Design and Installation of Embedded Culverts

Kamloops
March 12, 2002

Pilot 2

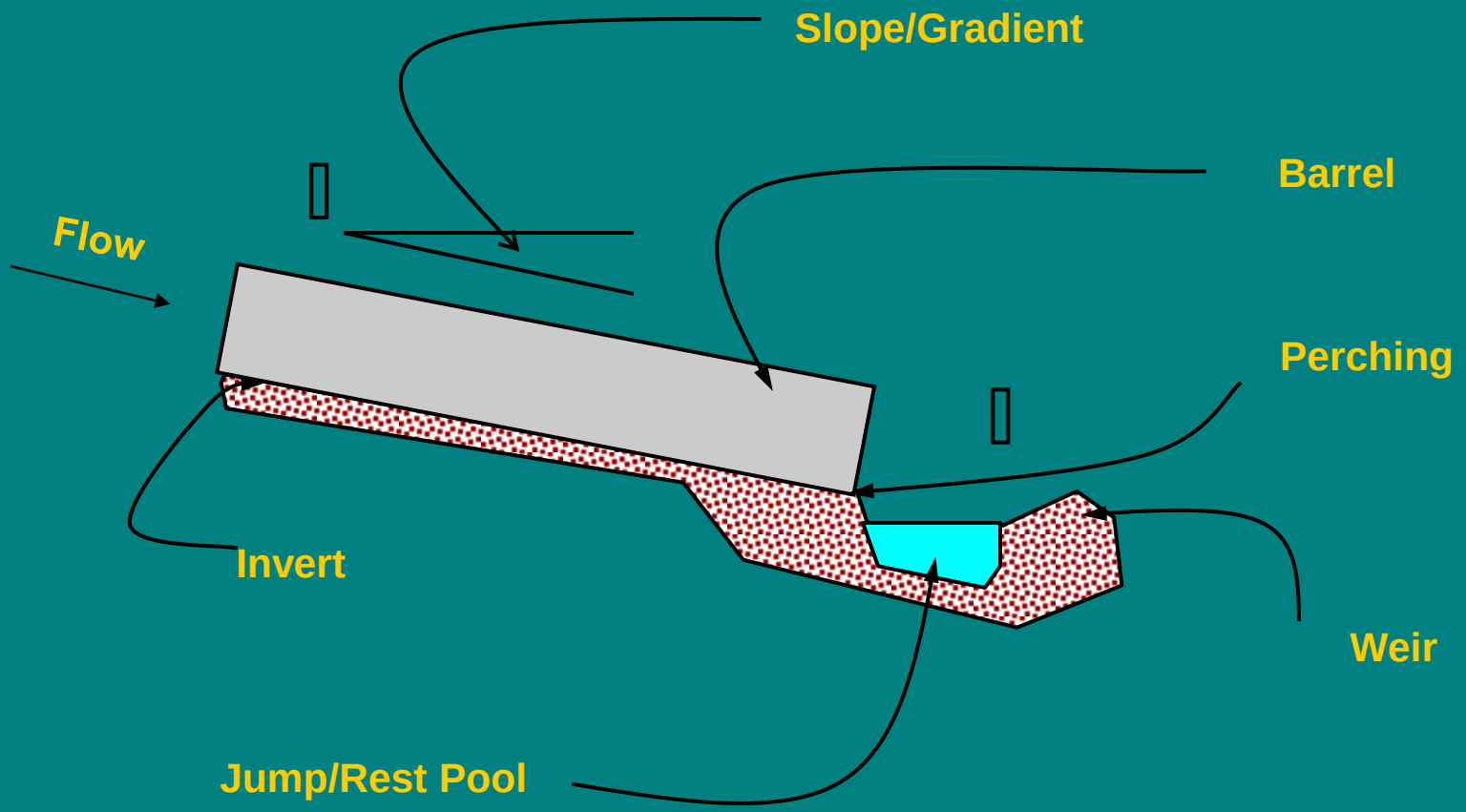
Part 2: Design

Part 2: Design

6 Main Topics

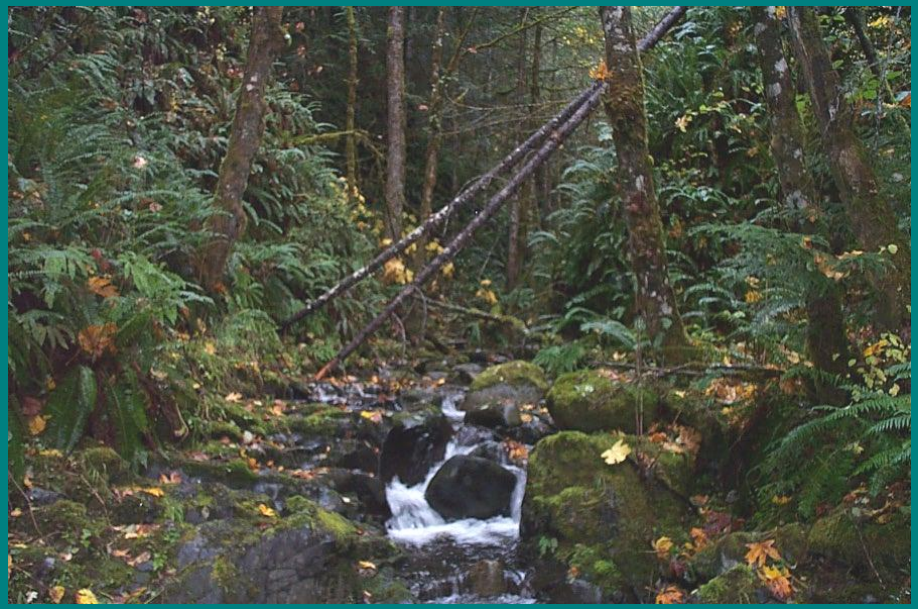
1. Evaluation of site suitability
2. Detailed streambed profile
3. Sizing the pipe
4. Design embedment
5. Embedment material
6. Design drawings

Culvert Terminology



1. Evaluation of Site Suitability

Should consider the following:



- Fish stream
- Stable stream channel
- Stream gradient ≤6%
- Stream channel width ≤2.5m
- Depth of excavatable fill
- Suitable for both stream and road geometry
- Evaluate diversion options

