6.0 CHAPTER 6 – CULVERT BARREL MEASUREMENTS (SBM2)

6.1 INTRODUCTION

For the purpose of this manual, culverts are defined as bridge structures that are completely surrounded by soil, and located below the surface of the roadway parallel to the general direction of the stream flow. Culverts are efficient and economical alternatives to conventional bridges and their use has increased significantly over the years. These advantages have encouraged an evolution in design methods that have led to thinner walls, use of new and innovative material combinations and shapes, and the development of larger span culverts.

Bridge-size culverts are defined as culverts having an equivalent diameter of 1500 mm or more. They are inspected on the same routine inspection intervals as those specified for bridges. Culverts with equivalent diameters less than 1500 mm are also routinely inspected if they are part of a low level crossing.

Corrugated metal culverts are flexible culverts that rely on ring compression and the support of the surrounding backfill to carry loads. If the backfill does not properly support the culvert, deformation of the culvert will occur. The sidewalls of the culvert will bend outward and the roof will sag. With further deformation, the roof of the culvert will flatten as it sags. Eventually, if the deformation is severe enough, the roof will curve downward into the culvert resulting in reverse curvature, and collapse may be imminent. In structural plate culverts, the longitudinal seams will often deform and crack under the action of the bending forces. In this last type of culvert, the seams are the weakest areas of the wall.

In order to assess the condition of culverts undergoing deformation, it is necessary to obtain measurements of the shape of the culvert and the extent of cracking in the longitudinal seams. The shape measurements are compared to the original design dimensions to determine the severity of the deformation. The extent of both the cracking and deformation will affect the Level 2 rating.

6.2 CULVERT INVENTORY INFORMATION

The inventory information found at the top of the Level 2 Culvert Barrel Measurement Inspection form contains the same inventory data found on the typical Level 1 and other Level 2 bridge and culvert inspection forms. Descriptions of these fields may be found in Section 1.3.2 of the Level 2 Inspection Manual or Section 4 of the Level 1 BIM Inspection Manual.

Ensure the date of the Level 2 inspection is recorded in the header information on the first page. This date will be echoed onto the last page of the SBM2 form.

In addition to the inventory data in the header of the form, the SBM2 form also provides additional information on the culvert, such as the plate arrangement, for up to three culverts. This additional inventory section of the SBM2 form is shown in Figure 6.1. The information in this section is extracted from BIS and auxiliary modules of BIS, such as the Culvert Information System (CIS). It is located immediately below the header information on page one of the SBM2 form, and is described in detail in the following sections.

CULVERT INFORMATION:

Number of Culverts ..

Pipe Num.	Design Span (or Dia.)/Rise	Type	Length	Corrugation Profile	Plate Thickness
1	..... x ..... mm	...	.....m	....x....mm	.../.../...mm
2	..... x ..... mm	...	.....m	....x....mm	.../.../...mm
3	..... x ..... mm	...	.....m	....x....mm	.../.../...mm

Figure 6.1 – SBM2, Culvert Information

6.2.1 NUMBER OF CULVERTS

This field represents the number of culverts that are at the site.

6.2.2 PIPE NUMBER

This applies to the number assigned to the culvert pipes at a particular site. Culvert pipes are numbered in the direction of increasing chainage, starting at the lowest station and increasing from west to east or from south to north. Refer to Figure 6.2.

