Classifying soils in the field is usually difficult to do precisely. One person may describe a soil as soft, another may say it is very soft. Similarly, whether a particular soil is a fine sand or very fine sand cannot usually be determined through field identification alone. To eliminate the subjectivity from these decisions, a series of laboratory classification tests has been developed. Nevertheless, field identification remains important. Experienced soils personnel can estimate most of these properties by making careful field observations and examining small samples of the soil. Even personnel without considerable soils experience can, using the field identification guidelines summarized here, generally describe the properties successfully.

Soil composition

Composition includes the grain size and range of particle sizes, shape, and plasticity. The plasticity of a soil refers to the range of moisture content that determines its plastic condition. The coarse-grained soils (sand and gravels) are described primarily on the basis of grain size, and the fine-grained soils (silts and clays) primarily on the basis of plasticity.

A guide to field identification by the grain size of coarse-grained soils is summarized in Table A1.1.

Table A1.1. Grain size identification (consistent with the *Canadian Foundation Engineering Manual*).

Soil Groups	Soil Type Name		Size Limits of Particles	Familiar Size Example
Coarse-grained soils	Boulders		200 mm (8 in) or larger	Larger than bowling ball
	Cobbles		60 mm (2½ in) – 200 mm (8 in)	Grapefruit
	Gravels	Coarse gravel	20 – 60 mm	Orange or lemon
		Medium gravel	6.0 – 20.0 mm	Grape or pea
		Fine gravel	2.0 – 6.0 mm	Rock salt
	Sands	Coarse sand	0.60 – 2.0 mm	Sugar
		Medium sand	0.20 – 0.60 mm	Table salt
		Fine sand	0.06 – 0.20 mm	Icing sugar
Fine-grained soils	Silts		0.02 – 0.06 mm	Cannot be discerned with naked eye at a distance of 200 mm (8 in)
	Clays		Less than 0.02 mm	Use simple field tests to distinguish between silts and clays (e.g., stickiness, dilatancy)

Soil consistency

The consistency of a cohesive soil—described as hard or soft—can be estimated from the pressure required to squeeze an undisturbed sample between the fingers. An undisturbed sample is one that is in its natural condition as on or in the ground; it has not been remoulded by any mechanical disturbance, such as bulldozer tracks.

If the soil is brittle (fails suddenly with little movement as it is squeezed), friable (crumbles easily), or sensitive (loses much of its strength when remoulded and then resqueezed), these terms should be included in the description of the soil's consistency.

A guide to estimating consistency in this way is summarized in Table A1.2.

Table A1.2. Consistency field test for cohesive soils.

Field Test	Term
Easily penetrated several centimetres by fist.	Very soft
Easily penetrated several centimetres by thumb.	Soft
Penetrated several centimetres by thumb with moderate effort.	Firm
Readily indented by thumb but penetrated only with great effort.	Stiff
Readily indented by thumbnail.	Very stiff
Indented with difficulty by thumbnail.	Hard

Soil density

The density of a non-cohesive soil may be estimated in the field by the ease with which a reinforcing rod penetrates the soil. It is quoted in relative terms, such as loose or dense. A guide to estimating soil density is summarized in Table A1.3.

Table A1.3. Soil density field test for non-cohesive soils.

Field Test	Term
Easily excavated with spade.	Very loose
Easily penetrated with 13 mm (0.5 in) reinforcing rod pushed by hand or, alternatively, shows some resistance to spade or penetration with hard bar.	Loose
Easily penetrated with 13 mm (0.5 in) reinforcing rod driven with a 2.25 kg (5 lb) hammer or, alternatively, shows considerable resistance to spade or penetration with hard bar.	Compact
Penetrated 0.3 m (1 ft) with 13 mm (0.5 in) reinforcing rod driven with 2.25 kg (5 lb) hammer or, alternatively, shows no penetration with hard bar or requires pick for excavation.	Dense
Penetrated only a few centimetres with 13 mm (0.5 in) reinforcing rod driven with 2.25 kg (5 lb) hammer or, alternatively, shows high resistance to pick.	Very dense

Soil compressibility

A soil's potential for compressibility is not easy to determine by visual examination alone. This is usually done by laboratory tests. However, if it is suspected that the soil will settle considerably under load, this should be reported.

There is a general relationship between consistency (as defined for cohesive soils) or soil density (as defined for non-cohesive soils) and compressibility. For example, the soft and loose soils are likely to compress considerably under loads.

Reporting soil description

In forming a description, the predominant particle size is what is used to describe the soil type. The relative content of other particle sizes modifies the description (e.g., sand GRAVEL with some silt).

A predominantly coarse-grained soil is termed either a gravel or a sand, depending on which component appears to be the more abundant. The less abundant component and the fines are used as modifiers; the least important component is stated first. For example, a soil with 30% fines (silt), 45% gravel, and 25% sand would be best described as sandy, silt GRAVEL. The terms in Table A1.4 are used to indicate various proportions by weight within the respective grain-size fractions.

Table A1.4. Soils description terms.

Descriptive Term	Example by Weight	Proportion
NOUN	GRAVEL, SAND, SILT, CLAY	>50%
"and"	and gravel, and silt, etc.	>35%
ADJECTIVE	gravelly, sandy, silty, clayey, etc.	20–35%
"Some"	Some sand, some silt, etc.	10–20%
"Trace"	Trace sand, trace silt, etc.	1–10%

For example:

- A "silty CLAY, trace of fine sand" would be >50% clay, 20–35% silt, and 0–10% sand.
- A "sandy GRAVEL with some cobbles" would be >50% gravel with 20–35% sand sizes and 10–20% cobbles.

Appendix 2. Vertical (parabolic) curves

The relative flatness, or "K" value of a vertical (parabolic) curve, is the horizontal length over which there is a 1% change of grade. The minimum length of a vertical curve is solved as the K value times "A," the algebraic difference between the entry and exit grades (LVC = K*A). When the length of the vertical curve (LVC) is equal to or exceeds the stopping sight distance (SSD), the K value is given by the expression:

Crest

$$K = \frac{SSD^2}{200\left(H_1^{0.5} + H_2^{0.5}\right)^2}$$

H_1 height of driver's eye: 1.05 m
H_2 height of object: one-lane road - 1.30 m (vehicle)
two-lane road - 0.15 m (object)

Sag

$$K = \frac{SSD^2}{200\left(H_3 + SSD\ \text{Tan}1^\circ\right)}$$

H_3 height of headlight: 0.6 m

Table A2.1. Minimum K values, where LVC > SSD.

		Crest		Crest	Sag
Design speed (km/h)	Minimum SSD[a] (m)	One-lane	Minimum SSD (m)	Two-lane	One-lane
20	40	1.7	20	1.0	2.1
30	65	4.5	35	3.1	5.1
40	95	9.6	50	6.3	8.5
50	135	19.4	70	12.3	13.4
60	175	32.7	90	20.3	18.7
70	220	51.6	110	30.3	24.0
80	270	77.8	135	45.7	30.8

[a] Values of minimum stopping sight distance apply to one-lane, two-way roads. For two-lane and one-lane, one-way roads, multiply the values of minimum SSD by a factor of 0.5.

When the LVC is less than the minimum SSD, the K values are solved by the expression:

Crest

$$K = \frac{2SSD}{A} - \frac{200\left(H_1^{0.5} + H_2^{0.5}\right)^2}{A^2}$$

Sag

$$K = \frac{2SSD}{A} - \frac{200\left(H_3 + SSD \text{ Tan } 1°\right)}{A^2}$$

Table A2.2. Minimum K values, where LVC < SSD.

Crest curve: One-lane, two-way road

Design speed (km/h)	A: 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20											0.2	0.6	0.9	1.2	1.3	1.5	1.6	1.6
30							1.6	2.9	3.6	4.1	4.3							
40				0.5	5.6	8.0	9.1	9.5										
50			8.9	16.5	19.0													
60		12.5	28.9	32.5														
70		42.5	51.4															
80	35.7	75.9																

Crest curve: Two-lane road

Design speed (km/h)	A: 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
20										0.3	0.6	0.7	0.8	0.9	0.9
30					0.6	1.9	2.5	2.9	3.0						
40			0.1	4.1	5.6	6.1									
50		2.4	10.1	12.1											
60		15.7	20.1												
70	10.3	29.0													
80	35.3														

Sag curve: One- and two-lane road

Design speed (km/h)	A: 2	3	4	5	6	7	8
20				0.4	1.4	1.8	2.0
30			2.4	4.3	4.9		
40		0.6	6.6	8.2			
50		6.2	12.2				
60		11.8	17.9				
70		17.3	23.5				
80		24.3	30.5				

Table A2.3. Vertical curve elements (crest curve, single-lane road).

A[a]	20 km/h	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h
Crest curve: single-lane road							
2							71
3					38	128	228
4				36	116	206	311
5			3	83	163	258	388
6			34	114	196	310	467
7			68	136	229	361	544
8		13	73	156	261	413	622
9		26	86	175	294	465	700
10		36	96	194	327	516	778
11		45	106	214	359	568	856
12	2	52	116	233	392	620	933
13	8	58	125	263	425	671	1011
14	13	63	136	272	457	723	1089
15	18	68	144	292	490	775	1167
16	21	72	154	311	523	826	1244
17	25	77	164	331	555	878	1322
18	28	81	173	350	588	929	1400
19	31	86	183	369	621	981	1478
20	33	90	193	389	653	1033	1555
21	36	95	202	408	686	1084	1633
22	37	99	212	428	719	1136	1711
23	39	104	221	447	751	1188	1789
24	41	108	231	467	784	1239	1867
Minimum SSD (m)	40	65	95	135	175	220	270

[a] Algebraic difference between the entry and exit grades (%).