2. Detailed Streambed Profile

- Use precise instruments
- Establish elevation benchmarks

Field Survey Reference Control

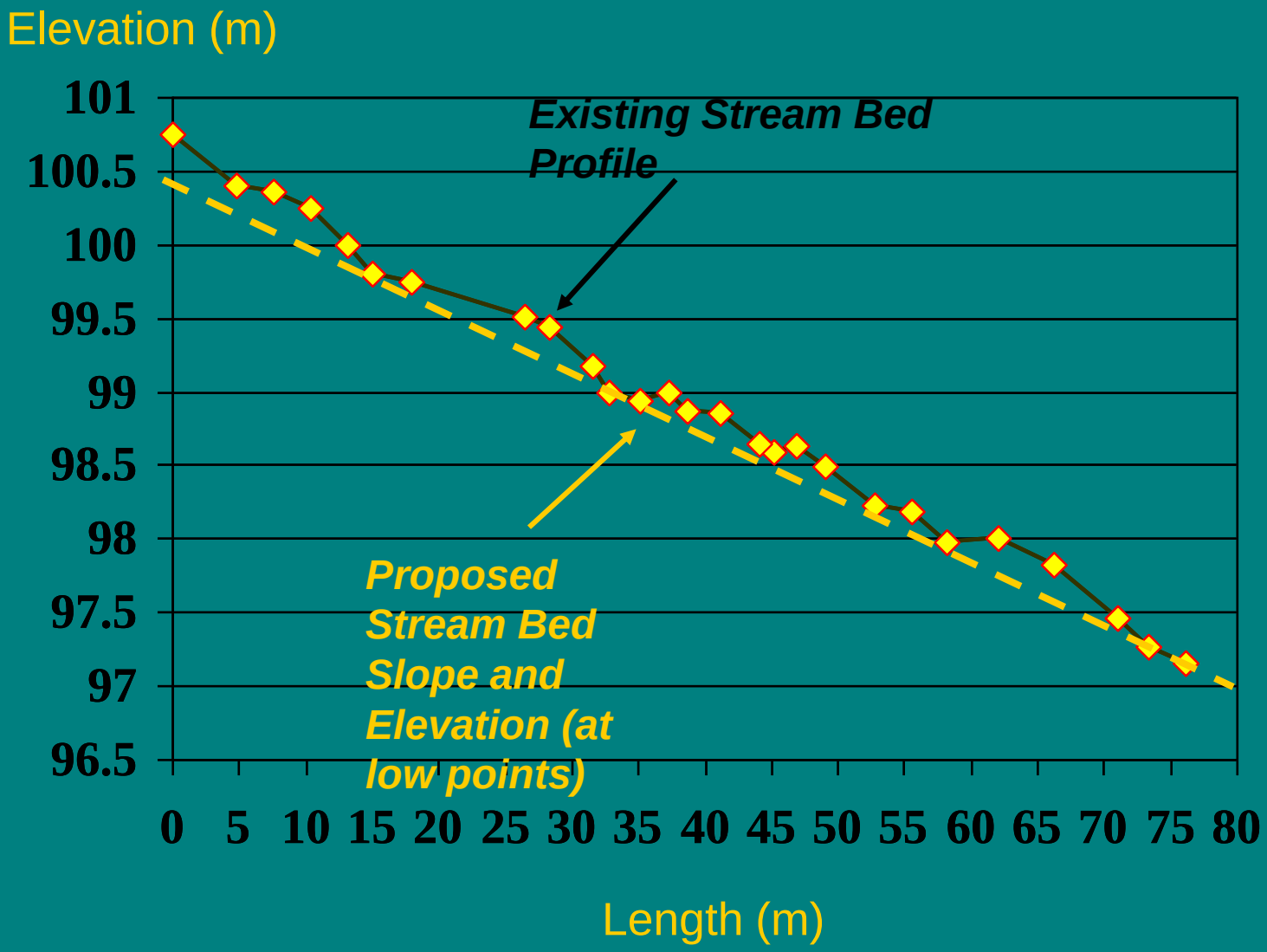
- Elevational benchmarks

- Horizontal reference stakes

Profile Length

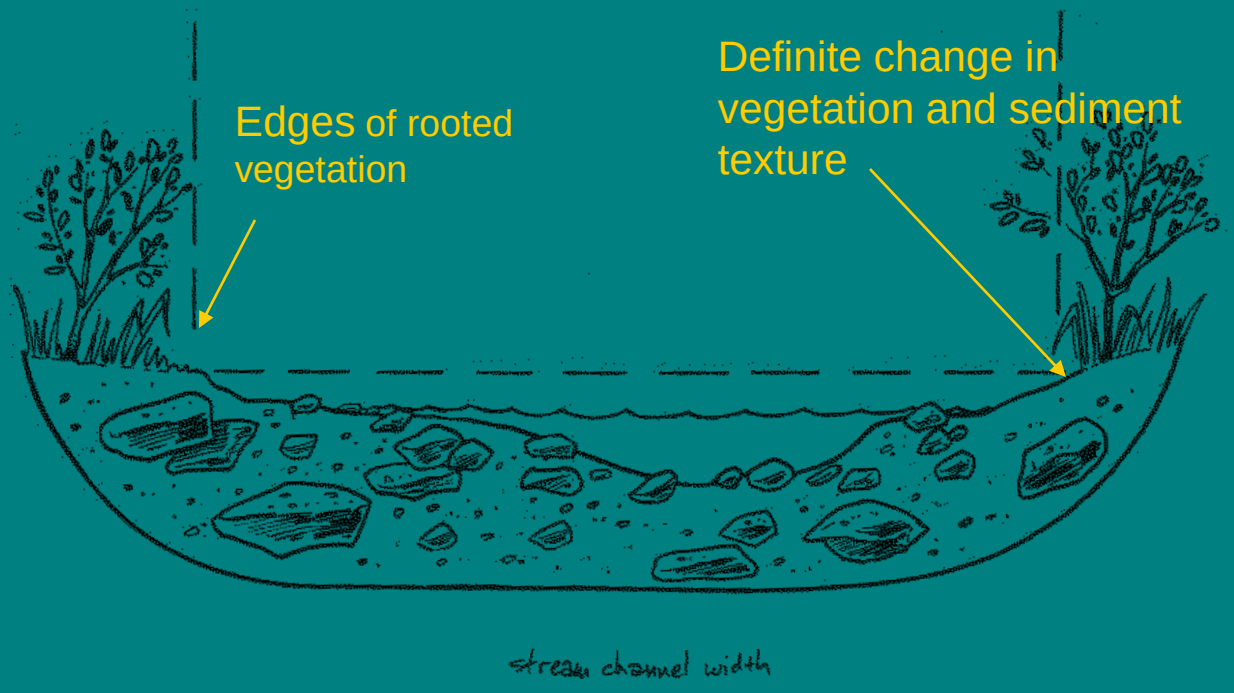
- Extended distance upstream and downstream (~50m minimum)
- note potential influences such as log/debris jams, bedrock, nick points

Detailed Streambed Profile



3. Sizing the Pipe

Stream Channel Width



- **Culvert diameter / span must span SCW at point of embedment**

Diameter/Span

- **Determination of Stream Channel Width with field measurements**
- **Use systematic approach to avoid skewing the results**

(FSCG - 6 equally spaced intervals along 100 m length)

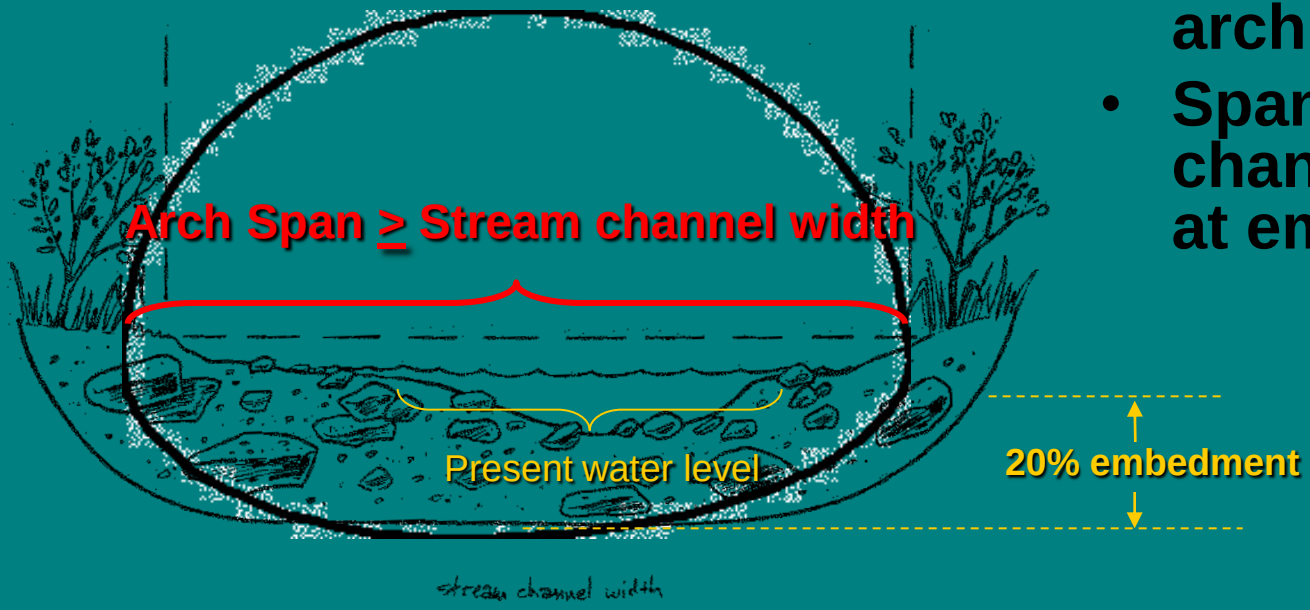
Depth of Embedment

- Round pipes - 40% of diameter or 0.6m, whichever is greater
- Pipe-arch - 20% of vertical rise of the arch

Round Pipes

- 40% of diameter or 0.6m, whichever is greater
- Span the stream channel width (SCW) at embedment depth

Arch Pipes



- Pipe-arch – 20% of vertical rise of the arch
- Span the stream channel width (SCW) at embedment depth

Check Q100

- **Check that Q100 will pass @ embedment depth**

Non-embedded pipe

Culvert Cross Sectional Area ~ 3 x Visible Highwater Area

- **Round pipe at 40% embedment => loss of 37% of area**
- **Arch pipe at 20% embedment => loss of 17% of area**

Check Q100

- Round pipe at 40% embedment -> loss of 37% of area

- Arch pipe at 20% embedment -> loss of 17% of area

Round Culvert X-sectional Area Required ~ 1.37 x (3 x visible high water area)

Arch Culvert X-sectional Area Required ~ 1.2 x (3 x visible high water area)

FPC Forest Road Regulations

– Require P.Eng. For :

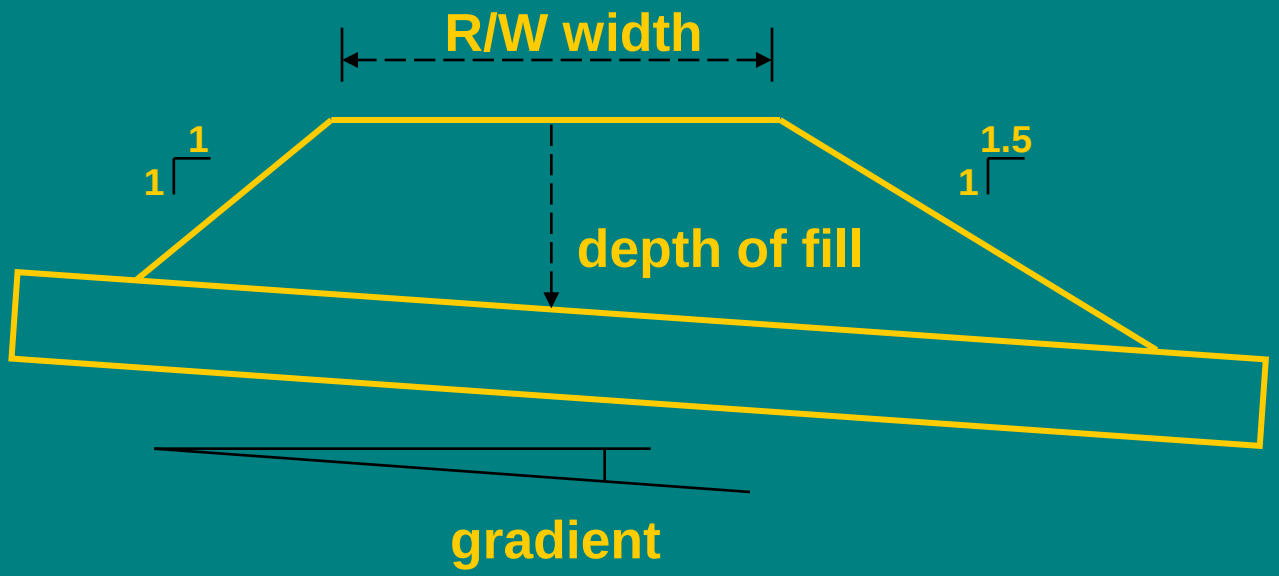
≥2000mm
or ≥6 m^3/s

Factors Influencing Culvert Length

- Depth of fill and fill slopes
- Road surface width
- Culvert gradient
- Skew angle of culvert to road

