MODULE 7: CULVERT INSTALLATION
TIER REVIEW APPROACH

TIER 1 (5-day review)

- **Replacing closed-bottom culverts** (0-0.5% slope, max length 30 m, max drainage area 20 km^2)
- **Replacing closed-bottom culverts with twin pipes** (0-0.5% slope, max length 30 m, max drainage area 20 km^2)
- **Removing (decommissioning) closed-bottom culverts**

TIER 2 (15-day review)

- **New closed-bottom culverts** (0-0.5% slope, max length 25 m, max drainage area 20 km^2)
- **All closed bottom culverts with baffles** (0.51-5%, max length 25 m (30 m for replacements), max drainage area 20 km^2)
- **Replacing an open-bottom culvert or a bridge with a closed-bottom culvert** (0-5%, max length 30 m, max drainage area 20 km^2)
- **Stream simulation culverts** (0-6%, max drainage area 20 km^2)

TIER 3 (requires a standard WAWA permit)

- Any crossing not sized for the 1 in 100-year flood event
- Any closed-bottom culvert that does not provide fish passage
- Installation of multiple (more than two pipe) closed-bottom culverts
- Any alterations resulting in a permanent wetland impact greater than 100 sq. m
- Any alterations in and within 30 m of a provincially significant wetland (PSW)
- Any alterations within a designated watershed or wellfield used as a source for public water supply
- Installing or replacing a closed-bottom culvert where there is an aquatic species (or habitat) at risk under the ***Species at Risk Act***
- Any other activity not approved under Tiers 1 and 2 or exceeding the guidelines

7.0 CULVERT INSTALLATION

The installation/construction of a watercourse crossing should have minimal impact on the stream flow, maintain natural stream morphology, preserve fish habitat, and provide fish passage.

When installed properly, culverts are an acceptable option for a permanent watercourse crossing.

7.1 BASIC STANDARDS

Under the Watercourse Alteration Certification Program, the following applies to culvert installations and must be strictly adhered to:

- Closed-bottom culverts must provide fish passage. Closed-bottom culverts without fish passage provisions (*i.e.* baffles) are only installed when the stream slope is $\leq$ 0.5% or the difference in elevation between the control riffles is 0.2 metres (8 in) or less, and the riffle to riffle distance is 40 metres (131 ft) or less. The maximum slope of a culvert permitted to be installed under the Watercourse Alteration Certification Program is 5.0%. A properly installed culvert requires the invert of the culvert to be embedded 0.2 times the culvert diameter (0.2D) or 0.45 metre (18 in), whichever is less. See Section 7.4.1 *Watercourse Gradient/Slope and Fish Passage*.
- A properly sized culvert must have the capacity to accommodate a 1 in 100-year runoff event. This does not mean it will occur only once in every 100 years. It means that there is a one percent probability of such an event occurring in any given year.
- Energy dissipation pools must be constructed at the outlet of all closed-bottom culverts where the stream slope is greater than 0.5%.
- All instream (*i.e.* below the bankfull width of a watercourse, whether wetted or not) work must be carried out in isolation of the stream flow.
- For watercourses depicted on the New Brunswick Hydrographic Network (NBHN) (GeoNB Map Viewer) and all other watercourses that meet the working definition of a watercourse (See Section 1.3.3 *Working Definition of a Watercourse*):
  - for circular closed-bottom culverts, the minimum diameter permitted for installation is 600 millimetres (24 in);
  - for pipe arch culverts, the minimum size is 680 x 500 millimetres (28 x 20 inches).

Note: The maximum drainage area permitted through certification is ≤ 20 km^2 (8 Mi^2), which will dictate the maximum diameter/end area allowed depending on the type of structure installed. Culvert crossings on watersheds greater than 20 km^2 (8 Mi^2) must undergo a thorough hydraulic analysis involving factors such as channel gradient, velocity of flow, the cross-sectional area of the channel, flood frequency, and ice formation.

- The maximum length permitted for all types of **new** culvert installations is 25 metres (82 ft). **Note**: The realignment of a stream beyond the upstream and downstream control riffles (see Section 7.4 *Fish Passage*) is not permitted under the Watercourse Alteration Certification Program. In addition, the control riffles must not be altered in any way. If this criterion cannot be met, an application for a standard watercourse and wetland alteration permit must be made using the online application program.

- The maximum length permitted for a culvert replacement is 30 metres (100 ft)

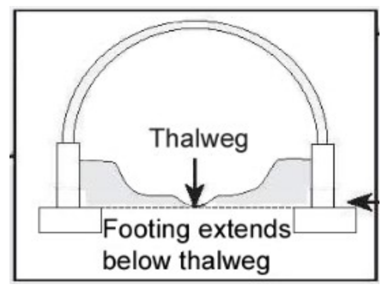
7.2 TYPES OF CULVERTS

A culvert is defined as a metal, concrete, or plastic structure that conveys water under a roadway whereby the top of the cover material is graded to form the travel surface.

The following provides information on the types of culverts available and their potential impacts on the aquatic environment. These culverts are listed from best to worst from a fish and fish habitat perspective.

Open-bottom culverts are similar to bridges. These culverts are founded on various types of footing support structures and can be made from steel, plastic, or concrete. See Figure 7-1.

Figure 7-1 Open-bottom culvert



Advantages:

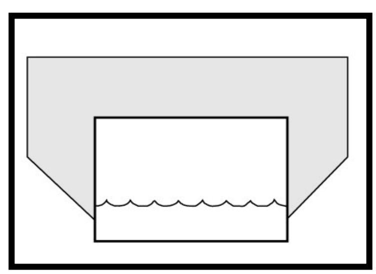
- Maintain the natural stream bed and stream gradient
- Pass all fish and other aquatic organisms
- Can better withstand flood events
- Less likely to be obstructed by beavers
- Less susceptible to corrosion

Disadvantages:

- Improper installation could result in scouring and erosion. See Module 8 *Installation of an Open-Bottom Culvert and Bridge Construction* for guidelines.
- The design, construction, maintenance is more complex
- The duration of construction is significantly increased over a closed-bottom culvert

Box culverts are similar to pipe arches. These culverts are useful in areas where the height of cover is limited as they require little cover material. They can be made from wood or concrete. See Figure 7-2.

Figure 7-2 Box culvert



Advantages:

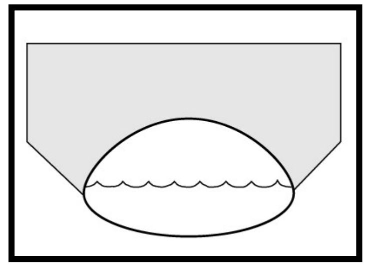
- Help maintain the natural channel width

Disadvantages:

- The wide, flat bottom may result in reduced water depth, potentially limiting fish passage

Pipe arch culverts are closed-bottom structures shaped such that the span is greater than the rise with a slightly convex bottom. They are made from steel or concrete. See Figure 7-3.

Figure 7-3 Pipe arch culvert



Advantages:

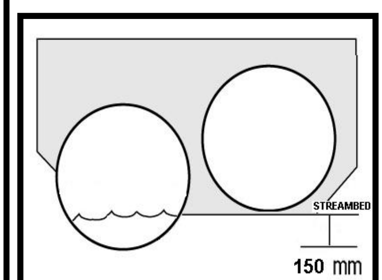
- Help retain the natural substrate in the culvert
- Useful in areas where the height of cover is a limiting factor

Disadvantages:

- The wide, slightly convex bottom may result in reduced water depth, potentially limiting fish passage

Multiple culverts are often used to pass high water flows in areas susceptible to flooding. A maximum of two culverts may be used at any given crossing. They are made from steel, concrete, or plastic. See Figure 7-4.

Figure 7-4 Multiple culvert



Advantages:

- Can be used where the road elevation is limited

Disadvantages:

- Are susceptible to ice or debris blockage obstructing fish migration and flooding upstream areas
- Require more work for proper installation and stabilization

Circular culverts are the most commonly used but can have the greatest impact on the fish and fish habitat. They are made from steel, concrete, or plastic. See Figure 7-5.

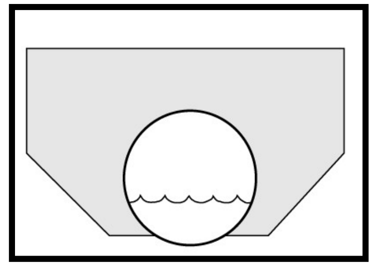
Advantages:

- Economical
- The quickest and easiest type to install

Disadvantages:

- Reduces the cross-sectional area of the channel, potentially increasing water velocity. This may disrupt fish migration, undermine the inlet or scour the stream bed at the outlet.
- They may require fish baffles to accommodate fish passage. Baffles will add cost and maintenance to the pipe. In addition, it will reduce the opening, which may result in an increase of diameter required to pass the stream flow.
- They are susceptible to ice or debris blockage obstructing fish migration and flooding upstream areas.

Figure 7-5 Circular culvert



7.3 CULVERT SIZING

Proper culvert sizing promotes fish passage and minimizes changes to the aquatic habitat and water flow. An undersized culvert may result in a complete washout of the culvert or increased water velocity through the pipe creating a barrier to fish passage and causing scouring at the outlet.

It is necessary to first calculate both the diameter and length required.

7.3.1 <u>Calculating Diameter: Parameters</u>

The two parameters required to calculate culvert diameter are:

- **Drainage area**: the area of land draining to the point along the watercourse where the crossing is to be constructed
- **Design flow**: the discharge which a structure can accommodate without exceeding maximum acceptable flow velocity

The **drainage area** is determined by following the steps below.