Table A2.4. Vertical curve elements (crest curve, double-lane road).

A[a]	20 km/h	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h
Crest curve: double-lane road							
2						21	71
3				7	47	87	137
4				40	80	121	183
5			20	60	102	152	229
6		4	34	74	122	182	274
7		13	43	86	142	212	320
8		20	50	98	163	243	366
9		26	56	111	183	273	411
10		30	63	123	203	303	457
11	4	34	69	135	223	334	503
12	7	37	75	147	244	364	548
13	9	40	82	160	264	394	594
14	12	43	88	172	284	425	640
15	13	46	94	184	305	455	686
16	15	49	100	197	325	486	731
17	17	52	107	209	345	516	777
18	18	55	113	221	366	546	823
19	19	58	119	233	386	577	868
20	20	61	125	246	406	607	914
21	21	65	132	258	427	637	960
22	22	68	138	270	447	668	1006
23	23	71	144	283	467	698	1051
24	24	74	150	295	488	728	1097
Minimum SSD (m)	20	35	50	70	90	110	135

[a] Algebraic difference between the entry and exit grades (%).

Table A2.5. Vertical curve elements (sag curve).

A[a]	20 km/h	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h
Sag curve							
2							
3			2	19	35	52	73
4		9	26	49	71	94	122
5	2	22	41	67	93	120	154
6	8	30	51	81	112	144	185
7	13	35	59	94	131	168	216
8	16	40	68	108	149	192	247
9	19	46	76	121	168	216	277
10	21	51	85	134	187	240	308
11	23	56	93	148	205	264	339
12	25	61	102	161	224	288	370
13	27	66	110	175	243	312	401
14	30	71	119	188	261	336	432
15	32	76	127	202	280	360	462
16	34	81	136	215	298	384	493
17	36	86	144	229	317	408	524
18	38	91	153	242	336	432	555
19	40	96	161	256	354	456	586
20	42	101	170	269	373	480	616
21	44	106	178	282	392	504	647
22	46	111	187	296	410	528	678
23	48	116	195	309	429	552	709
24	51	121	204	323	448	576	740
Minimum SSD (m)	20	35	50	70	90	110	135

[a] Algebraic difference between the entry and exit grades (%).

Appendix 3. Plotting data: plan and profile information

Plans/profiles and plotted cross-sections should be completed for the field survey. The plans and profiles should be prepared in 1 km sections on a 1 m plan/profile sheet with a minimum 200 m overlap between drawings. The plan/profile should be drawn to a scale of 1:2000 horizontally and 1:200 vertically.

The example plan/profile drawing in this appendix illustrates the plan and profile information requirements listed below. The drawing is available at the following Ministry of Forests website:
http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/guidetoc.htm

Plans should include all information pertinent to the project:

- north arrow with magnetic declination shown
- preliminary line traverse (include turning points, TPs)
- accumulated chainage and TP number at every fifth TP
- overlap between plans of 200 m
- chainage equations
- reference points and benchmarks plotted and labelled
- existing roads complete with road name
- existing structures (bridges, culverts, buildings, fences, etc.)
- existing services and utilities including but not restricted to telephone, power, gas, oil, sewer and water lines, and fences
- percent side slope and direction
- terrain features and direction (rock outcrops, creeks, rivers, swamps, wet areas, riparian zones, etc.)
- timber types, number, diameter, and species or stumps within the clearing widths
- designed L-line complete with curves
- curve information including radius (R), angle of intersection (IC), length of curve (LC), beginning of curve (BC), and end of curve (EC)
- accumulated L-line chainage at beginning and end of curves
- bearing of the L-line tangents shown on the plan to the nearest 30 seconds
- kilometre stations on the L-line
- 100 m of existing road alignment from junction or extension of existing points
- clearing and right-of-way boundaries

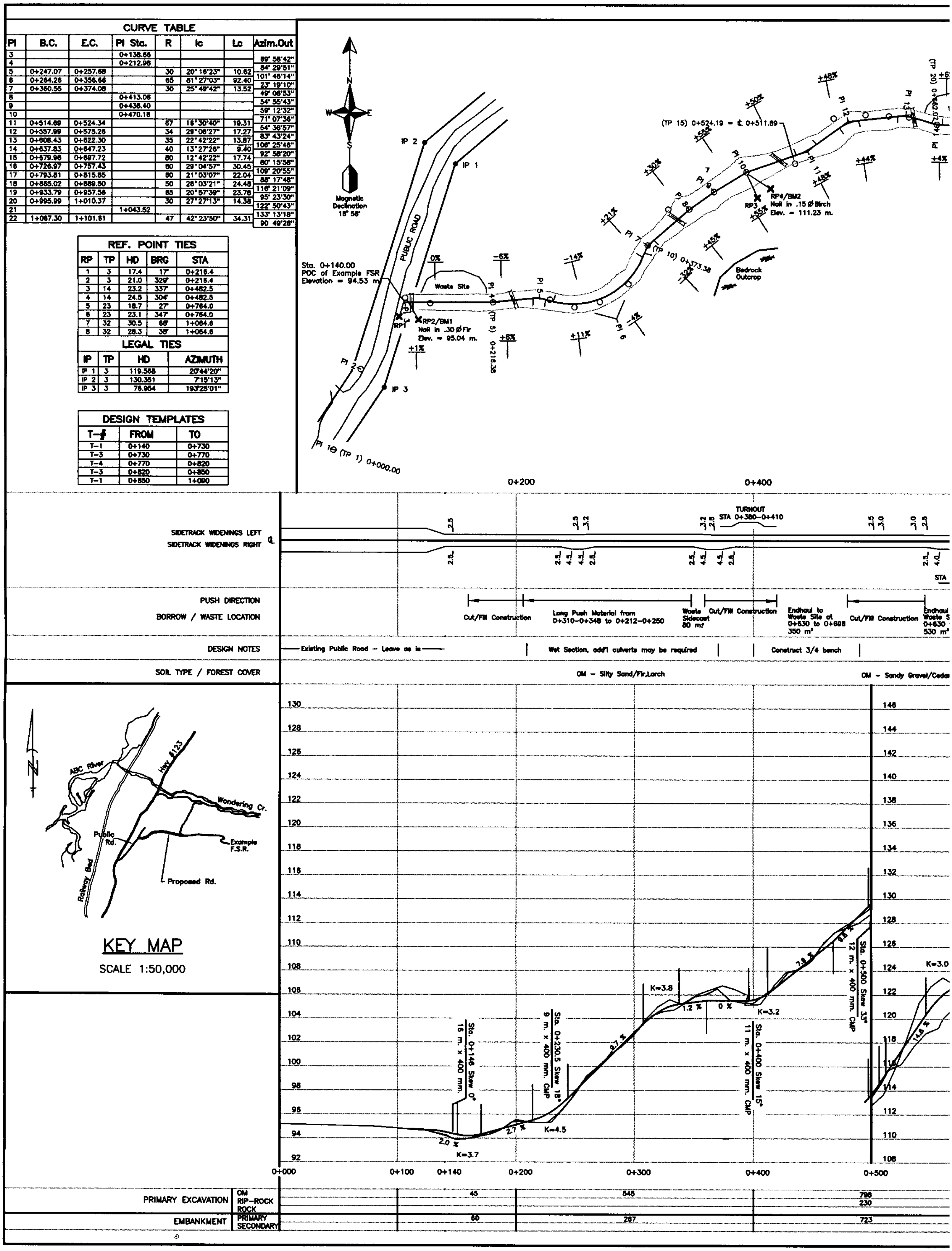
- title block indicating road name, kilometre, date of survey, and scale (horizontal and vertical)
- special notes indicating land district, road width, survey level, and datum of elevation
- all legal boundaries and plan numbers
- all monumentation found and tied within 300 m of the P-line, including a traverse tie table.

A key map should also be included on the first drawing of the set to a scale of 1:50 000. Note that no curves are required where I is less than or equal to 5°.

Profiles should include the following information:

- chainage and elevation equations
- description of soils (at least every 200 m or at soil change)
- terrain features (creeks, rivers, swamps, wet areas, riparian areas, etc.)
- penetration depths at swamps and wet areas to solid ground, if possible
- grade lines completed with percent grades labelled (adverse or negative)
- grade breaks at grade changes of 2% or less
- vertical curves at grade changes greater than 2%
- turnout locations and dimensions
- design notes (extra ditching, lateral ditching, road widenings, etc.)
- culvert locations with recommended diameter, length, and skew
- kilometre stations
- primary excavation and primary embankment volumes summarized in bank cubic metres at 200 m intervals
- secondary embankment (gravel) volumes summarized in bank cubic metres at 200 m intervals
- waste and borrow locations, quantities in bank cubic metres, and quantity movements
- scale: H = 1:2000; V = 1:200
- 100 m of existing road grade and horizontal alignment at junction
- balance points and direction of material movement
- position of cut and fill slope changes

- PWL and HWL, where applicable
- span lengths for bridges
- all control points
- design templates
- K values if used for vertical curves.