Factors Influencing Culvert Length

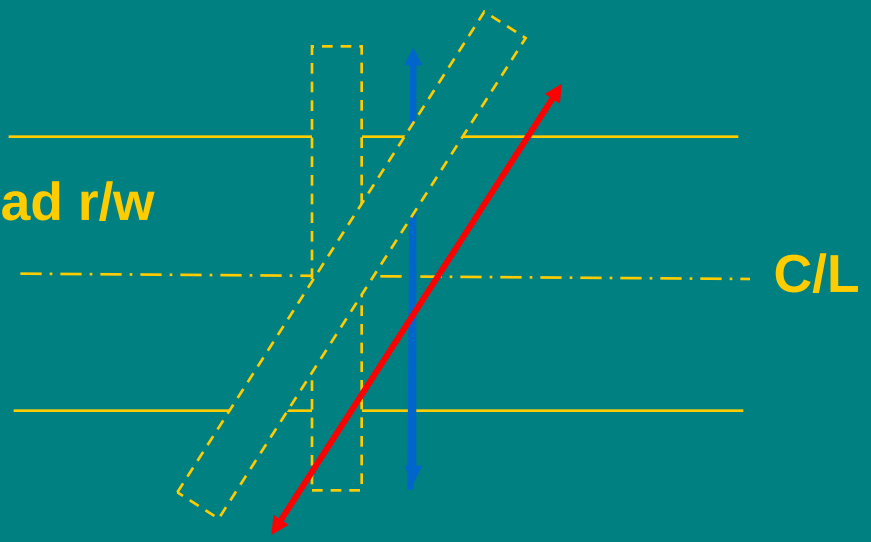
- **Include:**



Factors Influencing Culvert Length

- **Include:**

amount of skew to road r/w

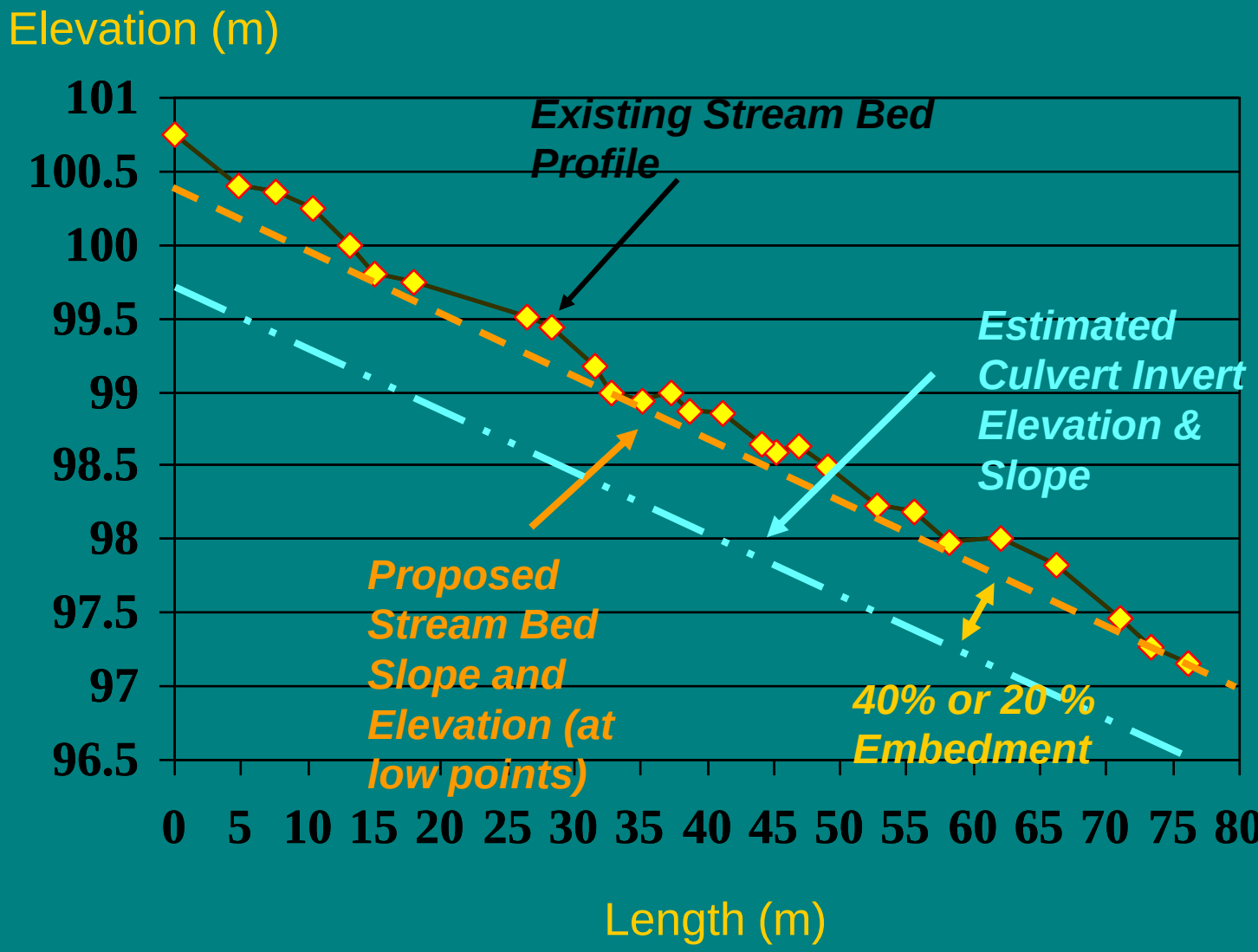


4. Design Embedment

Depth of Embedment

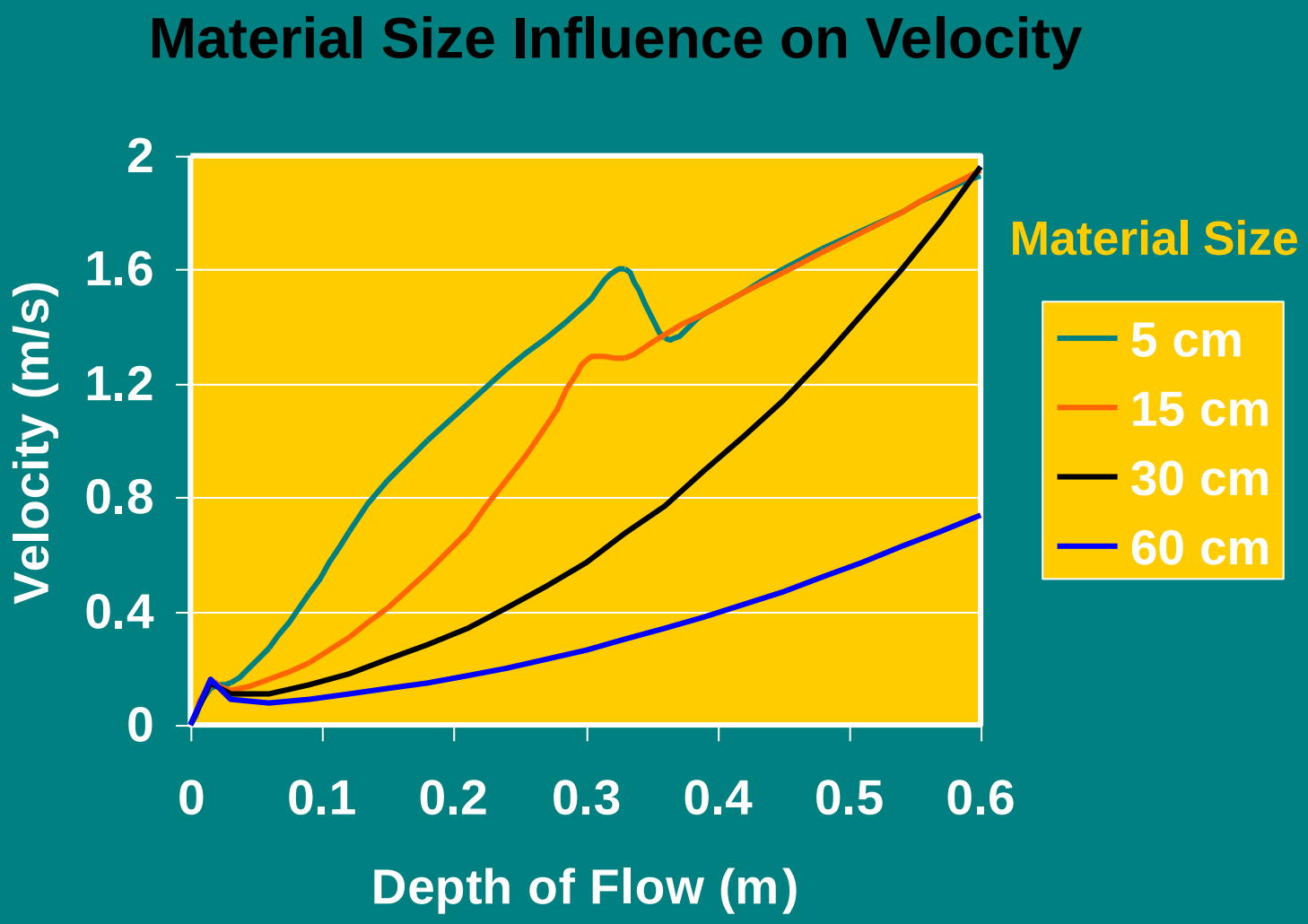
- Round pipes - 40% of diameter or 0.6m, whichever is greater
- Pipe-arch - 20% of vertical rise of the arch

Design Embedment



5. Embedment Materials

- Objective is to emulate/simulate natural streambed
- Fish passage is related to “Hydraulic Roughness” (HR)
- HR related to size of bed materials
- Bed materials, in turn, are related to water velocities and water depth in culvert which influence fish passage