- The first step is to delineate the watershed boundary, including all tributaries, upstream of the crossing site.
- Mark the location of the crossing site on a map (topographic or orthophoto) with a circle. See Figure 7-6.

Figure 7-6 Map of a watercourse with crossing site identified

- Highlight the main stem of the watercourse and all its tributaries upstream of the location.
- Mark small dots on the highest points throughout the basin perimeter surrounding the watercourse and its tributaries. See Figure 7-7.
- Beginning at the crossing site, connect the dots around the basin perimeter. The line should cross each contour line at right angles wherever possible.
- Delineation is complete when the basin perimeter is closed. See Figure 7-8.
- Using a **planimeter** or **dot grid**, measure the delineated area on the map to determine the drainage area upstream of the crossing location.

Note: Other options for determining the drainage area include the use of GIS, LiDAR, and the GeoNB Map Viewer.

Figure 7-7 A map identifying the highest elevation points surrounding the watercourse

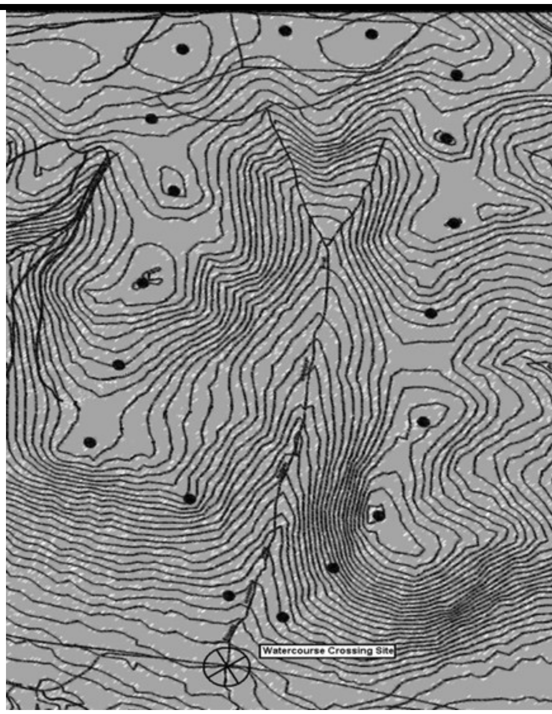
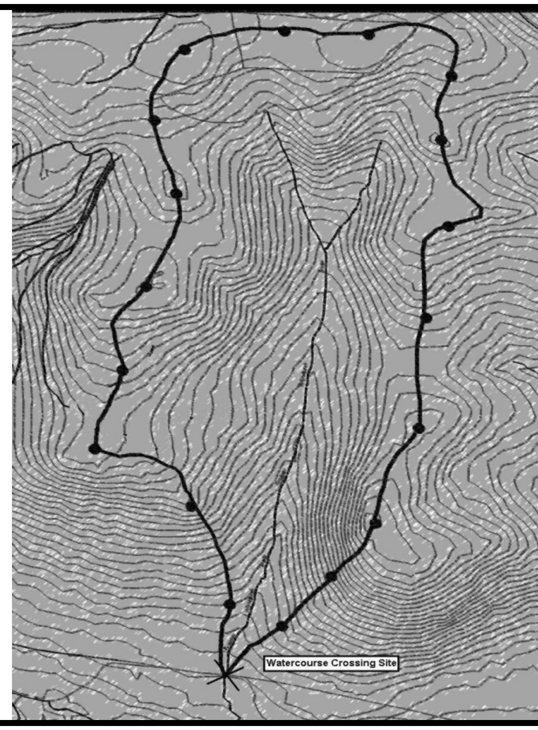


Figure 7-8 A map showing the delineated drainage area above the crossing site (312 ha)



The **design flow** is calculated using the drainage area as follows. See Example 7-1:

A = Drainage area upstream of the crossing location

Q = Design flow

Q (m^3/sec) = 1.64 A
Q (ft^3/sec) = 150 A

EXAMPLE 7-1
CALCULATING DESIGN FLOW

What is the design flow (Q) for a drainage area (A) equaling 312 hectares (as determined in Figure 7-8)?

Convert to km^2 = 312 ha / 100
= 3.12 km^2

Design Flow (Q) (m^3/sec) = 1.64 x drainage area (A)

= 1.64 x 3.12 km^2

= 5.12 m^3/sec

The design flow is 5.12 m^3/sec.

7.3.2 Calculating Diameter for a Closed-Bottom Culvert

The following steps are to be followed to determine the minimum culvert diameter necessary using a nomograph. See the example provided in Figure 7-9. Also, see the Appendices at the end of this manual for additional nomographs.

- Calculate the design flow (Q). See Section 7.3.1 *Calculating Diameter: Parameters*.
- On the headwater depth to diameter scale (HW/D), locate and mark the 1.5 increment. A 1.5 ratio is the standard used for culvert sizing in New Brunswick.
- On the discharge scale (Q), locate and mark the calculated design flow.
- Connect the two marked points and extend the line to the diameter of culvert scale (D).
- When the culvert diameter falls between two sizes, always use the larger one.

Note: During the installation of twin culverts, the combined capacity of the culverts must equal the calculated design flow (Q). In other words, the capacity of both culverts added together must equal or exceed the calculated 1 in 100-year runoff event design flow.

In order to confirm the required culvert capacity (m^2), first calculate the diameter of the site for one culvert and refer to the capacity (end area of the culvert (m^2)) shown in Table 7-1 for that culvert size. This value represents the minimum capacity to pass water within the 1 in 100-year runoff event. This table accounts for both the reduced end area of the embedded culvert, as well as the full end area of the over flow culvert.
When choosing the diameter of two culverts for a site, the addition of end area in (m^2) for both culverts must meet or exceed the full capacity (end area of the culvert (m^2)) determined for the site. See Example 7-2.

Table 7-1 End area reduction (based on 0.2D to a maximum of 0.45 m)					
Culvert diameter (D) (mm)	**Radius (m)**	**Depth of material in pipe (m)**	**End area of culvert (m^2)**	**Area occupied by material (m^2)**	**End area remaining (m^2)**
450	0.225	0.090	0.159	0.023	0.136
600	0.300	0.120	0.283	0.040	0.242
700	0.350	0.140	0.385	0.055	0.330
750	0.375	0.150	0.442	0.063	0.379
800	0.400	0.160	0.502	0.071	0.431
825	0.413	0.165	0.534	0.076	0.458
900	0.450	0.180	0.636	0.091	0.545
1000	0.500	0.200	0.785	0.112	0.673
1200	0.600	0.240	1.130	0.161	0.969
1400	0.700	0.280	1.539	0.219	1.320
1500	0.750	0.300	1.766	0.252	1.515
1600	0.800	0.320	2.010	0.286	1.724
1660	0.830	0.332	2.163	0.308	1.855
1800	0.900	0.360	2.543	0.362	2.181
1970	0.985	0.394	3.047	0.434	2.613
2000	1.000	0.400	3.140	0.447	2.693
2120	1.060	0.424	3.528	0.503	3.026
2200	1.100	0.440	3.799	0.541	3.258
2280	1.140	0.450	4.081	0.570	3.510
2400	1.200	0.450	4.522	0.587	3.934
2430	1.215	0.450	4.635	0.591	4.044
2590	1.295	0.450	5.266	0.613	4.653
2700	1.350	0.450	5.723	0.627	5.095
2740	1.370	0.450	5.893	0.632	5.261
2895	1.448	0.450	6.579	0.652	5.927
3000	1.500	0.450	7.065	0.665	6.400
3050	1.525	0.450	7.302	0.671	6.632
3300	1.650	0.450	8.549	0.701	7.848
3600	1.800	0.450	10.174	0.734	9.439