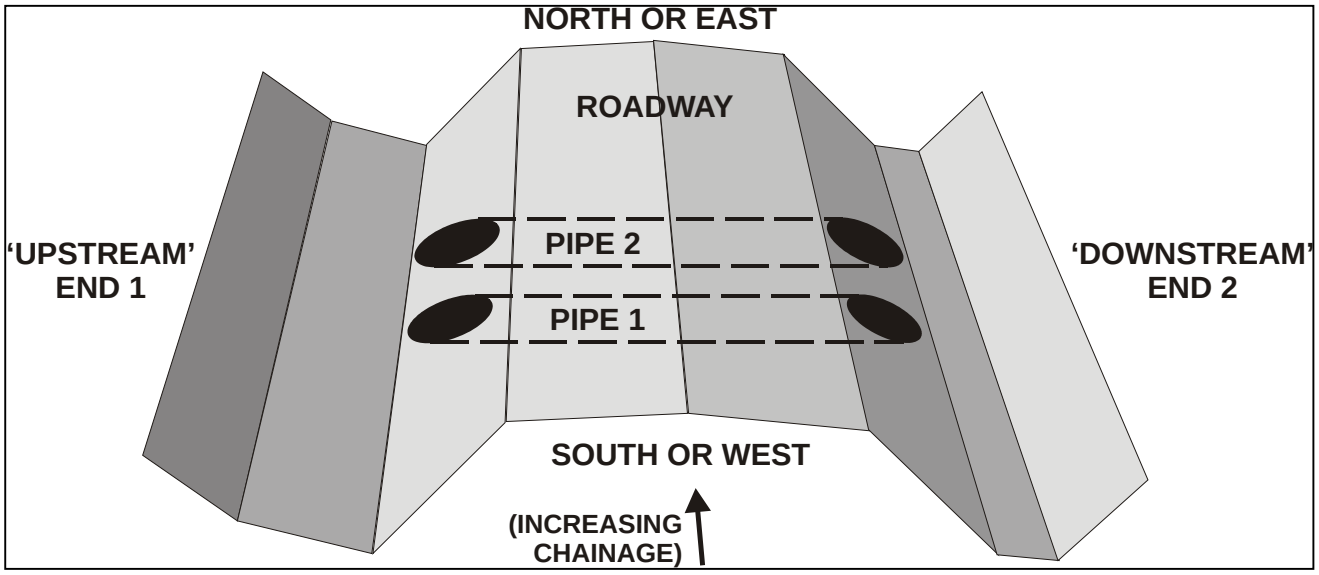

Figure 6.2 – Numbering Culvert Pipes

6.2.3 DESIGN SPAN (OR DIAMETER) / RISE

This is the original design information for the span and rise of the culvert, given to the nearest millimetre. For round culverts the design diameter of the culvert is shown in the first and second fields, representing the span and the rise. Refer to Figure 6.10 for definitions of the span and rise of a culvert.

6.2.4 CULVERT TYPE

This field represents the type of culvert structure as well as the material type. A complete list of the abbreviations used is found in the BIS Codes and Explanations Manual. The SBM2 Level 2 form is limited to corrugated metal, and flexible culverts.

6.2.5 LENGTH

This field is for the invert length of the culvert expressed to the nearest 0.1 metre. This measurement includes both bevel end lengths and the full barrel length. This value can be obtained from BIS or from the culvert design drawings.

6.2.6 CORRUGATION PROFILE

Corrugated steel pipes are manufactured with four corrugation profiles (pitch x depth): 38 x 6.5 mm, 68 x 13 mm, 76 x 25 mm, and 125 x 26 mm. Structural Plate Corrugated Steel Pipes are manufactured with a corrugation profile of 152 x 51 mm, 380 mm x 140 mm, or 400 mm x 150 mm. See Figure 6.3.

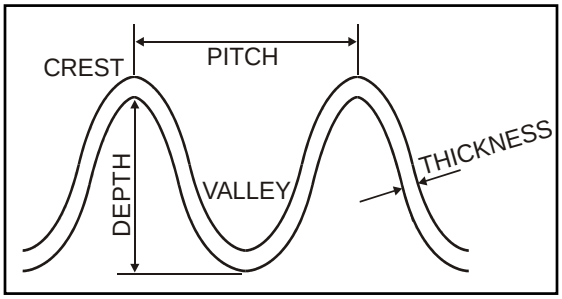

Figure 6.3 – Corrugated Steel Pipe Profile

6.2.7 PLATE THICKNESS

Corrugated steel pipes are manufactured with up to seven nominal thicknesses, depending on the corrugation profile: 1 mm, 1.3 mm, 1.6 mm, 2.0 mm, 2.8 mm, 3.5 mm, and 4.2 mm. Structural Plate Corrugated Steel Pipes are manufactured with five nominal plate thicknesses: 3 mm, 4 mm, 5 mm, 6 mm, and 7 mm. For a particular culvert pipe, the inspection form has provision to record up to three different plate thicknesses. See Figure 6.3.

The following fields shown in Figure 6.4 provide additional culvert information on the individual plate sections that make up the culvert pipe.

Pipe Num.	# of Rings	Top Arc Radius	Top Arc N	Side Arc Radius	Side Arc N	Bottom Arc Radius	Bottom Arc N	Corner Arc Radius	Corner Arc N
1	...	.....mm	...	.....mm	...	.....mm	...	.....mm	...
2	...	.....mm	...	.....mm	...	.....mm	...	.....mm	...
3	...	.....mm	...	.....mm	...	.....mm	...	.....mm	...

Special Features: .....

Figure 6.4 – SBM2, Additional Culvert Information

6.2.8 NUMBER OF RINGS

This field is the number of rings that make up the barrel section of the culvert pipe. A ring is defined as the area between two circumferential seams of the culvert. The length of rings may vary within the same culvert as shown in Figure 6.9.

6.2.9 ARC RADII AND CIRCUMFERENTIAL N COUNTS (TOP, SIDE, BOTTOM & CORNER ARCS)

A culvert that is a perfect circle will have a single value for the radius in all the Radius fields. This value is to be recorded in millimetres. Most flexible culverts however, are elliptical in shape or have an elliptical shape that is flattened in one direction, either in the longitudinal or the vertical. The shapes of these culverts are made from sections of plates that are bent to different radii.