Material Size Influence on Velocity
Velocity (m/s)
2
1.6
1.2
0.8
0.4
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Depth of Flow (m)
Material Size
5 cm
15 cm
30 cm
60 cm

Velocity Refuge (Shadows)

Roughness reduces velocity and creates shadows

Embedded pipes -modeling/simulating the natural streambed

"Rule of Thumb"

- **Size similar to that found in adjacent natural streambed**

Natural Stream Channel

Embedment Material

Range of Material Size

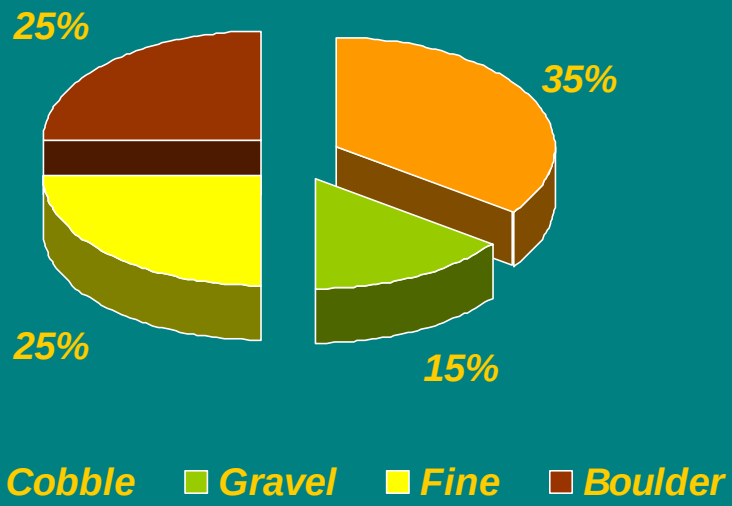
- **Design should specify composition and distribution sizes of material to be used**

Range of Material Size

- A range of substrate sizes (gradation) should be specified in the design
- Materials must be well graded to “seal” the streambed
- Ensure sufficient fines (sands & gravels) to “seal” the streambed
- Supplement with larger D90 material to help retain substrate
- D90 or greater particularly important on stream between 3 and 6%

Defn. **D90 is the size of which 90% of the material will be smaller than**

Range of Material Size



Rule of thumb - aka George Robison

General Size Distribution of Embedded Material

Substrate Volume Determination

- **Round pipe embedded 40%**
  ≃ 37% of area

$$\text{Area}_{(\text{Round})} = \pi(\text{Dia}/2)^2$$

- **Arch pipe embedded 20%**
  ≃ 17% of area

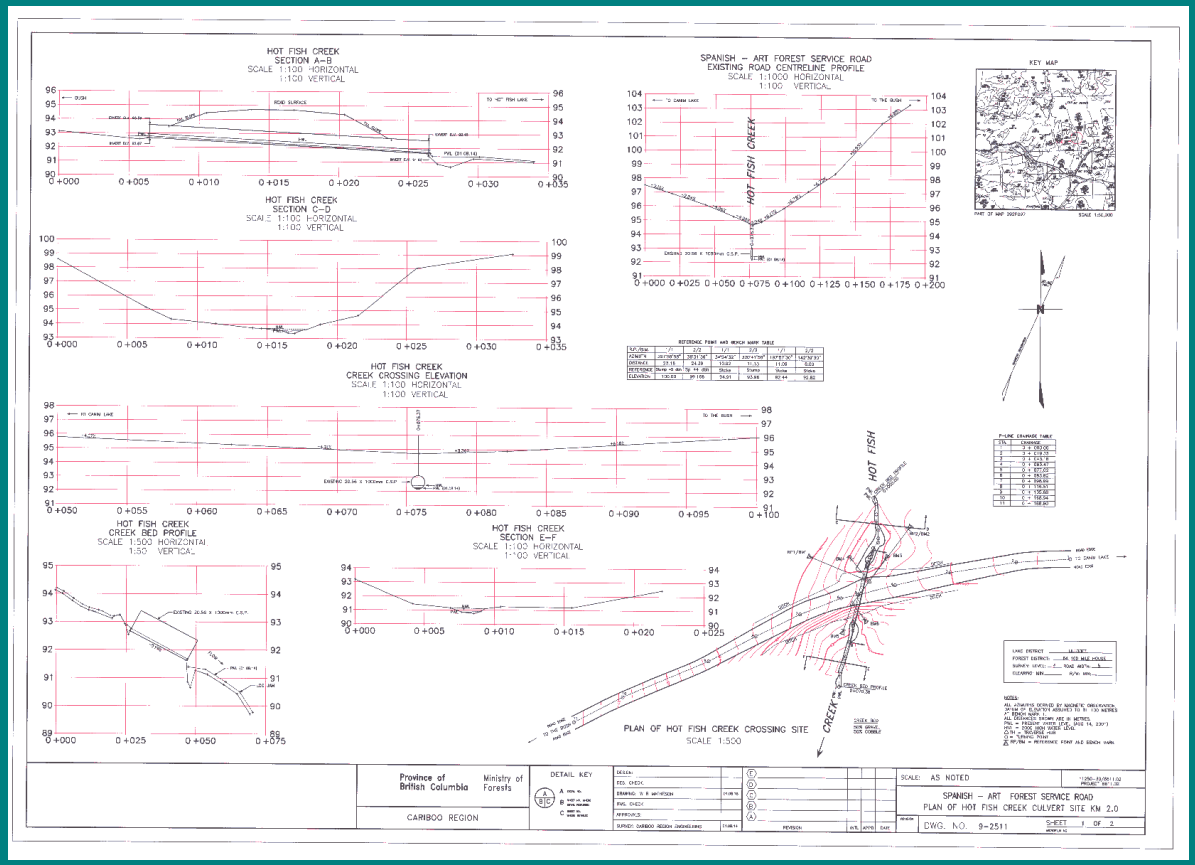
$\text{Area}_{(\text{Arch})}$ from manufacturer info

Design Drawings

Purpose

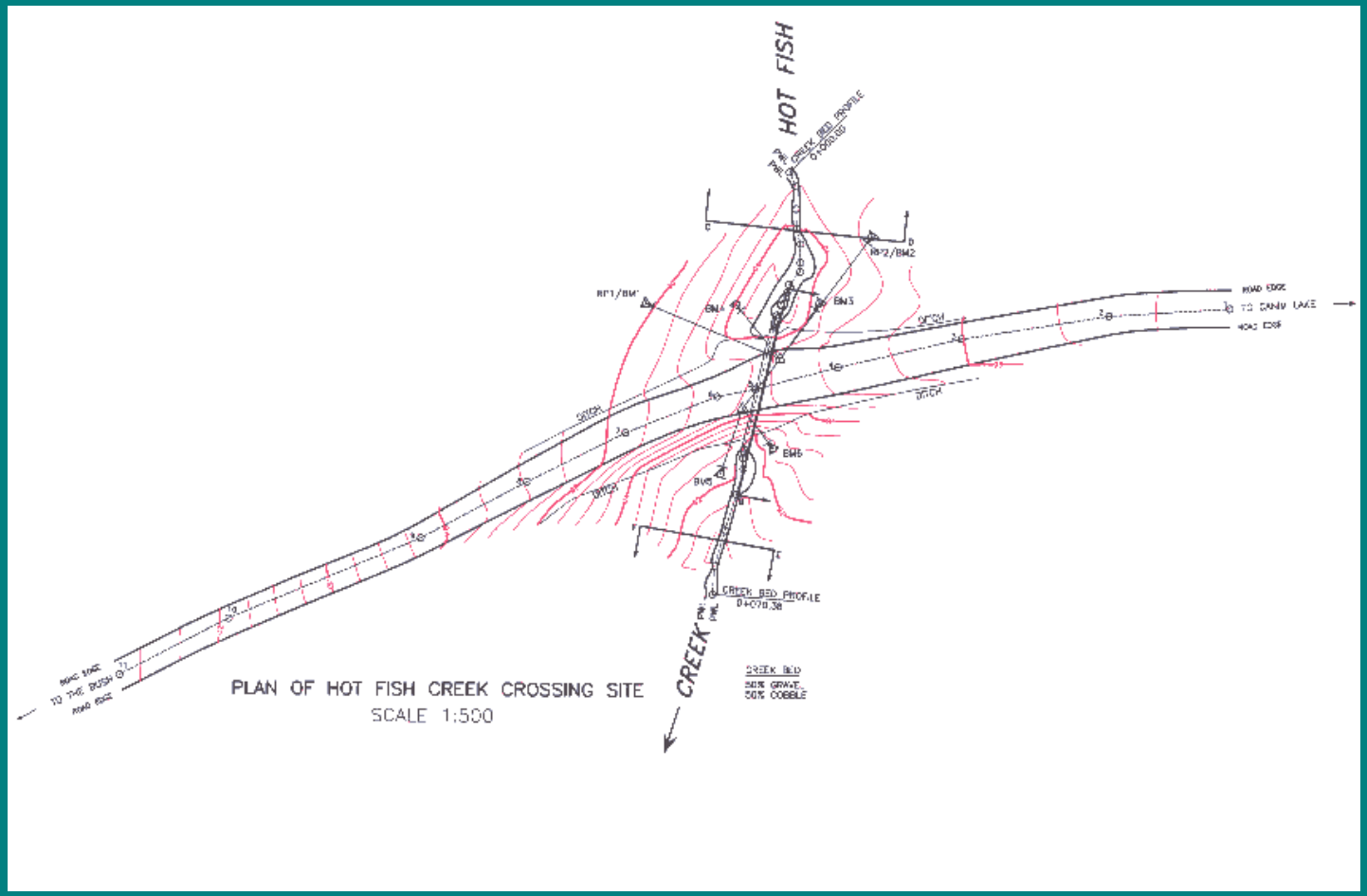
- Tools to “design” culvert to fit site
- Document proposed works and final product
- Provides material and construction specifications
- Provide construction referencing