CURVE TABLE

PI	B.C.	E.C.	PI Sta.	R	Ic	Lc	Azim.Out
3			0+138.66				89° 58'42"
4			0+212.98				84° 29'51"
5	0+247.07	0+257.68		30	20° 16'23"	10.62	101° 46'14"
6	0+264.26	0+356.66		65	81° 27'03"	92.40	23° 19'10"
7	0+360.55	0+374.08		30	25° 49'42"	13.52	49° 08'53"
8			0+413.06				54° 55'43"
9			0+438.40				59° 12'32"
10			0+470.18				71° 07'36"
11	0+514.69	0+524.34		67	16° 30'40"	19.31	54° 36'57"
12	0+557.99	0+575.26		34	29° 06'27"	17.27	83° 43'24"
13	0+608.43	0+622.30		35	22° 42'22"	13.87	106° 25'46"
14	0+637.83	0+647.23		40	13° 27'26"	9.40	92° 58'20"
15	0+679.98	0+697.72		80	12° 42'22"	17.74	80° 15'58"
16	0+726.97	0+757.43		60	29° 04'57"	30.45	109° 20'55"
17	0+793.81	0+815.85		60	21° 03'07"	22.04	88° 17'48"
18	0+865.02	0+889.50		50	28° 03'21"	24.48	116° 21'09"
19	0+933.79	0+957.56		65	20° 57'39"	23.78	95° 23'30"
20	0+995.99	1+010.37		30	27° 27'13"	14.38	122° 50'43"
21			1+043.52				133° 13'18"
22	1+067.30	1+101.81		47	42° 23'50"	34.31	90 49'28"

REF. POINT TIES

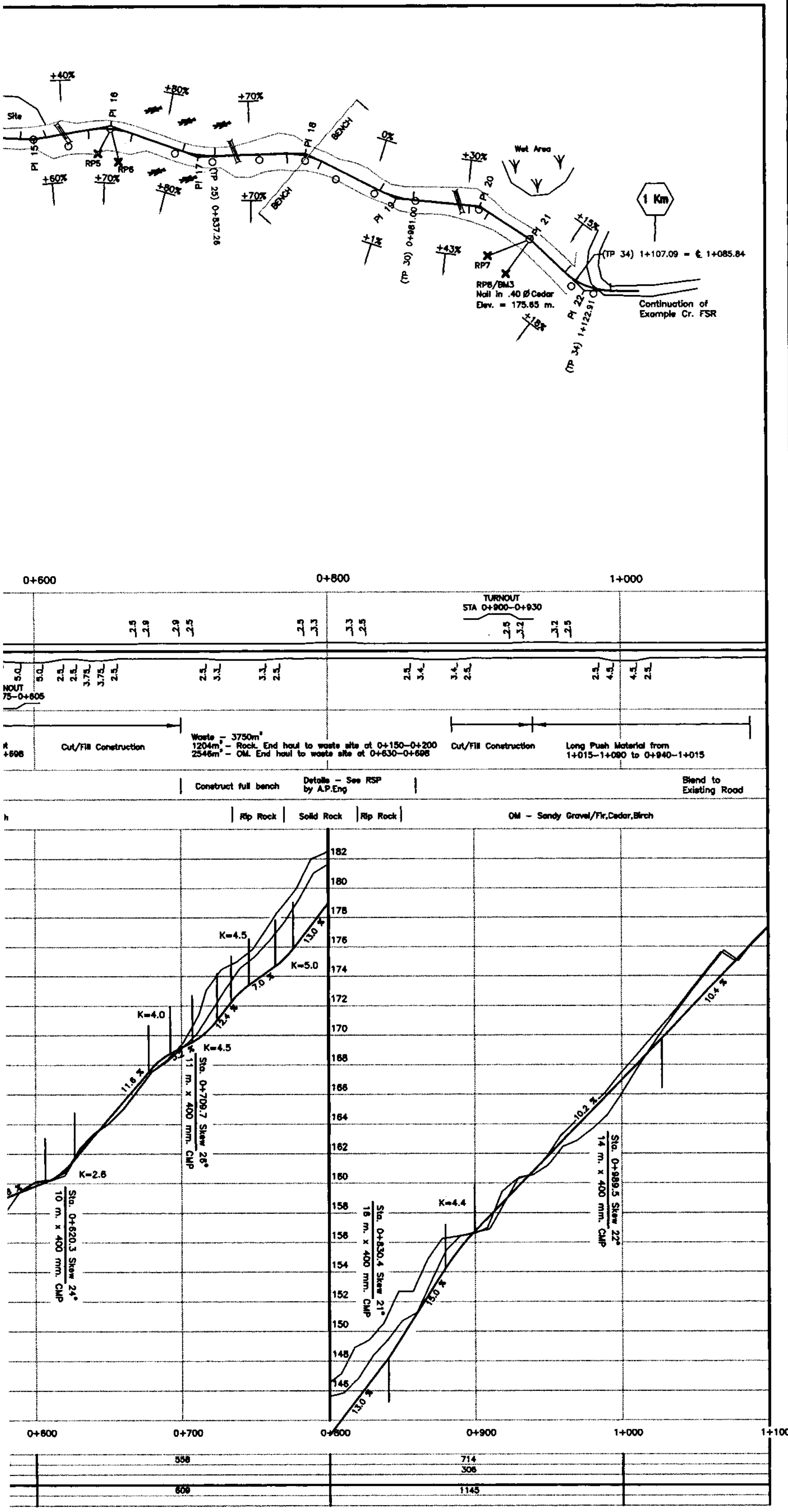
RP	TP	HD	BRG	STA
1	3	17.4	17°	0+216.4
2	3	21.0	329°	0+216.4
3	14	23.2	337°	0+482.5
4	14	24.5	304°	0+482.5
5	23	18.7	27°	0+764.0
6	23	23.1	347°	0+764.0
7	32	30.5	65°	1+064.6
8	32	28.3	35°	1+064.6

LEGAL TIES

IP	TP	HD	AZIMUTH
IP 1	3	119.568	20°44'20"
IP 2	3	130.351	7°15'13"
IP 3	3	76.954	193°25'01"

DESIGN TEMPLATES

T–#	FROM	TO
T–1	0+140	0+730
T–3	0+730	0+770
T–4	0+770	0+820
T–3	0+820	0+850
T–1	0+850	1+090



MOF EXAMPLE F.S.R.
PLAN/PROFILE
Km. 0 to Km. 1

Province of British Columbia
MINISTRY OF FORESTS

SCALE

PLAN	PROFILE
1 : 2000	H 1 : 2000 V 1 : 200

DESIGN SPECIFICATIONS

Stabilized Subgrade Width	– 5.0 meters
Ditch Width	– 1.25 meters
Design Speed	– 30 km/h
Crest Curves (min. 'K')	– 3.0
Sag Curves (min. 'K')	– 1.5
Survey Level : 3	Turnouts length: 15 m width: 2.5 m tapers: 7.5 m ea.

TEMPLATES

TEMPLATE #	MATERIAL	CUT	FILL	EMBANKMENT CORR. FACTOR
T–1	O.M. Dry	1.00 : 1	1.50 : 1	1.2
T–2	O.M. Wet	1.50 : 1	1.50 : 1	1.2
T–3	Rippable	0.75 : 1	1.25 : 1	1.0
T–4	Rock	0.25 : 1	1.25 : 1	0.8
T–5	Gravel		2.00 : 1	1.2

PLAN LEGEND

- PROPOSED C/L
- EXISTING ROAD
- CLEARING LIMITS
- LEGAL PROPERTY BOUNDARY
- PI # – POINT OF INTERSECTION (ON PROPOSED C/L)
- PLINE STATION (TP)
- CULVERT LOCATION
- CREEK
- INTERMITTENT CREEK
- RP – REFERENCE POINT
- B.M. – BENCH MARK
- IP 3 – IRON POST FOUND

CHAINAGE REVISION FROM P–LINE TO L–LINE

0+100.0 T.P. 5 = ℄ 0+099.6
Pline Station Hub No. Lline Station

PROFILE LEGEND

- L–LINE GROUNDLINE
- P–LINE GROUNDLINE
- L–LINE GRADE

	Date
Survey: (Engineering surveyor)	
Design: (Geometric road designer)	
Drawing:	
Checked:	
Approved:	

REV.	DESCRIPTION	BY	APPD.	DATE

Measures to Maintain Slope Stability, prepared by ____________ and dated ___/___/___ were incorporated into this geometric road design.