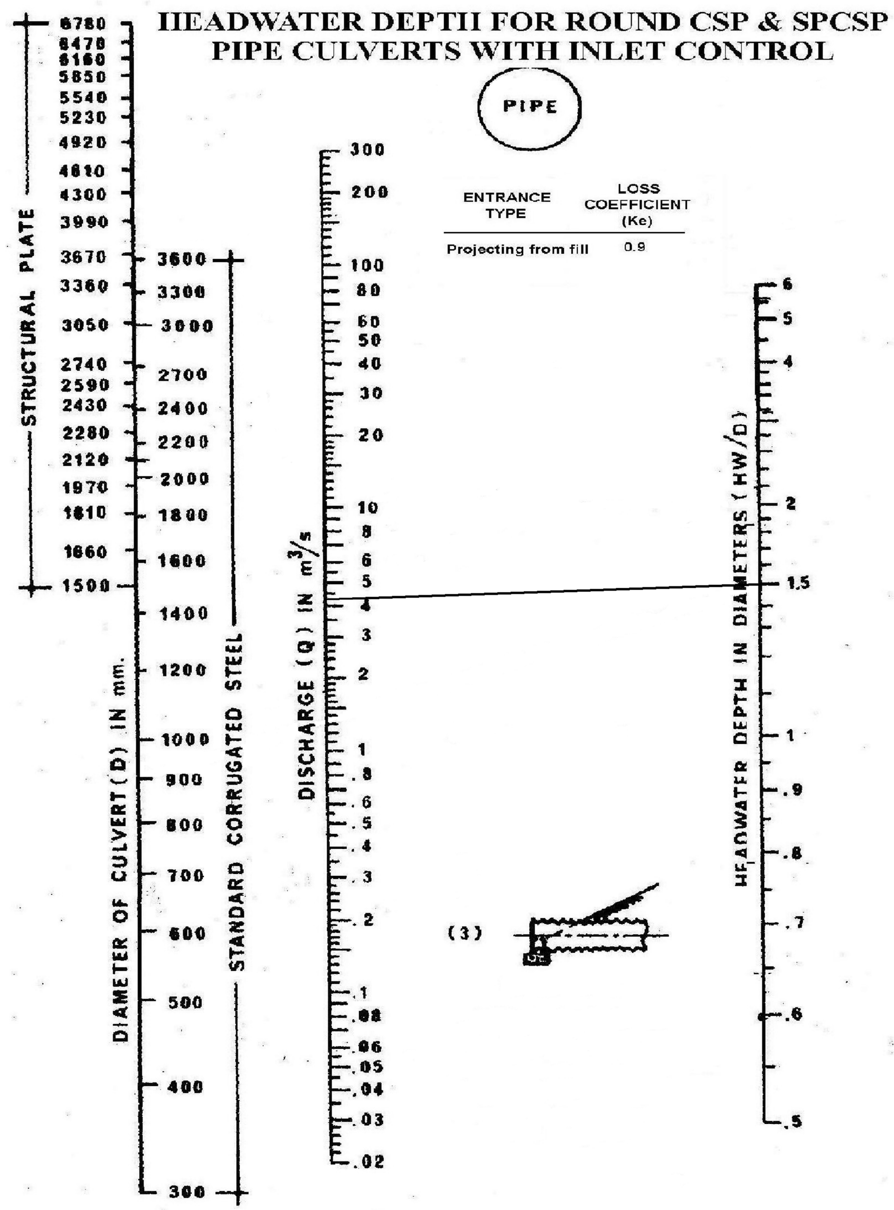
EXAMPLE 7-2
SIZING FOR TWIN CULVERTS

Calculate the diameter for two culverts equal in size using the end area capacity (m^2) of a 1600 mm culvert (use Table 7-1). Ensure the culvert to be installed within the watercourse is embedded at least 0.2D or 0.45 metre (18 in), whichever is less.

1600 mm culvert (end area (m^2))	= 2.011 m^2
Capacity of 2 culverts equal in size or greater than 2.011 m^2	= 1200 mm culvert (1.131 m^2 + 0.970 m^2) = 2.101 m^2

The addition of the end area (m^2) for the embedded 1200 mm culvert plus the full end area capacity of the 1200 mm culvert equals 2.101 m^2, which exceeds the minimum capacity required for the site (1600 mm culvert at 2.011 m^2).

Figure 7-9 Drainage area using a nomograph from Example 7-1



Maximum drainage area and their corresponding culvert diameter

The maximum allowable drainage area has been calculated for standard culvert sizes.

These tables have been calculated using nomographs. The loss of area from the embedment has also been accounted for in these tables. See the Appendices at the end of this manual for page-size nomographs.

Table 7-2 Drainage area and required diameter for circular CSP and plastic (with corrugated inner) culvert

HW/D = 1.5:1 and drainage coefficient of 1.64

Drainage Area (ha)	Culvert Diameter			
	Calculated		Required	
	(mm)	(inches)	(mm)	(inches)
≤14	450	18	600	24
> 14 to ≤ 28	600	24	700	27
> 28 to ≤ 52	750	30	900	36
> 52 to ≤ 61	800	32	900	36
> 61 to ≤ 79	900	36	1000	40
> 79 to ≤ 104	1000	40	1200	48
> 104 to ≤ 168	1200	48	1400	54
> 168 to ≤ 244	1400	54	1600	64
> 244 to ≤ 305	1500	60	1800	72
> 305 to ≤ 341	1600	64	1800	72
> 341 to ≤ 457	1800	72	2000	80
> 457 to ≤ 579	2000	80	2200	88
> 579 to ≤ 732	2200	88	2400	96
> 732 to ≤ 915	2400	96	2700	106
> 915 to ≤ 1220	2700	106	3000	118
> 1220 to ≤ 1585	3000	118	3300	130
> 1585 to ≤ 2000	3300	130	3600	142
> 2000	Subject to a separate application and review process			

Table 7-3 Drainage area and required diameter for circular concrete and plastic (with smooth inner sleeve) culvert

HW/D = 1.5:1 and drainage coefficient of 1.64

Drainage Area (ha)	Culvert Diameter			
	Calculated		Required	
	(mm)	(inches)	(mm)	(inches)
≤17	450	18	600	24
> 17 to ≤ 38	600	24	700	27
> 38 to ≤ 52	700	27	825	33
> 52 to ≤ 66	750	30	825	33
> 66 to ≤ 83	825	33	900	36
> 83 to ≤ 104	900	36	1000	42
> 104 to ≤ 155	1000	42	1200	48
> 155 to ≤ 216	1200	48	1400	54
> 216 to ≤ 285	1400	54	1600	64
> 285 to ≤ 371	1500	60	1660	66
> 371 to ≤ 475	1660	66	1800	72
> 475 to ≤ 587	1800	72	1970	78
> 587 to ≤ 734	1970	78	2120	84
> 734 to ≤ 863	2120	84	2280	90
> 863 to ≤ 1036	2280	90	2590	102
> 1036 to ≤ 1209	2430	96	2590	102
> 1209 to ≤ 1381	2590	102	2740	108
> 1381 to ≤ 1640	2740	108	2895	114
> 1640 to ≤ 1899	2895	114	3050	120
> 1899 to ≤ 2000	3050	120	3300	130
> 2000	Subject to a separate application and review process			

Table 7-4 Drainage area and required size for steel pipe arch closed-bottom culvert

HW/D = 1.5:1 and drainage coefficient of 1.64

Drainage Area (ha)	Culvert Size	
	(mm)	(inches)
≤ 22	600 x 500	28 x 20
> 22 to ≤ 33	800 x 580	32 x 24
> 33 to ≤ 46	910 x 660	37 x 27
> 46 to ≤ 61	1030 x 740	41 x 30
> 61 to ≤ 79	1150 x 820	46 x 33
> 79 to ≤ 122	1390 x 970	56 x 39
> 122 to ≤ 180	1630 x 1120	65 x 45
> 180 to ≤ 250	1880 x 1260	75 x 51
> 250 to ≤ 335	2130 x 1400	85 x 56
> 335 to ≤ 415	2060 x 1520	82 x 61
> 415 to ≤ 488	2240 x 1630	90 x 65
> 488 to ≤ 579	2440 x 1750	98 x 70
> 579 to ≤ 640	2590 x 1880	104 x 75
> 640 to ≤ 854	2690 x 2080	108 x 83
> 854 to ≤ 915	3100 x 1980	124 x 79
> 915 to ≤ 1037	3400 x 2010	136 x 81
> 1037 to ≤ 1341	3730 x 2290	149 x 92
> 1341	Subject to a separate application and review process	

7.4 FISH PASSAGE

When installing closed-bottom culverts, there are limitations on the watercourse slope to provide fish passage.

Slope is a crucial watercourse feature that is highly responsible for indicating the level of water velocity at any given point in a stream. The installation of closed-bottom culverts within high sloped watercourses has been known to create fish passage issues.

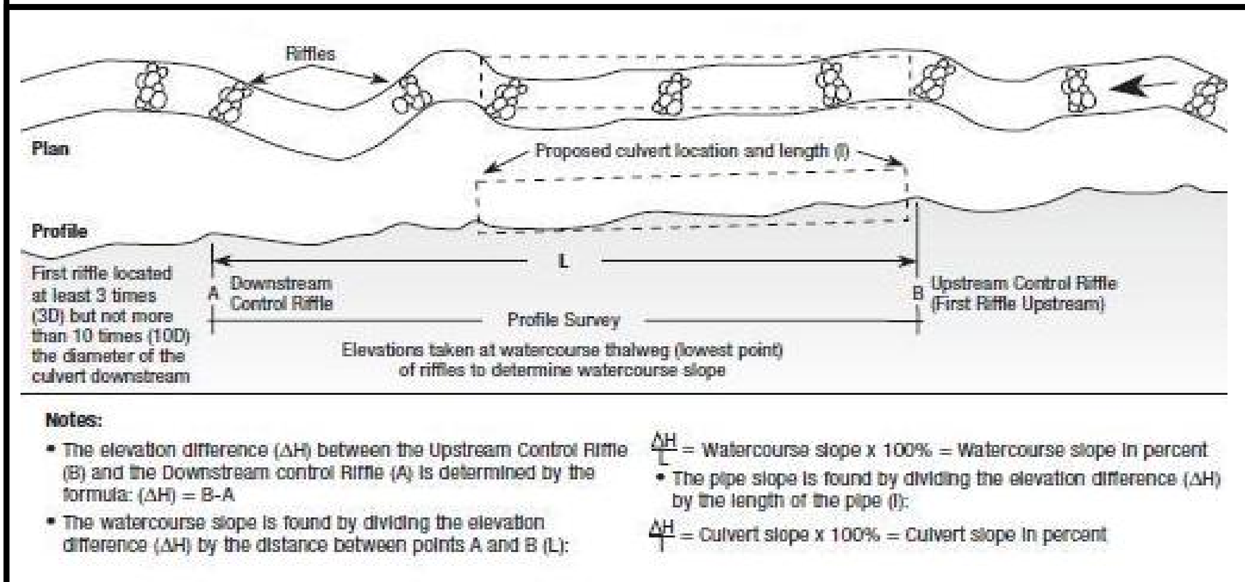
Given how vital slope is when considering the installation of a closed-bottom culvert, knowing how to measure it properly is extremely important.