Site Plan / Profiles



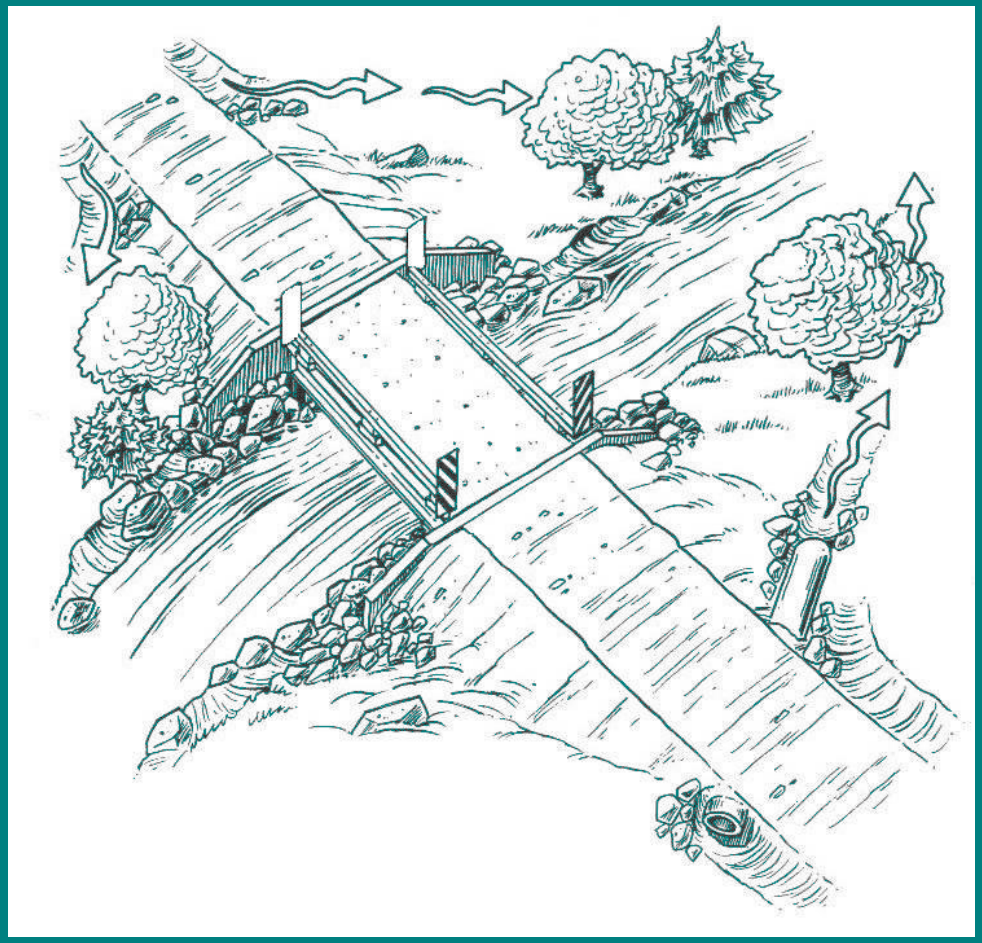
- Plan/profiles developed for the crossing
- design drawings developed from site plan / profiles
- used for design and documentation purposes

Site Plan



- contour map of the site

Fit Crossing to Site

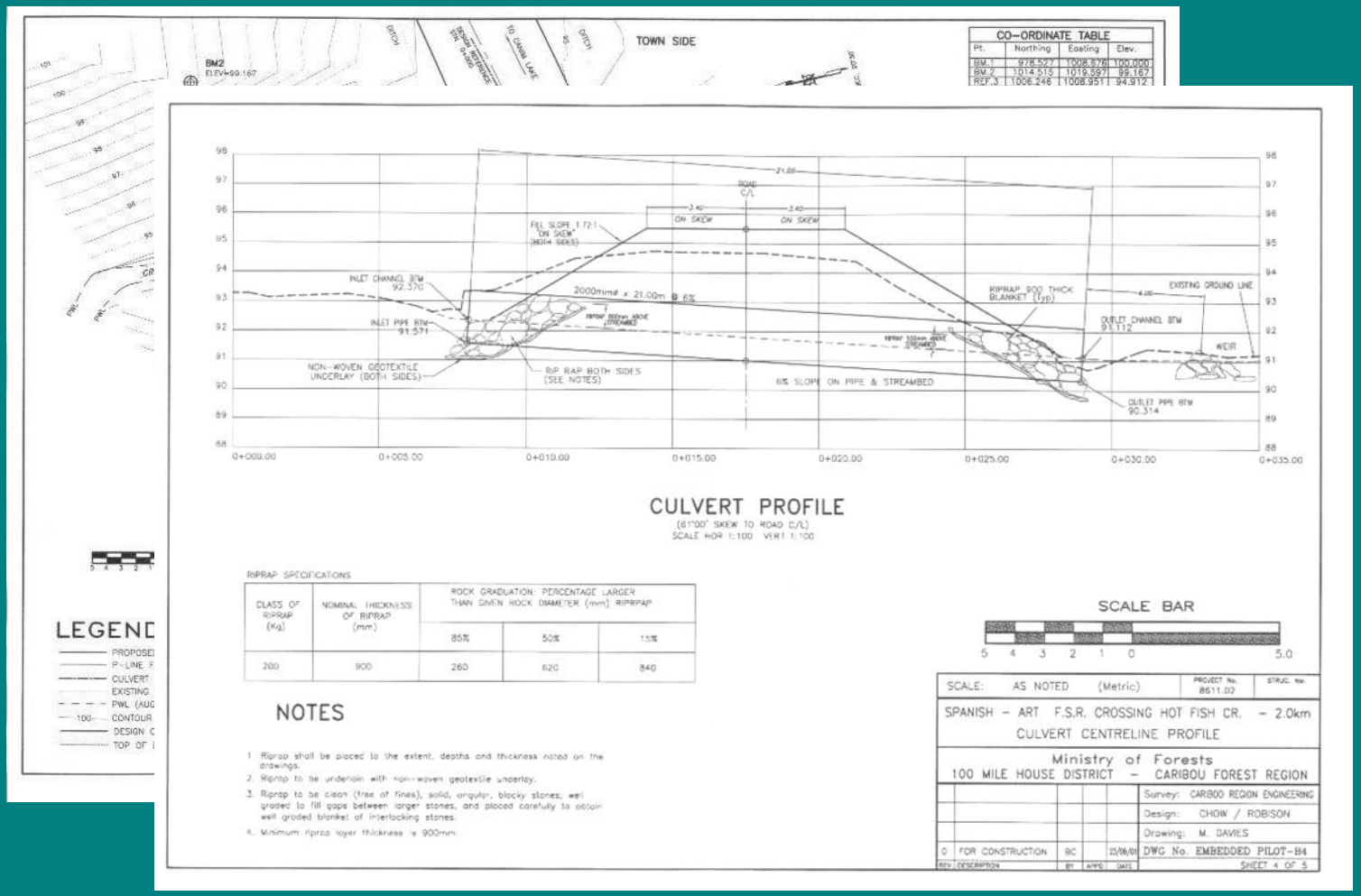


- The selected crossing structure should be suited to both the stream and road

- consider road drainage to minimize potential sediment delivery to the stream

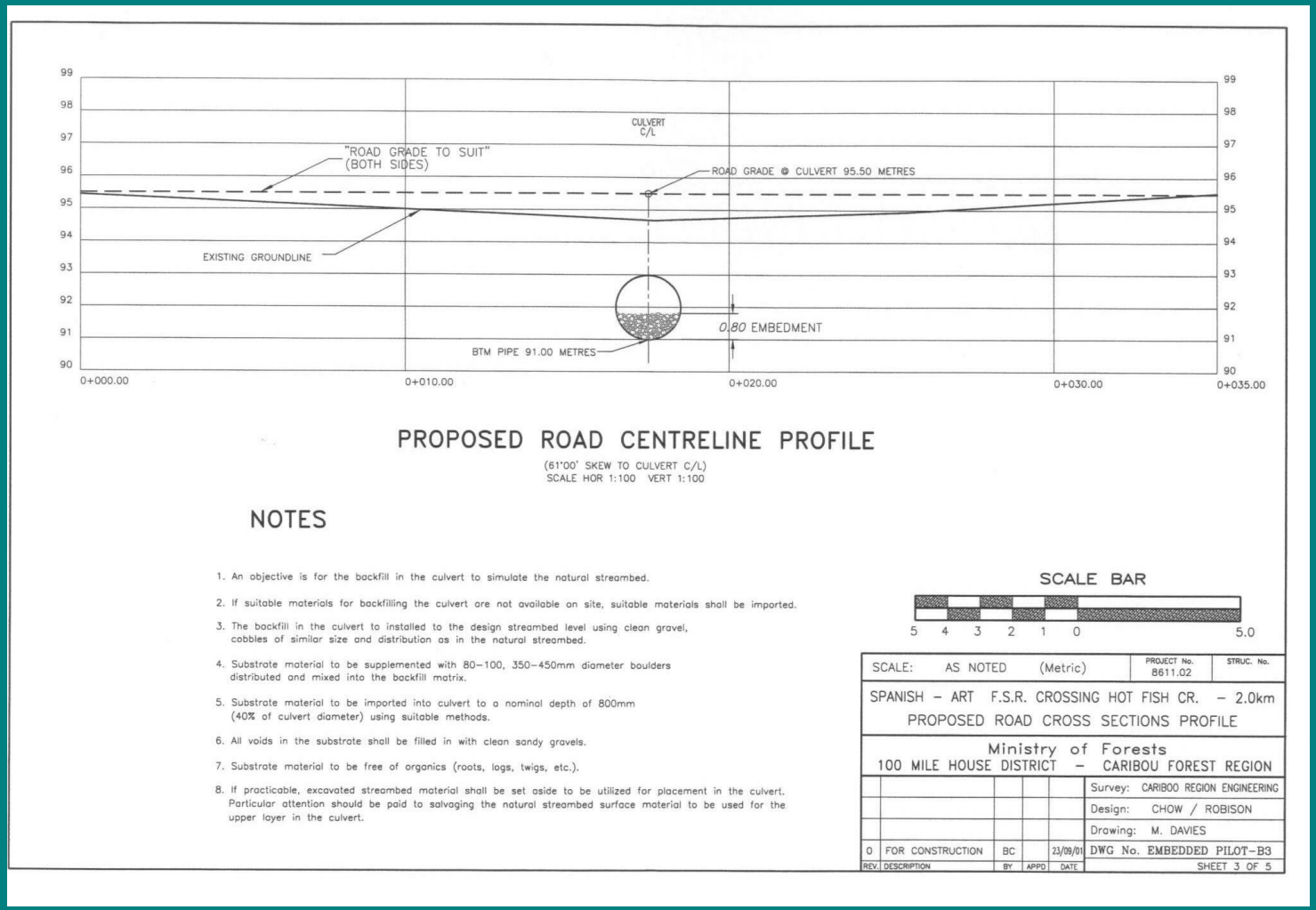
- avoid vertical dips, provide for roadway drainage