VOLUME SUMMARY

BANK CUBIC METERS			Kilometer Totals	Project Totals
EMBANKMENT	PRIMARY		2,840	2,840
	SECONDARY		430	430
	GRAVEL DEPTH		0.1 m	0.1 m
EXCAVATION	PRIMARY	RIP ROCK	536	536
		ROCK	0	0
		O.M.	2,660	2,660
BORROW			0	0
WASTE			4,710	4,710
TOTAL STRIPPING HA.			1.502	1.502

Drawing No. 11250–30/1234	Sheet 1 of 1	REV. 0

Appendix 4. Statement of construction conformance

Statement of Construction Conformance
(Construction of Bridges, Major Culverts, and Other Structures)

*TO BE SUBMITTED **AFTER** COMPLETION OF THE PROJECT*

Structure Identification No. / Name	**Road Name:**	**Location**
Forest District & Forest Region	**Crossing Name** (as applicable)	**Project No.** (as applicable)

Structure Description: ☐ Bridge ☐ Major Culvert ☐ Other ____________________ ____________________ ____________________ ____________________ ____________________	**List of Approved Design Drawings:** Drawing and Revision No. / Name of Designer/Date: ____________________ ____________________ ____________________ ____________________ ____________________ ____________________

I am a Professional Engineer or Professional Forester, and I have undertaken professional responsibility for all field reviews required with respect to this structure. I have taken steps as regulated under the Provincial Statute for my profession, and as required by good practice and in accordance with the division of professional responsibility specified in the Forest Practices Code (FPC) of British Columbia, in order to sign and seal this Statement of Construction Conformance as required by FPC, Forest Road Regulation Part 3, Section 13.

In my professional opinion:

- the as-built structure is in general conformance with the design drawings, specifications and all applicable supporting documents, including all design amendments, which supported the acceptance of the project by the appropriate authority;
- sufficient field reviews have been carried out at appropriate times during the construction work; and
- significant revisions to the drawings, specifications and supporting documents prepared for this project, including all design amendments, have been documented and marked on a set of design/construction drawings marked "as-built" and where necessary described in supporting documents.

As used herein, "field reviews" means field reviews of the work at the project site [and/or at the fabrication location(s), where applicable] considered necessary by, and at the discretion of, the registered professional engineer or professional forester (as appropriate) to confirm that the as-built structure is in general conformance with the approved design/construction drawings, specifications and other supporting documents prepared for this project.

Signature of Professional Engineer/Professional Forester		*(please affix professional seal here)*
Name of Professional Engineer/Professional Forester *(please print)*	DATE SIGNED YYYY M M DD | |	
EMPLOYER'S NAME AND ADDRESS (*please print*)		
PHONE NO.	FAX NO.	E-MAIL ADDRESS

November 2001

Appendix 5. Tables to establish clearing width

Clearing width

The **clearing width** is shown in Figure 2 of Chapter 1, "Road Layout and Design." Since clearing width calculations are straightforward, but very tedious, Tables A5.1 to A5.7 and accompanying Tables A and B have been developed for your convenience.

These tables provide **slope distances** (not the horizontal distances) for establishing suitable offset distances from road centreline to facilitate easy field marking of the upper and lower clearing width boundaries. Note that the offset slope distances in the tables depend on several factors:

- unstabilized subgrade width
- side slope angle of the natural ground surface
- angles of the fill and cut slopes.

Using the tables in this appendix, the **clearing width** is the sum of the width determined from the tables and any additional width to account for special circumstances (see "Additions to clearing width" in this appendix). The clearing width established from these tables may be expressed as:

Clearing width = offset distance on cut side of centreline (from tables) + offset distance on fill side of centreline (from tables) + additional width (if necessary)

For a specific subgrade width, these tables assume:

- no horizontal or vertical adjustments at the road centreline
- 0.3 m overburden thickness
- 3 m clearing allowance above the top of the cut slope to standing timber
- selection of the appropriate cut and fill slope angles
- a ditch depth of 0.5 m
- sidecast road construction with little or no longitudinal movement of material
- a minimum 3 m distance from the road shoulder to the lower side clearing width boundary.
- where there is road fill, the toe of the fill slope demarcates the lower clearing width boundary. Therefore, to establish the clearing width when using these tables, include additional width allowances as required (e.g., additional width will be required for debris and slash disposal on the lower side of the road below the toe of the fill slope).

Where the offset slope distance from the road centreline to the upper or lower clearing width boundaries exceeds 50 m, consider using alternative construction methods, such as retaining walls, to reduce the clearing width requirements.

Determining clearing width from tables in this appendix

The following procedure is recommended:

1. Select the appropriate unstabilized subgrade width table (the tables have been developed for unstabilized subgrade widths of 4, 5, 6, 7, 8, 9, and 10 m). This is done:
   - after adjusting the road subgrade width to compensate for cuts or fills (see “Adjustments to road subgrade width to compensate for cuts and fills at road centreline”)
   - after adjusting the road subgrade width to compensate for road surfacing materials (see “Additions to clearing width” in this appendix).
2. Choose the appropriate natural side slope angle in the selected subgrade width table.
3. Based on the expected soil type to be encountered during road construction, choose the appropriate cut and fill slope angles for application in the tables. Details about selecting cut and fill slope angles for road design are given in Appendix 1, “Field identification of soils.”
4. To establish the upper clearing width boundary, read the offset slope distance from the appropriate cut slope angle column—the offset distance given in the cut slope angle column is a slope distance between the road centreline and the upper clearing width boundary.
5. Use a two-step procedure to establish the lower clearing width boundary. Firstly, read the offset slope distance from the appropriate fill slope angle column—the offset distance given in the fill slope angle column is a slope distance between the road centreline and the toe of any fill slope. Secondly, include any additional width allowances such as those for slash disposal on the lower side of the road below the toe of the fill, sight distance, etc., as explained in “Additions to clearing width” in this appendix.

Adjustments to road subgrade width to compensate for cuts and fills at road centreline

Use of an adjusted road subgrade width in these tables for short sections of anticipated cuts or fills at the road centreline should be limited to the obvious locations in the field, such as where cuts are required through small ridges or fills across linear slope depressions less than 3 m deep. For longer sections of road through areas with deep gullies or high ridges, a geometric road design should be completed and the clearing width determined from these drawings.

1. To compensate for a cut at the centreline, adjust the road subgrade width as follows: Add 1 m to the subgrade width for every 0.3 m cut increment at centreline to determine the offset slope distance on the cut side of centreline. Subtract 1 m from the subgrade width for every 0.3 m cut increment at centreline to determine the offset slope distance on the fill side of centreline.

   For example, consider a 0.6 m deep cut at centreline on a 6 m wide unstabilized subgrade (assume no surfacing material is applied to the subgrade). Assume a natural side slope angle of 35% above and below the road centreline, and fill and cut slope angles of 1½H : 1V and 1H : 1V, respectively. In this case, adjust the unstabilized subgrade width by 2 m as follows:

   - Choose the appropriate cut slope angle column from Table A5.5 (8 m wide unstabilized subgrade) to determine the offset slope distance on the cut side of centreline. The offset slope distance from this table is 12 m.
   - Choose the appropriate fill slope angle column from Table A5.1 (4 m wide unstabilized subgrade) to determine the offset slope distance on the fill side of centreline. The offset slope distance from this table is 5 m.

   In this cut example, the clearing width (magnitude) is unchanged, but is shifted upslope with respect to the road centreline.

   If, because of shallow side slopes, the 0.6 m cut resulted in a through-cut instead of a fill slope, use the appropriate cut slope angle column from Table A5.1 (4 m wide unstabilized subgrade) to obtain the required offset slope distance from centreline to the lower clearing width boundary.

2. To adjust for fills at the centreline, reverse the above procedure. For example, to allow for a 0.6 m fill at centreline on a 6 m wide road, adjust the unstabilized subgrade width by 2 m as follows:

   - Choose the appropriate cut slope angle column from Table A5.1 (4 m wide unstabilized subgrade) to determine the offset slope distance on the cut side of centreline.
   - Choose the appropriate fill slope angle column from Table A5.5 (8 m wide unstabilized subgrade) to determine the offset slope distance on the fill side of centreline.

Additions to clearing width

Compensate for surfacing or ballasting material:

Before selecting the appropriate unstabilized subgrade width table, compensate for the thickness of surfacing or ballasting material anticipated to be placed over the unstabilzed subgrade surface. For example, where surfacing material is needed to provide a finished road-running surface, select a wider unstabilized subgrade width when determining the clearing width from the tables in this appendix. For every 0.3 m of surfacing depth, allow for an additional 1.0 m of unstabilized subgrade width.

For example, to obtain a 4 m wide finished road-running surface on subgrade soils that will require a 0.3 m thickness of gravel, select Table A5.2 (5 m wide unstabilized subgrade).

Compensate for other requirements:
Calculate the extra width required for turnouts, sight distance, snow removal, slash disposal, etc. required on the fill side of road centreline. To determine the lower clearing width boundary, add this extra width to the offset slope distance (fill side of centreline) given in the tables.

For example, if winter use of the road will require snow ploughing, the standing timber should be at least 4 m or more away from the road shoulder. Since the tables will only provide for a minimum of 3 m from the road shoulder to the lower clearing width boundary, simply add the additional 1 or 2 m to the offset slope distance. Where natural side slope angles are greater than 20% the extra width allowance should be converted to a slope distance, rounded up to the nearest metre, and then added to the offset slope distance determined from the tables.

Tables A5.1 to A5.7: Offset slope distances in metres from road centreline to upper (cut side) clearing width boundary and lower (fill side) clearing width boundary.