The top, side, bottom, and corner arcs of elliptical shaped culverts can have a variety of plate arrangements and different arc radii within the same culvert. The top and bottom arcs can have up to seven plates per ring and the sides up to four plates per ring. If the inspector needs to number the plates, they are listed in a counterclockwise direction starting from the beginning of the arc.

The plate arrangement is further defined by its circumferential N count. 'N' refers to the spacing of the bolts along the circumferential seam as shown in Figure 6.5. Typically, the nominal value for 'N' is 244 mm. Individual plate widths in the longitudinal direction are described as 3N, 4N, 5N and so forth.

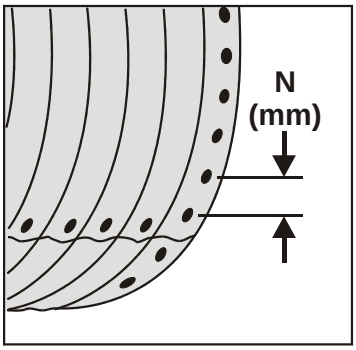

Figure 6.5 – Definition of N

6.2.10 SPECIAL FEATURES

This 'Special Features' item is extracted from the auxiliary module of BIS and is printed on the first dotted line of the Culvert Information section of the form. 'Special Features' refers to unique design features that are used on the barrel section of the culvert for extra strength and/or better soil to structure interaction. These special features include concrete thrust beams, unattached concrete slabs, concrete slab attached with shear connectors at the end sections of the barrel only, metal ribs with or without metal ears, and straw bales.

The second and third solid lines are character fields that can be used for comments, measurements, or any additional details about the culvert barrel shape.

6.3 LEVEL 2 INSPECTION SUMMARY – PAGE 1

After completing the Level 2 inspection, the inspector summarizes some basic information on page one of the SBM2 form. Inspection information is to be summarized for up to three culvert pipes. These will be the same pipes that are listed in the Culvert Inventory section of the form. This Summary Inspection Information section of the form is shown below in Figure 6.6.

SUMMARY INSPECTION INFORMATION:

Total Number of Pipes (or segments) Measured: _____

Pipe No.	Measured (Y/N)	No. of Measurements	No. of Rings Measured
1	_	___	___
2	_	___	___
3	_	___	___

Figure 6.6 – SBM2, Summary Inspection Information

6.3.1 TOTAL NUMBER OF PIPES (OR SEGMENTS) MEASURED

Record the number of culvert pipes or segments that were measured and recorded on the pages following in the SBM2 form. This section only allows the inspector to summarize the

information for up to 3 pipes, although the number can be higher if more pipes or segments were actually inspected.

6.3.2 PIPE NUMBER

This is the number assigned to the culvert. The culverts are numbered in the direction of increasing chainage, either from west to east or from south to north. The numbering should be consistent with the pipe numbers in the Culvert Inventory section described in Section 6.2.2 and Figure 6.2.

6.3.3 MEASURED (Y/N)

This is a 'yes' or 'no' field (Y/N) to summarize whether a particular culvert pipe was measured or not during this Level 2 inspection.

6.3.4 NUMBER OF MEASUREMENTS

The inspector totals the number of measurements that were taken in the particular culvert pipe during the Level 2 inspection and records the number in this field.

6.3.5 NUMBER OF RINGS MEASURED

The inspector totals the number of rings that were measured in the particular culvert pipe during the Level 2 inspection and records the value in this field.

6.3.6 COMMENTS

At the bottom of the first page of the SBM2 form, there are four lines provided for the inspector to make any additional comments that relate to the inspection.

6.4 INSPECTION DATA – PAGE 2

The second page of the SBM2 form is where the inspector records detailed barrel measurements for each culvert pipe at a particular site. Inspection data can be entered into the BIM system for up to three culvert pipes. If there are more than three pipes at a particular site and the additional pipes are in poor or suspect condition, the inspector shall perform the Level 2 barrel measurements on the additional pipes and record the results on additional sheets. However, only the first 3 pipes, as defined in the Culvert Inventory section on page one, will be recorded electronically.

A separate data page is to be used for each pipe inspected. More than one data page may be used for a particular pipe if required.

For each pipe, data will be gathered at intervals along the length of the culvert. For structural plate culverts, one set of data will be gathered in each ring with the rise and span measurements taken at the centre of the ring. For other flexible culverts, the data will be gathered at 3 m to 5 m intervals to suit the culvert.

Additional locations may be recorded as necessary if a notable feature would be missed by the established pattern. If measurements are taken in addition to the regular pattern, the inspector should ensure that the measurements are recorded in the proper location on the form. For example, if the inspector is recording data at 5 m intervals, yet there is a noteworthy condition at the 8 m mark, measurements in this area should be recorded between the rows with the 5 m and 10 m measurements on the form.

