Figure 6-13: A live check dam on a soil slope, about 2 months after completion

Figure 6-14: Live check dams about 3 months after completion, on a mixed debris slope

Planting method for potted tree seedlings

Potted seedlings from a forest nursery are planted at intervals across a soil slope.

- The desired quantity of potted seedlings, plus a 10% contingency, must be obtained from a well managed nursery. They must be healthy, undamaged and of a size appropriate to the specifications (usually 400 to 600 mm).
- When the ground is wet enough to support reasonable growth, the seedlings should be planted out.
- Pits should be dug that are at least 300 mm deep and 300 mm in diameter. The bigger the hole made, the better it is for the plant; but there must be a compromise between helping the plant and avoiding excessive disturbance to the slope.
- The pot must be removed carefully. If it is a polythene bag type, it should be sliced down the side with a razor blade, or torn carefully along the seam. Care must always be taken not to cut or damage the roots.
- The seedling is then planted in the pit, filling the soil carefully around the cylinder of roots and soil from the pot, and ensuring that there are no voids or cavities. The soil is firmed all around the seedling with gentle foot pressure.
- If available, a few handfuls of well-rotted compost should be mixed with the soil around the roots when backfilling the hole.
- Any weeds around the plant should be removed. Mulch should be added around the seedling, but with a slight gap so that it does not touch the stem.

Planting method for large bamboo planting

A section of the stem and root of a large bamboo is planted, usually at the base of a slope, on a stream bank or above a river training wall. It is about 2 metres in length.

- The method involves taking a very large rhizome and culm cutting, as is done for small grasses. Source clumps should be identified well in advance and an agreement reached with the owners.
- On the planting day, a suitable culm (stem) near the edge of the parent clump is selected and the rhizome (root) carefully dug out. The rhizome is cut where it branches from the main plant, to give at least 500 mm of rhizomatous root. Great care must be taken not to damage the buds and small roots. The culm is cut off about 2 metres above ground level.
- The root ball is wrapped in damp hessian jute and the big cutting transported to site for planting on the same day.
- A large hole (at least five times the size of the cutting's rhizome) is dug and the rhizome planted either upright or at right angles to the slope.
- The hole is carefully backfilled and the soil firmed as much as possible.
- The disturbed and surrounding soil is mulched well.
- A depression is formed around the roots to act as a water collection area. It should be watered thoroughly after planting and daily thereafter until rainfall is reliable.

APPENDIX A: SOURCES OF FURTHER INFORMATION

The references given below are just a few that the reader might find useful further reading with respect to slope stabilisation.

BS 8002:1994 *Code of practice for earth retaining structures*. British Standards Institution, UK

FOOKES, P.G, SWEENEY, M, MANBY, C.N.D, and MARTIN, R.P, 1985 *Geological and geotechnical aspects of low cost roads in mountainous terrain.* Engineering Geology, 21, 1/2 1 - 52.

GEOTECHNICAL CONTROL OFFICE 1984 *Geotechnical manual for slopes.* Civil Engineering Department, Hong Kong

GEOTECHNICAL CONTROL OFFICE 1993 *Geoguide 1. Guide to retaining wall design*. Civil Engineering Department, Hong Kong

GEOTECHNICAL ENGINEERING OFFICE 2000 *Highway Slope Maintenance.* Civil Engineering Department, Hong Kong

HOWELL, J.H, 1999 *Roadside Bio-engineering. Site Handbook and Reference Manual*. Department of Roads, Kathmandu, Nepal.

OVERSEAS ROAD NOTE 16, 1997. *Principles of low cost road engineering in mountainous terrain.* Transport Research Laboratory, UK.

SCHAFFNER, U 1987 *Road construction in the Nepal Himalaya. The experience from the Lamosangu - Jiri Road Project.* ICIMOD Occasional Paper No 8. International Centre for Integrated Mountain Development, Kathmandu, Nepal.

TURNER, A.K and SCHUSTER, R.L, 1996 *Landslides: Investigation and Mitigation*. TRB Special Report 247. Washington D.C. Transportation Research Board.

APPENDIX B: EXAMPLES OF SLOPE STABILISATION

Before considering typical applications, it is probably worth reiterating some points common to all types of failures

Firstly, the initial question that should be asked is - why has this particular location failed and not the adjoining sections? Usually, but not necessarily always, the answer involves water. It is therefore essential to locate the causes of the ingress of water into the failed area. If this arises from a drainage feature at or behind the crest of the failure, then the solution should incorporate every means to redirect the water away from the crest altogether or, if this is not practicable, to redirect the water down the edge of the failed area or to depress the water table within the failed mass using counterfort or drilled horizontal drains. If the water is causing more of an erosional problem due to seepage, then the solution might be to use herringbone drains or revetments or bio-engineering or a combination of these.

Secondly, thought then needs to be given to the two other most effective means of slope stabilisation; re-grading to reduce the steepness of the slope and toe weight - either by the construction of a toe berm or a retaining wall. Re-grading is usually only an option where the failure involves a cut or fill slope, but in steep side-long ground this may not be practicable. The construction of a toe berm, preferably using free-draining material, is a cheap option but not often possible due to lack of space. This then leaves the final option of a wall, and the advantages and disadvantages of the various types of construction are described in 4.3.

B.1 Failures above the road

B.1.1 Failures in colluvium

As noted in Section 2, one of the most common forms of slope instability is above-road planar failures in colluvium, usually with a failure surface limited by a competent underlying stratum such as bedrock, and daylighting adjacent to the road. Figure B-1 Case A shows a typical example in cross section, with an assumed failure surface and an assumed water table at failure, based on site observations (or perhaps in the case of a major failure, a ground investigation).

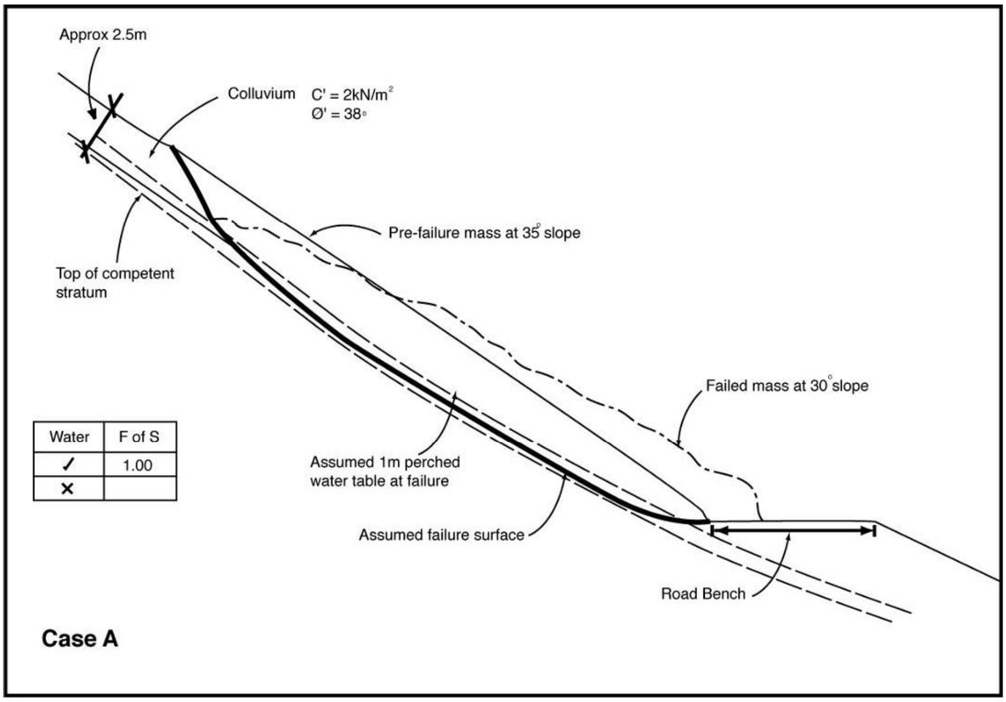
In the absence of reliable shear strength testing, shear strength parameters of $c' = 2$ kN/m^2 and $\phi' = 38°$ are assumed for the predominantly bouldery colluvium and by a process of trial and error with adjustments to the shape and depth of failure surface and the water table, a plausible mode of failure with a factor of safety of approximately 1.0 is obtained.

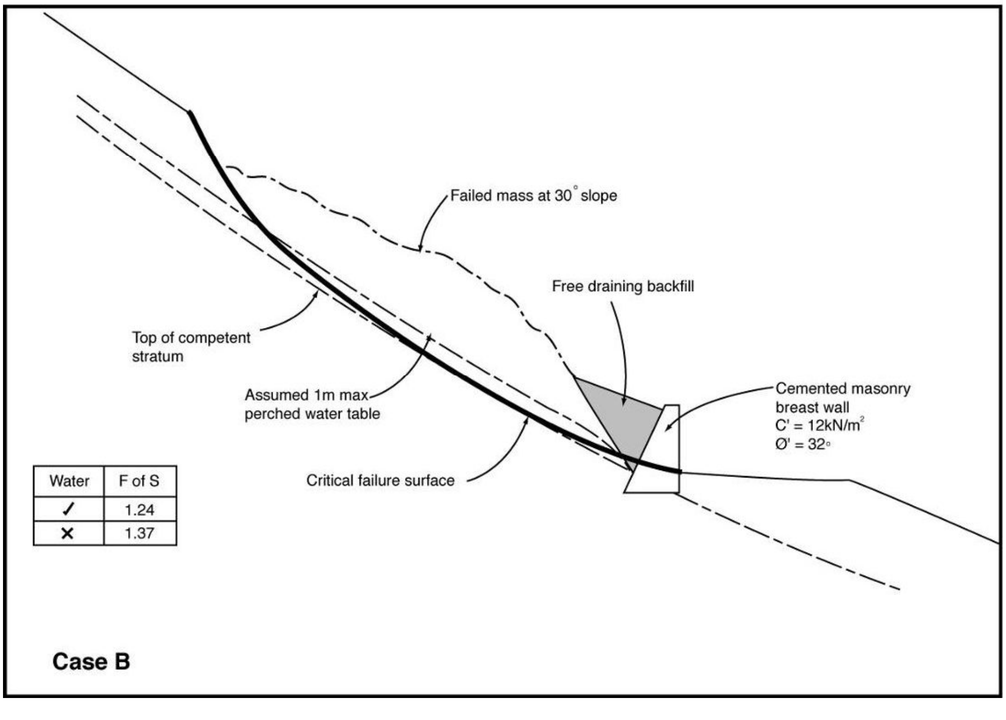
In view of the limited space at the base of the slope, the most appropriate stabilisation measures are likely to be water table lowering and a retaining wall at the toe.

With the assumed addition of a retaining wall, it is necessary to check the factors of safety for failure surfaces passing through or beneath the wall and, in this case, for a masonry wall, shear strength parameters of $c' = 12$kN/m^2 and $\phi' = 32°$ are considered appropriate (Case B). It can be seen that if the water table assumptions remain the same, this results in an increased factor of safety of 1.24. A separate analysis is necessary to check the stability of the retaining wall itself. If further measures are introduced to lower the assumed water table at failure by diverting the source of the water (if applicable) or by means of improved surface drainage (e.g. herringbone or horizontal drains), then the factor of safety of the slope could increase to as much as 1.37 depending on the effectiveness of the water table lowering measures.

Despite the many assumptions that this type of analysis requires in the absence of a detailed (and expensive) ground investigation and laboratory testing programme, it does provide a technical basis for the many engineering judgements that have to be made on site, and should be carried out wherever possible.

Figure B-1: Typical planar failure in colluvium





B.1.2 Failures in residual soils/weathered rock

Figure B-2 shows a feeder road in Nepal about five years after construction with cut slopes at 45° in residual soil and displaying no signs of instability or undue erosion.

By contrast, above-road failures in residual soils/weathered rock in Laos are very commonly seen where the cut slope has been formed at too steep an angle.

Figure B-2: Example of good cut slope construction

B.2 Failures below the road

B.2.1 Failures in loose fill slopes

As noted in section 2.1.2, road construction in Laos (and elsewhere) has often involved the formation of the road predominantly in cut and to dump the excess spoil as loose fill on the natural slopes below. Occasionally the road itself is formed partly on this loose fill, of which only the road formation itself might receive some form of compaction. Often the loose fill will consolidate and become covered in vegetation over a period of time, thus concealing its true nature, leading to below-road retaining walls inadvertently being founded within the fill layer. Sometimes the loose fill will continue to fail and erode, creating unsightly erosion scars and endangering the stability of adjacent road and the underlying natural ground, particularly if this comprises colluvium.

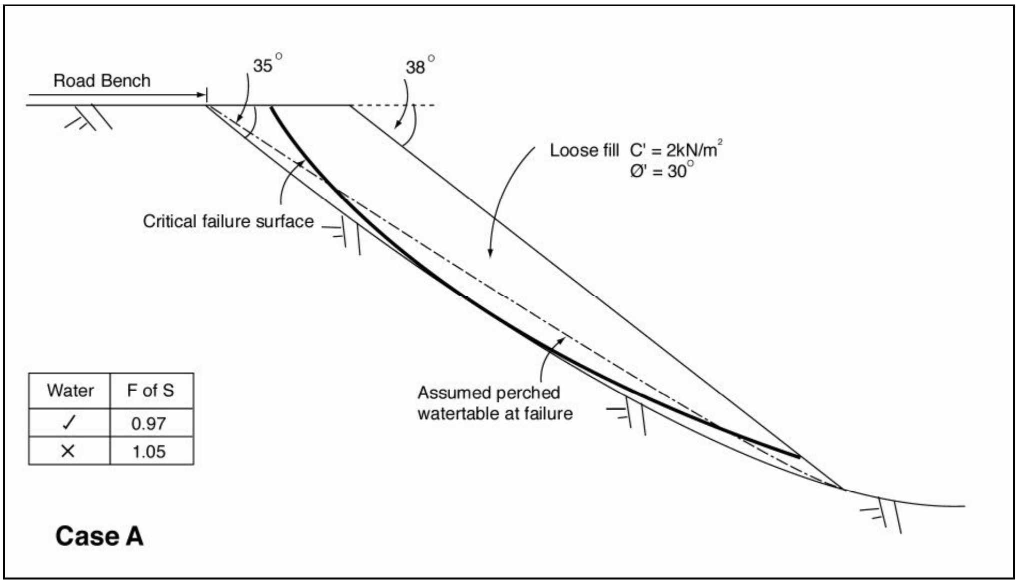
Figure B-3, Case A takes the case of a loose fill slope with an exposed slope angle of 38° (which is very commonly observed), overlying a natural slope of 35°. In its loose state, the shear strength parameters of the fill are assumed to be $c' = 2$ kN/m^2 and $\phi' = 30°$; in its compacted state these are assumed to increase to $c' = 2$kN/m^2 and $\phi' = 35°$.

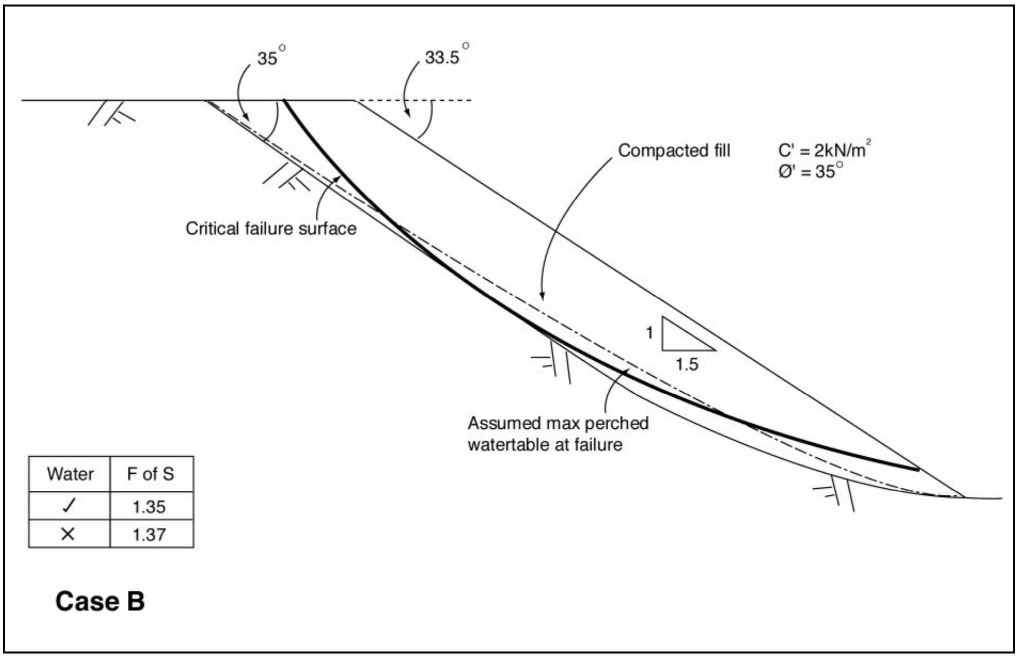
Due to its loose state, rainwater will rapidly percolate through the fill and possibly form a perched water table on the surface of the underlying natural ground. The factor of safety drops from just above unity to just below unity.