During the planning stage of a watercourse crossing installation, it is important to consider how fish passage will be provided through all stages of the project.

7.4.1 Watercourse Gradient/Slope and Fish Passage

The watercourse gradient/slope is determined by the difference in elevation between the first riffle upstream of the inlet of the culvert and the first riffle located at least three culvert diameters downstream of the outlet of the culvert, divided by the distance between these riffles. See Figure 7-10.

Figure 7-10 Determining the stream gradient

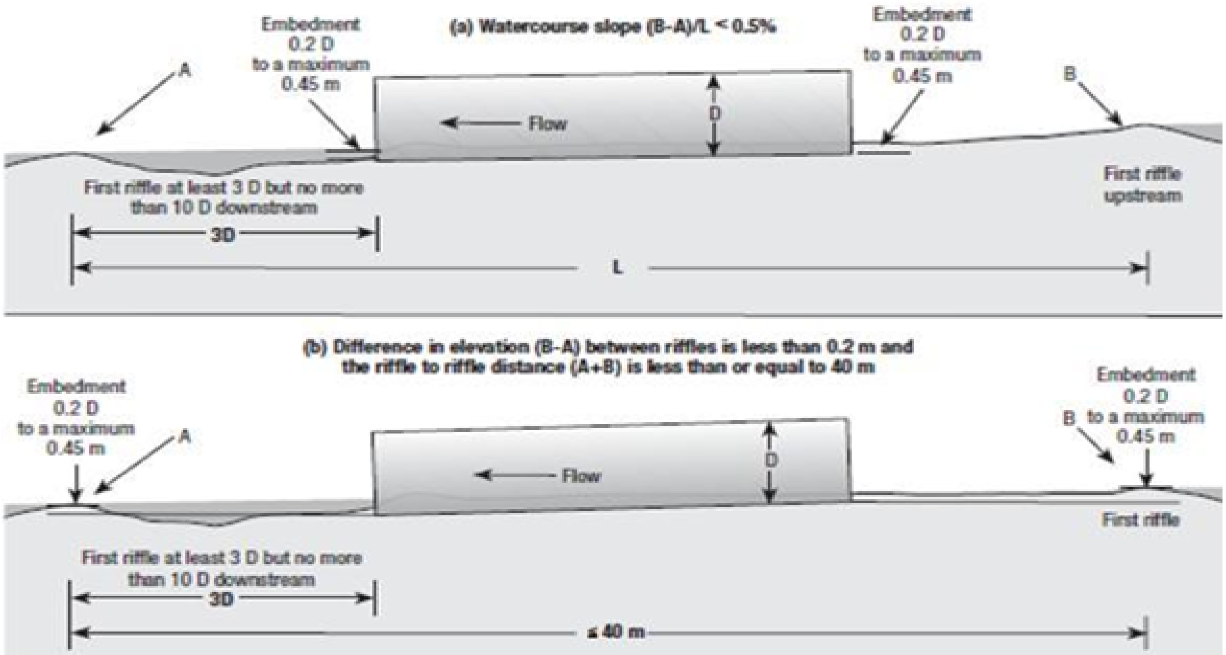


A closed-bottom culvert will pass fish when (a) the riffle to riffle slope is 0.5% or less or (b) the difference in elevation between the riffles is 0.2 metre (8 in) or less and the riffle to riffle distance is 40 metres (131 ft) or less. See Figure 7-11(a)+(b).

When the gradient of the stream bed is less than 0.5%, the culvert must be embedded 0.2 times the culvert diameter (0.2D) or 0.45 metre (18 in), whichever is less, below the bed of the watercourse at the proposed inlet and outlet locations. See Figure 7-11(a).

When the distance between the first riffle upstream of the inlet of the culvert and the first riffle located at least three culvert diameters downstream of the outlet is 40 metres (131 ft) or less, and the difference in elevation between the thalweg of these riffles is 0.2 metre (8 in) or less, the ends of the culvert must be embedded 0.2 times the culvert diameter (0.2D) or 0.45 metre (18 in), whichever is less, below the elevation of the thalweg of the corresponding riffle. See Figure 7-11(b).

Figure 7-11(a)+(b) Culvert installation when fish baffles are not required



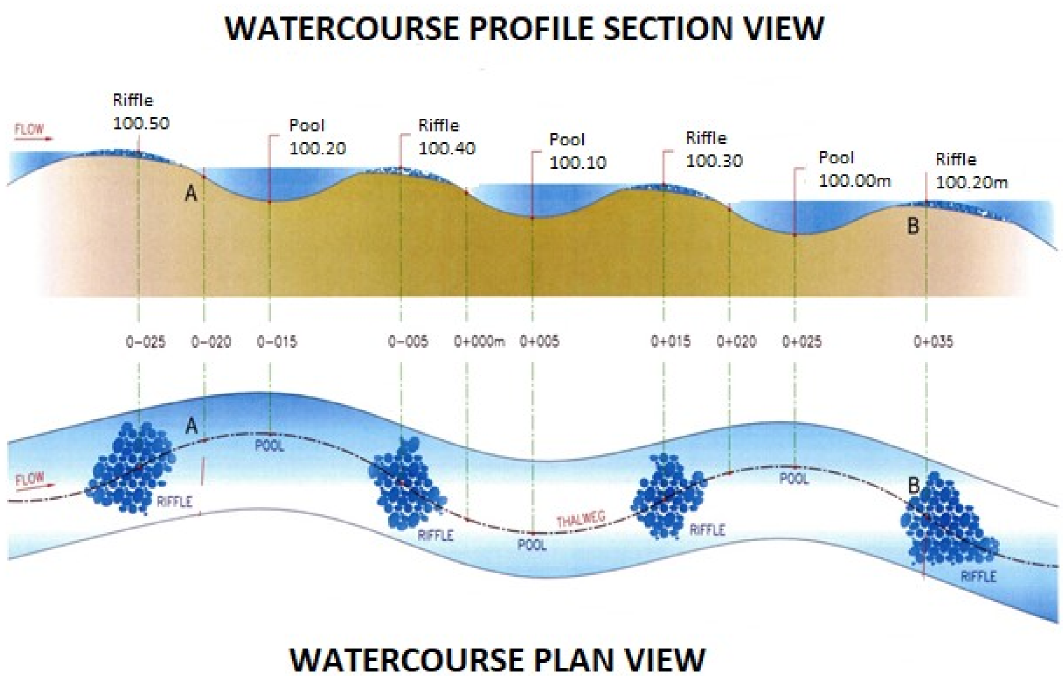
If these criteria cannot be met, a bridge or open-bottom culvert should be considered. If site specific conditions do not allow for an open-bottom structure, baffles are required in the culvert to provide fish passage.

Culverts requiring baffles are permitted under the Watercourse Alteration Certification Program up to a maximum culvert of 5%, provided the culvert is designed by a professional engineer licensed to practice in the province of New Brunswick and that stamped design drawings are submitted for review to the Department of Environment and Local Government.

7.4.2 Calculating Watercourse Gradient/Slope

Surveying a watercourse allows individuals to document and capture all of the watercourse features and record the precise slope within their proposed work space. See Figure 7-12.

Figure 7-12 Watercourse profile section and plan views (survey plan)



When elevations from the survey are all displayed in a watercourse profile/plan diagram as shown in Figure 7-12, designers can visually display how their proposed culvert is going to fit and what riffles will be utilized for the stream slope calculation. The formula for calculating watercourse slope is:

$$\text{Slope} = ((\text{Watercourse Elevation Difference}) / \text{Length}) \times 100$$

$$\text{Slope} = ((B - A) / L) \times 100$$

See Example 7-3.

EXAMPLE 7-3
CALCULATING WATERCOURSE SLOPE/GRADIENT (IN PERCENTAGE)

Slope = ((Watercourse Elevation Difference) / Length) x 100
Slope = ((B – A) / L) x 100

Where:
A = 100.2 m - the elevation of the thalweg at the natural undisturbed downstream control riffle

B = 100.35 m - the elevation of the thalweg at the natural undisturbed upstream control riffle

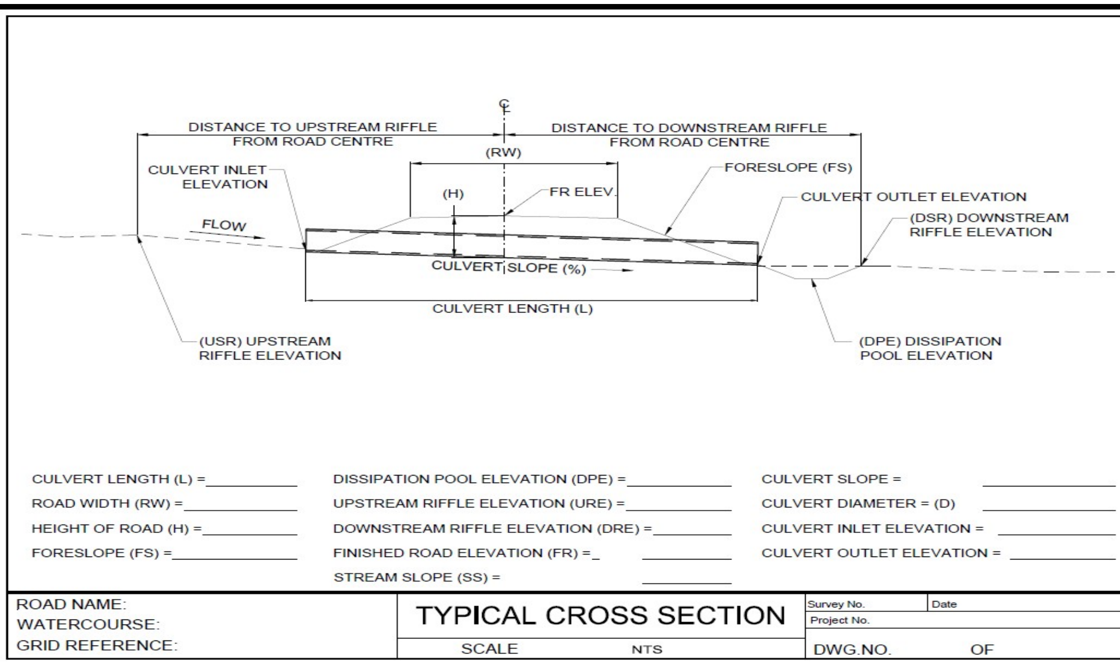
Length (L) = 55 m

Therefore: = ((100.35 m – 100.2 m) / 55 m) x 100 = 0.27 %

The watercourse gradient/slope is 0.27%.