6.4.1 INSPECTION DATA – HEADER INFORMATION:

The following data shown in Figure 6.7 will appear at the top of each page of inspection data. It serves as a summary for the pipe:

INSPECTION DATA: Pipe No.: _ No. of Measurements: ___ Rings Measured: ___

Figure 6.7 – SBM2, Inspection Data Header Information

6.4.1.1 Pipe Number (Pipe No.)

Record the assigned number of the culvert pipe that is being inspected on this page of the SBM2 form. This pipe number is to match the numbering established on page one of the SBM2 form.

6.4.1.2 Number of Measurements (No. of Measurements)

The inspector totals the number of measurements that were taken in the particular culvert pipe during the Level 2 inspection and records the number in this field. This value will be the same as the one recorded in the summary inspection information on the first page of the SBM2 form (Section 6.3.4).

6.4.1.3 Rings Measured

The inspector totals the number of rings that were measured in the particular culvert pipe during the inspection and records the value in this field. This value will be the same as the value recorded in the summary inspection information on the first page of the SBM2 form (Section 6.3.5).

6.4.2 LEVEL 2 MEASUREMENTS

The main section of the SBM2 form, shown in Figure 6.8, is for the measurements taken within the culvert. For each measurement, any previous inspection information from the BIM system will be echoed back for the inspector's information.

Measurements are taken from the top of the corrugation crest to the top of the corrugation crest on the opposite side of the culvert. Ensure measurements are taken parallel to the cross section of the culvert opening. If measurements are taken at an angle to the culvert,

they will be too large, and thus inaccurate. Measurements are generally taken at regular intervals as described in Section 6.4.

It is very important to ensure that the location of measurements are sufficiently marked and labeled to allow future measurements to occur at the same locations.

In general, it is not recommended that an electronic or laser measuring device be used if there is water or uneven debris in the bottom of the culvert. In this case, it is difficult to verify whether accurate vertical measurements are being taken.

The following data will be gathered at each interval:

	Rng No.	Ring Len. (m)	Stn. (m) *	Span (mm)	Def. %	Rise (mm)	Sag %	I C E	Longitudinal Cracks					
									#	Location ***			Min St.	# Blts
Last														
Now														
Last														
Now														
Last														
Now														
Last														
Now														
Comments:														

THESE ROWS REPEAT DOWN THE PAGE

Figure 6.8 – SBM2, Inspection Data

6.4.2.1 Ring Number (Rng No.)

This is the number assigned to the ring. The rings are numbered starting at the upstream end of the barrel, excluding the bevel. If the culvert is not a stream crossing, the upstream end will be taken as the left end when looking in the direction of increasing highway chainage, from west to east or from south to north. See Figure 6.9.

6.4.2.2 Ring Length (Ring Len.)

This is the nominal length of the ring in metres to the nearest 0.01m. See Figure 6.9.

6.4.2.3 Station (Stn.)

This is the station where the rise and span measurements are taken. It is measured in metres to the nearest 0.1m from the upstream (left) end of the barrel. It does not include the bevel. See Figure 6.9.

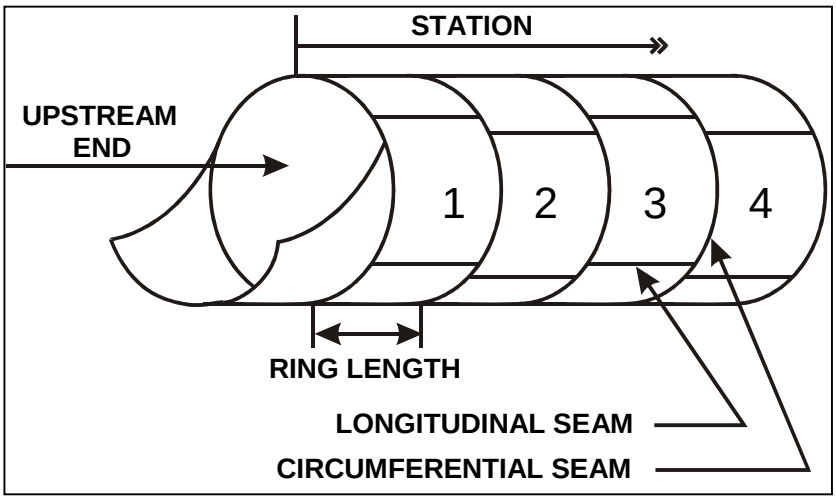

Figure 6.9 – Culvert Barrel Layout

6.4.2.4 Span

This is the measured span of the culvert in millimetres. The span is a horizontal measurement and is measured from the inside crest to the opposite inside crest. See Figure 6.10.