Had the fill been properly benched into the underlying ground and compacted throughout (Case B), then only considering a failure surface within the compacted fill indicates a factor of safety of more than 1.3, even with the assumption of a perched groundwater table - now very unlikely due to the greater impermeability of the compacted fill and the creation of benching to break up the interface between the fill and the natural ground. Of course, in considering the stability of the entire slope, further trial failure surfaces would need to be examined passing through the underlying natural ground. Nonetheless, this example does serve to demonstrate the importance of compacting fill slopes, and of the inherent instability of dumped loose fill.

In terms of stabilisation of existing loose fill slopes, there is very little that can be economically justified in terms of the road network If the road itself is being threatened, then the construction of a below-road retaining wall may be necessary, the wall foundation being taken down through the fill to a competent underlying stratum. Bio-engineering measures in the loose fill below the wall may also help to aid stability and reduce the prospects for erosion. If the road is not threatened, then bio-engineering measures alone, particularly for shallow fills, may be appropriate.

Figure B-3: Typical failure in fill





B.2.2 Failures in natural ground

Where failures occur in the natural ground, they are often due to a wider scale instability, such as that indicated in Figure B-4 or failures of greater complexity. Such failures may be above, below or encompass the road and may require very detailed investigation and analysis. However, some failures below the road may arise from uncontrolled road surface runoff.

In the latter case, such failures may not be appropriate for detailed analysis. The most important factor is to ensure that the uncontrolled disposal of water downslope is prevented in future. If uncontrolled roadside drainage cannot be guaranteed, then it might be appropriate to form an upstand at the valley side edge of the road to contain the water until it can be discharged safely downslope, preferably into a natural drainage course.

As far as any erosion scar itself is concerned, if the road is threatened then a roadside retaining wall may be necessary, the rehabilitation of the eroded surface downslope best tackled using bio-engineering techniques.

B.3 Failures cutting through the entire road bench

Figure B-4 Case A shows a typical example of a “sinking area” in cross-section. Essentially these failures are usually identical to the type of failure dealt with in B.1.1 except that they have a deeper failure surface, often 5-10 metres below ground level.

The main cause of failure can be twofold; either excess water entering the unstable area at its crest, or removal of toe support due to high level river stages or course changes at its base, or a combination of the two. This example assumes a moderate groundwater table and toe support removal and the same shear strength parameters as B.1.1. In practice, many of these large-scale, deep seated landslides are controlled by adverse geological structures.

If nothing is done to stabilise the slope, movement down slope will occur during the next period of prolonged heavy rainfall, the material accumulating at the toe being removed by the next high river stage. As a consequence any support at the toe will have to be designed to act as a stream/river scour protection as well as a gravity retaining wall. This type of failure is usually very costly to stabilise.

Figure B-4, Case B shows the effect of a major 8m high toe support gabion wall and the consequent increase in factor of safety to only 1.06. This small increase in factor of safety is not uncommon in this type of circumstance, primarily due to the large scale nature of the landslide. However, the prime effect of the wall is to prevent, or at least reduce the incidence of progressive failure, bringing about a gradual stabilisation of the entire slope and to prevent continuing river scour. Further increases in factor of safety will be brought about by additional measures to reduce peak groundwater levels.

Figure B-4 also highlights the difficulty of constructing a satisfactory retaining wall immediately above or below the road, so that the base of the wall is adequately founded in intact material below the failure surface.

There are likely to be similar cases where the scale of the failure is so large (e.g. affecting several hundred metres of road) and the potential cost of the stabilisation measures so high that remedial work cannot be contemplated for the immediate future. There will be other cases where some movement has occurred, but not to any significant extent.

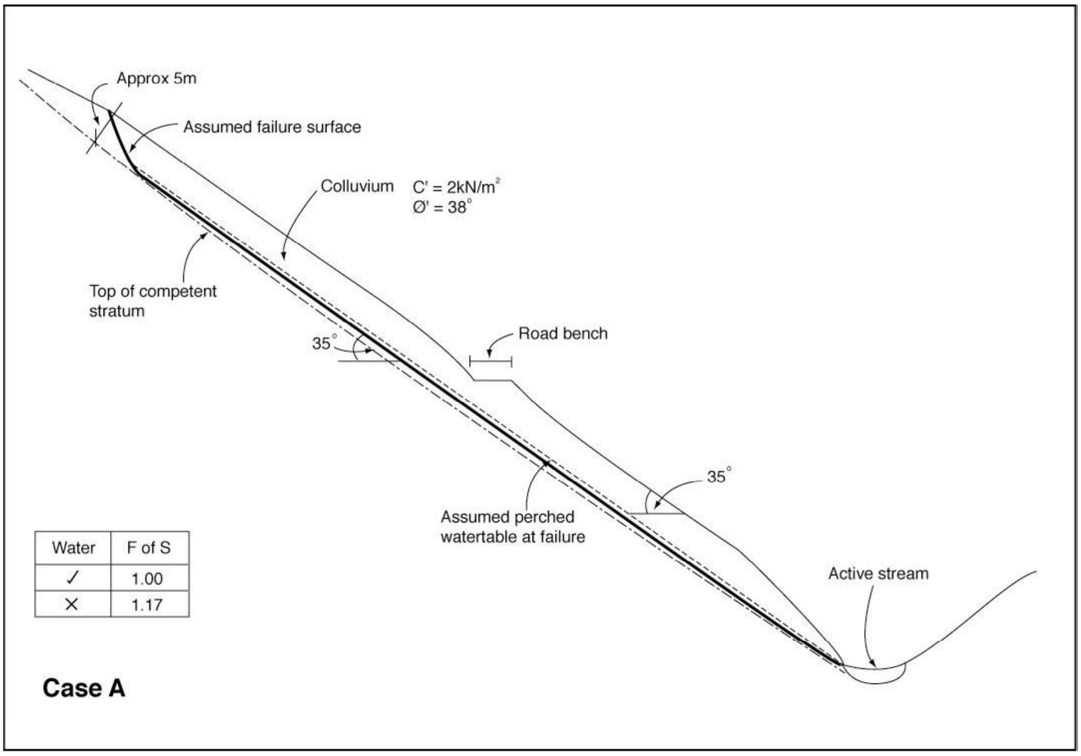
In both cases it is strongly recommended that road movements are monitored before and after each wet season to check whether the movements are accelerating or relatively static (see Section 3.5), so that future stabilisation measures can be properly assessed and prioritised.

There will be instances where the scale of the failure is so large and the depth of movement so great that the only long-term economic course of action is to search for an alternative alignment and abandon the affected section of road. In these cases, the environmental and social consequences of abandoning the existing road need very careful consideration, and the new alignment carefully investigated, designed and constructed to ensure that the same problems are not encountered or initiated.

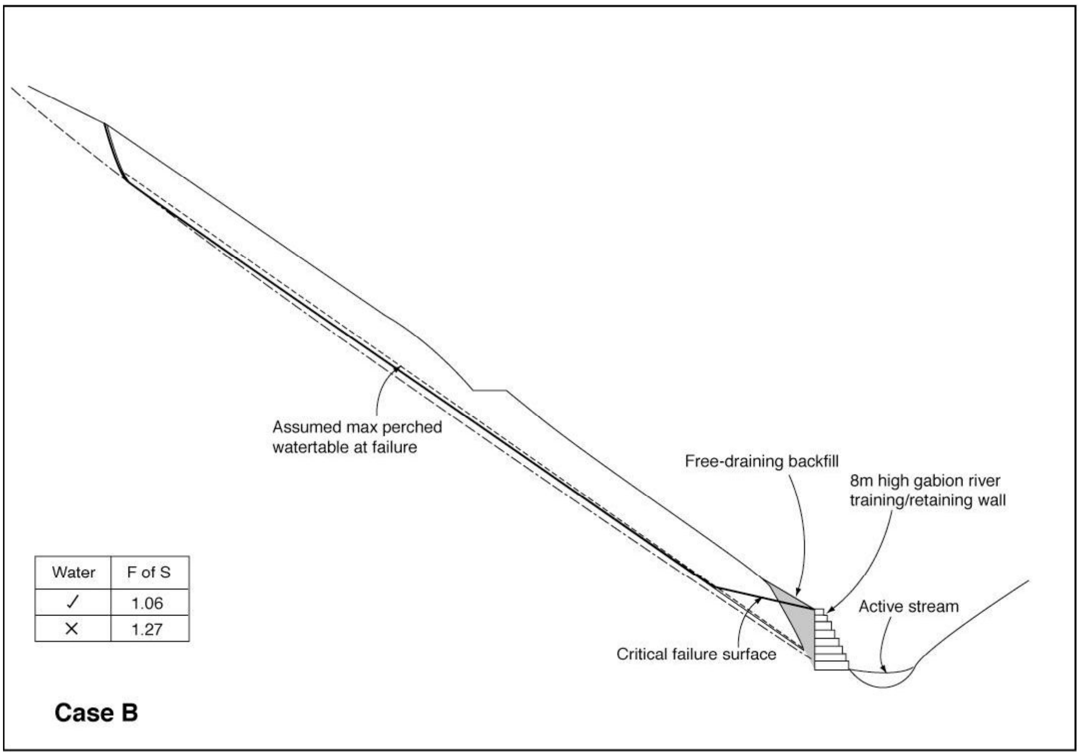
B.4 Wall failures

As noted in Section 2.3, wall failures due solely to an inadequacy of the structural integrity of the wall itself are comparatively rare in Laos. “Sinking” areas accepted, wall failures above the road are much more likely to be due to overloading from the retained ground, whereas wall failures below the road do appear to be the result of inadequate founding (e.g. the wall has not been founded on a competent stratum) or soil erosion (e.g. the toe of the wall has become exposed and under-scoured). In both cases the remedy will usually be to increase the depth of the foundation, either by underpinning or by total reconstruction.

Figure B-4: Typical translational or planar failure through road bench



Water	F of S
✓	1.00
×	1.17



Water	F of S
✓	1.06
×	1.27

APPENDIX C: SLOPE MAINTENANCE REPORT FORMS

C.1 Landslide Report Form

C.2 Retaining Wall Report Form

Examples of completed forms can be found in the Slope Maintenance Site Handbook

LANDSLIDE REPORT

Location (road and km):	
Date of report:	Reporter's name:

Situation		Material		Blockage		Failure	
Above road		Rock		Whole road		Whole road	
Below road		Debris		Part of road		Part of road	
Through road		Soil		Side drain only		Side drain only	

Geometry of slipped area			Topography	
Length (perpendicular to road)	m		Original slope angle	
Width (parallel to road)	m		Failure angle	
Depth (estimated)	m			
Estimated volume (L x W x D)	m^3		Associated retaining wall	

Sketch of failure/additional notes:

Probable cause of failure:

Consequences if nothing done:

WALL REPORT

Location (road and km):

Date of report:	Reporter's name:

Situation		Type		Nature of distress		Distress due to:	
Above road		Mortared masonry		Cracking		Sliding	
Below road		Composite masonry		Tilting		Overturning	
		Gabion		Bulging		Sinking	
		Other (name)				Slope failure	

Geometry			Shape			
				Sloping	Vert	Horiz
Affected length (parallel to road)	m					
Total length	m		Front face			
Width at base	m		Back face			
Height	m		Base			

Sketch of failure/additional notes:

Probable cause of failure:

Consequences if nothing done:

APPENDIX D: LANDSLIDE MAPPING PROCEDURE

The procedure described below is a standard way of assessing the response to a slope failure. It describes the way in which landslides should be assessed in order to determine the seriousness of a failure. The forms given in Appendix C may be used with this procedure.

Procedure for the mapping of large and complex landslides

Procedural steps		**Action**
Stage 1	Initial observations of the geomorphology. Look at the general locality and situation of the site: • make a note of the exact location so that you can direct others to the site if necessary; • see if it is in a part of the landscape where instability would be expected; • see if the joint orientation of the rocks, outcropping on the hillside around the site, indicate that the cause of the failure may be due to rock structure, either as planes of weakness or movement of water along fractures; • look at other sites in the area: they may have a similar geomorphic situation and a similar life progression.	**Observe**
Stage 2	Sketch the site from the road or other good observation point	
(a)	Draw the main features: • concentrate on getting the general proportions correct; • estimate the length from top to bottom: record this on the drawing; • estimate the width across the base: record this; • sometimes the landslide may be very complex, and some additional sub-drawings may help.	**Draw**
(b)	Look for the landslide zones: • scar; • transport; • debris. Note that you cannot yet see whether there is a zone of cracking above the scar. You do not have to record these zones on the drawing, but the completed drawing should be sufficiently well illustrated and labelled to let another person recognise which zones are present and where they are.	**Draw**
(c)	Examine the material forming the original hill slope: • debris; • soft rock; • hard rock; • alternating hard and soft rocks. All of these could be present on one landslide. The drawing should show where they are. You will have to check your classes during the site walkover (Stage 3b).	**Describe and draw**
(d)	Sketch a slope profile of the site from top to bottom. Angles do not have to be precise, but should indicate relative steepness. It can be augmented with more detail (e.g. with slope measurements) as you walk up the slide. Note that slopes >35° can be unstable unless composed of solid rock.	**Draw**
(e)	Sketch the surface water drainage: • streams; • any springs that may be visible from where you are standing.	**Draw**
(f)	Sketch areas of rock outcrop.	**Draw**
(g)	Landmarks: note any obvious landmarks on the site, such as prominent trees. This will help you to keep your bearings as you walk over and around the site.	**Draw**

Procedural steps		Action
Stage 3	Walkover survey	
(a)	Walk up the centre of the slide to the crown (head of scar). Measure the angles of major slope units. If the slope is too steep or dangerous, walk around the edge, looking into the scar.	**Measure**
(b)	Rock: visit each rock outcrop. Measure any relevant rock planes or observe how the planes relate to the slope and failure planes. Make sure that the rocks observed are true outcrops (attached to solid rock beneath) and not simply large boulders partly buried on the slope. Check the weathering grade: • hard rock is from weathering grades 1 to 4 and often rings when struck with a hammer); • soft rock is in weathering grade 5 or greater, and gives a dull thud when struck with a hammer). Note the: • uniformity or layering (bedding) of the rock units; • degree of weathering (hardness and discoloration of minerals) of the rocks; • degree of fracturing/jointing, especially any open fractures/joints; • signs of water movement along fractures.	**Measure and describe**
(c)	Debris and slope: indicate the area of the slide that is occupied by debris: • location and extent of landslide debris; • composition of debris; • wetness of debris; • depth of debris / depth of failure plane; • location, orientation and size of any cracks in the debris or on the slope; • any back-tilted slope, where water may collect (if this is present, it indicates a deep-seated circular failure – a shear failure); • tilted trees: these can indicate subsiding ground; • disrupted engineering structures, e.g. masonry surface drains; • points of ground water seepage.	**Describe and draw**
(d)	Margins and top. Look for the following. • Cracks in the ground: cracks are most frequent above the head of a slide, but they often occur also around the sides. The presence of cracks shows that the ground is under tension and that it will probably fail, and soon. Note the location, dimensions and orientation of the cracks. This information tells you where, and in which direction, the ground is under tension. The area of cracking tells you the area over which failure is taking place; • Streams, springs, irrigation channels or drainage structures, especially masonry drainage ditches. These features may be sending water into the slide. They may either have caused it in the first place, or they may be contributing to further failure. Irrigation channels and masonry drainage ditches should be inspected closely for any signs of cracking and leakage; • Irregular topography, not due to rock outcrops. This may indicate the presence of an old landslide, in which case you will have to survey the whole of this, too. Continue walking up the slope above the landslide until there is no further evidence of instability. This may mean walking at least fifty metres higher than the landslide scar, and much further if necessary.	**Draw**
(e)	Base of the slide: describe the features and ground conditions at the base. Possibilities are as follows. • Intact road. Instability is from above only. The road may be buried but the road itself is not disrupted by the slide plane. Note: if the road is disturbed, the road cannot be at the base and the slope condition at the base must come under one of the three categories below. • Stable, undisturbed hill slope. • Unstable hill slope. Cracked ground, landslide or topography that collects water. • Stream, with a possible risk of bank erosion and undercutting of slope.	**Describe**

Procedural steps		**Action**
Stage 4	General assessment	
(a)	Causes and mechanisms of instability. Based on your observations, assess whether any part of the failure is due to the following causes. Mark them on your plan of the site. Surface water • Erosion, or soaking of surface to cause shallow sliding. • Effects of water infiltrating from surface. Causes shallow failures. Ground water • Ground water causes increased pore water pressure at depth. • Failure plane is often deeper than in surface water failure. Weathering • Rock shear strength is reduced by weathering. Rock strength is reduced as constituent minerals are broken down into weathering products and clay minerals. Physical bonds between rock constituents are weakened or broken. The rock can fail along weakened fracture planes or through its body (mass). Undercutting • Slope is undercut by a flowing stream or by the opening up of a road cutting. • Incision (downcutting) or lateral scour by streams is a major cause of slope failure. The initial failure can work rapidly up slope. Addition of weight • Weight added usually by landslide debris from above or by the dumping of spoil, or the construction of a road fill.	**Describe**
(b)	History and life progression of slide. Assess the likely evolution of the slide from its current condition into the future. Possibilities are as follows. • Stable slope formed, or will stabilise naturally • Single failure to stable rock plane or stable slope configuration. This is a relatively rare situation. • Further movement is expected, by a less serious mechanism. 'Less serious mechanism' means a movement at a depth shallower than that of the original failure. This means that the instability is going through post-slide adjustment. • Repeated movement expected, by the initial mechanism or another equally serious. • Further movement is expected, by a more serious mechanism. 'More serious mechanism' means a movement at a greater depth than that involved in the original failure, or a mass movement involving a different cause or mechanism.	**Describe**
(c)	Severity of instability Fill in the Check List for Assessing Severity of Slope Instability (see below). This does not quantify the severity (it is still impossible to do so in a way which permits meaningful comparisons) but allows you to assess the severity rapidly. On the check list, the criteria in each category get progressively larger, more difficult and harder to rectify. Therefore in assessing severity, you should look at how far down each list you have ticked each of the twelve categories.	**Check list**