Once the watercourse gradient is confirmed and the culvert diameter has been sized, use the survey diagram (see Figure 7-12) and the existing site conditions drawing (see Figure 5-8) to develop a cross-section drawing. See Figure 7-13.

Figure 7-13 Typical cross-section



Note: Plan to leave room for the addition of a dissipation pool (if required) or an extension of the existing one.

In replacement sites, it is very common to have a much larger footprint than what was previously there. This will inevitably mean a new realignment of the site to match up with the existing stream conditions. A well-drawn “existing site” drawing will allow designers to see where the new culvert is going to tie-in. Before this can happen, determine the new culvert length. See Section 7.5 *Calculating Culvert Length*.

7.5 CALCULATING CULVERT LENGTH

Culvert length must be determined prior to installation. Culverts that are too short or too long can become unstable because of scouring and result in fish passage problems.

7.5.1 Culvert Length when Using Rip-Rap

The parameters required to calculate culvert length are as follows. See Figure 7-14.

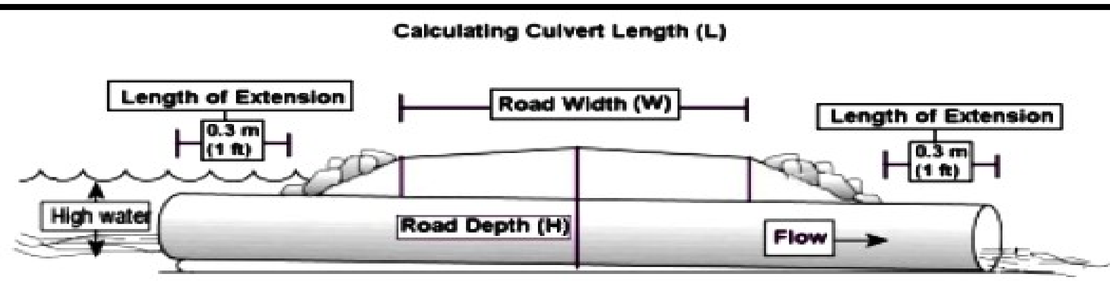
L - length of culvert required

W - road width

H - total height from stream bed to the road surface (culvert diameter/rise plus height of cover)

0.6 m - culverts must extend 0.3 metre (1 ft) beyond the toe of the fill at both the upstream and downstream ends

Figure 7-14 Parameters for calculating culvert length



Where the road crosses the watercourse at a right angle, proper culvert length can be calculated using the following formula:

For 1.5:1 foreslopes

L (m) = W + 3H + 0.6 m   or   L (ft) = W + 3H + 2 ft

See Example 7-4.

EXAMPLE 7-4
CALCULATING CULVERT LENGTH

What is the recommended length of a 1200 millimetres culvert if the roadway is 6 metres wide? The height of fill over the culvert is half the culvert diameter.

1200 mm / 1000	= 1.2 m
Total Height (H)	= 1.2 m + 0.6 m (*half the diameter*) = 1.8 m
Length (L)	= W + 3H + 0.6 m = 6.0 m + 3(1.8 m) + 0.6 m = 12 m

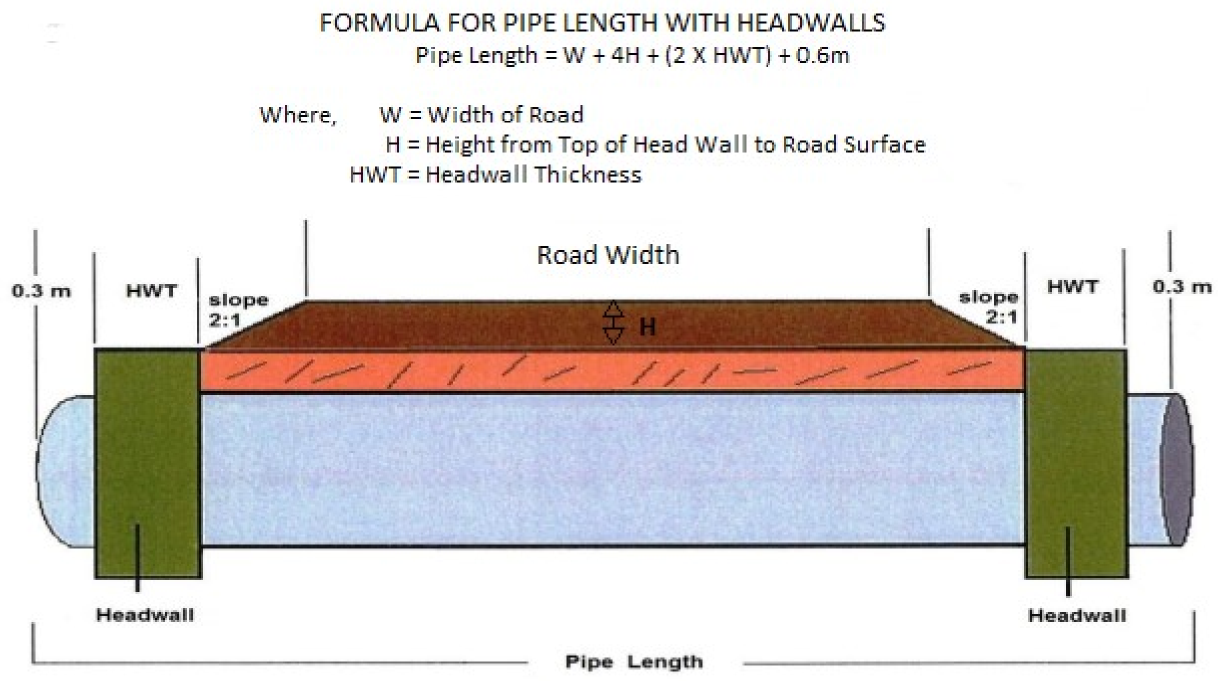
The recommended culvert length is 12 metres.

- In situations where guide rails are to be installed, ensure their placement is accounted for within the proposed road width.
- When calculating the height (H), the thickness of the culvert must be taken into account.
- If the roadway meets the watercourse crossing at an angle, it is necessary to add 1% to the culvert length for each 1% skew from the perpendicular.

7.5.2 Culvert Length when Using Headwalls

See Figure 7-15 for the formula to use to calculate the culvert length when headwalls are to be used.

Figure 7-15 Calculating culvert length with headwalls



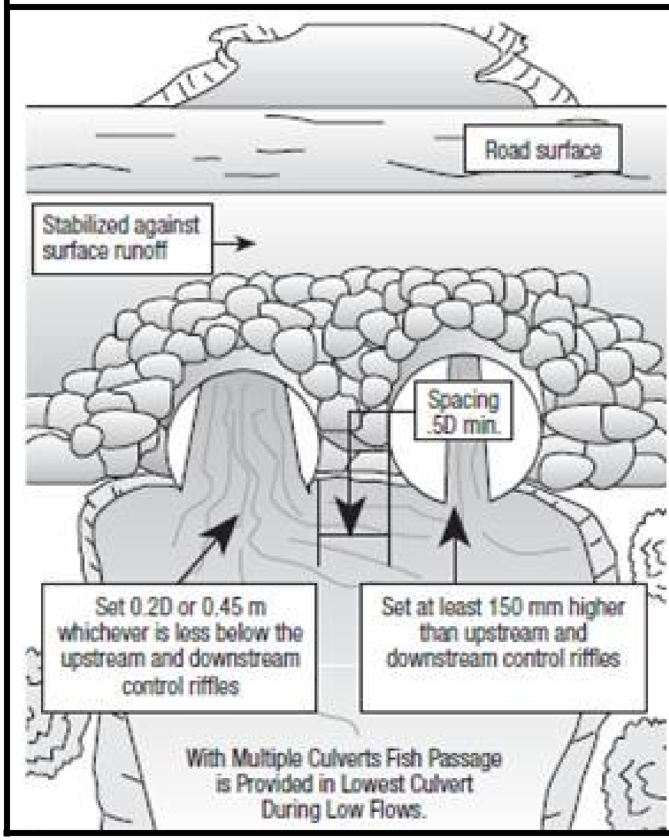
7.6 MULTIPLE CULVERTS

The guidelines for installing multiple culverts are as follows:

- A maximum of two culverts may be installed.
- One culvert must be located in the thalweg of the channel with the ends embedded below the thalweg of the upstream and downstream riffles and the inlet invert (bottom) of the second culvert must be set at least 150 millimetres (6 in) higher than control riffles so that during low flow conditions, all the water will flow through the lower culvert. See Figure 7-16. If this is not feasible, the overflow culvert must be designed with a blind weir (baffle without a notch) installed at least 300 mm in height at the upstream end of the pipe.
- If two culverts are used at a single crossing, the combined capacity of the culverts must equal the calculated design flow (Q). In other words, the capacity of both culverts added together must equal or exceed the calculated 1 in 100-year runoff event design flow. See Section 7.3.2 *Calculating Diameter for a Closed-Bottom Culvert*.