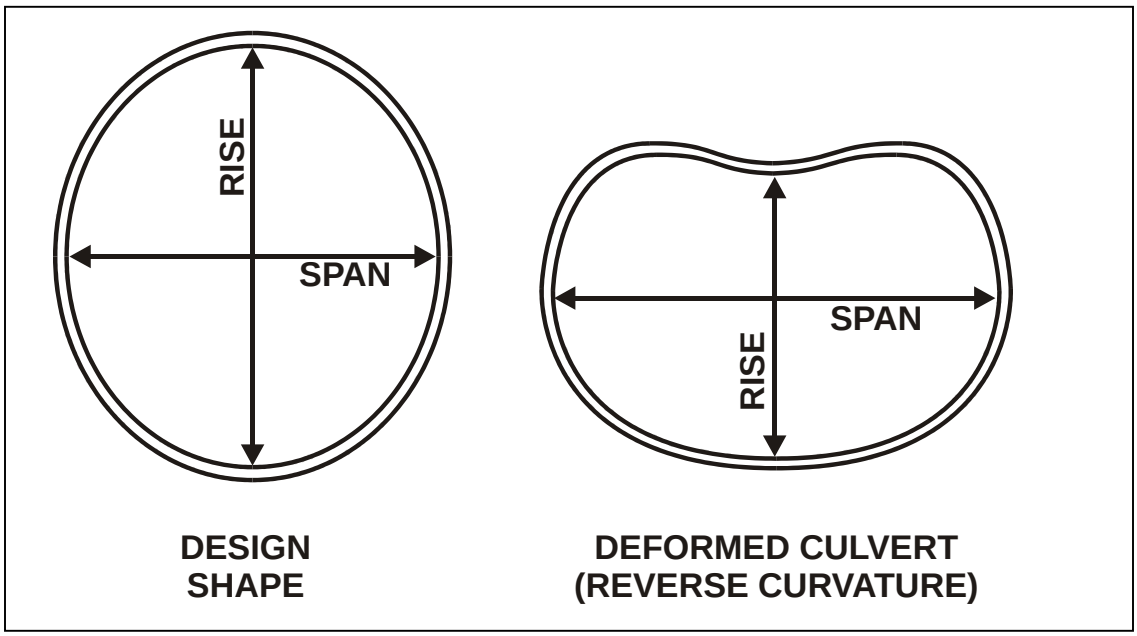

Figure 6.10 – Measurement of Rise and Span

6.4.2.5 Deflection (Def. %)

This is the percent difference between the measured span and the design span. The deflection is positive when the measured span is greater than the design span, such

as when the deflection is outwards. Record the percent deflection to one decimal point.

% Deflection = ((Measured Span – Design Span) / Design Span) X 100

6.4.2.6 Rise

This is the measured rise of the culvert in millimetres and it is measured from the inside crest of the crown to the inside crest of the invert. See Figure 6.10.

If ice, silt or other uniform and level obstruction prevents a full crown to invert measurement, the measurement of crown to top of obstruction is to be recorded. If the obstruction is not uniform, the inspector shall undertake reasonable measures to remove the obstruction and enable the measurement of the rise.

6.4.2.7 Sag (Sag %)

This is the percent difference between the measured rise and the design rise. It is positive if the measured rise is less than the design rise such as if the culvert sags downwards. Record the percent sag to one decimal point.

% Sag = ((Design Rise – Measured Rise) / Design Rise) X 100

This calculation is not performed and this field is left blank if there is ice, debris or another obstruction inside the culvert (i.e. the 'ICE' field is 'Y'). See Section 6.4.2.8 below, for further information.

6.4.2.8 ICE

This indicates whether the rise measurement is an accurate and true measurement. If the rise is not measurable due to the presence of ice, debris or other obstruction, if the floor is bulged, or if the obstruction is level and uniform, enter 'Y.' Otherwise, enter 'N.'

If the obstruction is level or uniform, such as smooth ice, the inspector may still measure the Rise as described in Section 6.4.2.6. The top of Figure 6.11 illustrates the measurement of the Rise when there is a level obstruction in the culvert.