Design Drawings



Culvert Profile

Design Drawings



PROPOSED ROAD CENTRELINE PROFILE

(61°00' SKEW TO CULVERT C/L)
SCALE HOR 1:100 VERT 1:100

NOTES

1. An objective is for the backfill in the culvert to simulate the natural streambed.
2. If suitable materials for backfilling the culvert are not available on site, suitable materials shall be imported.
3. The backfill in the culvert to installed to the design streambed level using clean gravel, cobbles of similar size and distribution as in the natural streambed.
4. Substrate material to be supplemented with 80–100, 350–450mm diameter boulders distributed and mixed into the backfill matrix.
5. Substrate material to be imported into culvert to a nominal depth of 800mm (40% of culvert diameter) using suitable methods.
6. All voids in the substrate shall be filled in with clean sandy gravels.
7. Substrate material to be free of organics (roots, logs, twigs, etc.).
8. If practicable, excavated streambed material shall be set aside to be utilized for placement in the culvert. Particular attention should be paid to salvaging the natural streambed surface material to be used for the upper layer in the culvert.

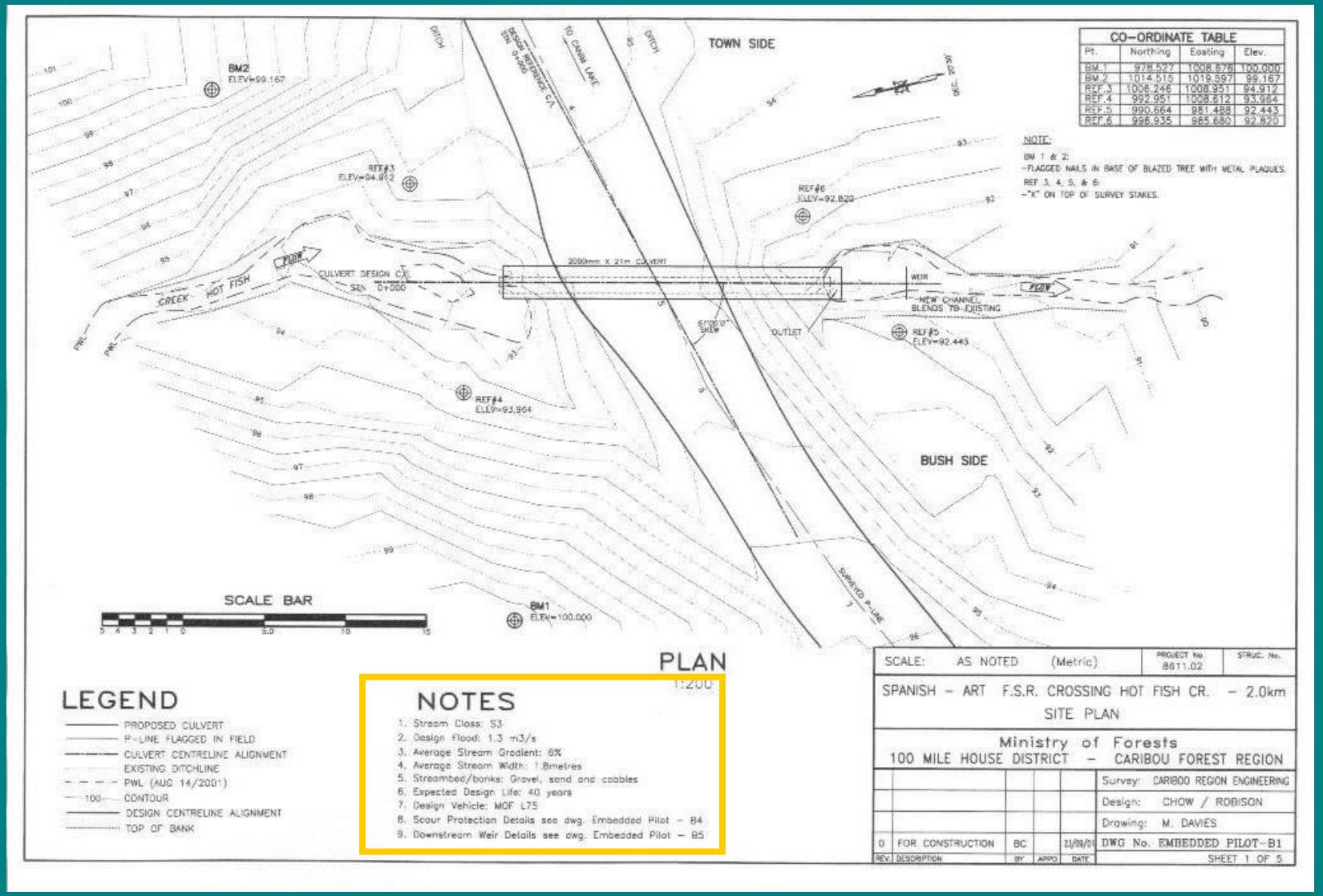
SCALE BAR

5 4 3 2 1 0 5.0

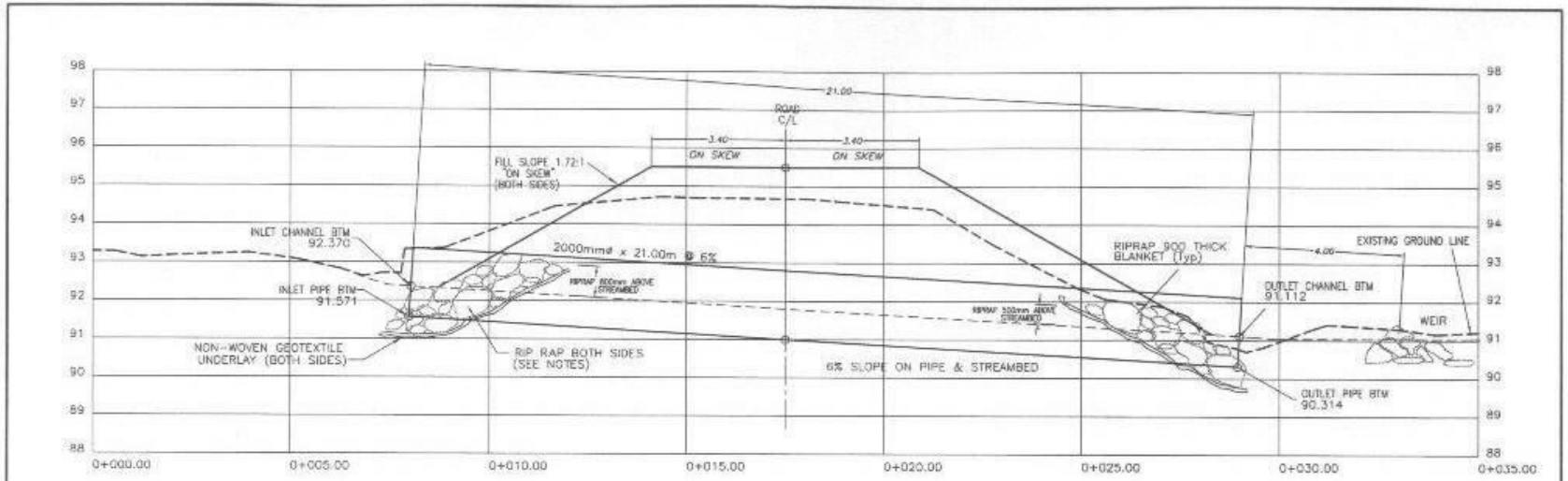
SCALE: AS NOTED (Metric)				PROJECT No. 8611.02	STRUC. No.
SPANISH – ART F.S.R. CROSSING HOT FISH CR. – 2.0km PROPOSED ROAD CROSS SECTIONS PROFILE					
Ministry of Forests 100 MILE HOUSE DISTRICT – CARIBOU FOREST REGION					
				Survey: CARIBOO REGION ENGINEERING	
				Design: CHOW / ROBISON	
				Drawing: M. DAVIES	
0	FOR CONSTRUCTION	BC		23/09/01	DWG No. EMBEDDED PILOT-B3
REV.	DESCRIPTION	BY	APPD	DATE	SHEET 3 OF 5

Road profile

Plan Drawing



Riprap Specifications



CULVERT PROFILE

(61°00' SKEW TO ROAD C/L)
SCALE HOR 1:100 VERT 1:100

RIPRAP SPECIFICATIONS

CLASS OF RIPRAP (Kg)	NOMINAL THICKNESS OF RIPRAP (mm)	ROCK GRADUATION: PERCENTAGE LARGER THAN GIVEN ROCK DIAMETER (mm) RIPRPAP		
		85%	50%	15%
200	900	260	620	840