- Culverts must be placed a minimum of 1 metre (3 ft) or 0.5D apart, whichever is greater, such that a compacter can fit between the pipes to allow for proper compaction.

Figure 7-16 Twin culvert installation (upstream looking downstream)



7.7 TIMING OF INSTALLATION

All culvert installations must be carried out between June 1st and September 30th of the same year, preferably during low water conditions. Construction should proceed diligently to help minimize any unnecessary environmental problems and minimize impacts to fish.

Note: Longer projects benefit from water-control methods which provide fish passage (*e.g.* a diversion channel).

Work and project extensions outside of this window will not be approved through the Watercourse Alteration Certification Program. If there are unforeseen issues that prevent the project from being completed prior to the September 30th deadline, DELG should be contacted as soon as possible to discuss next steps.

7.8 CLOSED-BOTTOM CULVERT INSTALLATION

The steps for installing a culvert have been separated into the following categories:

- General Practices
- Working in Isolation of the Stream Flow
- Installation
- Backfilling
- Stabilization
- Road Approaches

7.8.1 General Practices

The following must be followed when using machinery in or near a watercourse.

- A backhoe or an excavator must be used to prepare a firm bed for the placement of the structure
- All work must be carried out with machinery stationed outside the wetted portion of the channel (fording is not permitted)
- Machinery must be in good working order and must not be leaking any fuel, lubricants, or hydraulic fluid and must be cleaned/degreased to prevent any deleterious substance from contaminating the wetland and to help minimize the spread of invasive plant species
- Machinery must not be washed/refueled in or near a watercourse/wetland; this practice is not limited to the crossing site but anywhere that contaminated overland runoff seeps or drains into a watercourse/wetland

Prior to the culvert being installed, if machinery must cross the watercourse, it must do so using a temporary structure or portable bridge that completely spans the channel in order to minimize the potential for erosion and sedimentation. See Section 8.10 *Temporary Bridges* for the associated guidelines. Machinery must not ford a watercourse at any time during the installation, replacement, or maintenance of a watercourse crossing.

Clearing and grubbing activities within 30 metres (100 ft) of the watercourse must be limited to the footprint on the approaches and the roadside ditches (if included). Clearing activities may occur prior to June 1st (to avoid the nesting season) if all other applicable federal and provincial requirements are met. Grubbing shall not take place until construction of the crossing is ready to begin.

7.8.2 Working in Isolation of the Stream Flow

All activities in the wetted footprint of the channel must be carried out in isolation of the stream flow.

When working in a watercourse, it is necessary to isolate the work site from the stream flow to reduce the impact of silt and fine particulate matter on fish and their habitat. Effective techniques of water control include using cofferdams in combination with a pump-around system and temporary diversion channels.

Use the appropriate water control method prior to any culvert installation. Consider the settings, such as valley slope, height of stream banks, stream gradient, and stream flow when making this decision.

See Section 6.1 *Water Control Measures when Working in a Watercourse (How to Work in Isolation of Stream Flow)* for more details.

7.8.3 Installation

Culvert installation will differ depending on the type of stream bed. Use the appropriate method as described in the following.

Stream Bed Foundation

Install culverts on a firm and uniform stream bed to provide adequate support and to prevent sagging. The natural stream bed may be either firm or soft, and the bed for the culvert should be prepared using the appropriate guidelines such that the natural slope and elevation of the stream bed is maintained.

Soft Stream Bed

- Where the stream bed is soft, excavate to firm ground and replace with enough clean gravel to bring the stream bed back up to the level at which the invert of the culvert is to be placed.
- Excavation of the stream bed should be kept to the footprint of the reach of channel the culvert is going to occupy.

Firm Stream Bed

- If the stream bed is firm, excavate the footprint of the reach of channel the culvert is going to occupy to the proper embedment depth below the thalweg of the control riffles.

Stream Bed Rock Size and Impermeability

The substrate in new channels or culvert approaches should be a mix consisting of rock that mimics what is present naturally in the watercourse. Large rocks may cause fish passage issues and in cases where a large size class of rock is needed to reduce erosion then it should be buried below stream bed elevation with and topped with appropriately sized impermeable substrate at least 200 mm (8 in) thick.

The new stream bed mix should have a wide range of particle sizes and must include enough silts and fines (particles less than 2 mm in diameter) to fill interstitial spaces and create an impermeable surface. Fines should be washed into the stream bed with a hose until the water runs clear. If subsurface flow is still evident then more fines and washing may be required.

Small particle sizes are of critical importance for stream bed mixes as a lack of these fines can cause water to flow below the surface of the new channel. It should never be assumed that sediment will be transported from upstream to plug the stream bed as this process could take years.

Placement of Culvert

Place culverts on a uniform slope with the culvert invert (bottom) embedded 0.2D, up to a maximum of 0.45 metre (18 in), below the thalweg of both the upstream and downstream control riffle, as described in Section 7.4 *Fish Passage*. This helps ensure that there will be water inside the culvert during low flow conditions. See Figure 7-11.

Align the culvert as closely as possible with the natural channel. The realignment of a stream beyond the upstream and downstream control riffles (see Section 7.4 *Fish Passage*) is not permitted under the Watercourse Alteration Certification Program. In addition, the control riffles must not be altered in any way. If this criterion cannot be met, an application for a standard watercourse and wetland alteration permit must be made using the online application program.

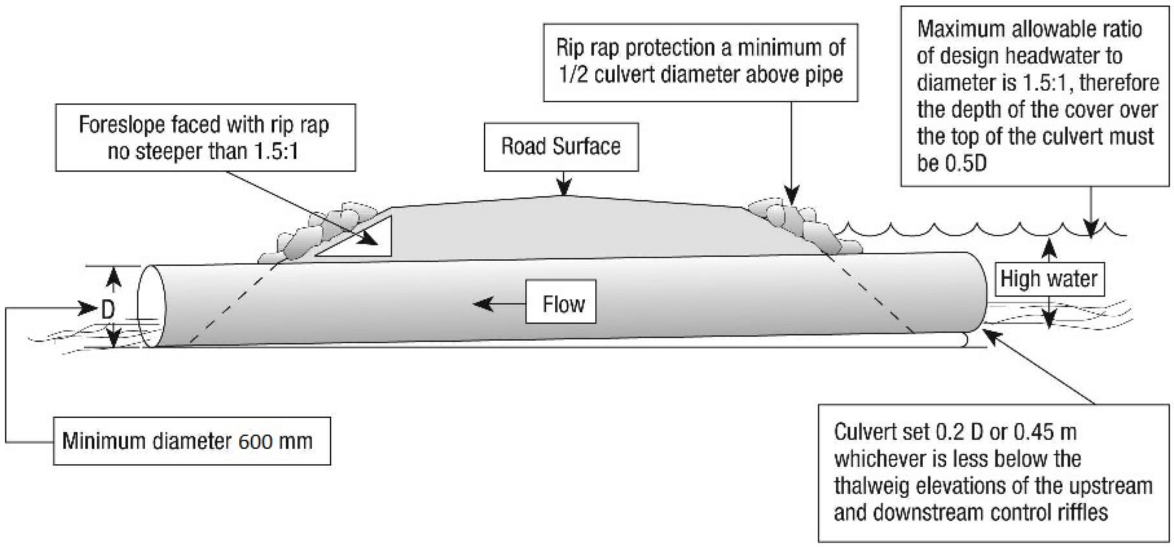
Unless headwalls are used, the culvert must extend a minimum of 0.3 metre (1 ft) beyond the upstream and downstream toe of the rip-rapped foreslopes developed around the structure.

The foreslopes the rip-rap is to be placed on must be no steeper than 1.5 horizontal to 1 vertical and the minimum thickness of the layer of rip-rap must be 1.33 times the maximum rock size used.

Before the culvert begins to convey the stream flow, rip-rap (or headwalls and wingwalls) must be placed at both ends of the culvert to an elevation of at least half the culvert diameter (rise) above the top of the pipe and a minimum of one pipe diameter (span) on each side of the culvert. See Figure 7-17 for general culvert installation guidelines.

Note: If using a headwater depth to diameter ratio of 1:1 or less, then utilizing half the culvert diameter as the minimum requirement for depth of cover is not required. In this case, use the manufacturer’s guidelines.