Procedural steps		**Action**
Stage 5 Determination of site treatment		
You should now have as much information as you are able to obtain from a straightforward site investigation without specialist advice and equipment.		**Refer to diagnostic table below**
Question	**Functional implication**	**Action if the answer is "yes"**
Is the site subject to a deep-seated (several metres depth and usually failing through rock) shear or rotational failure?	Major reinforcing, anchoring or physical support required.	If the failure plane can be identified, use retaining walls to support the toe. Alternatively, it may be possible to remove weight from higher up the slope by debris removal/heavy trimming.
Is the slope very long (greater than about 30 metres), steep and in danger of a mass failure?	Reinforcing or physical support is required. Armouring is also required.	If suitable foundations are available, use retaining walls to break the slope into smaller, more stable lengths.
Is the foot of the slope undermined, threatening the whole slope above?	Strong physical support is required.	Consider the necessity of building revetment, toe or prop walls.
Is there a distinct overhang or are there large boulders poorly supported by a soft, eroding band?	Localised physical support or anchoring are required.	Consider prop walls or dentition work to support the overhang.
Does the slope have a rough surface; or is it covered in loose debris; or is it a fractured rocky slope; or does it have any very steep or overhanging sections, however small?	*Armouring is required, but only after the slope has been altered to stop it shedding loose material.*	Trim the slope as far as possible to attain a smooth, clean surface with a straight profile in cross-section.
Is there water seepage, a spring or groundwater on the site, or a danger of mass slumping after heavy rain?	Deep drainage is required.	Consider the advisability of a surface or sub-surface drainage system, depending on site conditions.
Is the slope made up of poorly drained material, with a high clay content?	Techniques used on this sort of material must be designed to drain rather than accumulate moisture.	There is a danger of shallow slumping. Investigate the need for a surface or sub-surface drainage system, depending on site conditions.
Is the site a major gully, subject to occasional erosive torrents of water?	Major drainage is already present; heavy armouring is required.	Use masonry check dams to reduce the scouring effect.
Stage 6 **Implementation of site treatment**		
It should now be possible to move to the detailed survey of the site, so that you can assess the exact position and quantities of the structures that you require. These can then be designed on the basis of the national standards, and the works tendered and implemented in the usual ways. It is recommended that all significant failures are examined by an appropriately qualified and experienced engineering geologist before stabilisation measures are scheduled and designed.		**Refer to standard engineering design drawings**

Check list for assessing severity of slope instability

Within each section of this check list, the conditions are described in order of increasing severity. A site that can be described by the first category in each section is relatively mild and straightforward to stabilise. A site that is described by the last category in each section is a very severe problem, often requiring large-scale civil engineering works to repair.

Road: .... **Chainage:** .... **Observer:** .... **Date:** ....

1 LOCATION OF SLIDE

- ☐ Off road alignment but within MPWT responsibility
- ☐ Above road - any distance
- ☐ Below road - any distance
- ☐ Between roads, *i.e.* above one road and below another
- ☐ Through road (slide is above and below road)

2 TYPE OF SLOPE AFFECTED

- ☐ Road cutting but not hill slope
- ☐ Hill slope but not road cutting
- ☐ Road cutting plus hill slope
- ☐ Embankment, fill or spoil slope

3 SLOPE CONDITIONS ABOVE SLIDE (above road, if road is at top of slide)

- ☐ Crest of ridge, or gentle slope (less than 35°)
- ☐ Stable, undisturbed hill slope
- ☐ Unstable hill slope. Cracked ground, another landslide or topography that collects water
- ☐ Cut-off drain or take-out drain

4 SLOPE CONDITIONS BELOW SLIDE (or below road, if road is at base)

- ☐ Stable, undisturbed hill slope
- ☐ Intact road at base of slide (road may be buried, but if it is disturbed, road is **not** at base)
- ☐ Unstable hill slope. Cracks, landslide or topography collecting water
- ☐ Stream

5 GENERAL TYPE OF FAILURE

- ☐ Erosion, rilling or gullying up to 2 m deep
- ☐ Gully more than 2 m deep
- ☐ Mass movement (slide, flow or fall)

6 MATERIAL FORMING ORIGINAL (FAILED) SLOPE

- ☐ Debris, colluvium or alluvium
- ☐ Soft rock (weathering grade 5 or equivalent)
- ☐ Hard rock (weathering grades 1 - 4)
- ☐ Alternating hard and soft rocks

7 FAILURE MECHANISM

- ☐ Erosion (rill, gully or pipe)
- ☐ Plane failure in rock (slide, fall)
- ☐ Collapse (fall with disintegration)
- ☐ Flow or shear failure (slump or slide)
- ☐ Undermining

8 CAUSE OF FAILURE

- ☐ Surface water. Erosion, or soaking of surface: shallow slide/flow
- ☐ Ground water, causing increased pore water pressure at depth
- ☐ Addition of spoil or landslide debris
- ☐ Weathering
- ☐ Undercutting of slope by stream or road cutting

9 DEPTH OF FAILURE

- ☐ Less than 25 mm Erosion
- ☐ 25 - 100 mm }
- ☐ 100 - 250 mm } Slide, slump,
- ☐ 250 - 1000 mm } flow or fall
- ☐ More than 1000 mm }

10 LENGTH OF FAILURE (top to bottom)

- ☐ Up to 15 m
- ☐ 15 - 75 m
- ☐ 75 - 150 m
- ☐ More than 150 m

11 HISTORY OF SLIDE

- ☐ Not moved within the last 5 years
- ☐ Moved within the last 5 years but not this year
- ☐ Moved this year for the first time
- ☐ Moves every year by initial mechanism - diminishing
- ☐ Moves every year by initial mechanism - constant or getting worse

12 LIFE PROGRESSION OF SLIDE

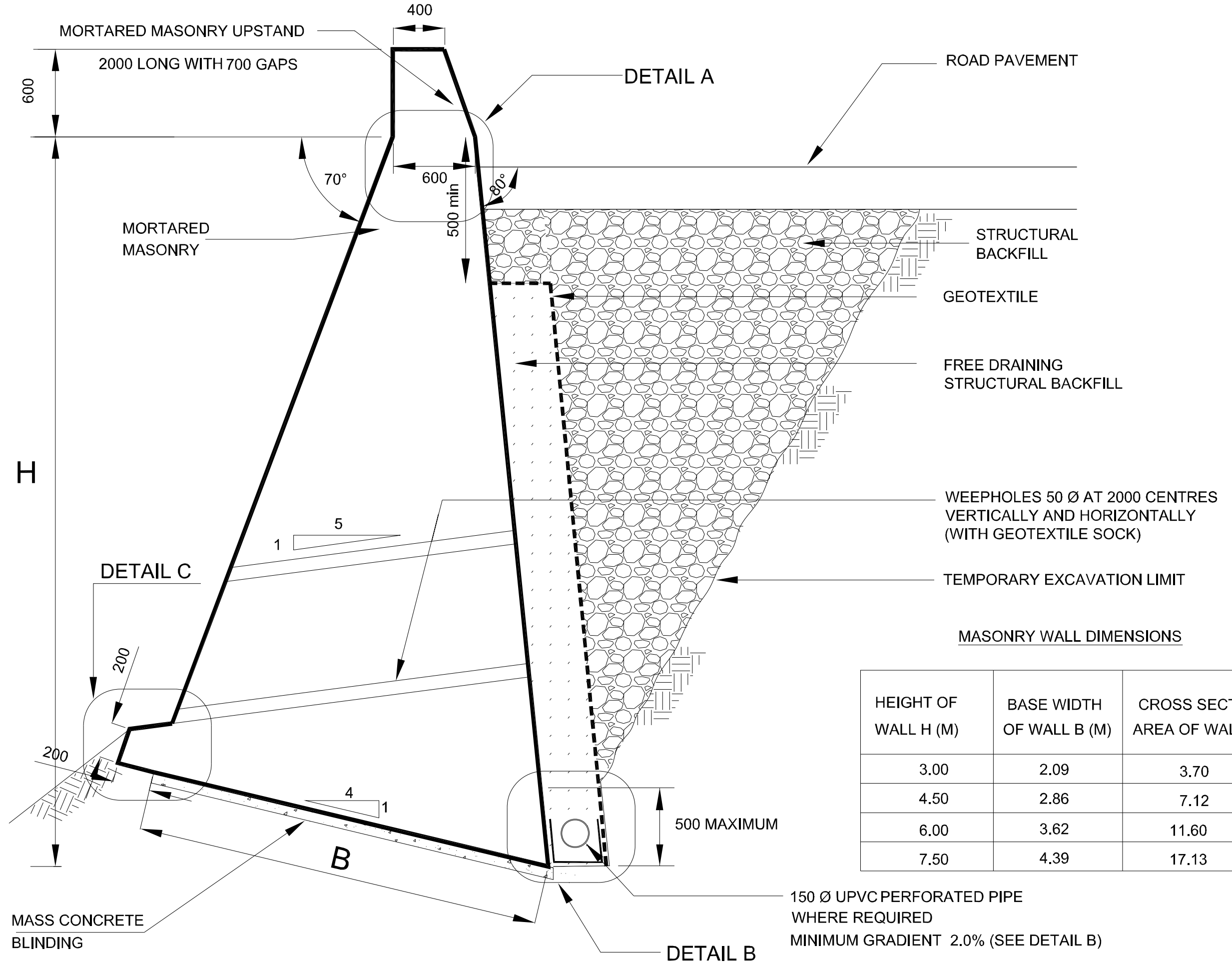
- ☐ Stable slope formed, or will stabilise naturally
- ☐ Further movement expected, by less serious mechanism (post-slide adjustment)
- ☐ Repeated movement expected, by initial mechanism or another equally serious

N.B. The above checklist is designed principally with bio-engineering measures in mind. Large and deep seated landslides will require review by a suitably qualified and experienced engineering geologist; river bank erosion will require review by a suitably qualified and experienced river engineer.

APPENDIX E: TYPICAL DETAILS FOR SLOPE STABILISATION, DRAINAGE AND BIO-ENGINEERING WORKS

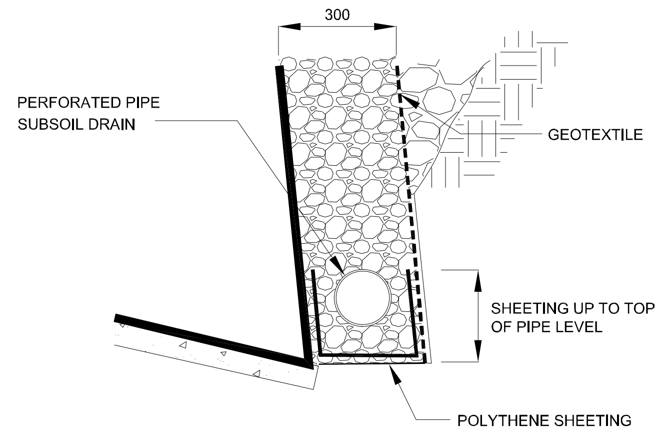
The drawings that follow show suggested typical details for slope stabilisation, drainage and bio-engineering works that may form the basis of construction work in Laos on low volume roads. Since they show only typical details, they may require substantial revision to meet the requirements of a particular site.

Drawing No	Title
SMM/DWG/001	Masonry retaining wall
SMM/DWG/002	Gabion retaining wall
SMM/DWG/003	Reinforced concrete retaining wall
SMM/DWG/004	Slope protection
SMM/DWG/005	Slope and roadside drainage
SMM/DWG/006	Pipe culverts (1)
SMM/DWG/007	Pipe culverts (2)
SMM/DWG/008	Gabion earth reinforcement
SMM/DWG/009	Gabion check dams
SMM/DWG/010	Grass slips and grass planting lines
SMM/DWG/011	Shrub and tree planting
SMM/DWG/012	Hardwood cuttings
SMM/DWG/013	Brush layering, fascines and palisades
SMM/DWG/014	Large bamboo planting
SMM/DWG/015	Live check dam and vegetated stone pitching



MASONRY WALL DIMENSIONS

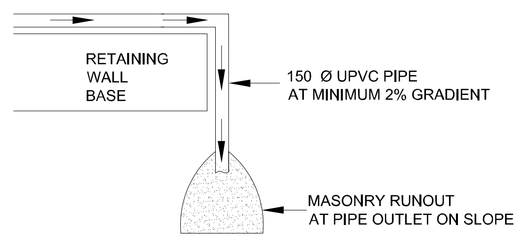
HEIGHT OF WALL H (M)	BASE WIDTH OF WALL B (M)	CROSS SECTION AREA OF WALL (M^2)
3.00	2.09	3.70
4.50	2.86	7.12
6.00	3.62	11.60
7.50	4.39	17.13



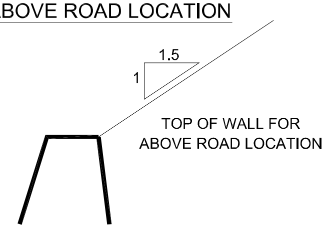
DETAIL B

SUBSOIL DRAIN
DETAIL AT END OF RETAINING WALL

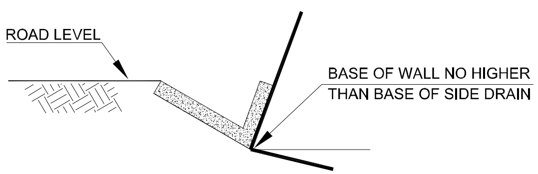
PLAN VIEW



DETAIL A
FOR ABOVE ROAD LOCATION



DETAIL C
FOR ABOVE ROAD LOCATION



NOTES

1. FOUNDATION LEVEL TO BE APPROVED BY ENGINEER PRIOR TO WALL CONSTRUCTION.
2. SOFT SPOTS UNDER THE FOUNDATION TO BE REMOVED AND REPLACED WITH MASS CONCRETE.
3. WHEN INSTRUCTED BY THE ENGINEER, FOUNDATION LEVEL TO BE CHECKED USING DYNAMIC CONE PENETROMETER.
4. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE INDICATED

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

TYPICAL DETAILS
MORTARED MASONRY RETAINING WALL

SMM/DWG/ 001

Scale : NTS

Drw	App	Rev
Chk	Date	Date

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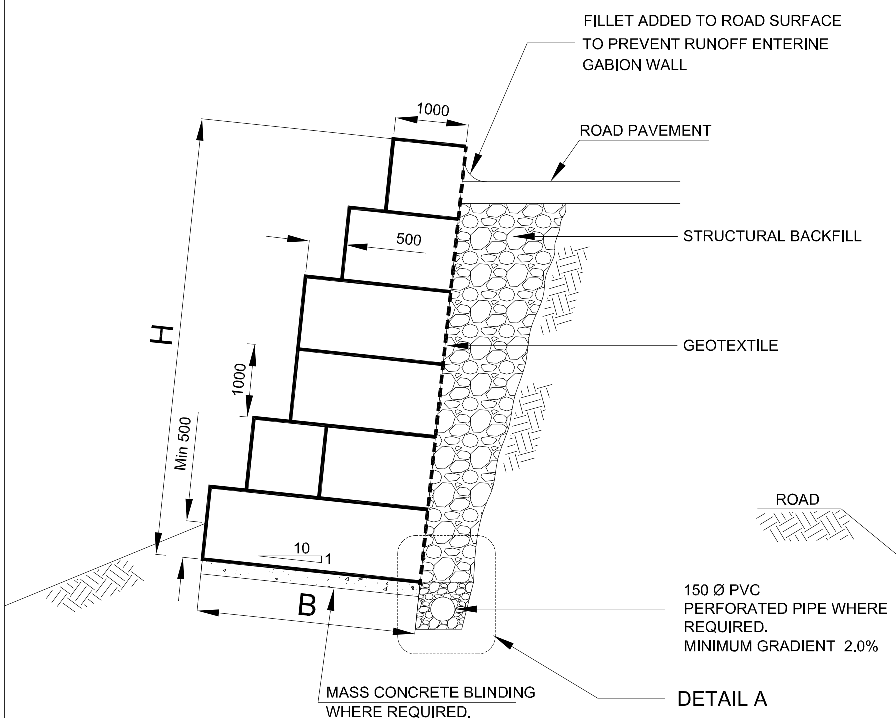
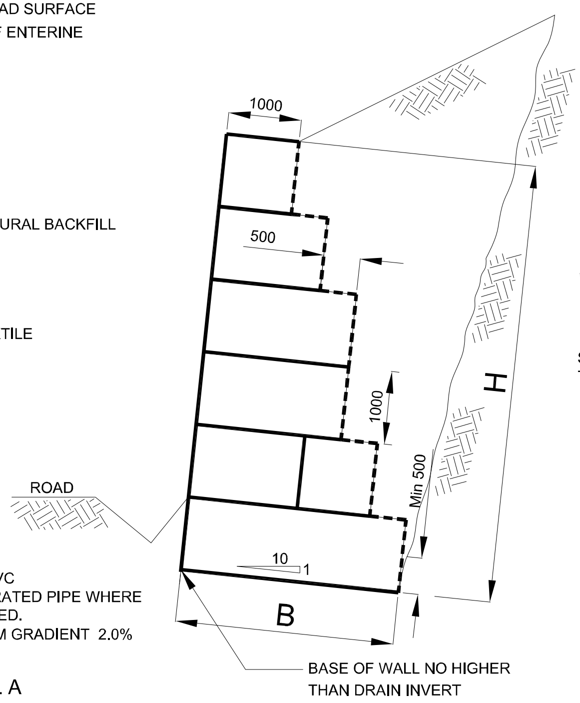
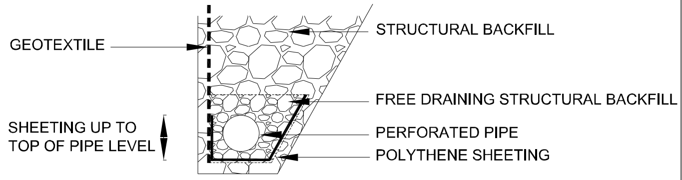