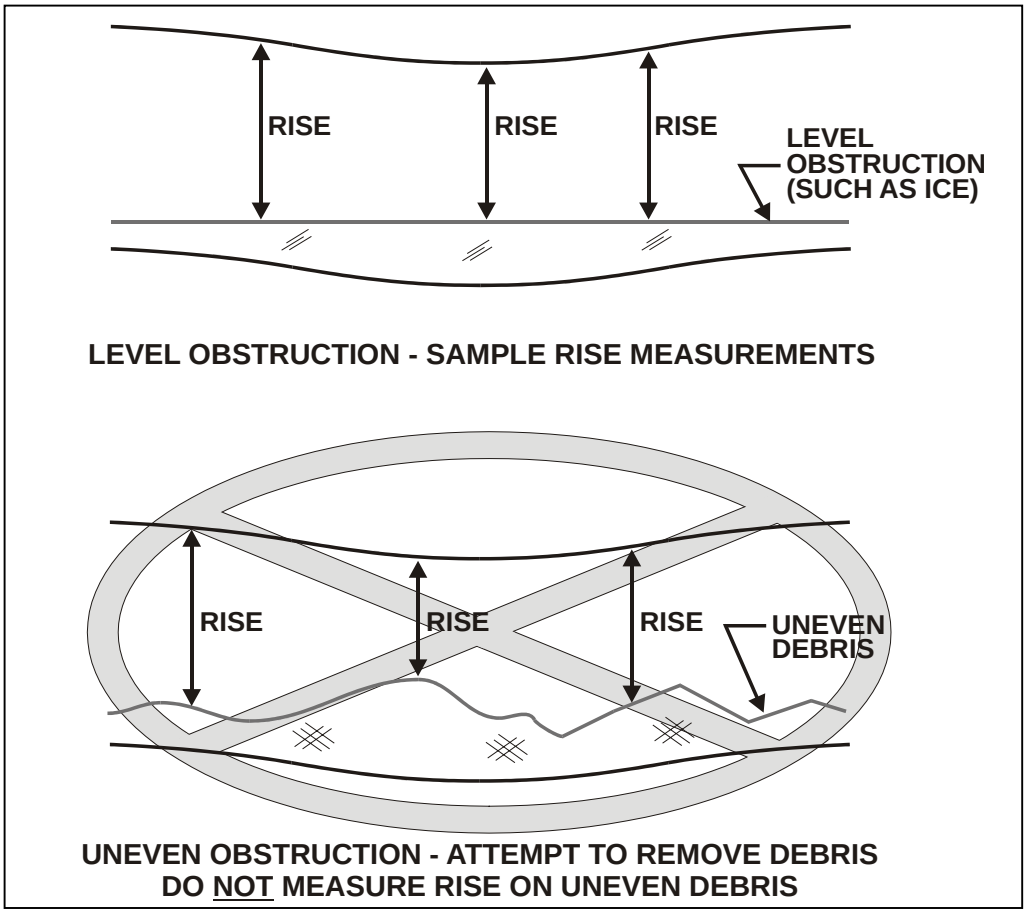

Figure 6.11 – Measurement of Rise with Obstructions

6.4.2.9 Longitudinal Cracks

This section is used for recording information regarding longitudinal cracks in each section of the culvert. The longitudinal seams in SPCSP and riveted CSP culverts are designed to carry the full ring compression in the culvert. They are also required to keep the plates together and aligned, and prevent infiltration of the backfill material.

It is believed that the bending strength of a bolted seam is less than 75% of that of the plates, thus longitudinal cracks may occur along the longitudinal seams in flexible culverts, originating at the bolt holes. Excessive bending strains, improper lapping of plates, and perhaps over-torquing of the bolts can cause longitudinal seams to crack.

A properly lapped seam is one with the bolts in the valley nearer to the visible edge of the plate than the bolts in the crest as in Figure 6.12, 'Correct Lap'. If cracks are found, the ends of the cracks should be marked and dated. The remaining steel between the bolt holes of the largest crack is also measured and recorded as described in Section 6.4.2.9.3.

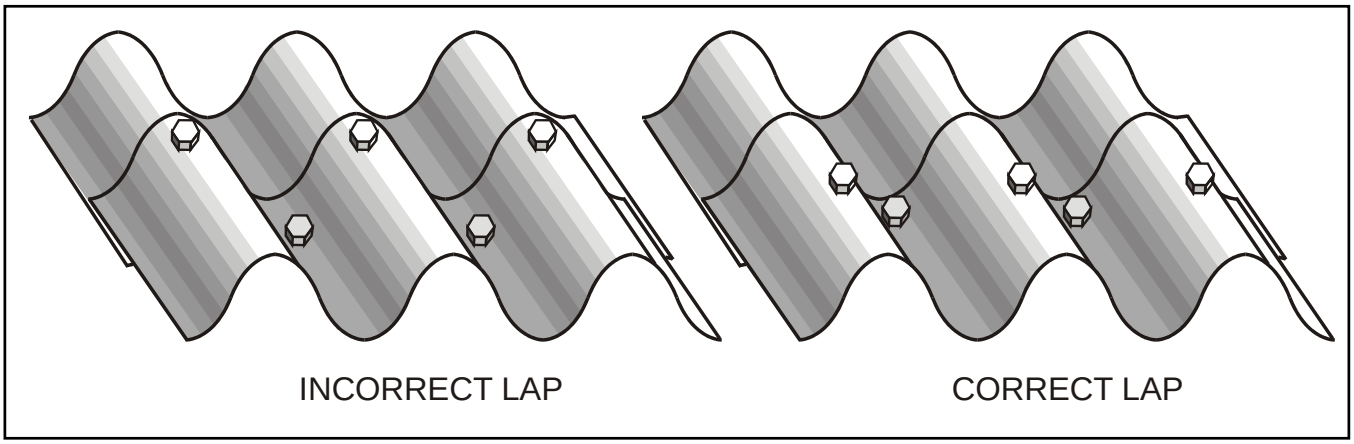

Figure 6.12 – Incorrect and Correct Lapping of Longitudinal Seams in Culverts

6.4.2.9.1 Number of Longitudinal Cracks (Longitudinal Cracks - #)

This is the number of longitudinal seams that are cracked in the ring that is being inspected.