NOTES

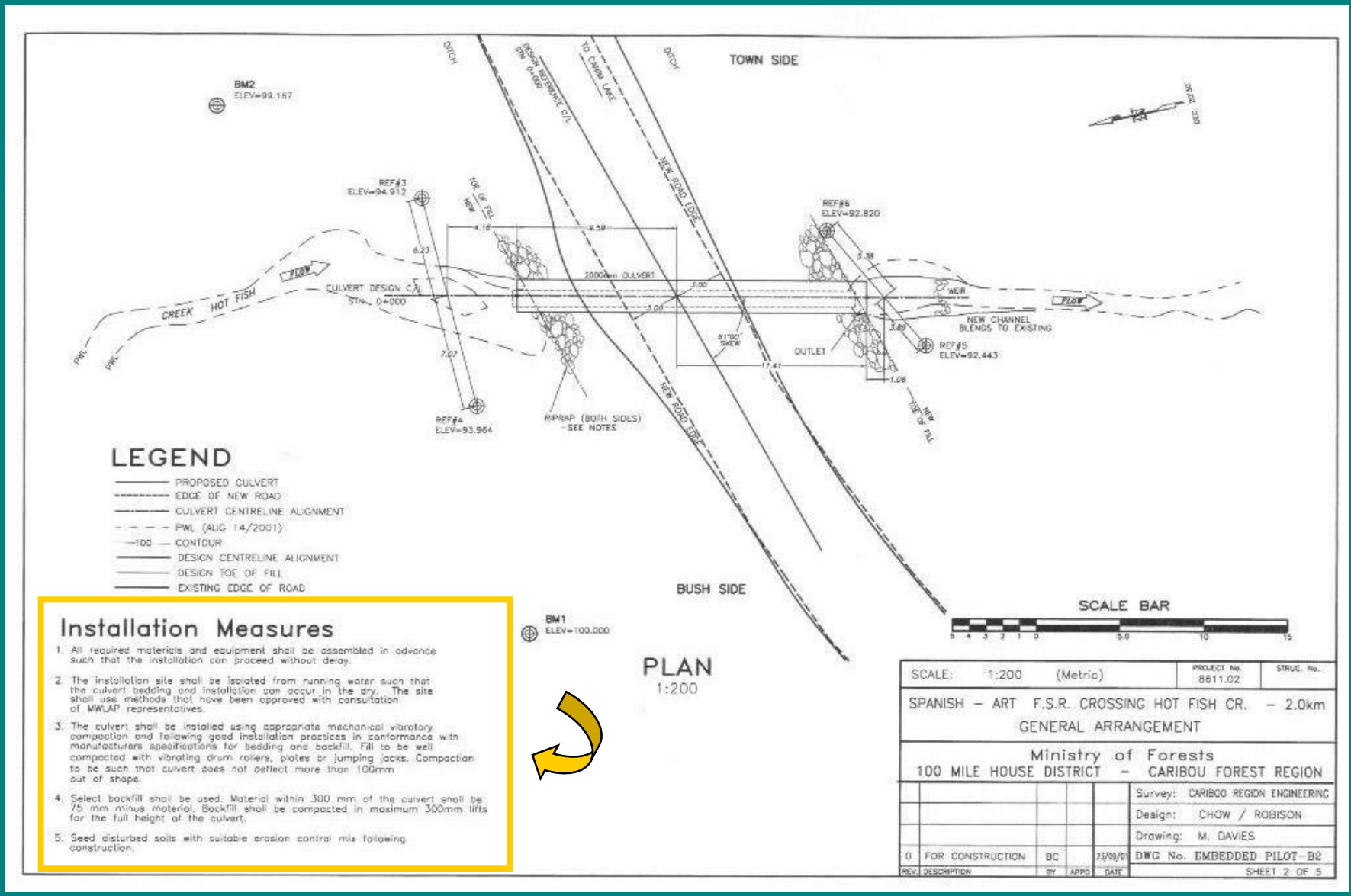
1. Riprap shall be placed to the extent, depths and thickness noted on the drawings.
2. Riprap to be underlain with non-woven geotextile underlay.
3. Riprap to be clean (free of fines), solid, angular, blocky stones; well graded to fill gaps between larger stones, and placed carefully to obtain well graded blanket of interlocking stones.
4. Minimum riprap layer thickness is 900mm.

SCALE BAR

5 4 3 2 1 0 5.0

SCALE: AS NOTED (Metric)				PROJECT No. 8611.02	STRUC. No.
SPANISH – ART F.S.R. CROSSING HOT FISH CR. – 2.0km CULVERT CENTRELINE PROFILE					
Ministry of Forests 100 MILE HOUSE DISTRICT – CARIBOU FOREST REGION					
				Survey: CARIBOO REGION ENGINEERING	
				Design: CHOW / ROBISON	
				Drawing: M. DAVIES	
0	FOR CONSTRUCTION	BC		23/06/01	DWG No. EMBEDDED PILOT-B4
REV.	DESCRIPTION	BY	APPD	DATE	SHEET 4 OF 5

Installation Measures



LEGEND

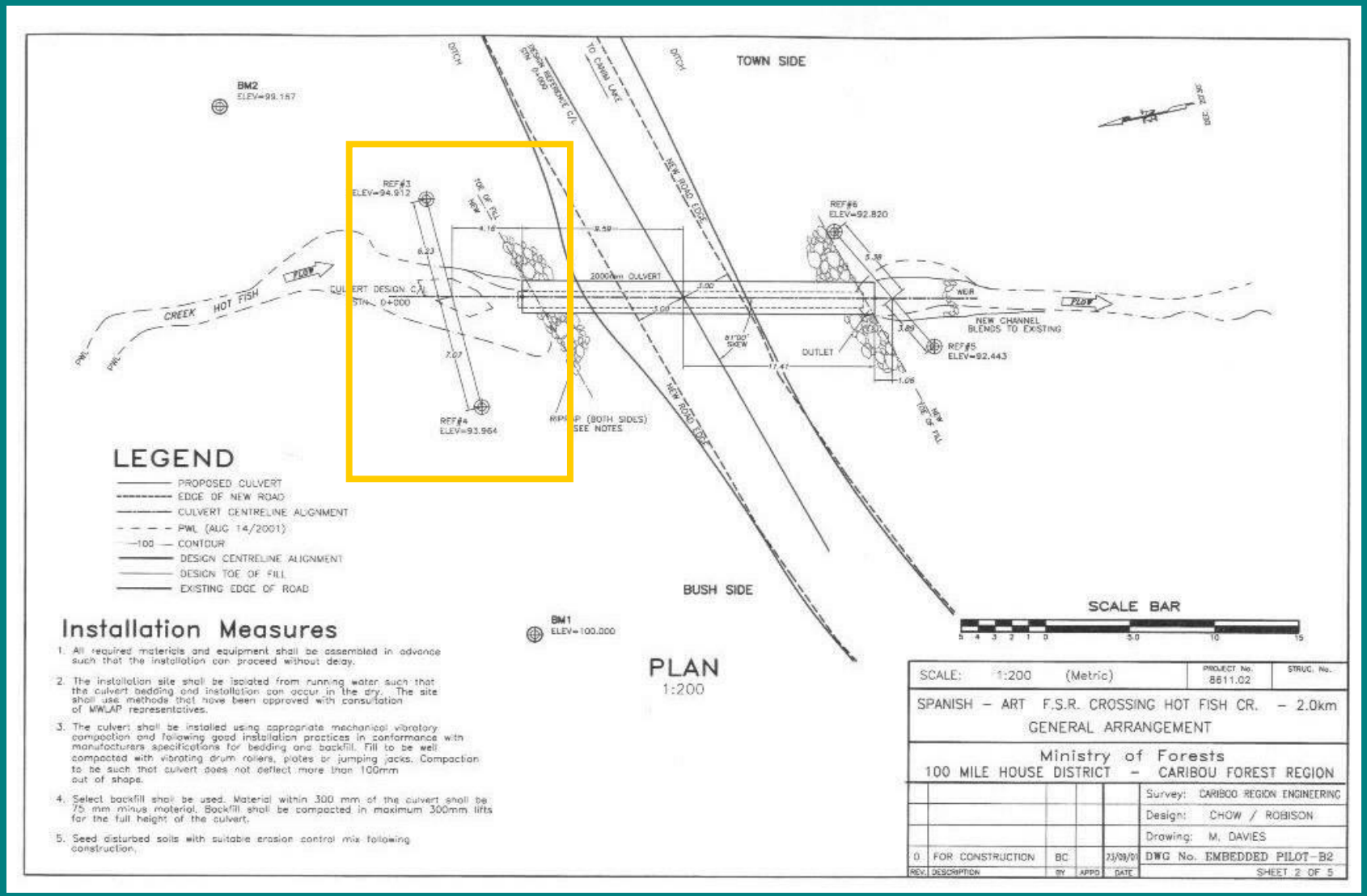
- PROPOSED CULVERT
- EDGE OF NEW ROAD
- CULVERT CENTRELINE ALIGNMENT
- PWL (AUG 14/2001)
- 100 — CONTOUR
- DESIGN CENTRELINE ALIGNMENT
- DESIGN TOE OF FILL
- EXISTING EDGE OF ROAD