PROFILE 1



PROFILE 2



DETAIL A

GABION WALL DIMENSIONS

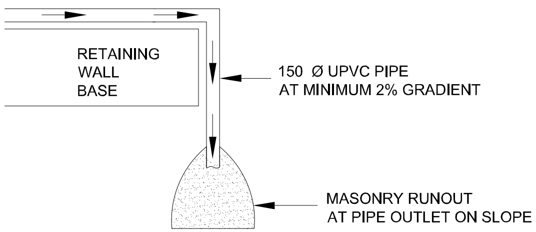
HEIGHT OF WALL H (M)	BASE WIDTH OF WALL B (M)		CROSS SECTION AREA OF WALL (M^2)	
	PROFILE 1	PROFILE 2	PROFILE 1	PROFILE 2
2.00	1.50	1.50	2.50	2.50
3.00	2.00	1.50	4.50	4.00
4.00	2.00	2.00	6.50	6.50
5.00	2.50	2.50	9.00	9.00
6.00	3.00	3.00	12.00	12.00

DETAIL A

SUBSOIL DRAIN

DETAIL AT END OF RETAINING WALL

PLAN VIEW



NOTES

1. FOUNDATION LEVEL TO BE APPROVED BY ENGINEER PRIOR TO WALL CONSTRUCTION.
2. SOFT SPOTS UNDER THE FOUNDATION TO BE REMOVED AND REPLACED WITH MASS
3. POLYTHENE SHEETING MINIMUM 250 MICRON THICKNESS
4. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE INDICATED

Project	Drawing Title	SMM/DWG/ 002		
MPWT - SEACAP 21-03-DFID SLOPE STABILISATION TRIALS ON ROUTE 13N AND ROUTE 7	**TYPICAL DETAILS** GABION RETAINING WALL	Scale : NTS		
		Drw	App	Rev
		Chk	Date	Date

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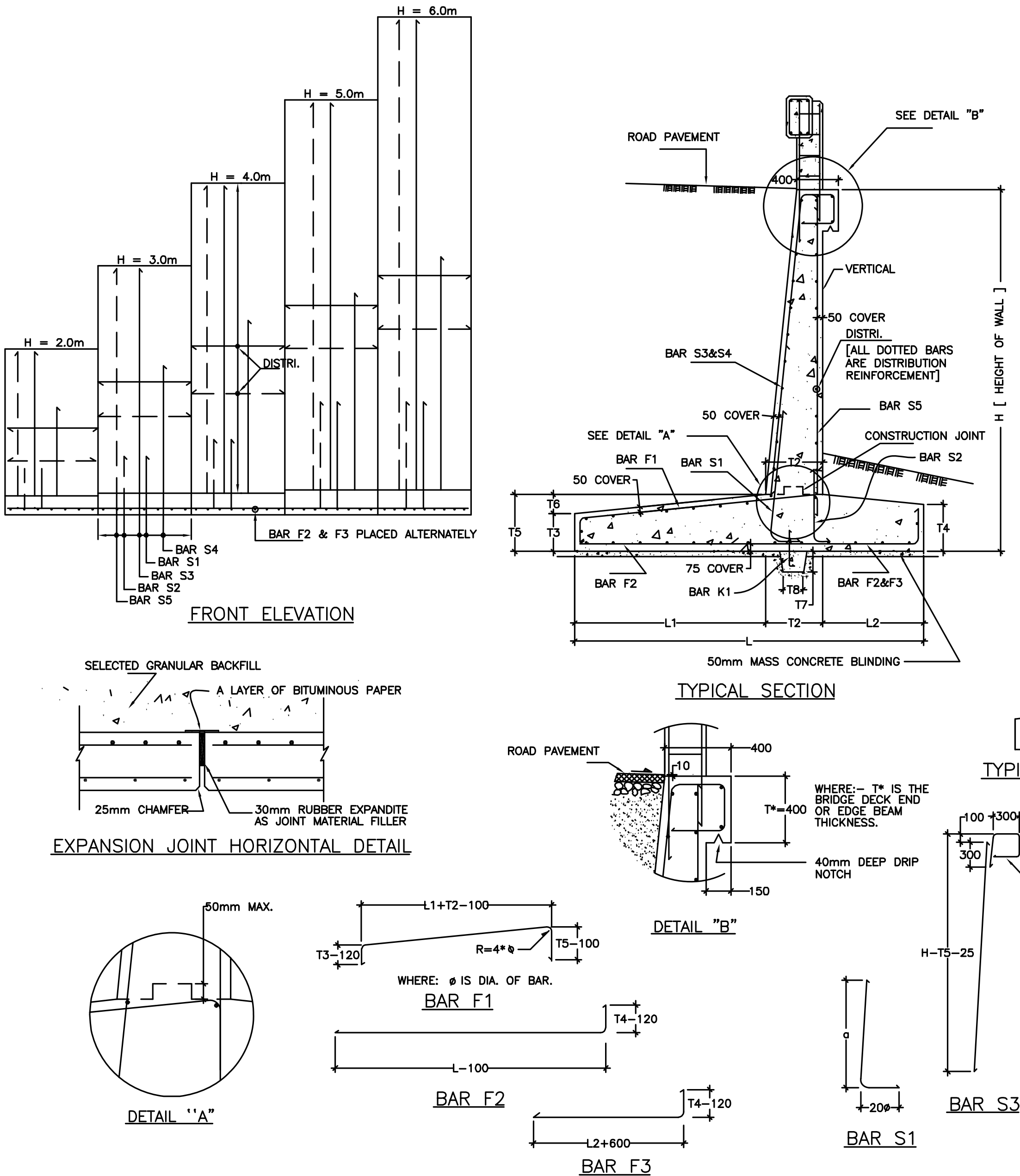


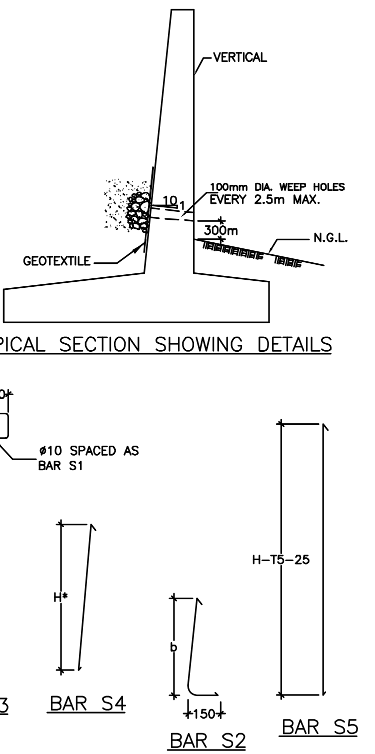


TABLE OF DIMENSIONS OF THE WALL (M), REINFORCEMENT STEEL SIZE, SPACING (MM) AND QUANTITIES PER LINEAR METER OF WALL

H	2.00		3.00		4.00		5.00		6.00	
T1	0.25		0.25		0.25		0.25		0.25	
T2	0.25		0.30		0.35		0.40		0.45	
T3	0.20		0.20		0.21		0.22		0.30	
T4	0.21		0.24		0.28		0.32		0.40	
T5	0.25		0.30		0.35		0.40		0.50	
T6	0.05		0.10		0.14		0.18		0.21	
T7	–		–		–		–		0.20	
T8	–		–		–		–		0.25	
L1	0.80		1.20		1.40		1.80		2.05	
L2	0.45		0.60		0.75		0.85		1.00	
L	1.50		2.10		2.50		3.00		3.50	
H*	1.07		1.57		2.08		2.37		2.81	
	ø	SPACING	ø	SPACING	ø	SPACING	ø	SPACING	ø	SPACING
Bar S1	12	180	16	190	20	210	20	140	24	150
Bar S2	10	250	10	270	10	300	10	320	10	280
Bar S3	12	360	16	380	20	420	20	280	24	300
Bar S4	12	360	16	380	20	420	20	280	24	300
Bar S5	10	250	10	270	10	300	10	320	10	280
Bar F1	10	140	12	140	16	170	20	200	20	170
Bar F2	10	440	10	440	12	360	12	320	16	420
Bar F3	10	440	10	440	12	360	12	320	16	420
Bar K1	–	–	–	–	–	–	–	–	10	450
DISTR. BAR	10	250	10	270	10	300	10	320	10	280
CONCRETE QUANTITY [cu.m/m]	0.78		1.29		1.84		2.50		3.46	
REINFOR. QUANTITY [kg/m]	43.10		74.50		114.00		172.90		265.40	

	HEIGHT OF WALL [m]				
	2.0	3.0	4.0	5.0	6.0
a [mm]	480	640	890	940	1460
b [mm]	430	480	530	580	680

NOTES

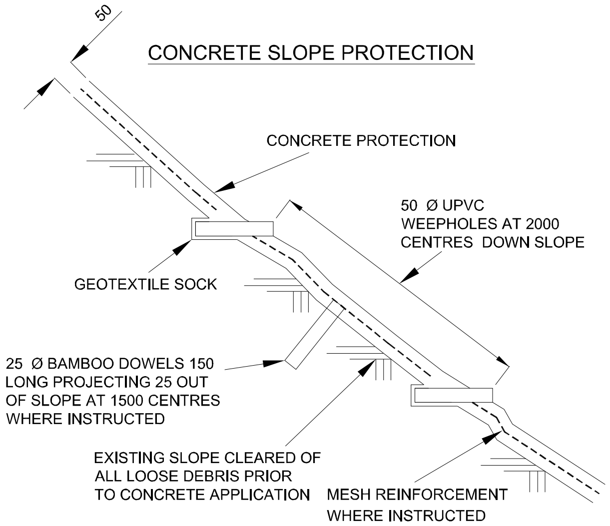
1. FOUNDATION TO BE APPROVED BY THE ENGINEER PRIOR TO WALL CONSTRUCTION. THE MINIMUM ALLOWABLE BEARING CAPACITY TO BE 150 kN/m2 FOR WALL HEIGHTS LESS THAN 3m AND 200 kN/m2 FOR WALL HEIGHTS FROM 3m TO 6m
2. SOFT SPOTS UNDER THE FOUNDATION TO BE REPLACED WITH MASS CONCRETE
3. WHEN INSTRUCTED BY THE ENGINEER, FOUNDATION LEVEL TO BE CHECKED USING DYNAMIC CONE PENETROMETER
4. STRUCTURAL BACKFILL MATERIAL TO BE USED FOR BACKFILL BEHIND THE WALL
5. EXPANSION JOINTS TO BE PROVIDED AT 15m INTERVALS
6. PAVEMENT LOADING ASSUMED TO BE AASHTO HL–93=HS20–44
7. CONCRETE SHALL BE GRADE 20, DEFORMED BAR REINFORCEMENT SHALL HAVE MINIMUM YIELD STRENGTH OF 500 MPA
8. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED
9. WALL DETAIL ONLY APPICABLE WHERE WALL IS LOCATED IMMEDIATELY BELOW AND ADJACENT TO THE ROAD

Project	Drawing Title		
MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL	TYPICAL DETAILS REINFORCED CONCRETE RETAINING WALL	SMM/DWG/003	ລາວ ຄອນຊາວຕິ້ງກຸບ ຈຳກັດ LAO CONSULTING GROUP; ເອັສດີ & ເອັກຊ໌ພີ ຄອນຊາວແຕັນສ໌ ກຸບ SD & XP Consultants Group; Scott Wilson; www.scottwilson.com

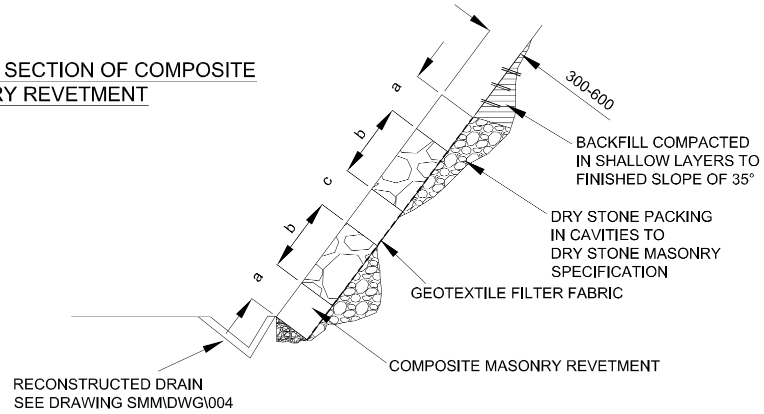
Scale : NTS

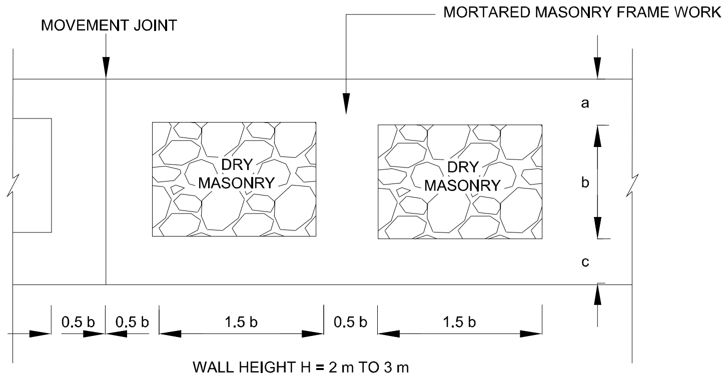
Drw	App	Rev
Chk	Date	Date

CONCRETE SLOPE PROTECTION

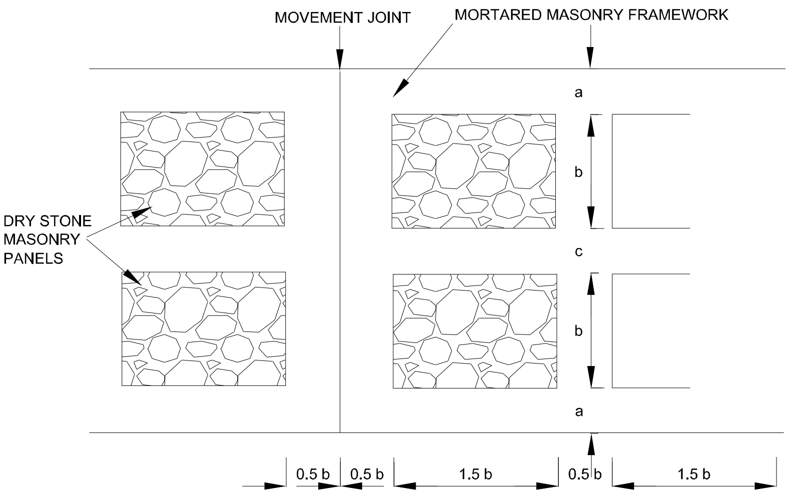


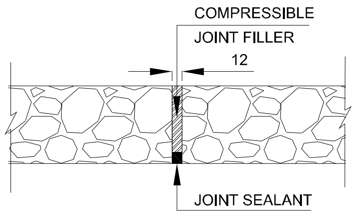
CROSS - SECTION OF COMPOSITE MASONRY REVETMENT





FRONT ELEVATION OF COMPOSITE MASONRY REVETMENT





MOVEMENT JOINT DETAIL

PANEL LAYOUT DIMENSIONS						
WALL HEIGHT (H) m	2	3	3.5	4	5	6
DIMENSIONS (a) m	0.6	0.75	0.5	0.6	0.6	0.75
DIMENSIONS (b) m	0.8	1.5	1.0	1.15	1.4	1.75
DIMENSIONS (c) m	0.6	0.75	0.5	0.5	1.0	1.0

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE INDICATED .
2. THE CONCRETE USED FOR SLOPE PROTECTION SHALL BE GRADE 20