Figure 7-17 Guidelines required for culvert installation



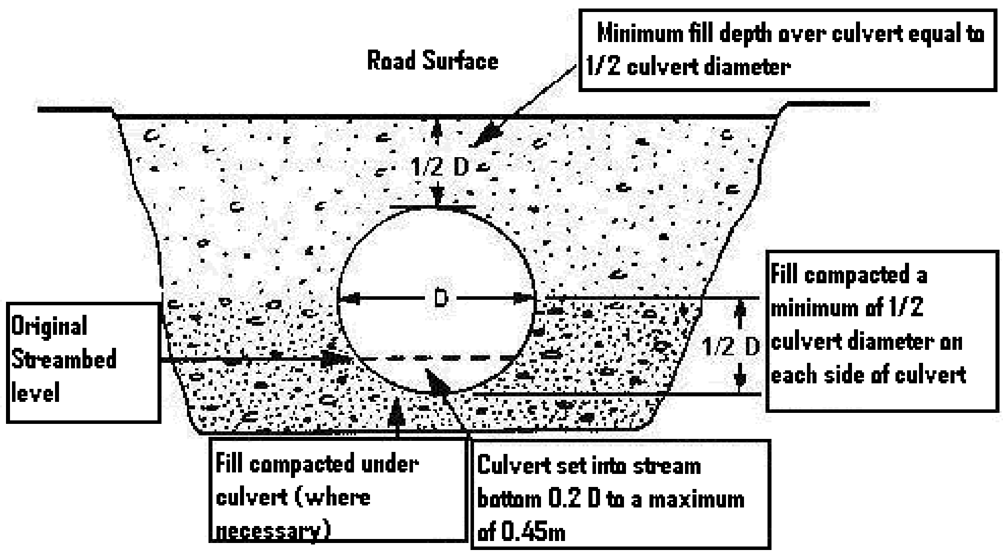
7.8.4 Backfilling

Once the culvert has been placed on a firm bed at the proper depth below the control riffles, begin the process of backfilling. When properly placed, backfill should equalize the support to both sides of the culvert. The backfill must be compacted sufficiently to prevent culvert shifting and washouts. The following guidelines should be followed.

- Backfill material
  - Ideally, aggregate should be sourced from a quarry. Backfill must be composed of clean, well-graded, pit run gravel less than 5 centimetres (2 in) in diameter, or coarse granular sand.
  - Backfill material should not consist of mud, fine sand, or silt as these soils may contribute to culvert washouts and downstream sedimentation.
- Backfill machinery
  - Backfill must be placed around and over a culvert with an excavator or backhoe.
  - Compaction can be achieved using hand tampers or machinery such as tamping rollers or vibrating compactors.
- Backfill placement. See Figure 7-18.
  - Compact backfill evenly on both sides in 10 to 15 centimetres (4 to 6 in) thick layers. Balance the layers on both sides to prevent the culvert from being deflected out of shape. This will help prevent any shifting or lifting of the culvert and ensure that there are no voids or soft spots in the backfill material.
  - Compact the backfill by hand up to the haunches of the culvert. When compacting below the haunches, do not force backfill under the culvert.
  - Cover material must be placed to a minimum height of half the culvert diameter/rise above the pipe.

Note: Before backfilling begins, ensure that adequate room is left for the 0.3 metre (1 ft) extension and the thickness of the rip-rap.

Figure 7-18 Guidelines for properly backfilling a culvert
*Minimum depth of cover must be equal to manufacturer's spec



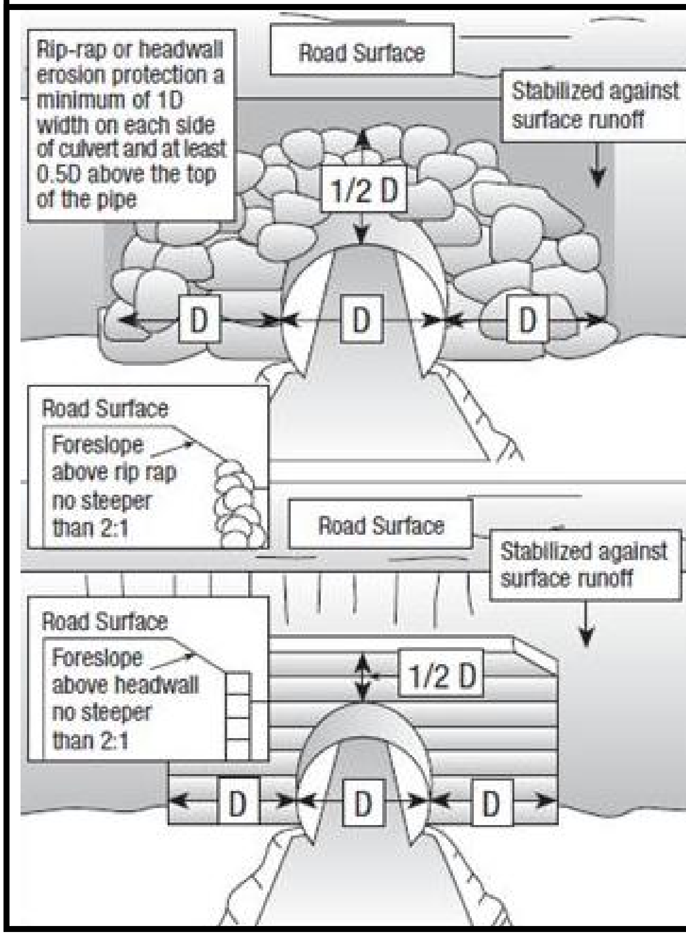
7.8.5 Stabilization

The ends of a culvert can be stabilized using rip-rap or headwalls and wingwalls. These structures protect the fill material around the ends of the culvert against scouring and erosion. The general guidelines for use of these stabilization techniques are as follows:

- As a minimum, these stabilization techniques must protect the portion of the foreslopes of the road around the ends of the culvert from the elevation of the stream bed to half the diameter/span of the structure above the top of the culvert and for a minimum distance of one culvert diameter/span on each side of the culvert. See Figure 7-19.
- Stabilize the foreslopes immediately following the installation, before it begins to convey the stream flow.
- The foreslopes above the rip-rap or headwalls/wingwalls can be stabilized with vegetation provided the foreslopes are no steeper than a 1.5 to 1 slope. See Figure 7-19.

The following information is specific to each stabilization technique.

Figure 7-19 Foreslope stabilization around a culvert



Rip-rap

Rip-rap is defined as durable broken rock, cobble or boulders placed over exposed soil to provide an erosion-resistant cover.

- Rip-rap must be clean, durable, non-ore-bearing, non-toxic rock and must not be obtained from a watercourse nor from within 30 metres (100 ft) of a watercourse/wetland.
- Rip-rap must be irregular in shape with at least 70% of the material having a smallest dimension of not less than 15 centimetres (6 in).
- The foreslopes the rip-rap is to be placed on must be no steeper than 1.5 horizontal to 1 vertical.
- The minimum thickness of the layer of rip-rap must be 1.33 times the maximum rock size used.
- Rip-rap must not be dumped or pushed over the shoulder of the foreslopes but must be placed into position in a controlled manner.

Headwalls

Headwalls are vertical walls that are aligned parallel to the roadway and tied into the slopes of the road embankment. Headwalls may be used alone or in conjunction with rip-rap. Headwalls are an effective means of achieving the desired road width, where factors are limiting the length of the culvert.

Headwalls are designed to:

- Retain the roadway embankment preventing fill material from entering the watercourse
- Anchor the culvert against potential buoyancy or uplifting
- Provide support to the culvert inlet and outlet to help maintain the shape and waterway opening of the culvert

- Increase the hydraulic efficiency of the culvert
- Prevent saturation of the backfill

When constructing headwalls:

- Excavate the location for the headwalls below the anticipated depth of scour
- Use squared timber, concrete, steel, gabions, etc. to construct the structure
- Tie the headwalls into the foreslope for stability

Wingwalls

Wingwalls are lateral walls similar to headwalls except that they extend upstream and downstream from the outside corners of the headwalls at an oblique angle to the road embankment.

The information listed in the headwalls section also applies to the construction of wingwalls.

7.8.6 Road Approaches

Road approaches should be straight and stable with minimal slope for 30 metres (100 ft) on both sides of the watercourse crossing.

Locate off-takes or cross-drainage culverts at least 30 metres (100 ft) from watercourses/wetlands. If the topography permits, construct off-take ditches on both sides of the road.

Where property ownership allows, roadside ditches must end at least 30 metres (100 ft) from watercourses/wetlands and water directed through an off-take ditch. Ditches must never discharge directly into a watercourse/wetland.

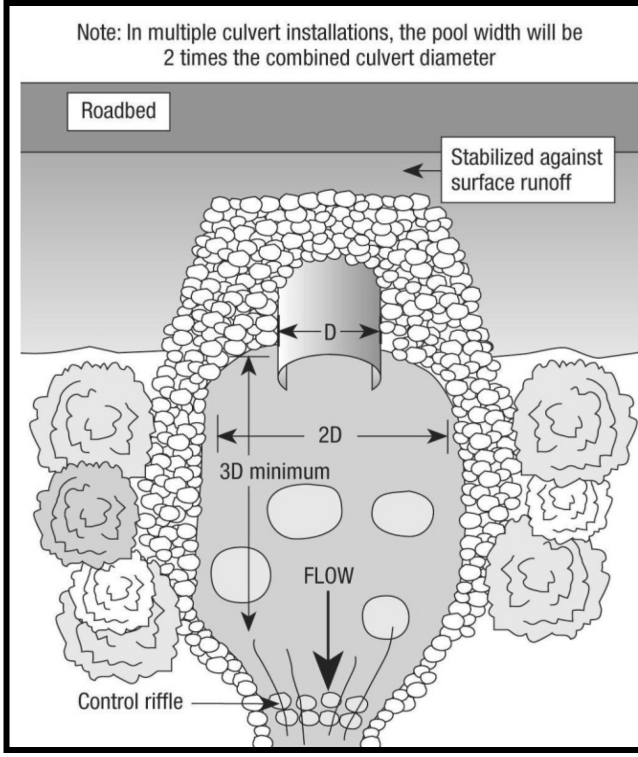
Clearing and grubbing activities within 30 metres (100 ft) of the watercourse must be limited to the footprint on the approaches and the roadside ditches (if included). Clearing activities may occur prior to June 1st (to avoid the nesting season) if all other applicable federal and provincial requirements are met. Grubbing shall not take place until construction of the crossing is ready to begin.