Table A5.1 -- Unstabilized Subgrade Width = 4 m

NATURAL SIDE SLOPE ANGLE	FILL SLOPE ANGLE			CUT SLOPE ANGLE				
%	1H : 1V	1-1/2H : 1V	2H : 1V	1/4H : 1V	3/4H : 1V	1H : 1V	1-1/2H : 1V	2H : 1V
0-20	5	5	5	6	7	7	8	10
21-30	5	5	5	6	7	8	9	14
31-35	5	5	5	6	8	8	10	18
36-40	5	5	7	6	8	9	11	Use Table B
41-45	5	5	Use Table A	7	8	10	13	
46-50	5	7		7	9	10	15	
51-54	5	10	Use alternate construction methods	7	10	12	26	Use alternate construction methods
55-57	5	13		7	10	12	34	
58-60	5	19		7	10	13	48	

Table A5.2 -- Unstabilized Subgrade Width = 5 m

NATURAL SIDE SLOPE ANGLE	FILL SLOPE ANGLE			CUT SLOPE ANGLE				
%	1H : 1V	1-1/2H : 1V	2H : 1V	1/4H : 1V	3/4H : 1V	1H : 1V	1-1/2H : 1V	2H : 1V
0-20	5	5	5	7	7	8	9	11
21-30	5	5	6	7	8	9	10	16
31-35	5	5	8	7	8	9	11	20
36-40	5	6	10	7	9	10	12	Use Table B
41-45	5	7	Use Table A	7	9	11	14	
46-50	5	9		7	10	12	17	
51-54	5	12	Use alternate construction methods	7	10	13	29	Use alternate construction methods
55-57	5	16		7	11	14	37	
58-60	6	23		8	11	15	54	

Table A5.3 -- Unstabilized Subgrade Width = 6 m

NATURAL SIDE SLOPE ANGLE	FILL SLOPE ANGLE			CUT SLOPE ANGLE				
%	1H : 1V	1-1/2H : 1V	2H : 1V	1/4H : 1V	3/4H : 1V	1H : 1V	1-1/2H : 1V	2H : 1V
0-20	6	6	6	7	8	9	10	12
21-30	6	6	6	7	9	10	11	17
31-35	6	6	8	7	9	10	12	22
36-40	6	7	13	8	9	11	14	Use Table B
41-45	6	9	Use Table A	8	10	12	16	
46-50	6	11		8	10	13	18	
51-54	7	15	Use alternate construction methods	8	11	14	32	Use alternate construction methods
55-57	7	19		8	12	15	41	
58-60	8	28		8	12	16	60	

Table A5.4 -- Unstabilized Subgrade Width = 7 m

NATURAL SIDE SLOPE ANGLE	FILL SLOPE ANGLE			CUT SLOPE ANGLE				
%	1H : 1V	1-1/2H : 1V	2H : 1V	1/4H : 1V	3/4H : 1V	1H : 1V	1-1/2H : 1V	2H : 1V
0-20	7	7	7	8	9	9	10	13
21-30	7	7	8	8	9	10	12	19
31-35	7	7	10	8	10	11	13	
36-40	7	8	Use Table A	8	10	12	14	Use Table B
41-45	7	11		8	11	12	16	
46-50	7	14		8	11	14	20	
51-54	8	18	Use alternate construction methods	9	12	15	35	Use alternate construction methods
55-57	8	23		9	13	16	44	
58-60	9	33		9	13	17		

Table A5.5 -- Unstabilized Subgrade Width = 8 m

NATURAL SIDE SLOPE ANGLE	FILL SLOPE ANGLE			CUT SLOPE ANGLE				
%	1H : 1V	1-1/2H : 1V	2H : 1V	1/4H : 1V	3/4H : 1V	1H : 1V	1-1/2H : 1V	2H : 1V
0-20	7	7	7	8	9	10	11	14
21-30	7	7	9	8	10	11	12	20
31-35	7	8	11	8	10	12	14	
36-40	7	10	Use Table A	8	11	13	16	Use Table B
41-45	8	12		9	11	14	18	
46-50	8	16		9	12	15	22	
51-54	9	21	Use alternate construction methods	10	13	17	38	Use alternate construction methods
55-57	10	27		10	14	18	49	
58-60	11	39		10	14	19		

Table A5.6 -- Unstabilized Subgrade Width = 9 m

NATURAL SIDE SLOPE ANGLE	FILL SLOPE ANGLE			CUT SLOPE ANGLE				
%	1H : 1V	1-1/2H : 1V	2H : 1V	1/4H : 1V	3/4H : 1V	1H : 1V	1-1/2H : 1V	2H : 1V
0-20	8	8	8	9	10	11	11	14
21-30	8	8	10	9	11	12	13	21
31-35	8	10	13	9	11	13	15	
36-40	8	12	Use Table A	9	12	14	17	Use Table B
41-45	9	15		10	12	15	20	
46-50	10	19		10	13	16	23	
51-54	10	24	Use alternate construction methods	10	14	18	41	Use alternate construction methods
55-57	11	31		10	15	19	53	
58-60	12	45		11	16	20		

Table A5.7 -- Unstabilized Subgrade Width = 10 m

NATURAL SIDE SLOPE ANGLE	FILL SLOPE ANGLE			CUT SLOPE ANGLE				
%	1H : 1V	1-1/2H : 1V	2H : 1V	1/4H : 1V	3/4H : 1V	1H : 1V	1-1/2H : 1V	2H : 1V
0-20	8	8	8	9	10	11	12	15
21-30	8	9	11	9	11	12	14	Use Table B
31-35	8	11	15	10	12	13	16	
36-40	9	13	Use Table A	10	12	14	18	
41-45	10	16		10	13	16	21	
46-50	11	21		10	14	17	25	
51-54	12	27	Use alternate construction methods	11	15	19	45	Use alternate construction methods
55-57	13	36		11	16	21	58	
58-60	14	50		11	17	22		

Tables A & B: These following two tables are referenced in Tables A5.1 to A5.7

Table A

Offset slope distance for **2H:1V fill slope** angles

NATURAL SIDE SLOPE ANGLE	Unstabilized Subgrade Width						
%	4 m	5 m	6 m	7 m	8 m	9 m	10 m
36-38	Use tables above			13	15	17	19
40				16	18	21	23
42	9	13	16	19	22	25	28
44	12	17	22	26	30	34	37
46	20	28	35	41	46	50	
48	44	Use alternate construction methods					

Table B

Offset slope distance for **2H:1V cut slope** angles

NATURAL SIDE SLOPE ANGLE	Unstabilized Subgrade Width						
%	4 m	5 m	6 m	7 m	8 m	9 m	10 m
21-25	Use tables above						17
26-28							20
30							22
32				20	21	23	24
34				22	24	25	27
36	19	21	23	25	27	29	31
38	22	24	27	29	32	34	36
40	26	29	32	35	38	41	
42	32	36	39	43	47	50	
44	42	52	Use alternate construction methods				

Appendix 6. Sample road inspection and maintenance report

ROAD INSPECTION AND MAINTENANCE REPORT

Date: Y M D	*File No.*	*Road Name*	*Road Project No.*	
Forest Region	*Forest District*	*Local Road Name*	*Local Road No.*	
Licensee or Agency	*Forest Licence or TSL*	*Road Permit or CP No.*	*Amendment No. or Block No.*	*Road Section No.*

GPS Co-ordinates at Start of Inspection:

Other Tenure Comments:

Inspect for the following items to ensure integrity of the road:

Structural Integrity:		Drainage Systems:	
• Tension cracks visible	SI-01	• Natural drainage patterns maintained	DS-01
• Cutslope failures	SI-02	• Culverts clear and working	DS-02
• Fill slope failures	SI-02	• Culverts washed out	DS-03
• Slides or mass land movements	SI-04	• Culvert and /or ends damaged	DS-04
• Shoulder slumps	SI-05	• Culvert markers	DS-05
• Frost boils	SI-06	• Adequate fill over culverts	DS-06
• Subgrade unable to support wheel loads	SI-07	• Ditch blocks in place and working	DS-07
• Washouts	SI-08	• Adequate cross-drain culverts	DS-08
Road Surface:		• Undersized cross-drain or stream culverts	DS-09
• Depth of surface material adequate	RS-01	• Ditches scoured	DS-10
• Potholes	RS-02	• Ditches unobstructed (debris, grass, vegetation)	DS-11
• Washboard	RS-03	• Ditchline sloughing	DS-12
• Rutting from vehicle wheels	RS-04	**Safe Fish Passage:**	
• Windrows present	RS-05	• Fish stream culvert inlets and outlets	FP-01
• Damage from cattle	RS-06	• Inadequate structure	FP-02
• Road surface erosion	RS-07	**Road Safety:**	
• Sediment transport from road prism	RS-08	• Site distances	SA-01
• Dust	RS-09	• Brushing	SA-02
Bridge Surface		• Snags and danger trees	SA-03
• Waterway opening free of logs and debris	BS-01	• Other road hazards (loose rocks, stumps, etc.)	SA-04
• Bearing surfaces free of gravel and dirt	BS-02	• Traffic control signs	SA-04
• Wood stringers free of dirt accumulations	BS-03	• Road radio frequencies posted	SA-06
• Running planks missing or damaged; nails protruding	BS-04		
• Damaged guide rails or curbs	BS-05		
• Gravel build-up on bridge deck	BS-06		

Location (km) or GPS Co-ord	Comments and/or Code	Remedial Works to Be Completed by Date:	Remedial Works Completed Date:

Additional Comments Regarding Inspection:
Comments Regarding Remedial Actions:

Sign-off of Inspection:							
Inspector	*Y*	*M*	*D*	*Licensee or Agency Specialist*	Y	M	D
Sign-off of Completion of Remedial Maintenance Works:							
Inspector	*Y*	*M*	*D*	*Licensee or Agency Specialist*	Y	M	D

Appendix 7. Sample road deactivation inspection report

ROAD DEACTIVATION INSPECTION REPORT

Date: Y M D	*File No.*	*Road Name*	*Road Project No.*	
Forest Region	*Forest District*	*Local Road Name*	*Local Road No.*	
Licensee or Agency	*Forest Licence or TSL*	*Road Permit or CP No.*	*Amendment No. or Block No.*	*Road Section No.*

GPS Co-ordinates at Start of Inspection:

Deactivation Prescription Information

Deactivation Level:	*Temporary:* ☐	*Semi-Permanent:* ☐	*Permanent:* ☐
Type of Vehicle Usage:	*4 WD:* ☐	*ATV:* ☐	*None:* ☐

Date Deactivation Work Completed:

Date That Area Was Grass Seeded or Planted:

Inspect for the following items to ensure integrity of the road:

Vehicle Usage		Road Prism and Water Management	
• Road still passable for intended vehicle use	DV-01	• Re-vegetation satisfactory	DW-01
Stability		• Road surface erosion	DW-02
• Pullback failures	DS-01	• Sediment transport form road prism	DW-03
• Cutslope failures	DS-02	• Cross-ditches functional	DW-04
• Fill slope failures	DS-03	• Ditch blocks functional	DW-05
• Slide or mass land movements	DS-04	• Excessive ditch sediment transport	DW-06
Road Safety		• Ditches unobstructed (debris, grass, vegetation)	DW-07
• Deactivation warning signs in place	DR-01	• Bridges and stream culverts functional	DW-08
• Snags and danger trees felled	DR-02	• Stream crossing structures allow for safe fish passage (constructed or modified after June 15, 1995)	DW-09
• Other road hazards present (loose rocks, stumps, etc.)	DR-03		

Location (km) or GPS Co-ord.	Comments and/or Code	Remedial Works to Be Completed by Date:	Remedial Works Completed Date:

Location (km) or GPS Co-ord.	Comments and/or Code	Remedial Works to Be Completed by Date:	Remedial Works Completed Date:

Additional Inspection Comments:
Comments Regarding Remedial Actions:

Sign-off of Inspection:							
Inspector	*Y*	*M*	*D*	*Licensee or Agency Specialist*	*Y*	*M*	*D*
Sign-off of Completion of Remedial Works:							
Inspector	*Y*	*M*	*D*	*Licensee or Agency Specialist*	*Y*	*M*	*D*

Appendix 8. Example field data form for deactivation field assessments

Road name / Road permit: ________________________________ Page: _____ of _____
Date: ________________________________
Recorded by: ________________________________
Weather conditions: ________________________________

Road station: start/end	Estimated construction difficulty (optional)	Prescription symbol for deactivation technique	Comments	Terrain / soils	Natural ∠ upslope (%)	Natural ∠ downslope (%)	Road gradient (%)	Road width (m)	Fill slope length (m)	Fill slope angle (%)	Cut slope height (m)	Cut slope angle (%)	Stability/ surface erosion problems?

Legend:

Data Entry Field	Description
Road station: start/end	Road station (e.g., 1+250)
Estimated construction difficulty and/or estimated equipment time	Optional data entry field: If necessary, give relative ranking of difficulty to carry out the major works prescribed, and or estimated equipment time to carry out the prescribed action. This information may be useful to estimate unit costs (e.g., easy, average, difficult)
Prescription symbol for deactivation technicque	Examples: X (cross-ditch), RMC (remove metal culvert), P9 (pull 9 m). Symbols are often combined at specific locations. For example, at a single culvert location the deactivation prescription may be "Remove metal culvert" and "cross-ditch"
Comments	Important observations, which may include, for example: areas of seepage; width/length of tension cracks; hazard/consequence/risk of damage to neighbouring resources; requirement for professional field reviews; armouring requirements; source of armour; current motor vehicle access conditions; locations where access must be restored; locations of required benching and ramping for road fill pullback; worker safety concerns; condition of pipe and wood box culverts; condition of bridges; evidence of scour on road; evidence of unstable cuts/fills; landslides; vegetative cover; composition of cut and road fill materials; evidence of woody debris in road fill; evidence of temporary woody debris-supported materials along toe of road fill; location of large gravel pits; landings, etc.
Terrain/soils	Surficial material types of natural terrain (colluvium, bedrock, till, etc.) and texture of natural soils (sand, silt, sand and gravel, etc.)
Natural ∠ Upslope (%)	Slope angle of natural terrain above road cut
Natural ∠ Downslope (%)	Slope angle of natural terrain below toe of road fill
Road gradient (%)	Average gradient of road
Road width (m)	Width of road
Fill slope length (m)	Length of fill slope below outer edge of road
Fill slope angle (%)	Slope angle of fill slope
Cut slope height (m)	Height of cut slope
Cut slope angle (%)	Slope angle of cut slope
Stability/surface erosion	Examples: TC (tension crack), SE (surface erosion), FF (fill failure), LS (landslide)

Appendix 9. Example road deactivation prescription content requirements

Examples are presented below showing the linkage between various site and project conditions and the minimum content of a road deactivation prescription.

Example 1: A road is prescribed for semi-permanent deactivation with 4-wheel drive vehicle access. The road traverses gentle terrain with no landslide hazard. There are a few crossings of S6 streams, and some cross-drain culverts on the road. The risk of damage to adjacent resources is low or minimal. Deactivation measures are limited to water management techniques (such as cross-ditches, waterbars, and back-up of some stream culverts) and revegetation of exposed soils using a suitable grass seed and legume mixture.

- *Example Prescription Content Requirements*: For this project, a scale topographic map showing the locations of recommended actions corresponding to the chainages of field markings may be sufficient for communication of the required works to field crews (and review and approval by the district manager, if required).

Example 2: A road is prescribed for semi-permanent deactivation with 4-wheel drive vehicle access. The road traverses gentle to moderate terrain with no landslide hazard. There are many culvert and bridge crossings of S5 and S4 streams, and many cross-drain culverts along the road. The soils are fine-grained and prone to erosion. The area is in a wet belt. The risk of sediment transport to aquatic resources and aquatic habitat from existing sediment sources is high. Deactivation measures include water management techniques such as cross-ditches, waterbars, removal or back-up of cross-drain culverts, and removal or back-up of stream culverts, and other measures such as repair of bridges and revegetation of exposed soils using a suitable grass seed and legume mixture.

- *Example Prescription Content Requirements*: In this case, the basic minimum requirement of a deactivation prescription would be a 1:5000 scale map (or other suitable scale) showing the locations of the actions corresponding to the chainages of field markings, and a tabular summary (spreadsheet) to accompany and complement the map. The tabular summary should provide more detailed information such as general site conditions, the size of existing culverts and bridges, sediment transport hazards and consequences, and methods to control sediment transport, including the measured chainages along the road and the corresponding actions. In this case, the prescription should clearly identify the fish streams and the timing windows for working in and about a stream, as developed and provided by a designated environment official.

Example 3: A road is prescribed for semi-permanent deactivation with 4-wheel drive vehicle access. The road is located on a mid-slope, and traverses steep terrain and areas of moderate to high likelihood of landslides. (**Note:** A qualified registered professional must prepare a deactivation prescription where the road crosses areas with a moderate or high likelihood of landslides, as determined by a terrain stability field assessment [TSFA].) There are visual indicators of road fill instability, surface soil erosion, and previous road fill washouts along the road. The road is located in a wet belt, and receives high annual precipitation. The road crosses many deeply incised S5 streams contained in gullies tributary to an S2 stream downslope of the road. Deactivation measures include water management techniques such as cross-ditches, and removal or back-up of stream culverts, long segments of partial road fill pullback to maintain motor vehicle access, and revegetation of exposed soils using a suitable grass seed and legume mixture. There is an existing high risk of potential damage to public utilities, a highway, and the S2 stream from potential fill slope failures.

- *Example Prescription Content Requirements*: This is a more complex project, involving deactivation prescriptions for unstable terrain. Reporting may include more detailed observations and assessment of terrain stability. In this case, the basic minimum requirement of a deactivation prescription would include a 1:5000 scale map showing the locations of the actions corresponding to the chainages of field markings, a tabular summary (spreadsheet) to accompany and complement the map, and a detailed letter or report. The prescription should clearly identify the timing windows for working in and about streams that are tributary to the S2 stream, developed and provided by a designated environment official. The prescription should also specify the need for any professional field reviews during the deactivation work.

Appendix 10. Landslide risk analysis

Introduction

This appendix provides:

- an example of a procedure for carrying out a qualitative landslide risk analysis, including an example qualitative landslide risk matrix (Table A10.1).
- an example of a qualitative landslide hazard table (Table A10.2)
- examples of qualitative landslide consequence tables (Tables A10.3–A10.11)

Landslide risk analysis is a systematic use of information to determine the landslide hazard (likelihood of landslide occurrence) and the consequence of a landslide at a particular site, thereby allowing an estimate of the risk to adjacent resources from a landslide occurrence.