Project
MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title
TYPICAL DETAILS
SLOPE PROTECTION

SMM/DWG/ 004

Scale : NTS

Drw	App	Rev
Chk	Date	Date

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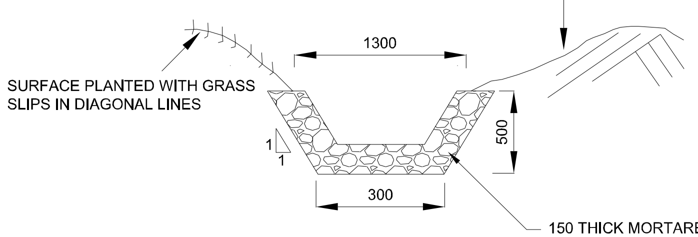
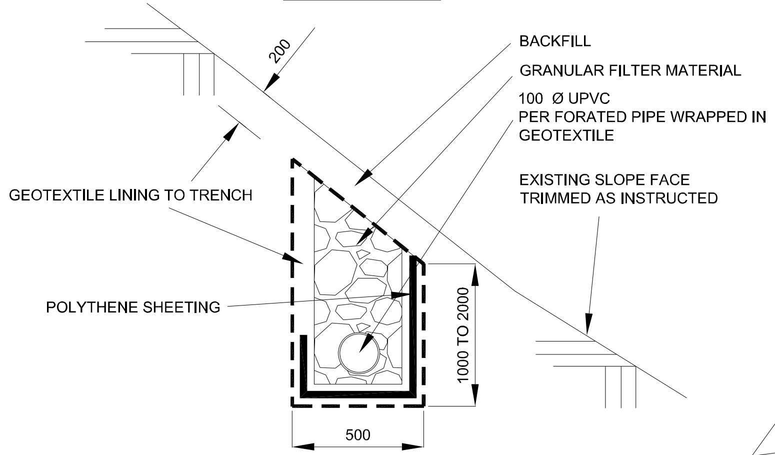
SLOPE SURFACE DRAINS

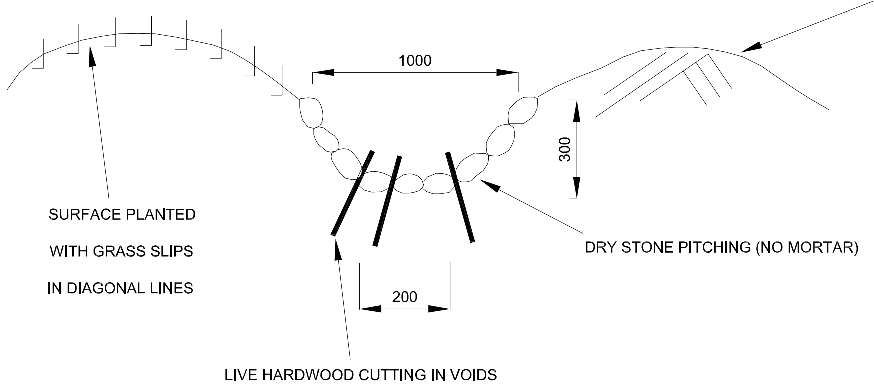
MAIN DRAINS



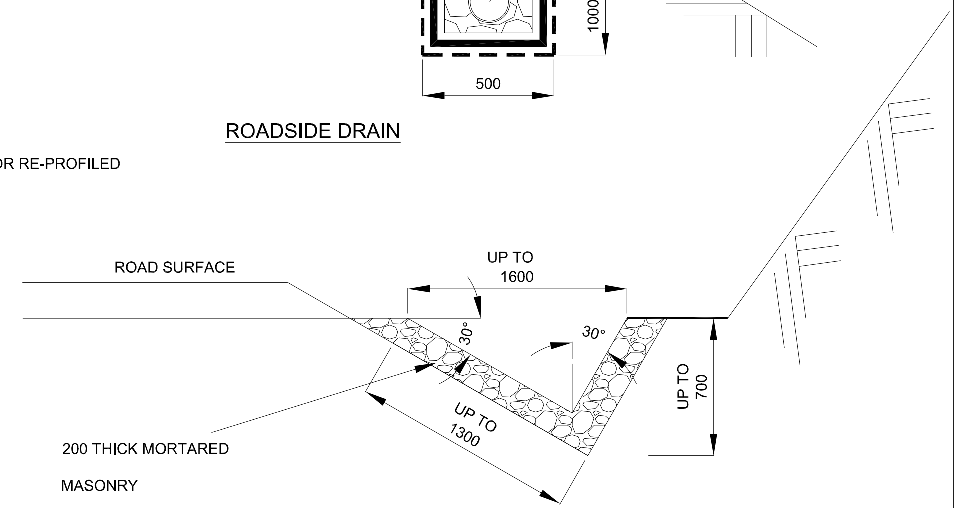
SUBSOIL DRAIN



BRANCH DRAINS ON SLIP DEBRIS



ROADSIDE DRAIN



NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED .
1. ROADSIDE DRAIN SIZE TO SUIT DISCHARGE REQUIREMENTS .

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

TYPICAL DETAILS
SLOPE AND ROADSIDE DRAINAGE

SMM/DWG/005

Scale : NTS

Drw	App	Rev
Chk	Date	Date

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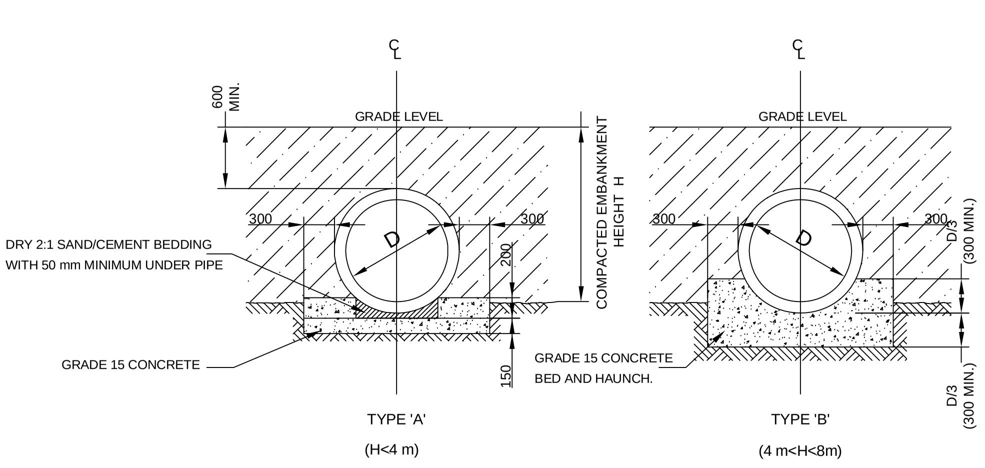
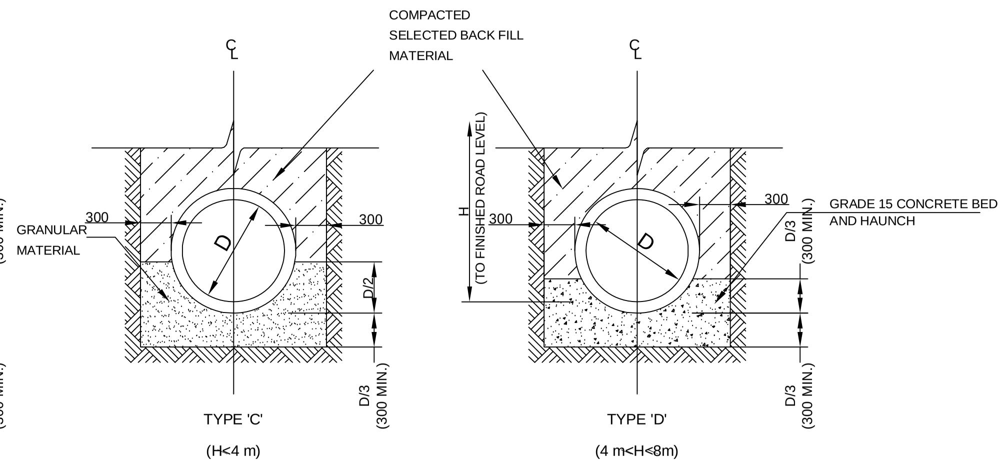
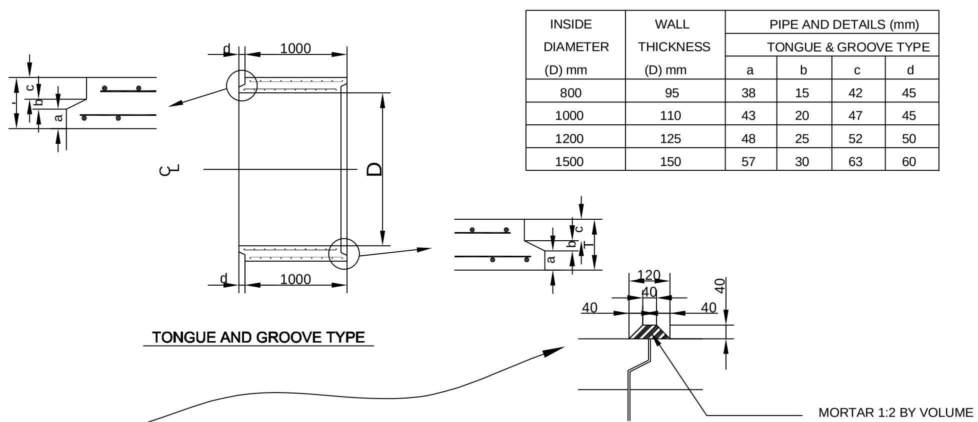


BEDDING FOR PIPES THROUGH EMBANKMENTS

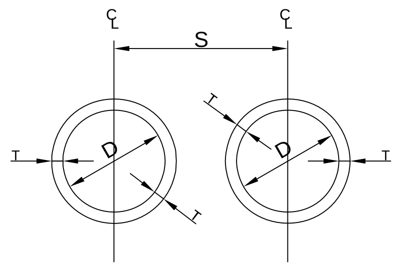


BEDDING FOR PIPES IN CUT TRENCHES



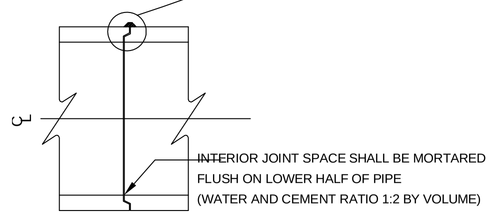
INSIDE DIAMETER (D) mm	WALL THICKNESS (D) mm	PIPE AND DETAILS (mm) TONGUE & GROOVE TYPE			
		a	b	c	d
800	95	38	15	42	45
1000	110	43	20	47	45
1200	125	48	25	52	50
1500	150	57	30	63	60

TONGUE AND GROOVE TYPE



INTERNAL DIA.	800	1000	1200	1500
SPACING, S	1400	1700	1900	2250

MULTIPLE PIPE CULVERTS



CONNECTION DETAILS

INSIDE DIAMETER (D) mm	WALL THICKNESS (T) mm	MIN CIRCULAR REINFORCEMENT (cm2/m) INNER CAGE	MIN CIRCULAR REINFORCEMENT (cm2/m) OUTER CAGE	CRUSHING LOAD TO PRODUCE 0.3 mm CRACK WIDTH AND 300 CRACK LENGTH (kg/m)	MAXIMUM CRUSHING LOAD (kg/m)	ULTIMATE STRENGTH FOR 15 & 30 cm CONCRETE CYLINDER AT 28 DAYS AGE MPa	OVER FILL ON R.C PIPE CULVERT NOT MORE THAN (m)
800	95	5.8	4.1	8.160	12.240	26	10.00
1000	110	7.0	5.2	10.200	15.300		
1200	125	8.9	6.8	12.2400	18.360		
1500	150	12.5	9.5	15.300	22.950	40	11.00

PIPE DETAILS

NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS INDICATED OTHERWISE
2. FOR EMBANKMENT HEIGHTS GREATER THAN 8 METRES A FULL CONCRETE SURROUND OF THICKESS D/3 (MINIMUM 300) SHALL BE PROVIDED.

Project

MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL

Drawing Title

TYPICAL DETAILS

PIPE CULVERTS (1)

SMM/DWG/006

Scale at A3 :		
Drw	App	Rev
Chk	Date	Date

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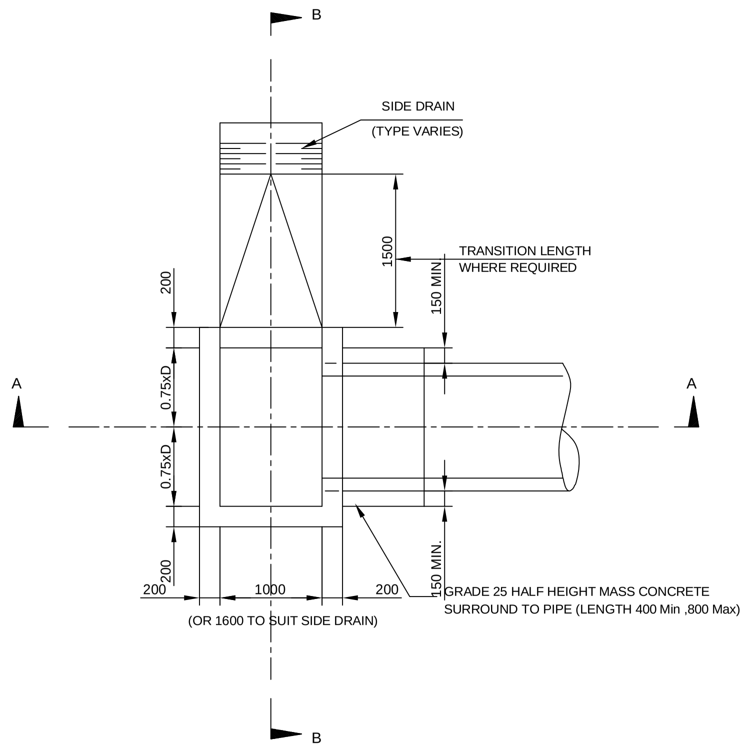
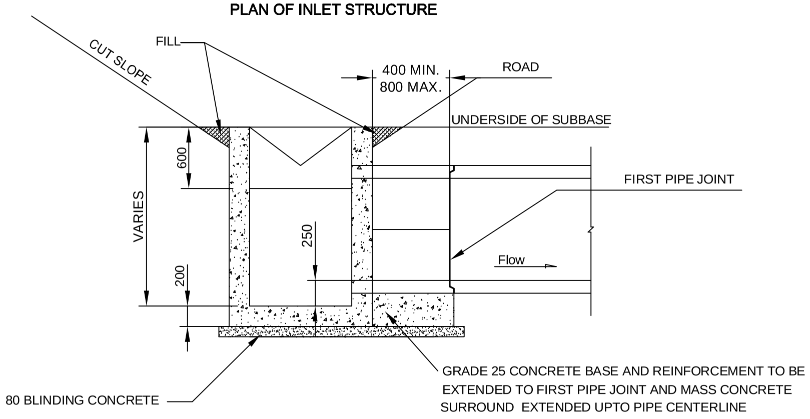
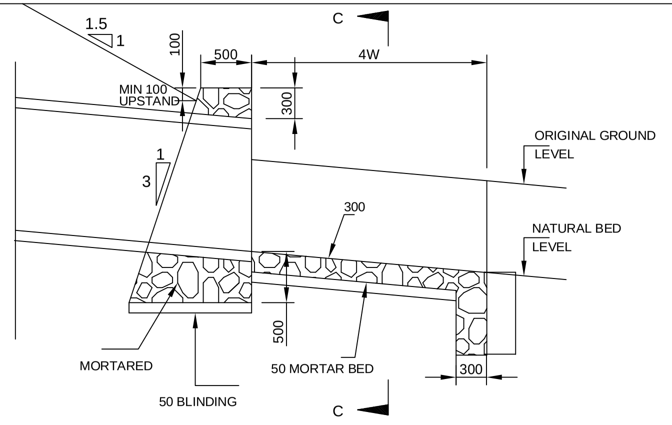
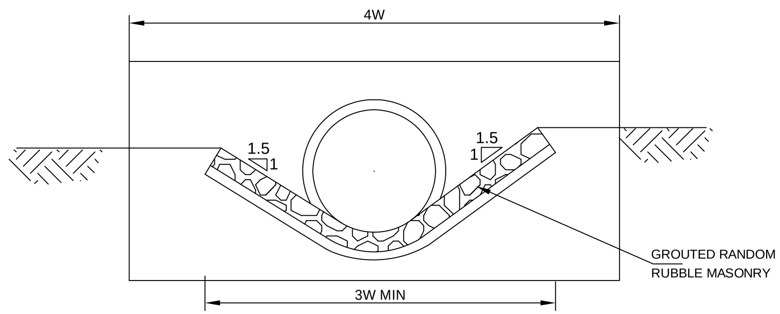


PLAN OF INLET STRUCTURE

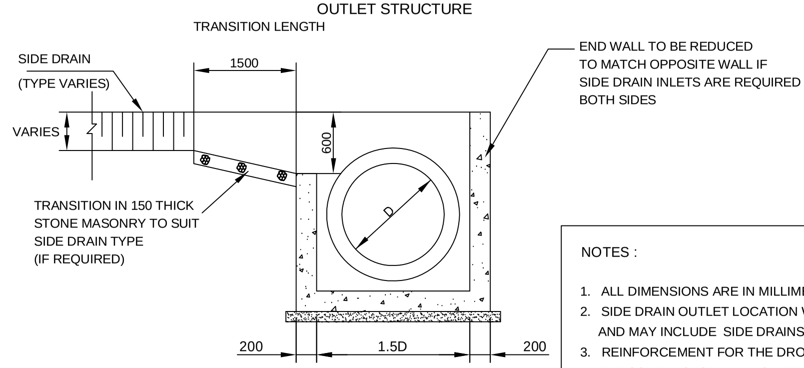


SECTION A-A





SECTION C - C
OUTLET STRUCTURE



SECTION B-B

NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS INDICATED OTHERWISE.
2. SIDE DRAIN OUTLET LOCATION WILL VARY ACCORDING TO SITE CONDITIONS. AND MAY INCLUDE SIDE DRAINS.
3. REINFORCEMENT FOR THE DROP INLET STRUCTURE SHALL BE DESIGNED BY THE CONTRACTOR AND AGREED WITH THE ENGINEER.