7.9 ENERGY DISSIPATION POOLS

The use of an energy dissipation pool at the outlet of a culvert serves two purposes:

- To dissipate the energy from incoming water and to prevent brook destabilization and scouring at the outlet. If scouring occurs at the outlet, it may create a “hanging” culvert, preventing fish passage.
- To provide a resting area for migrating fish. The energy dissipation pool should be sized to ensure the stability of the pool during peak flood flows.

Figure 7-20 Energy dissipation pool



Energy dissipation pools must be constructed at the outlet of all closed-bottom culverts, where the stream slope is greater than 0.5%. See Figure 7-20. In situations where an energy dissipation cannot be constructed, or does not meet the guidelines (see Section 7.9.1 *Design*), an application for a standard WAWA permit must be made using the online application program.

Note: Energy dissipation pools are not required for stream simulation culverts. See Section 7.10 *Stream Simulation Culverts*.

7.9.1 Design

Appropriate channel protection must be designed to prevent scour and erosion at the outlet of the culvert such that the natural bed and banks can withstand the flow velocity during a peak runoff event.

To prevent scour and erosion, the entire energy dissipation pool should be stabilized and lined with rip rap at least 1.5 times the thickest rock. The size and placement of rip-rap must be resilient enough to withstand velocities produced by the 1:100 year flood event.

Three to five large boulders (1 metre (3 ft) in diameter, embedded 50%) should be staggered in the energy dissipation pool in order to further dissipate energy and provide fish habitat. The top of the boulders should not protrude above the elevation of the outlet control riffle.

The average depth of the pool must be a minimum of 1 metre (3 ft).

The width at the bottom of the dissipation pool is to be two times the culvert diameter (D). The length at the bottom of the dissipation pool is to be three times the culvert diameter (D).

An appropriate amount of fine granular material, gravel borrow, or pit run material (20% fines, does not include clays) should be mixed with the rock mixture to ensure that the interstitial spaces are filled so that water is not lost. When completed properly and to ensure fish passage, water should flow over the rip rap and not completely disappear.

To avoid sedimentation of the watercourse downstream, the newly constructed energy dissipation pool should be “washed” or “flushed” thoroughly to dislodge any fine material. The wash-water should be pumped away from the watercourse to prevent sedimentation of the watercourse. Once the water is running clean, then the permanent watercourse can be re-directed through the culvert.

After construction is complete, ensure to stabilize all disrupted soils to avoid erosion and sedimentation of the watercourse. Short term strategies include the use of hay/straw mulch. However, for long term stability, shrubs, bushes, and/or trees should also be planted to establish root growth.

7.10 STREAM SIMULATION CULVERTS

A stream simulation culvert is a closed-bottom culvert featuring a natural stream bed within the structure, which mimics the substrate found in the watercourse and adds roughness to reduce water velocities. This design methodology has existed in some form for decades and is also known as an “embedded” design or “stream smart” design.

Note: Fisheries and Oceans Canada (DFO) is currently reviewing and updating fish passage guidelines and new guidelines are currently in development. Since these new guidelines center on stream simulation designs, proponents are encouraged to adopt this design in lieu of closed-bottom culverts with baffles. It is expected that all closed-bottom culverts, with few exceptions, will eventually be required to be designed as stream simulation culverts.

Under the Watercourse Alteration Certification Program, stream simulation culverts can be installed up to a 6% slope. The main guidelines of the Fish-stream Crossing Guidebook (available at https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-resource-use/resource-roads/fish-stream_crossing_web.pdf) has been incorporated in this manual.

For watercourses with gradients above 6%, the United States Forest Services Guide for Stream Simulation (available at https://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/hi_res/%20FullDoc.pdf) should be consulted. These designs are not covered under the Watercourse Alteration Certification Program and will require a standard WAWA permit.

Stream simulation should conform to four design parameters, which are described in the follow sections. The parameters, coined by the Maine Department of Transportation (https://www.maine.gov/mdot/publications/docs/brochures/pocket_guide_stream_smart_web.pdf) as the four “S”s are:

- Span the Stream
- Set the Elevation Right
- Slope Matches the Stream
- Substrate in the Crossing

In addition to the information in the sections below, the installation guidelines in Section 7.8 *Closed-Bottom Culvert Installation*, should be followed.

7.10.1 Span the Stream

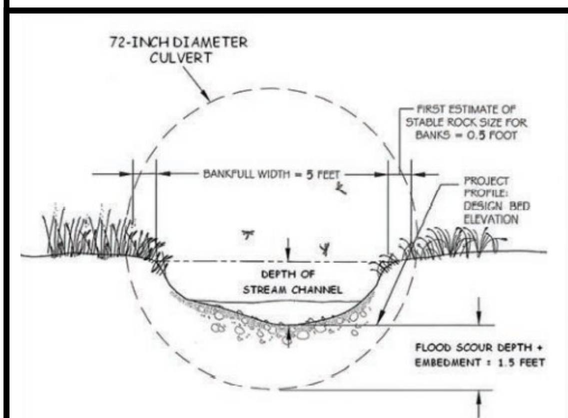
The culvert must be sized at least 1.2 times the bankfull width (BFW) of the watercourse. The BFW can be determined through a stream survey that is conducted outside of the area influenced by an existing structure (sediment deposition, channel incision) in cases of culvert replacements. See Section 5.1 *Terminology* and Figure 5-1. Spanning the stream ensures that there is no constriction of the watercourse which often results in debris jams, destructive hydraulic effects or increased risks of structure failure. The culvert must also be sized to accommodate a 1 in 100-year runoff event accounting for the depth of fill in the structure, though this criterion is often met by sizing greater than BFW. See *Appendix D: End Area Reductions – Round Pipes with Stream Simulation* for more information on sizing.

For culvert replacements, consideration of fill depth, bedrock, underground utilities, or the permissibility of road closures may necessitate additional technical help in design and construction.

Unfamiliarity with this design approach may mean that it will take time for local suppliers to create or stock structures that can facilitate stream simulation. For instance, common structures used in other jurisdictions include box culverts with lids and large, corrugated aluminum pipes.

There is no minimum or maximum size for stream simulation culverts provided that BFW sizing is followed. However, culverts smaller than 1800 mm (72 in) can pose problems with adding substrate into the pipe. See Figure 7-21.

Figure 7-21 Stream simulated culvert cross-section



7.10.2 Set the Elevation Right

Circular culverts should be embedded to at least 0.4 times the diameter of the pipe; arches and boxes are to embedded to at least 0.2 times the height.

Ideally the bottom of the culvert should be located at the scour line (the depth of the deepest pool not including any scour pool in the watercourse above and below the culvert) so that the stream bed in the culvert is unlikely to erode enough to expose the culvert bottom. If bedrock is encountered than an open-bottom structure or bridge should be used.

7.10.3 Slope Matches the Stream

The culvert must match the existing stream gradient such that there is no break in slope from the watercourse to the substrate in the crossing. This will ensure there is no excess substrate accumulation at the inlet or headcut formation at the outlet.

A stream gradient measured from the first upstream and first downstream riffles at an existing crossing may under or over estimate the natural stream gradient. The gradient of the stream should ideally be determined from a reference reach outside the influence of an existing structure in cases of culvert replacements. See Section 7.4.2 *Calculating Watercourse Gradient/Slope* on how to conduct a stream survey.

7.10.4 Substrate in the Crossing

Substrate within the culvert must match the natural stream bed material found in the watercourse. Either reclaimed stream bed material or a mix similar to what is present naturally should be used.

The new stream bed mix should have a wide range of particle sizes and must include enough silts and fines (particles less than 2 mm in diameter) to fill interstitial spaces and create an impermeable surface. Fines should be washed into the stream bed with a hose until the water runs clear. If subsurface flow is still evident then more fines and washing may be required.

Sediment laden water generated by this process must be captured at the downstream end and pumped into a densely vegetated area a sufficient distance from a watercourse/wetland to filter any silt from the runoff before it returns to a watercourse/wetland.

For streams larger than 2 metres (6.6 ft) in width, large rocks should be placed in a meandering pattern within the culvert and embedded 50% of their diameter. See *Appendix D: End Area Reductions – Round Pipes with Stream Simulation*. Larger rocks should also be placed to act as banks along the sides of the culvert.

If the watercourse substrate consists mostly of silt, sand and fine gravel then proper embedment of the structure should allow for the deposition of material inside of the pipe sufficient to provide passage for fish.

7.11 REPLACING CULVERTS

For guidelines on replacing a closed-bottom culvert with an open-bottom culvert, see Section 8.3.8 *Replacing a Closed-Bottom Culvert with an Open-Bottom Culvert*. For guidelines on replacing a closed-bottom culvert with a bridge, see Section 8.9.1 *Replacing a Closed-Bottom Culvert with a Bridge*.

When replacing a culvert, the length of the new culvert must not exceed 30 metres (100 ft).

All other guidelines for culvert sizing, fish passage, timing of installation, and culvert installation must be followed. See Section 7.3 to Section 7.9.