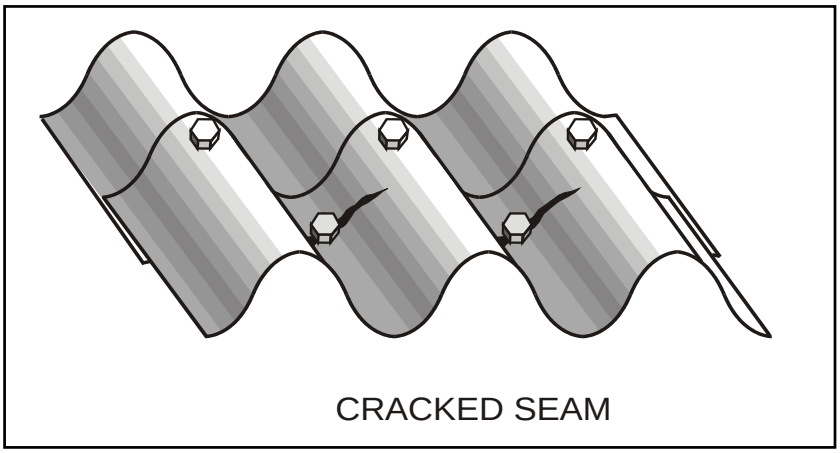

Figure 6.13 – A cracked Longitudinal Seam

6.4.2.9.2 Location of Longitudinal Cracks (Longitudinal Cracks - Location * * *)

This is the location of the cracked longitudinal seams. The face of a clock is used to designate the seam locations when looking downstream. For example, twelve o'clock is straight up, and two o'clock is at the upper right side when facing the downstream end.

This data item also is used to record whether the longitudinal seams are correctly or incorrectly lapped by recording an '**I**' for an incorrect lap, or a '**C**' for a correct lap after the clock number. For example, record '2I' for a cracked seam at 2 o'clock that has an incorrect lap, and '10C' would be recorded for a crack at 10 o'clock with a correct lap. Up to three locations may be entered on the form.

Refer to Section 6.4.2.9 for definitions of incorrectly or correctly lapped seams.

6.4.2.9.3 Minimum Steel Remaining Between Bolts (Longitudinal Cracks - Min St.)

The inspector records the lowest measured steel remaining in millimetres between cracks for all of the cracked longitudinal seams in the ring.

6.4.2.9.4 Number of Cracked Bolts Holes (Longitudinal Cracks - # Blts)

This is the number of bolt holes that have cracks originating from them in a given ring.

6.4.2.10 Comment Lines

There are 4 lines for comments at the bottom of the Inspection Data page. The direction of the ends of the culvert for the first and last rings should be recorded for information and verification. For example, 'Ring 1 = West' and 'Ring 10 = East'. The inspector can also use this area to record any additional comments that relate to the inspection.

6.4.3 BARREL RATING CONDITION SUMMARY (SBM2 RATING SUM.)

This is the General Barrel Condition Rating as determined according to Table 6.1 from the inspection data. The rating for the current inspection will be determined after the inspection data is entered. The ratings from the previous inspection, if entered into the BIM system, will also be displayed.

The inspector shall summarize the Level 2 inspection data for each culvert at the bottom of each Inspection Data Page.

SBM2 Rating Sum.:	%/I	9-7	6/5	4	3	2/1		%/I	9-7	6/5	4	3	2/1
LAST							NOW						

Figure 6.14 – SBM2, Barrel Rating Condition Summary

6.4.3.1 Percent Inspected (%/I)

Record the percent of the culvert pipe that was inspected during this Level 2 inspection to the nearest 5%.

6.4.3.2 Percent of the Inspected Pipe in Each Rating Category (9-7, 6/5, 4, 3, 2/1)

Record the percent of the pipe that falls within each of the rating categories: 9-7, 6-5, 4, 3, 2/1. The rating assigned to each section, and therefore each row on the SBM2 form, will be the lowest rating for that section. The worst case governs the rating.

Since this section only refers to the area of the pipe that was actually inspected, the total from all the rating categories should total 100%, even if less than 100% of the pipe was inspected. These should be recorded to the nearest 5%. A more isolated area may be recorded as 1%.