Project

MPWT - SEACAP 21
SLOPE MAINTENANCE MANUAL

Drawing Title

TYPICAL DETAILS
PIPE CULVERTS (2)

SMM/DWG/007

Scale : NTS

Drw LCG, PG	App	Rev C
Chk NAC	Date	Date

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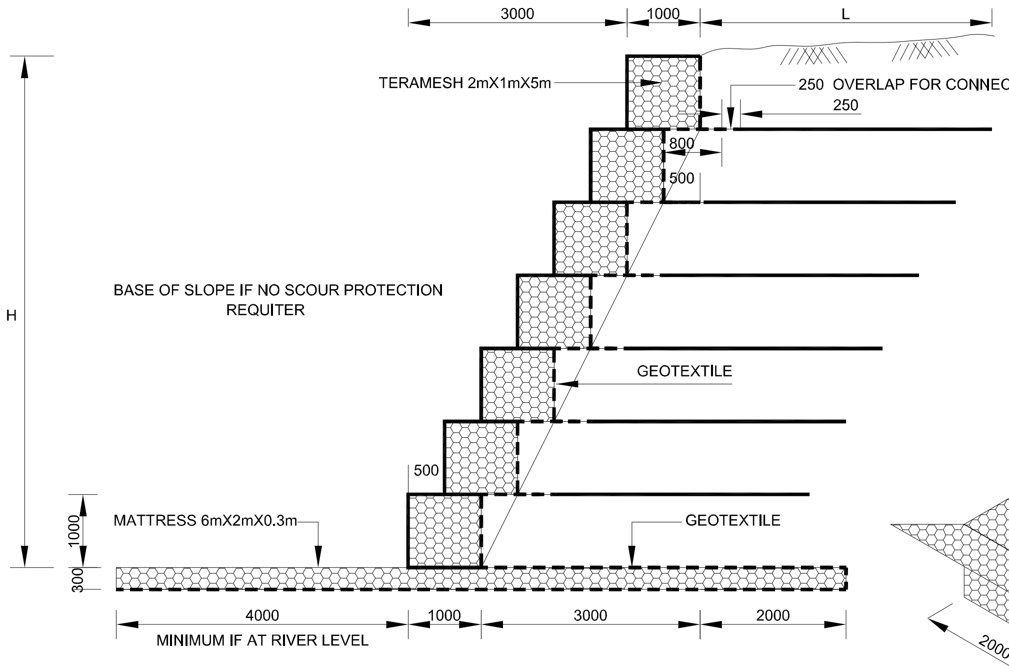
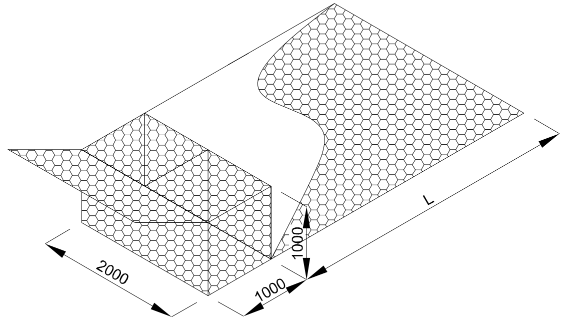
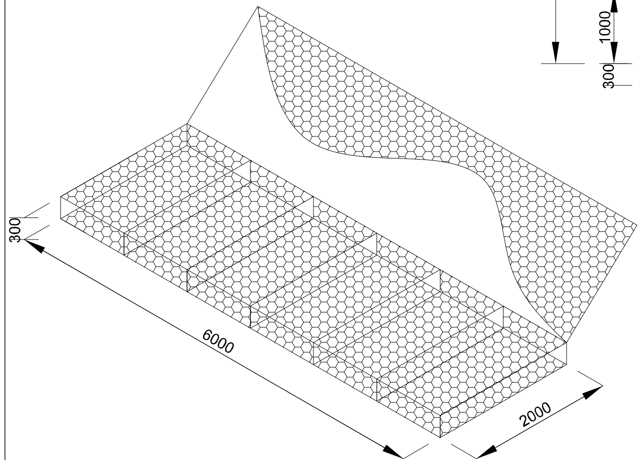
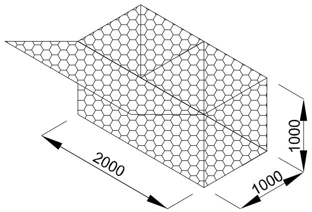




GABION EARTH REINFORCEMENT



MATTRESS 6mX2mX0.3m
(ONLY REQUIRED FOR RIVER SCOUR PROTECTION)



BOX 2mX1mX1m

NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE INDICATED
2. OMIT MATTRESS IF NO STREAM AT TOE OF SLOPE BUT BURY BOTTOM GABION BOX
3. GENERALLY L= 0.6 H

Project MPWT - SEACAP 21-03-DFID SLOPE STABILISATION TRIALS ON ROUTE 13N AND ROUTE 7	Drawing Title **TYPICAL DETAILS** GABION EARTH REINFORCEMENT	SMM/DWG/ 008 Scale : NTS Drw / App / Rev Chk / Date / Date

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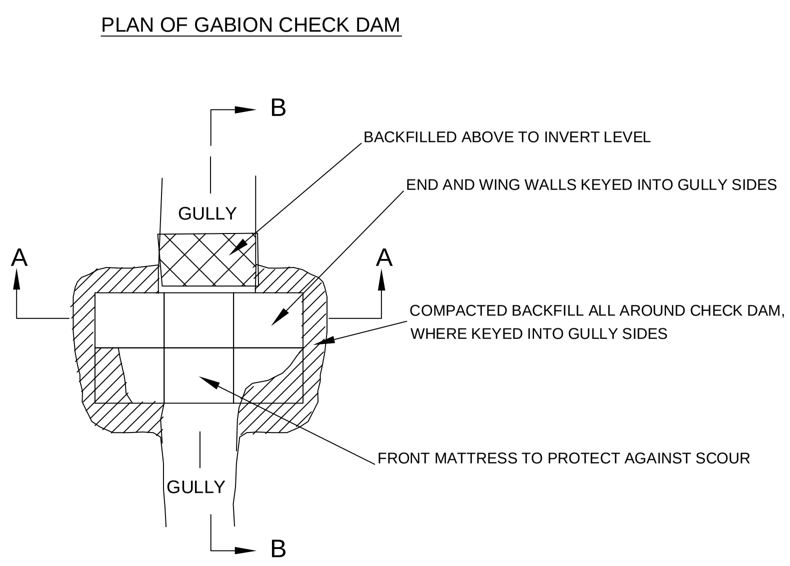
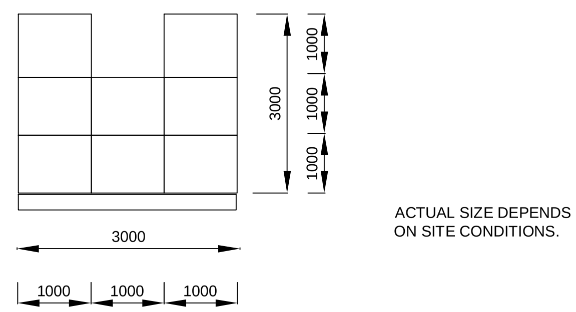
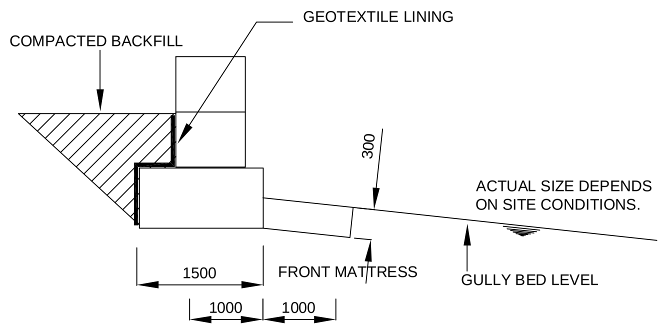




SECTION A-A



SECTION B-B

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED .

Project	Drawing Title	SMM/DWG/ 009
MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL	**TYPICAL DETAILS** GABION CHECK DAMS	Scale : NTS

Drw	App	Rev
Chk	Date	Date

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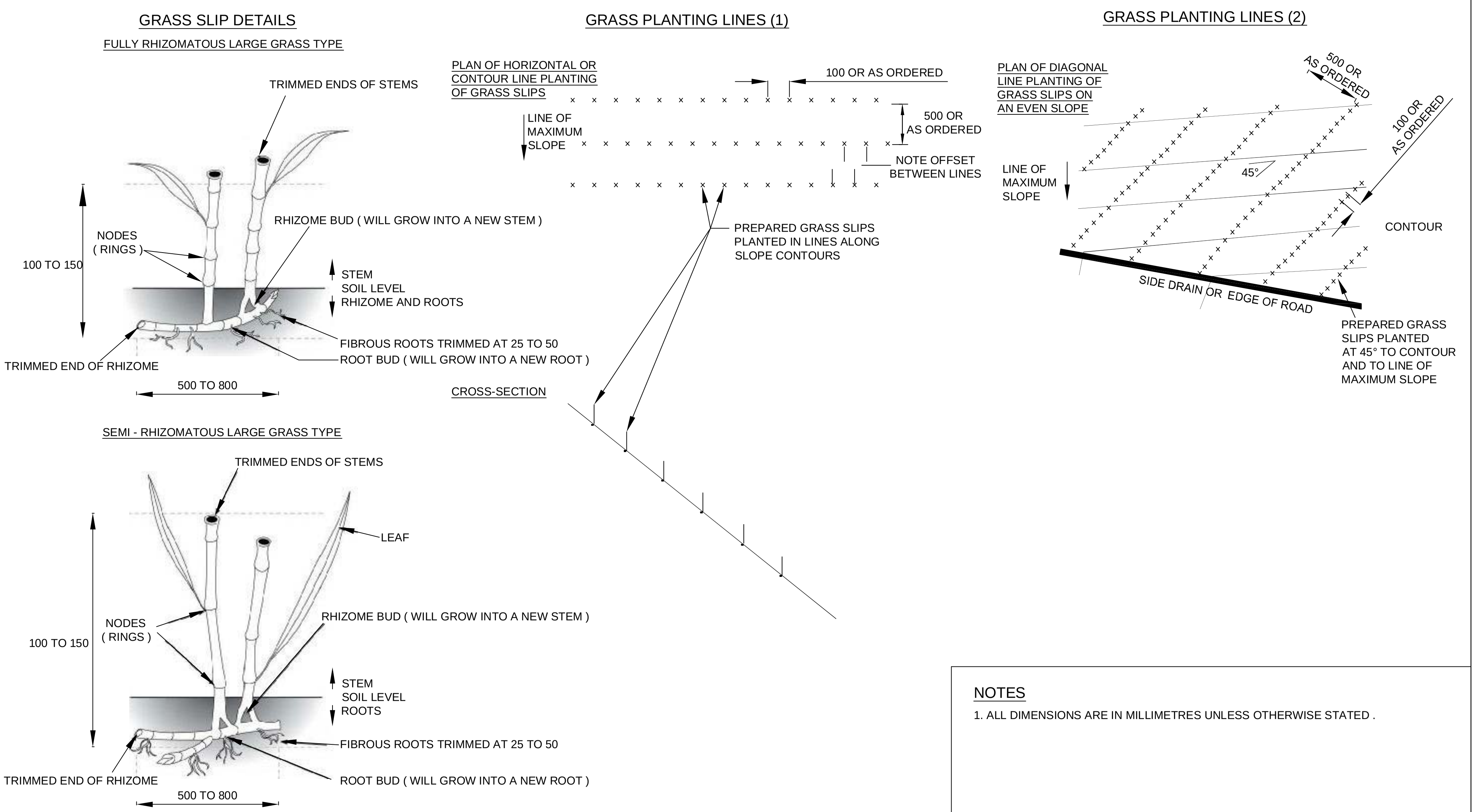

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED .

Project	Drawing Title	SMM/DWG/ 010
MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL	**TYPICAL DETAILS** GRASS SLIPS AND GRASS PLANTING LINES	Scale : NTS

Drw	App	Rev
Chk	Date	Date

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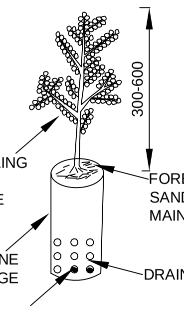
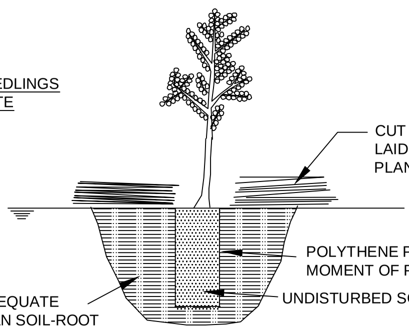
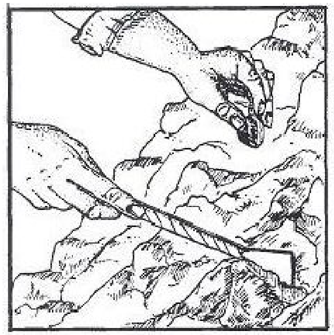
SHRUB AND TREE SEEDLINGS

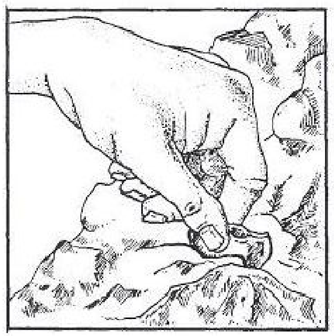




DIRECT SEEDING OF SHRUBS AND TREES



STEP 1 . MAKE A SMALL HOLE IN A CREVICE IN THE SOIL AND ROCK OF THE SLOPE , USING A STEEL BAR.



STEP 2 . PUSH THE SEED INTO THE CREVICE AND COVER WITH 5 TO 10 MM OF SOIL

NOTES

1. AVERAGE DENSITY AND NUMBER OF SEED PER HOLE TO BE AS PER DRAWING OR ENGINEER'S ORDER.
2. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED .

Project

MPWT - SEACAP 21
SLOPE MAINTENANCE MANUAL

Drawing Title

TYPICAL DETAILS
SHRUB AND TREE PLANTING

SMM/DWG/ 011

Scale : NTS

Drw	App	Rev
Chk	Date	Date

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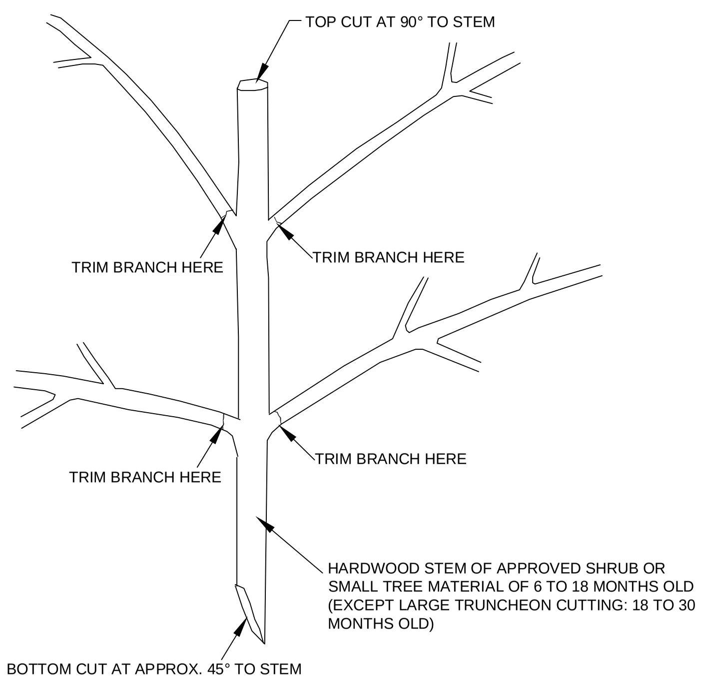
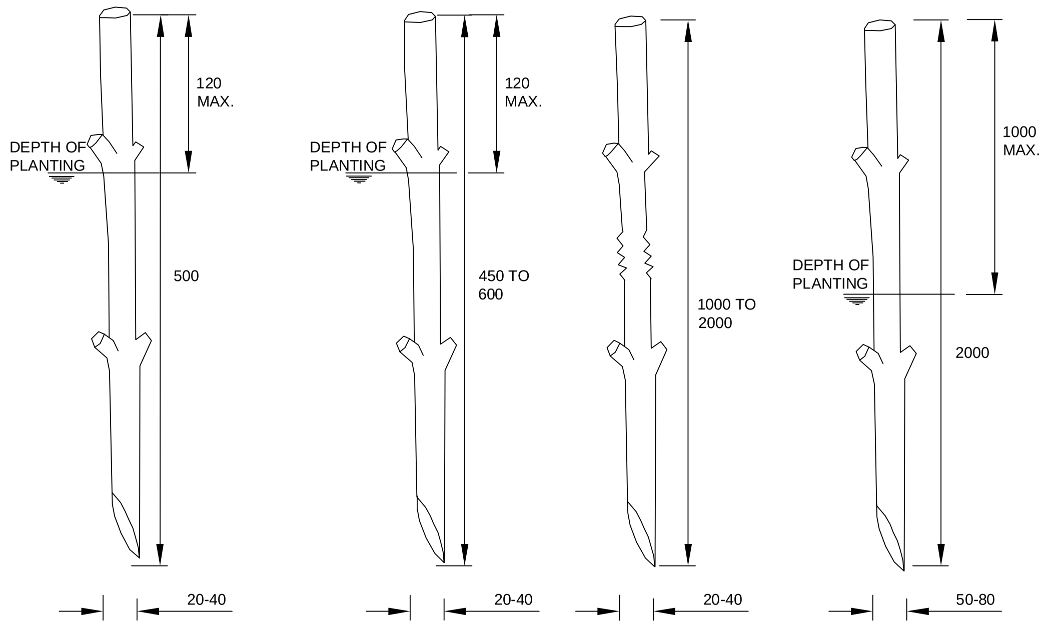
PREPARATION OF HARDWOOD CUTTINGS



HARDWOOD CUTTINGS



NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED .

Project	Drawing Title	SMM/DWG/ 012
MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL	**TYPICAL DETAILS** HARDWOOD CUTTINGS	Scale : NTS

Drw	App	Rev
Chk	Date	Date

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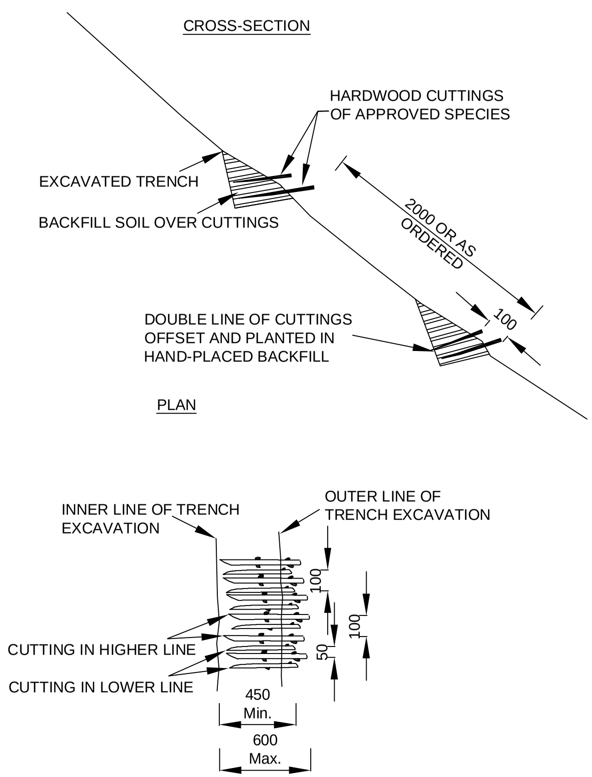
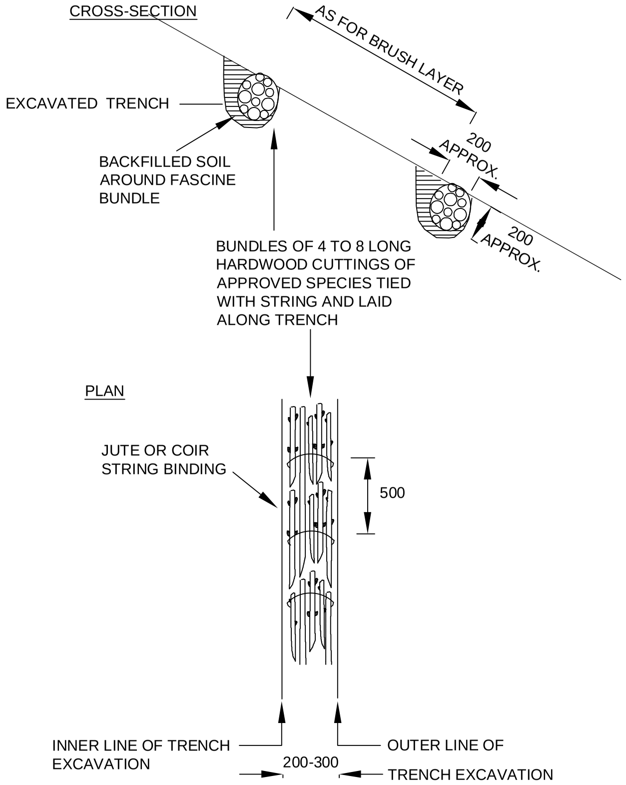
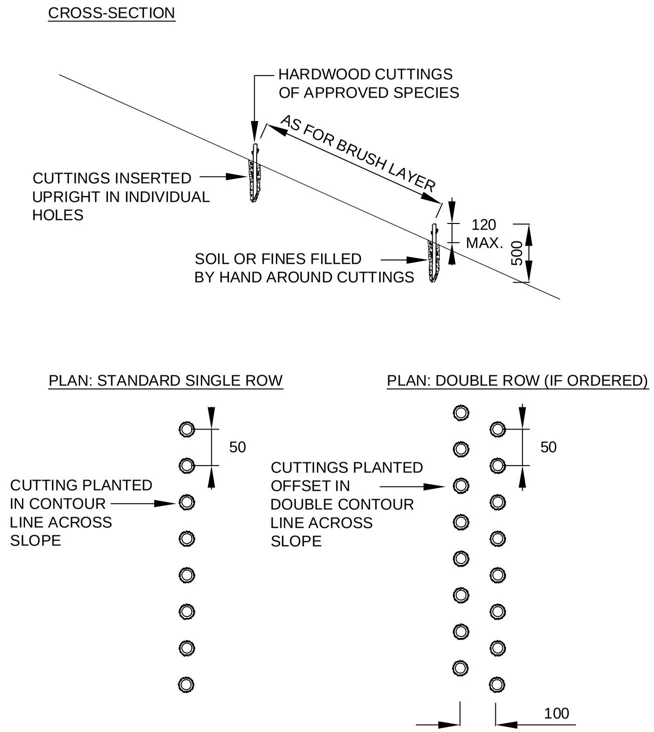
BRUSH LAYERING



FASCINES



PALISADES



NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED .

Project	Drawing Title	
MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL	**TYPICAL DETAILS** BRUSH LAYERIMG, FASCINES AND PALISADES	SMM/DWG/013

Scale : NTS		
Drw	App	Rev
Chk	Date	Date

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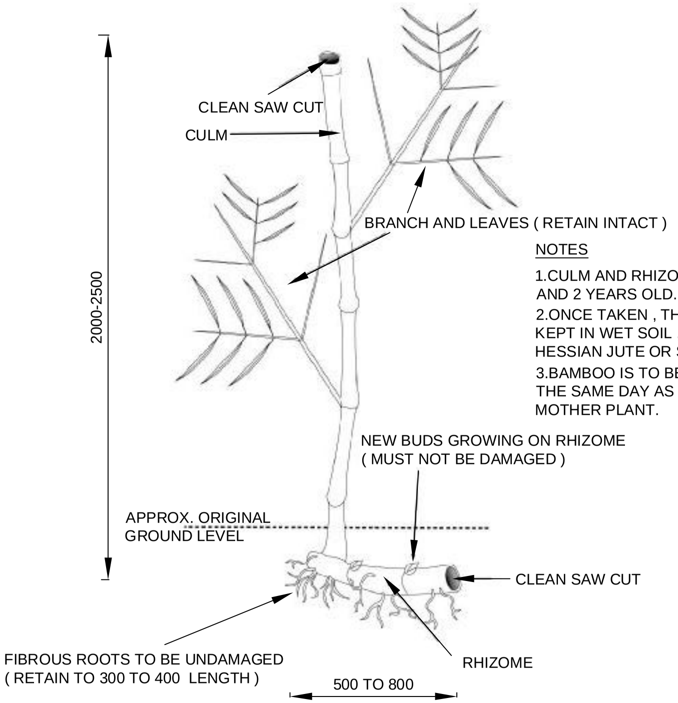
DETAIL OF PLANTING MATERIAL



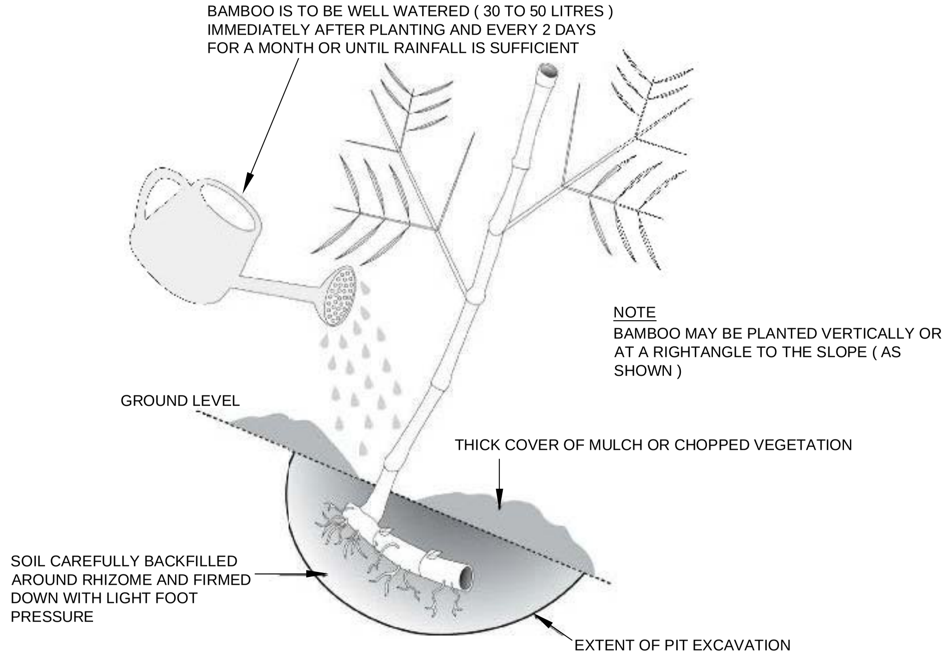
NOTES

1.CULM AND RHIZOME ARE TO BE BETWEEN 1 AND 2 YEARS OLD.

2.ONCE TAKEN , THE RHIZOME IS TO BE KEPT IN WET SOIL , BOUND LOOSELY IN HESSIAN JUTE OR SIMILAR BAG.

3.BAMBOO IS TO BE PLANTED ON SITE ON THE SAME DAY AS IT IS TAKEN FROM THE MOTHER PLANT.

PLANTING DETAIL



NOTE

BAMBOO MAY BE PLANTED VERTICALLY OR AT A RIGHTANGLE TO THE SLOPE (AS SHOWN)

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED .

Project	Drawing Title			
MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL	**TYPICAL DETAILS** LARGE BAMBOO PLANTING	SMM/DWG/014		
		Scale : NTS		
		Drw	App	Rev
		Chk	Date	Date

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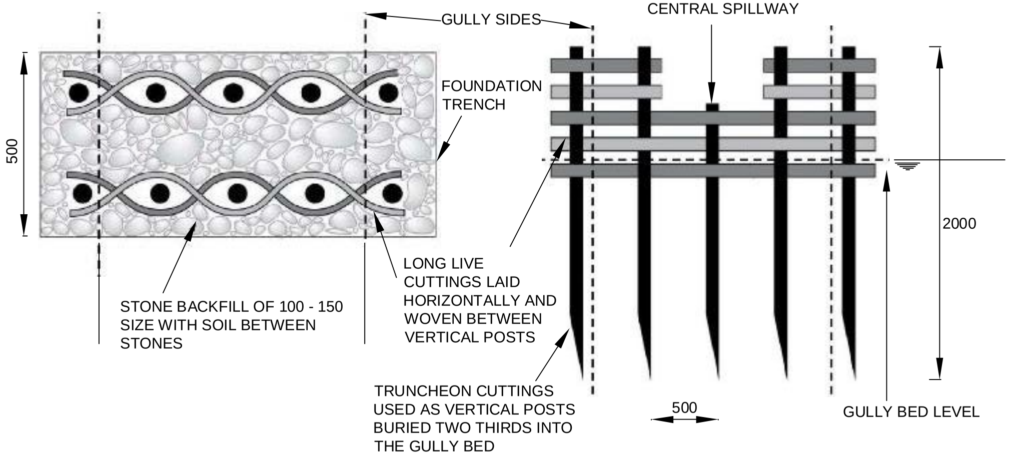
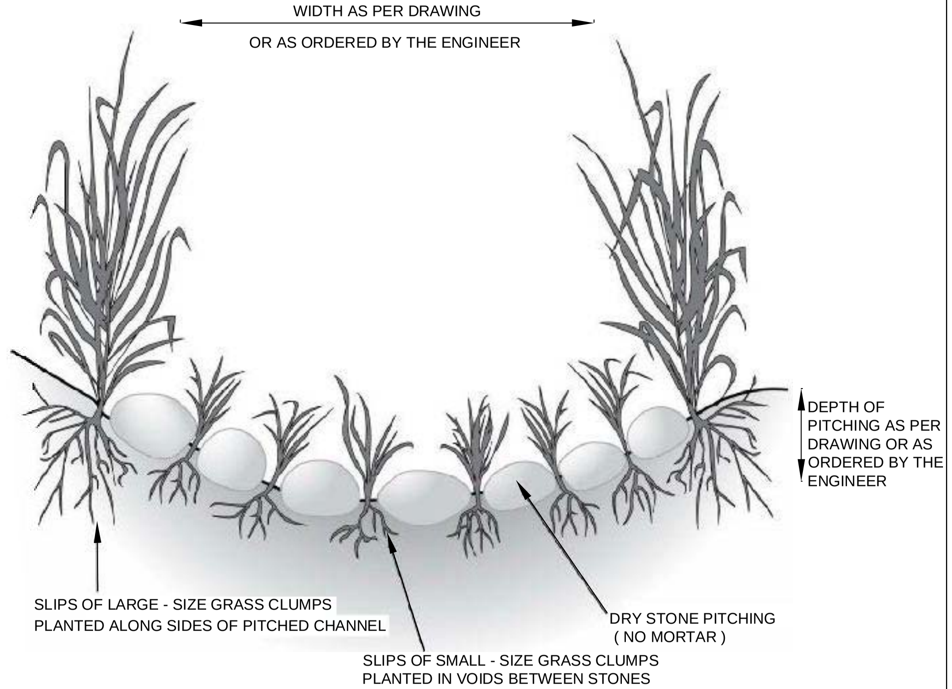
LIVE CHECK DAM



VEGETATED STONE PITCHING



NOTES :

1. HARDWOOD CUTTING OF APPROVED SPECIES MAY BE ORDERED INSTEAD OF GRASS SLIPS
2. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED .

Project	Drawing Title	SMM/DWG/015
MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL	**TYPICAL DETAILS** LIVE CHECK DAM AND VEGETATED STONE PITCHING	Scale : NTS; Drw; App; Rev; Chk; Date; Date

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APPENDIX-I

CONVERTING MIXED TRAFFIC TO ESAL'S

APPENDIX D
CONVERSION OF MIXED TRAFFIC TO EQUIVALENT SINGLE AXLE LOADS FOR PAVEMENT DESIGN

D.1 GENERAL CONSIDERATIONS

Part I of this Guide outlines the fact that estimates of the amount of traffic and its characteristics play a primary role in the pavement design and analysis process. Parts II and III require traffic information for design of pavement structures. This Appendix provides guidelines for estimating the number of equivalent single axle loads which can be expected to be applied to a pavement during a specified design period or to estimate equivalent axle load applications that have been applied to existing pavements. Although typical and historical traffic parameters are furnished in this Appendix for illustrative purposes, pavement designers and analysts are cautioned to use the best locally available data to represent specific site conditions. Such traffic data should be available from the designing agency as part of its regular traffic monitoring effort. As the science of pavement design and management matures, it is vital that a close working relationship exists among these groups.

There are currently major initiatives underway to improve the quality of traffic data. Statistically based programs for traffic monitoring are being adopted in many states. Microcomputer technology is rapidly improving the ability of planners to assemble better traffic data using automatic vehicle classifiers and weigh-in-motion (WIM) installations.