Notes:
The examples of the qualitative landslide hazard table, landslide consequence tables, and landslide risk matrix provided are for illustration only and should not be considered a procedural standard. The tables and matrix should be modified, or a different risk-ranking method that varies in detail and complexity, should be adapted to suit site-specific requirements.

Qualitative landslide risk analysis satisfies most forestry practice needs where relative risk rankings are sufficient to provide guidance for decision making. This method of risk analysis, however, has limitations and in some circumstances it may be advantageous to use a quantitative landslide risk analysis method.

Landslide risk

Landslide risk = Landslide hazard × Landslide consequence
= Likelihood of landslide occurrence × [(Element at risk) × (Vulnerability of that element at risk from a landslide)]

Table A10.1 is an example of a qualitative landslide risk matrix for a specific element at risk. It combines a relative landslide hazard rating and a relative landslide consequence rating that represents the vulnerability of that element at risk. The term "vulnerability" refers to the fact that an element at risk may be exposed to different degrees of damage or loss from a landslide.

Table A10.1 uses a 5 × 3 matrix, consisting of five qualitative ratings of landslide hazards (VH, H, M, L, and VL) described in Table A10.2, and three qualitative ratings of landslide consequences (H, M, L) described in Tables A10.3–A10.11.

Table A10.1. Example of a qualitative risk matrix.

Risk of Damage to Element at Risk		Landslide Consequence: Low	Landslide Consequence: Mod	Landslide Consequence: High
	Very Low	*VL*	*VL*	*L*
	Low	*VL*	*L*	*M*
Landslide Hazard	**Mod**	*L*	*M*	*H*
	High	*M*	*H*	*VH*
	Very High	*H*	*VH*	*VH*

Landslide hazard

Landslide hazard is the likelihood of a particular landslide occurring. It is dependent on the type and magnitude of the landslide of significance for a specified element at risk. The **landslide of significance** is the smallest landslide that could adversely affect the element at risk.

For example, if the element at risk is a fish stream, the landslide of significance is the smallest landslide that could reach, and adversely affect, the stream. The landslide of significance usually has the greatest probability of occurrence of any landslide to affect the element at risk. For a specific site, landslides that are smaller or larger than the landslide of significance could occur. For example, a smaller landslide event would have a greater likelihood of occurrence compared to the landslide of significance, but would usually have no adverse effect on a fish stream. Similarly, a larger landslide event would have a much smaller chance of occurring compared to the landslide of significance, but would result in greater damage and therefore have an adverse effect on a fish stream.

Different elements at risk often have different landslides of significance. It is possible that the same element at risk could be potentially subject to two or more different types of landslides at the same time, and therefore could be subject to two or more different landslide hazards. Assuming the same type of landslide, the landslides of significance for different elements at risk could be quite different, and therefore the hazards could be quite different.

Description of a landslide hazard for forestry purposes should include an estimate of landslide characteristics, such as:

- the likely path of a landslide event
- the dimensions of the transportation and deposition areas

- the type of materials involved (e.g., source area material type)
- the volumes of material removed and deposited.

In Table A10.2, the **example of range of annual probability** (Column 2) and **example of qualitative description** for a range of annual probability (Column 3) are only included to give users some physical idea of the meaning of the relative qualitative ratings in Column 1.

Additionally, some users may relate better to a 20-year period of time (approximating the life of a logging road) than to an annual probability. For this reason, Column 4 in Table A10.2 provides an **example of range of probability** of landslide occurrence for the landslide of significance for a specific element at risk assuming a 20-year design life. For illustrative purposes, the following example shows that a **Moderate** hazard rating (annual probability [Pa] of 1/100) corresponds to an 18% chance that at least one landslide event will occur in 20 years.

<u>Example:</u>

According to probability theory, the long-term probability of occurrence (Px) is related to the annual probability of occurrence (Pa) by the following:

Px = $1-[1-(1/Pa)]^x$, where Px is the probability of at least one landslide occurring within the specified time period "x" years.

For a service life of 20 years (i.e., x = 20), and a Pa of 1/100,

$$P20 = 1-[1-(1/100)]^{20}$$
$$= 0.18 \text{ or } 18\%$$

This means that there is an 18% chance of the 1 in 100-year event occurring within the 20-year service life of the road. If the service life of the road is doubled to 40 years (i.e., x = 40), the chance of the 1 in 100-year event occurring within the 40-year service life rises to 33%.

Landslide consequence

Landslide consequence is the product of the element at risk and the vulnerability of that element at risk from a landslide. Tables A10.3–A10.11 are examples of landslide consequence tables that express consequence in terms of three relative qualitative ratings: H, M, and L. In this scheme, if there is no likely consequence, the consequence is assumed to be less than low, or nil, as appropriate. The elements at risk included in these consequence tables include:

Table	Element at risk
Table A10.3	Human life and bodily harm
Table A10.4	Public and private property (includes building, structure, land, resource, recreational site and resource, cultural heritage feature and value, and other features)
Table A10.5	Transportation system/corridor
Table A10.6	Utility and utility corridor
Table A10.7	Domestic water supply
Table A10.8	Fish habitat
Table A10.9	Wildlife (non-fish) habitat and migration
Table A10.10	Visual resource in scenic area
Table A10.11	Timber value (includes soil productivity)

Table A10.2. Example of a qualitative landslide hazard table.

Intended for use in qualitative landslide hazard and risk analyses for terrain stability field assessments, and for preparation of measures to maintain slope stability and road deactivation prescriptions.

Landslide hazard is the likelihood of a particular landslide occurring. It is dependent on the type and magnitude of the **landslide of significance** for a specified element at risk. Refer to text for further discussion.

Column (1) **Relative qualitative rating of landslide occurrence** for the landslide of significance for a specific element at risk	**Column (2)** **Example of range of *annual* probability** (Pa) of landslide occurrence for the landslide of significance for a specific element at risk[a,b,c]	**Column (3)** **Example of qualitative description** for range of *annual* probability (Pa)[c]	**Column (4)** **Example of range of probability** of landslide occurrence for the landslide of significance for a specific element at risk[a,c] **(assumes a 20-year design life)**
Very High (VH)	Annual probability (Pa) >1/20	Pa of 1/20 indicates that a landslide is imminent (or likely to occur frequently) for an existing road, or would occur soon after road construction in the case of new road development, and well within the lifetime of the road. In the case of past landslide activity, landslides occurring within the past 20 years generally have clear and relatively fresh signs of disturbance.	>64% chance that at least one event will occur in 20 years
High (H)	Annual probability (Pa) 1/100 to 1/20	Pa of 1/100 indicates that a landslide can happen (or is probable) within the approximate lifetime of the existing or proposed road. In the case of past landslide activity, landslides occurring between 20 and 100 years are usually identifiable from deposits and vegetation, but may not appear fresh.	64% chance that at least one event will occur in 20 years
Moderate (M)	Annual probability (Pa) 1/500 to 1/100	Pa of 1/500 indicates that a landslide within a given lifetime of the existing or proposed road is not likely, but possible. In the case of past landslide activity, landslides occurring between 100 and 500 years may not be easily identified.	18% chance that at least one event will occur in 20 years
Low (L)	Annual probability (Pa) 1/2500 to 1/500	Pa of 1/2500 indicates that the likelihood of a landslide is remote within the lifetime of the road. In the case of past landslide activity, landslides occurring between 500 and 2500 years are difficult to identify.	4% chance that at least one event will occur in 20 years
Very Low (VL)	Annual probability (Pa) <1/2500	Pa < 1/2500 indicates that the likelihood of a landslide is very remote within the lifetime of the road.	1% chance that at least one event will occur in 20 years

(Modified after Resource Inventory Committee 1996)

Notes:
a. Assume that ranges of probability apply to a 1-km segment of road.
b. Annual probability (Pa) of 1/100, for example, means an event with an estimated return period of 100 years.
c. The **example of range of annual probability** (Column 2) and **example of qualitative description** for a range of annual probability (Column 3) are only included to give users some physical idea of the meaning of the relative qualitative ratings in Column 1.

Tables A10.3–A10.11. Examples of qualitative landslide consequence tables.

Intended for use in qualitative landslide hazard and risk analyses for terrain stability field assessments, and for preparation of measures to maintain slope stability and road deactivation prescriptions.

Notes:

- **Consequence** is the product of the element at risk and the vulnerability of that element at risk from a landslide.
- Only a few "examples of factors to consider" are provided. There may be others depending on the scale of assessment and the project and site conditions.
- The tables are **examples only** and would likely change depending on the scale of assessment (temporary spur road, versus permanent mainline, versus secondary road, versus provincial highway, etc.).
- For most elements at risk, only broad values are applied (e.g., utilized building or structure versus abandoned building or structure; active transportation system/corridor versus non-active transportation system/corridor, critical utility, or utility corridor).
- The ratings in the consequence tables for the various elements at risk should not be compared.
- **If there is no likely consequence, consider the consequence <low or nil.**

Table A10.3. Example of consequences to human life and bodily injury.

Examples of factors to consider:

- Includes forestry workers and the general public.
- Important factors include landslide path, volume, and speed, numbers of individuals affected, likelihood of people being within the landslide path, and their time of exposure.

Consequence	Examples
High	• Loss of life or injury, OR • Constant exposure to moderate or high potential landslide hazard.
Moderate	• Intermittent or low exposure to moderate or high potential landslide hazard, OR • Constant exposure to low potential landslide hazard.
Low	• Intermittent or low exposure to low potential landslide hazard.