The crack or deformation criteria for a Level 2 rating at each station is described as follows in Table 6.1:

Level 2 General Barrel Rating	Cracked Longitudinal Seams		Deformation (% of Span or Rise)
	Number	Remaining Steel (mm)	
9-7	0	N/A	No Deformation
6	0	N/A	5% or less
5	0	N/A	More than 5% and not more than 7%
4	1	50 or more	More than 7% and not more than 10%
3	1	Less than 50	More than 10% and not more than 15%
	2	50 or more	
2	2	Less than 50	More than 15% and not more than 20%
1	2	Less than 30	More than 20%
	3+	Any	

Table 6.1 – Level 2 General Barrel Ratings

6.5 OTHER SBM2 ITEMS – LAST PAGE

Refer to Section 1.5 for instructions on completing the last page of the SBM2 form. The last page shares a common format with the other Level 2 forms.

Culvert File Number: ....
Legal Land Location: ...-..-...-..-.
Latitude/Longitude : ...../.....
Road Auth./Region : .../..
Bridge or Town Name: .....
Stream Name : .....
Highway #:Cntrl Sec: ....:...
Road Classification: .....-...
AADT/Year : .-...../..
Detour Length : ...km

Structure Usage : ..
Year Built : ../..
Clear Roadway/Skew: ....m/...Deg

Prev. Insp. Date : ____/__/__ (YMD)
Insp. Req'd Date : ____/__/__ (YMD)
(based on _____)

Current Insp. Date: ____/__/__ (YMD)
Inspector's Code : ____

CULVERT INFORMATION:

Number of Culverts ..

Pipe Num.	Design Span (or Dia.)/Rise	Type	Length	Corrugation Profile	Plate Thickness
1	..... x ..... mm	...	.....m	....x....mm	.../.../...mm
2	..... x ..... mm	...	.....m	....x....mm	.../.../...mm
3	..... x ..... mm	...	.....m	....x....mm	.../.../...mm

Pipe Num.	# of Rings	Top Arc Radius	Top Arc N	Side Arc Radius	Side Arc N	Bottom Arc Radius	Bottom Arc N	Corner Arc Radius	Corner Arc N
1	...	.....mm	...	.....mm	...	.....mm	...	.....mm	...
2	...	.....mm	...	.....mm	...	.....mm	...	.....mm	...
3	...	.....mm	...	.....mm	...	.....mm	...	.....mm	...

Special Features: .....
_____
_____

SUMMARY INSPECTION INFORMATION:

Total Number of Pipes (or segments) Measured: _____

Pipe No.	Measured (Y/N)	No. of Measurements	No. of Rings Measured
1	_	___	___
2	_	___	___
3	_	___	___

Comments:

Inspection Data Notes:
* Barrel station measured from left end of barrel (not including bevel)
** Crack Location measured clockwise looking in direction of increasing station.
Example - 2I,10C for 2 o'clock incorrect lap & 10 o'clock correct lap

INSPECTION DATA: Pipe No.: _ No. of Measurements: ___ Rings Measured: ___

	Rng No.	Ring Len. (m)	Stn. (m) *	Span (mm)	Def. %	Rise (mm)	Sag %	I C E	Longitudinal Cracks					
									#	Location ***			Min St.	# Blts
Last														
Now														
Last														
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Comments:														

SBM2 Rating Sum.:	%/I	9-7	6/5	4	3	2/1		%/I	9-7	6/5	4	3	2/1
LAST							NOW						

LEVEL 1 INSPECTION (INFORMATION ONLY) Level 1 date: ____/__/__

Structural Condition Rating: __% Sufficiency Rating: __% Estimated Remaining Life of Structure: __ years Special Comments for Next Inspection:
Next Scheduled Level 1 inspection: ____/__/__ Current Cycle: __months

ITEMS REQUIRING IMMEDIATE ATTENTION:

LEVEL 2 INSPECTION SPECIAL REQUIREMENTS:

Y => Snooper: __ Lift: __ Traffic control: __ Boat: __ Ladder: __ Other: _____

INSPECTOR:

Recommended Cycle __ months OR Next Insp. Date ____/__/__ (blank for default) Recommended Additional Cycles: _ (blank for default, 0 for discontinue)		
Inspector's Code: ___	Inspector's Name: _____	Class: _
Assistant's Code: ___ Assistant's Code: ___	Assistant's Name: _____ Assistant's Name: _____	Class: _ Class: _
Comments: _____ _____		

REVIEWER: Review Date: ____/__/__

Approved Cycle __ months OR Next Insp. Date ____/__/__ (blank for default) Approved Additional Cycle: _ (blank for default, 0 for discontinue)\		
Reviewer's Code: ___	Reviewer's Name:_____	Class: _
Comments: _____ _____		
Default No. of Inspections: _ Default Cycle: __ months	Number completed to date: __ Next Inspection Required Date ____/__/__	