Installation Measures

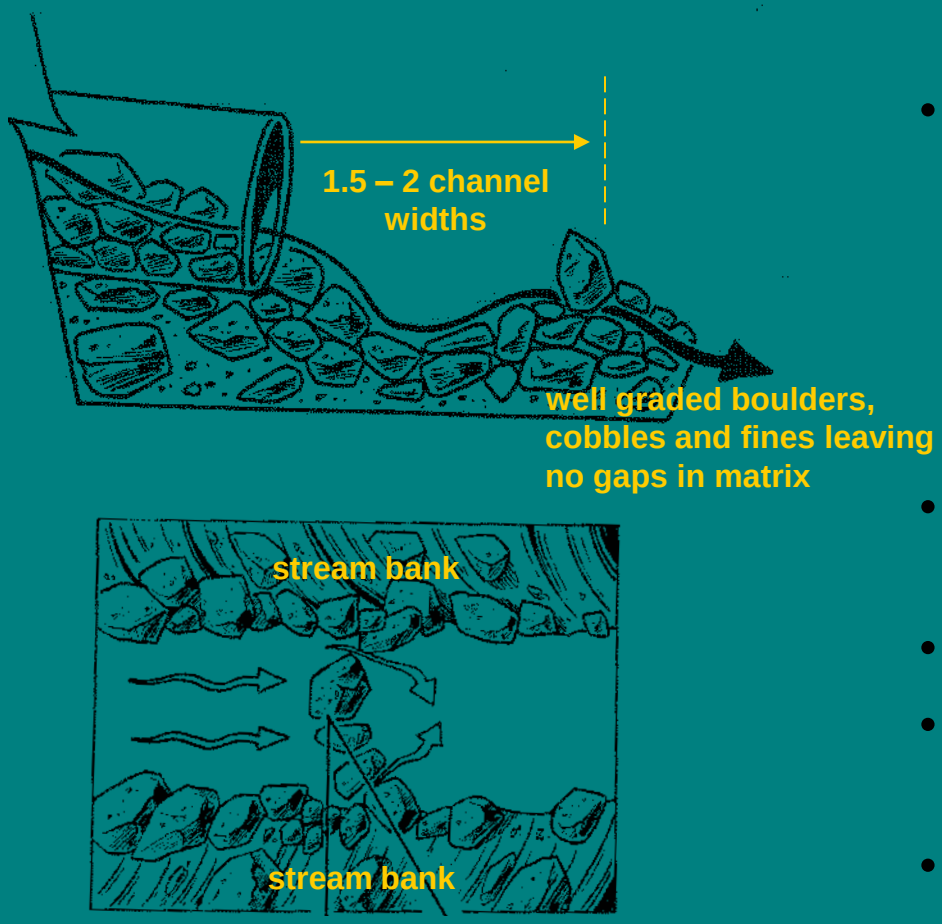
1. All required materials and equipment shall be assembled in advance such that the installation can proceed without delay.
2. The installation site shall be isolated from running water such that the culvert bedding and installation can occur in the dry. The site shall use methods that have been approved with consultation of MWLAP representatives.
3. The culvert shall be installed using appropriate mechanical vibratory compaction and following good installation practices in conformance with manufacturers specifications for bedding and backfill. Fill to be well compacted with vibrating drum rollers, plates or jumping jacks. Compaction to be such that culvert does not deflect more than 100mm out of shape.
4. Select backfill shall be used. Material within 300 mm of the culvert shall be 75 mm minus material. Backfill shall be compacted in maximum 300mm lifts for the full height of the culvert.
5. Seed disturbed soils with suitable erosion control mix following construction.

SCALE: 1:200 (Metric)			PROJECT No. 8611.02	STRUC. No.
SPANISH – ART F.S.R. CROSSING HOT FISH CR. – 2.0km GENERAL ARRANGEMENT				
Ministry of Forests 100 MILE HOUSE DISTRICT – CARIBOU FOREST REGION				
			Survey: CARIBOO REGION ENGINEERING	
			Design: CHOW / ROBISON	
			Drawing: M. DAVIES	
0 FOR CONSTRUCTION	BC		23/09/01	DWG No. EMBEDDED PILOT-B2
REV. DESCRIPTION	BY	APPD	DATE	SHEET 2 OF 5

Installation Referencing

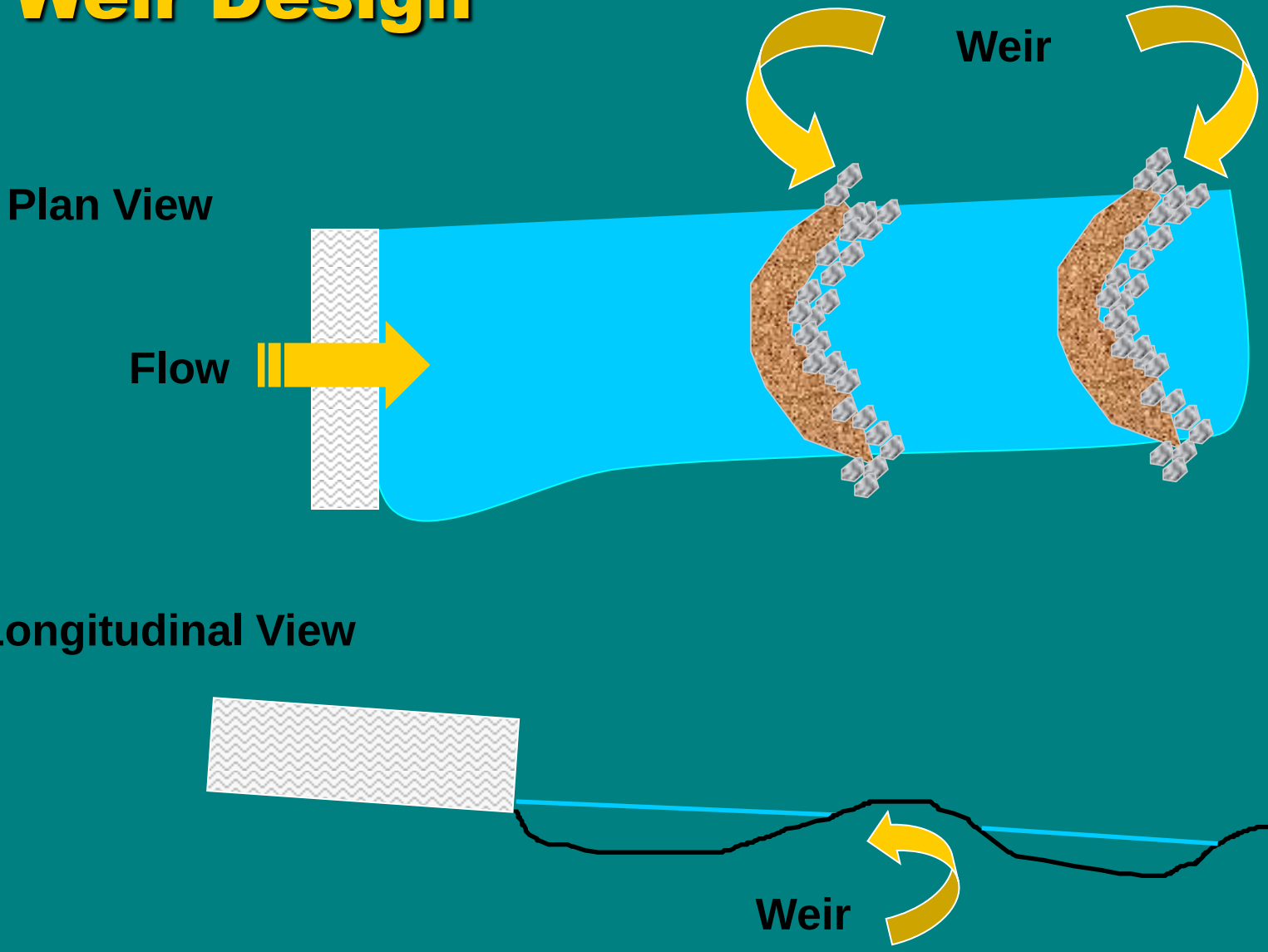


Other Details ie. Weir Design

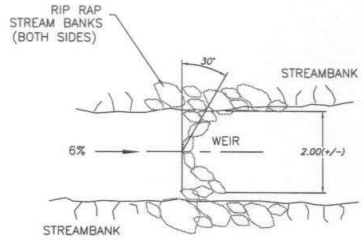


- A downstream weir may required as part of the design to be installed within 1.5 – 2 channel widths downstream of culvert outlet
- Assists in maintaining adequate low flow depth
- Helps retain substrate
- Prevents formation of plunge pool
- Particularly important where stream gradient is > 3%

Weir Design

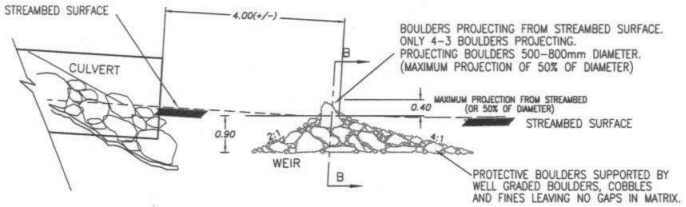


Weir Design



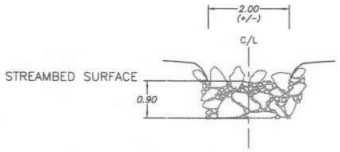
WEIR PLAN

SCALE 1:100



WEIR PROFILE

SCALE HOR 1:100 VERT 1:100



WEIR SECTION B–B

SCALE HOR 1:100 VERT 1:100

SCALE BAR

5 4 3 2 1 0 5.0

SCALE: AS NOTED (Metric)				PROJECT No. 8611.02	STRUC. No.
SPANISH – ART F.S.R. CROSSING HOT FISH CR. – 2.0km WEIR DETAILS					
Ministry of Forests 100 MILE HOUSE DISTRICT – CARIBOU FOREST REGION					
					Survey: CARIBOO REGION ENGINEERING
					Design: CHOW / ROBISON
					Drawing: M. DAVIES
0	FOR CONSTRUCTION	BC		23/09/01	DWG No. EMBEDDED PILOT–B5
REV.	DESCRIPTION	BY	APPD	DATE	SHEET 5 OF 5

Design should include:

- Stream data
- Plan
- Profile
- Construction referencing (vertical / horizontal)
- Materials specifications
- Installation specifications
- other details (riprap, weir, etc.)