Table A10.4. Example of consequences to public and private property (building, structure, land, resource, recreational site and resource, cultural heritage feature and value, and other features).

Examples of factors to consider:

- Applies where there is no threat to human life or bodily injury. If there is, refer to "Consequences to human life and bodily injury" table.
- Important factors include landslide path, volume, and speed, utilization of building or structure, land and resource present, direct and indirect costs, continuity or duration of any effects, and extent of damage.

Consequence	Examples
High	• Destruction of, or excessive (non-reparable) damage to, utilized building, structure, or cultural heritage feature, OR • Excessive, or continual moderate, adverse effects on land, cultural heritage value, or other resource.
Moderate	• Moderate (reparable) damage to utilized building, structure, or cultural heritage feature, OR • Excessive damage (non-reparable) to non-utilized building or structure, or to less significant cultural heritage value, OR • Moderate, or continual minor, adverse effects on land, cultural heritage value, or other resource.
Low	• Minor (inconvenient) damage to utilized building, structure, or cultural heritage feature, OR • Moderate (reparable) damage to non-utilized building or structure, or to less significant cultural heritage value, OR • Minor adverse effects on land, cultural heritage value, or other resource.

Table A10.5. Example of consequences to transportation system/corridor.

Examples of factors to consider:

- Applies where there is no threat to human life or bodily injury. If there is, refer to "Consequences to human life and bodily injury" table.
- Important factors include landslide path, volume and speed, type of transportation corridor/system, utilization of transportation corridor/system, duration of disruption, availability of alternative routes, direct and indirect costs, and extent of damage.

Consequence	Examples
High	• Destruction of, or extensive (not easily reparable) damage to, active transportation system/corridor, OR • Long-term (> 1 week) disruption to transportation system/corridor.
Moderate	• Moderate (easily reparable) damage to active transportation system/corridor, OR • Excessive damage (non-reparable) to non-active transportation system/corridor, OR • Short-term (1 day – 1 week) disruption to transportation system/corridor.
Low	• Minor (inconvenient) damage to active transportation system/corridor, OR • Moderate (reparable) damage to non-active transportation system/corridor, OR • Very short (< 1 day) disruption to transportation system/corridor.

Table A10.6. Example of consequences to utility and utility corridor.

Examples of factors to consider:

- Applies where there is no threat to human life or bodily injury. If there is, refer to "Consequences to human life and bodily injury" table.
- Important factors include landslide path, volume and speed, type of utility, utilization of (how critical is) utility or utility corridor, duration of disruption, availability of alternative service, direct and indirect costs, and extent of damage.

Consequence	Examples
High	• Destruction of, or extensive (not easily reparable) damage to, critical utility or utility corridor, OR • Long-term (> 1 week) disruption to critical utility or utility corridor.
Moderate	• Moderate (easily reparable) damage to critical utility or utility corridor, OR • Excessive damage (non-reparable) to non-critical utility or utility corridor, OR • Short-term (1 day – 1 week) disruption to critical utility or utility corridor.
Low	• Minor (inconvenient) damage to critical utility or utility corridor, OR • Moderate (easily reparable) damage to non-critical utility or utility corridor, OR • Very short (< 1 day) disruption to critical utility or utility corridor.

Table A10.7. Example of consequences to domestic water supply.

Examples of factors to consider:

- Important factors include landslide path, volume of the landslide, amount of sedimentation, duration of sedimentation, water quality and quantity, extent of damage to works, intake, and storage, effect on chlorinating, cumulative effects (previous slides), and availability of alternative sources of domestic water supply.

Consequence	Examples
High	• Permanent loss of quality; short-term loss of supply.
Moderate	• Short-term disruption of quality; short-term loss of supply.
Low	• Water quality degraded but potable; no disruption or damage to water supply infrastructure; effect < 1 day.

Table A10.8. Example of consequences to fish habitat (includes riparian management area).

Examples of factors to consider:

- Important factors include landslide path, volume of the landslide, amount of sedimentation, duration of sedimentation, hydraulic connectivity, location of deposition zone relative to fish stream or watercourse connected to fish stream, deposition zone size/volume, and type of deposition material.
- Cumulative effects and previous slides may increase or decrease consequence rating.
- For a high consequence rating:
  – consider where the permanent loss is located (directly or indirectly downslope of a failure site),
  – consider the stream channel and the riparian zone,
  – consider the requirements of the federal *Fisheries Act*. Federal legislation takes precedence over provincial legislation.

Consequence	Examples
High	• Permanent loss of habitat; likely not feasible to restore habitat, but sediment should be controlled at source.
Moderate	• Habitat damaged but can be restored through intervention; source of sediment can be controlled.
Low	• Limited habitat damage that can be eliminated or controlled through natural processes within 1 year. Source of sediment can be restored to pre-landslide condition through minor work (e.g., grass seeding, silt fences).

Table A10.9. Example of consequences to wildlife (non-fish) habitat and migration.

Examples of factors to consider:

- Important factors include landslide path, area of landslide track, type of deposition material, species present, species status (red to yellow), rarity of affected habitat, and size of home range.
- The major effect of a landslide on wildlife is on the habitat of that species, or on the habitat of the species on which that species depends. Effects on migrating wildlife are minimal.
- Is rehabilitation/mitigation possible? Successful mitigation depends on species and habitat.

Consequence	Examples
High	• The affected species is rare, endangered, or a management concern (e.g., identified wildlife), OR • Permanent loss of habitat or migration route; likely not feasible to restore habitat, OR • Permanent adverse effects on wildlife population need to be assessed, OR • The affected area is large relative to the locally available habitat and/or the affected habitat is rare (there is no suitable adjacent habitat).
Moderate	• Habitat damaged or migration route temporarily interrupted but can be restored through intervention, OR • Wildlife populations disrupted but no permanent effect on population, OR • The affected species is not rare or endangered, although it may be of management concern (e.g., identified wildlife), OR • The affected area is being managed for wildlife, has been set aside for wildlife, or has been identified as wildlife habitat (in a resource plan).
Low	• Limited damage to habitat; no disruption to migration route, OR • Damage could be restored through natural processes within one growing season, OR • The wildlife species is not of management concern (e.g., it has not been designated as rare, endangered, or as identified wildlife), OR • The affected area is not being managed for wildlife, has not been set aside for wildlife, and has not been identified as wildlife habitat (in a resource plan).

Table A10.10. Example of consequences to visual resources in a scenic area.

Examples of factors to consider:

- Important factors include expected landslide path, size and numbers of landslides in perspective view area, and duration of visible adverse effects on scenic areas.
- Applies only where there is reasonable expectation for visible alteration of the landscape in scenic area (there are no legal obligations to manage visual resources outside a scenic area).
- Criteria used to develop Visual Sensitivity Class (VSC) ratings include: visual absorption capability (the measure of the landscape's ability to accept change), biophysical rating (measure of topographical relief and vegetation variety), viewing condition (viewing duration and proximity), and viewer rating (numbers of people and their expectations).

Consequence	Examples
High	• Visible site disturbance of any amount within scenic area designated as Visual Sensitivity Class (VSC) 1 or 2.
Moderate	• Visible site disturbance up to 7% of the landform area as measured in perspective view (for both in-block and landform situations) within scenic area designated as Visual Sensitivity Class (VSC) 3 or 4, and where visible adverse effect on a scenic area should have disappeared by the time visually effective green-up is achieved.
Low	• Visible site disturbance up to 15% of the landform area as measured in perspective view (for both in-block and landform situations) within scenic area designated as Visual Sensitivity Class (VSC) 5, and where visible adverse effect on a scenic area may not have disappeared by the time visually effective green-up is achieved.

Table A10.11. Example of consequences to timber values.

Examples of factors to consider:

- Applies where there is no threat to human life or bodily injury. If there is, refer to "Consequences to human life and bodily injury" table.
- Applies where there is no threat of damage to building, structure, land, resource, recreational site and resource, cultural heritage feature and value, and other feature. If there is, refer to "Consequences to public and private property" table.
- Important factors include landslide size, age of merchantable timber, time remaining to reach a harvestable state, and timber value ($\$/m^3$).
- Note shift from "consequences to soil productivity or growing site potential" to simply "consequences to timber values." It is assumed that areas of high-value timber directly correlate to areas of high soil productivity.

Consequence	Examples
High	• Destruction of mature harvestable timber stands and the timber value is in the top third for the region (implies a high site productivity area), and the ground area adversely affected by the landslide is large.
Moderate	• Destruction of mature harvestable timber stand and the timber value is in the middle third for the region, and the ground area adversely affected by the landslide is large, OR • Destruction of juvenile timber stands that are within about 20–35 years of potential harvest and the future timber value at a harvestable stage will be in the top or middle third for the region, and the ground area adversely affected by the landslide is large.
Low	• Destruction of mature harvestable timber stands and the timber value is in the top third for the region, and the ground area adversely affected by the landslide is small, OR • Destruction of mature harvestable timber stand and the timber value is in the bottom third for the region (implies a low site productivity area), and the ground area adversely affected by the landslide is large, OR • Destruction of juvenile timber stands that are more than 35 years away from potential harvest and the future timber value at a harvestable stage will be in the top or middle third for the region, and the ground area adversely affected by the landslide is large.