History has clearly shown that while it may be possible to accurately measure today's traffic, the characteristics of this traffic change over time. With the exception of interruptions during petroleum shortages in recent years, a rather constant increase in traffic is evident. This type of information, plus forecasts of population, land use, economic factors, etc., are used by transportation planners to forecast future travel. At the local level, such forecasts are generally developed on a system basis and on most high level highways for specific corridors. These should be used in the pavement design process.

From 1970 to 1983, the percent of the total volume made up of passenger cars and buses (on rural Interstate highways) decreased from 77 to 63, while the percent of the traffic stream made up of 5-axle or more combinations increased from 9 to 17. Between 1970 and 1983, the total equivalent single axle loads increased by 105 percent. The significant point is that if pavements had been designed in 1970, assuming a constant traffic growth for all types of vehicles, a serious underdesign of pavements would have resulted.

Users of this Guide are cautioned that what are discussed are nationwide summary data. Trends within a given state, or corridor within a state, may vary significantly. This can happen for a number of reasons, including economic conditions, industry locational patterns, truck weight laws, enforcement intensity, equipment changes by the trucking industry, etc. Pavement designers should be particularly sensitive to the changes which will likely take place on the nationwide basis as a result of the Surface Transportation Assistance Act (STAA) of 1982. As a result of this legislation, there may well be (1) significant changes in both truck weights within particular vehicle categories and shifts to different equipment (twin trailers), (2) changes in position of load application due to wider trucks, and (3) increased intensity of use on certain routes designated for these new vehicle configurations. Additionally, deregulation of the trucking industry will likely change the portion of trucks traveling empty in many corridors.

These discussions highlight the need for each state to be conducting a comprehensive program of traffic counting, vehicle classification, and truck weighing. These changing traffic trends can be expected to have significant influences on the lives of existing pavements and on the design of new pavements.

To use the pavement design procedures presented in this Guide, mixed traffic must be converted to an equivalent number of 18-kip single axle loads. The procedure for accomplishing this conversion includes:

(1) derivation of load equivalence factors,
(2) conversion of mixed traffic to 18-kip equivalent single axle load (ESAL) applications, and
(3) lane distribution considerations.

To express varying axle loads in terms of a single design parameter, it is necessary to develop axle load equivalence factors. These factors, when multiplied by the number of axle loads within a given weight category, give the number of 18-kip single axle load applications which will have an equivalent effect on the performance of the pavement structures.

Load equivalency factors represent the ratio of the number of repetitions of any axle load and axle configuration (single, tandem, tridem) necessary to cause the same reduction in PSI as one application of an 18-kip single axle load. Load equivalency factors are presented later in Tables D.1 through D.18 for a range of pavement structural combinations, axle configurations, and terminal serviceability values of 2.0, 2.5, and 3.0. Appendix MM of Volume 2 presents the AASHO Road Test-based equations that were used to generate these tables. It also provides some support for extending the tables to tridem axle loadings.

The prediction of traffic (ESAL's) for design purposes must rely on information from past traffic, modified by factors for growth or other expected changes. Most states, in cooperation with FHWA, accumulate past traffic information in the form of truck weight study data W-4 tables. Typical information includes: (1) axle weight distributions in 2,000-lb. intervals, (2) ESAL's for all trucks weighed, (3) ESAL's per 1,000 trucks weighed by truck class, (4) ESAL's for all trucks counted, and (5) percent distribution of ESAL's by truck class.

To arrive at the design ESAL's, it is necessary to assume a structural number (SN) for flexible pavements or slab thickness (D) for rigid pavements, and then select the equivalence factors listed in Tables D.1 through D.18. The use of an SN of 5.0 or a D of 9 inches for the determination of 18-kip single axle equivalence factors will normally give results that are sufficiently accurate for design purposes, even though the final design may be somewhat different. If in error, this assumption will usually result in an overestimation of 18-kip equivalent single axles. When more accurate results are desired and the computed design is appreciably different (1 inch of PCC for rigid or 1 inch of asphalt concrete for flexible) from the assumed value, a new value should be assumed, the design 18-kip ESAL traffic (w_{18}) recomputed, and the structural design determined for the new w_{18}. The procedure should be continued until the assumed and computed values are as close as desired.

If the number of equivalent axle loads represents the total for all lanes and both directions of travel, this number must be distributed by direction and by lanes for design purposes. Directional distribution is usually made by assigning 50 percent of the traffic to each direction, unless special considerations (such as more loaded trucks moving in one direction and more empty trucks in the other) warrant some other distribution. In regard to lane distribution, most states assign 100 percent of the traffic in each direction (i.e., 50 percent of the total) to the design lane. Some states have developed lane distribution factors for multilane facilities. The range of factors used is presented below.

Number of Lanes in Both Directions	Percent of 18-kip ESAL Traffic in Design Lane
1	100
2	80–100
3	60–80
4 or more	50–75

If lane or directional distribution factors are utilized and pavements are designed on the basis of distributed traffic, consideration should be given to the use of variable cross sections. Heavier structural sections in the outside lanes should be considered if warranted by the lane distribution analysis.

In view of the increased emphasis on improved traffic monitoring made possible by weigh-in-motion (WIM) and automatic vehicle classification and counting, it is recommended that each state develop appropriate factors for multilane facilities.

D.2 CALCULATING ESAL APPLICATIONS

When calculating ESAL's for the design of a particular project, it is convenient to convert the estimated traffic distribution into truck load factors. Two methods of calculating truck load factors from W-4 information are summarized in the following paragraphs of this section.

Where axle load information is available from a weigh station that can be assumed to be representative of traffic for the pavement to be designed, the truck load factor can be calculated directly. For example, assume that the data in Figure D.1 illustrates the weighing of 5-axle, tractor semi-trailer trucks at a specific weigh station. Traffic (load) equivalency factors are obtained from Table D.4, the number of axles represents the grouping or distribution of weights

Table D.1. Axle Load Equivalency Factors for Flexible Pavements, Single Axles and p_t of 2.0

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0002	.0002	.0002	.0002	.0002	.0002
4	.002	.003	.002	.002	.002	.002
6	.009	.012	.011	.010	.009	.009
8	.030	.035	.036	.033	.031	.029
10	.075	.085	.090	.085	.079	.076
12	.165	.177	.189	.183	.174	.168
14	.325	.338	.354	.350	.338	.331
16	.589	.598	.613	.612	.603	.596
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.59	1.56	1.55	1.57	1.59
22	2.49	2.44	2.35	2.31	2.35	2.41
24	3.71	3.62	3.43	3.33	3.40	3.51
26	5.36	5.21	4.88	4.68	4.77	4.96
28	7.54	7.31	6.78	6.42	6.52	6.83
30	10.4	10.0	9.2	8.6	8.7	9.2
32	14.0	13.5	12.4	11.5	11.5	12.1
34	18.5	17.9	16.3	15.0	14.9	15.6
36	24.2	23.3	21.2	19.3	19.0	19.9
38	31.1	29.9	27.1	24.6	24.0	25.1
40	39.6	38.0	34.3	30.9	30.0	31.2
42	49.7	47.7	43.0	38.6	37.2	38.5
44	61.8	59.3	53.4	47.6	45.7	47.1
46	76.1	73.0	65.6	58.3	55.7	57.0
48	92.9	89.1	80.0	70.9	67.3	68.6
50	113.	108.	97.	86.	81.	82.

Table D.2. Axle Load Equivalency Factors For Flexible Pavements, Tandem Axles and p_t of 2.0

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0000	.0000	.0000	.0000	.0000	.0000
4	.0003	.0003	.0003	.0002	.0002	.0002
6	.001	.001	.001	.001	.001	.001
8	.003	.003	.003	.003	.003	.002
10	.007	.008	.008	.007	.006	.006
12	.013	.016	.016	.014	.013	.012
14	.024	.029	.029	.026	.024	.023
16	.041	.048	.050	.046	.042	.040
18	.066	.077	.081	.075	.069	.066
20	.103	.117	.124	.117	.109	.105
22	.156	.171	.183	.174	.164	.158
24	.227	.244	.260	.252	.239	.231
26	.322	.340	.360	.353	.338	.329
28	.447	.465	.487	.481	.466	.455
30	.607	.623	.646	.643	.627	.617
32	.810	.823	.843	.842	.829	.819
34	1.06	1.07	1.08	1.08	1.08	1.07
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.76	1.75	1.73	1.72	1.73	1.74
40	2.22	2.19	2.15	2.13	2.16	2.18
42	2.77	2.73	2.64	2.62	2.66	2.70
44	3.42	3.36	3.23	3.18	3.24	3.31
46	4.20	4.11	3.92	3.83	3.91	4.02
48	5.10	4.98	4.72	4.58	4.68	4.83
50	6.15	5.99	5.64	5.44	5.56	5.77
52	7.37	7.16	6.71	6.43	6.56	6.83
54	8.77	8.51	7.93	7.55	7.69	8.03
56	10.4	10.1	9.3	8.8	9.0	9.4
58	12.2	11.8	10.9	10.3	10.4	10.9
60	14.3	13.8	12.7	11.9	12.0	12.6
62	16.6	16.0	14.7	13.7	13.8	14.5
64	19.3	18.6	17.0	15.8	15.8	16.6
66	22.2	21.4	19.6	18.0	18.0	18.9
68	25.5	24.6	22.4	20.6	20.5	21.5
70	29.2	28.1	25.6	23.4	23.2	24.3
72	33.3	32.0	29.1	26.5	26.2	27.4
74	37.8	36.4	33.0	30.0	29.4	30.8
76	42.8	41.2	37.3	33.8	33.1	34.5
78	48.4	46.5	42.0	38.0	37.0	38.6
80	54.4	52.3	47.2	42.5	41.3	43.0
82	61.1	58.7	52.9	47.6	46.0	47.8
84	68.4	65.7	59.2	53.0	51.2	53.0
86	76.3	73.3	66.0	59.0	56.8	58.6
88	85.0	81.6	73.4	65.5	62.8	64.7
90	94.4	90.6	81.5	72.6	69.4	71.3

Table D.3. Axle Load Equivalency Factors for Flexible Pavements, Triple Axles and p_t of 2.0

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0000	.0000	.0000	.0000	.0000	.0000
4	.0001	.0001	.0001	.0001	.0001	.0001
6	.0004	.0004	.0003	.0003	.0003	.0003
8	.0009	.0010	.0009	.0008	.0007	.0007
10	.002	.002	.002	.002	.002	.001
12	.004	.004	.004	.003	.003	.003
14	.006	.007	.007	.006	.006	.005
16	.010	.012	.012	.010	.009	.009
18	.016	.019	.019	.017	.015	.015
20	.024	.029	.029	.026	.024	.023
22	.034	.042	.042	.038	.035	.034
24	.049	.058	.060	.055	.051	.048
26	.068	.080	.083	.077	.071	.068
28	.093	.107	.113	.105	.098	.094
30	.125	.140	.149	.140	.131	.126
32	.164	.182	.194	.184	.173	.167
34	.213	.233	.248	.238	.225	.217
36	.273	.294	.313	.303	.288	.279
38	.346	.368	.390	.381	.364	.353
40	.434	.456	.481	.473	.454	.443
42	.538	.560	.587	.580	.561	.548
44	.662	.682	.710	.705	.686	.673
46	.807	.825	.852	.849	.831	.818
48	.976	.992	1.015	1.014	.999	.987
50	1.17	1.18	1.20	1.20	1.19	1.18
52	1.40	1.40	1.42	1.42	1.41	1.40
54	1.66	1.66	1.66	1.66	1.66	1.66
56	1.95	1.95	1.93	1.93	1.94	1.94
58	2.29	2.27	2.24	2.23	2.25	2.27
60	2.67	2.64	2.59	2.57	2.60	2.63
62	3.10	3.06	2.98	2.95	2.99	3.04
64	3.59	3.53	3.41	3.37	3.42	3.49
66	4.13	4.05	3.89	3.83	3.90	3.99
68	4.73	4.63	4.43	4.34	4.42	4.54
70	5.40	5.28	5.03	4.90	5.00	5.15
72	6.15	6.00	5.68	5.52	5.63	5.82
74	6.97	6.79	6.41	6.20	6.33	6.56
76	7.88	7.67	7.21	6.94	7.08	7.36
78	8.88	8.63	8.09	7.75	7.90	8.23
80	9.98	9.69	9.05	8.63	8.79	9.18
82	11.2	10.8	10.1	9.6	9.8	10.2
84	12.5	12.1	11.2	10.6	10.8	11.3
86	13.9	13.5	12.5	11.8	11.9	12.5
88	15.5	15.0	13.8	13.0	13.2	13.8
90	17.2	16.6	15.3	14.3	14.5	15.2

Table D.4. Axle Load Equivalency Factors for Flexible Pavements, Single Axles and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.	102.	79.	60.	53.	55.

Table D.5. Axle Load Equivalency Factors for Flexible Pavements, Tandem Axles and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013
14	.026	.041	.042	.033	.027	.024
16	.044	.065	.070	.057	.047	.043
18	.070	.097	.109	.092	.077	.070
20	.107	.141	.162	.141	.121	.110
22	.160	.198	.229	.207	.180	.166
24	.231	.273	.315	.292	.260	.242
26	.327	.370	.420	.401	.364	.342
28	.451	.493	.548	.534	.495	.470
30	.611	.648	.703	.695	.658	.633
32	.813	.843	.889	.887	.857	.834
34	1.06	1.08	1.11	1.11	1.09	1.08
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.75	1.73	1.69	1.68	1.70	1.73
40	2.21	2.16	2.06	2.03	2.08	2.14
42	2.76	2.67	2.49	2.43	2.51	2.61
44	3.41	3.27	2.99	2.88	3.00	3.16
46	4.18	3.98	3.58	3.40	3.55	3.79
48	5.08	4.80	4.25	3.98	4.17	4.49
50	6.12	5.76	5.03	4.64	4.86	5.28
52	7.33	6.87	5.93	5.38	5.63	6.17
54	8.72	8.14	6.95	6.22	6.47	7.15
56	10.3	9.6	8.1	7.2	7.4	8.2
58	12.1	11.3	9.4	8.2	8.4	9.4
60	14.2	13.1	10.9	9.4	9.6	10.7
62	16.5	15.3	12.6	10.7	10.8	12.1
64	19.1	17.6	14.5	12.2	12.2	13.7
66	22.1	20.3	16.6	13.8	13.7	15.4
68	25.3	23.3	18.9	15.6	15.4	17.2
70	29.0	26.6	21.5	17.6	17.2	19.2
72	33.0	30.3	24.4	19.8	19.2	21.3
74	37.5	34.4	27.6	22.2	21.3	23.6
76	42.5	38.9	31.1	24.8	23.7	26.1
78	48.0	43.9	35.0	27.8	26.2	28.8
80	54.0	49.4	39.2	30.9	29.0	31.7
82	60.6	55.4	43.9	34.4	32.0	34.8
84	67.8	61.9	49.0	38.2	35.3	38.1
86	75.7	69.1	54.5	42.3	38.8	41.7
88	84.3	76.9	60.6	46.8	42.6	45.6
90	93.7	85.4	67.1	51.7	46.8	49.7

Table D.6. Axle Load Equivalency Factors for Flexible Pavements, Triple Axles and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0000	.0000	.0000	.0000	.0000	.0000
4	.0002	.0002	.0002	.0001	.0001	.0001
6	.0006	.0007	.0005	.0004	.0003	.0003
8	.001	.002	.001	.001	.001	.001
10	.003	.004	.003	.002	.002	.002
12	.005	.007	.006	.004	.003	.003
14	.008	.012	.010	.008	.006	.006
16	.012	.019	.018	.013	.011	.010
18	.018	.029	.028	.021	.017	.016
20	.027	.042	.042	.032	.027	.024
22	.038	.058	.060	.048	.040	.036
24	.053	.078	.084	.068	.057	.051
26	.072	.103	.114	.095	.080	.072
28	.098	.133	.151	.128	.109	.099
30	.129	.169	.195	.170	.145	.133
32	.169	.213	.247	.220	.191	.175
34	.219	.266	.308	.281	.246	.228
36	.279	.329	.379	.352	.313	.292
38	.352	.403	.461	.436	.393	.368
40	.439	.491	.554	.533	.487	.459
42	.543	.594	.661	.644	.597	.567
44	.666	.714	.781	.769	.723	.692
46	.811	.854	.918	.911	.868	.838
48	.979	1.015	1.072	1.069	1.033	1.005
50	1.17	1.20	1.24	1.25	1.22	1.20
52	1.40	1.41	1.44	1.44	1.43	1.41
54	1.66	1.66	1.66	1.66	1.66	1.66
56	1.95	1.93	1.90	1.90	1.91	1.93
58	2.29	2.25	2.17	2.16	2.20	2.24
60	2.67	2.60	2.48	2.44	2.51	2.58
62	3.09	3.00	2.82	2.76	2.85	2.95
64	3.57	3.44	3.19	3.10	3.22	3.36
66	4.11	3.94	3.61	3.47	3.62	3.81
68	4.71	4.49	4.06	3.88	4.05	4.30
70	5.38	5.11	4.57	4.32	4.52	4.84
72	6.12	5.79	5.13	4.80	5.03	5.41
74	6.93	6.54	5.74	5.32	5.57	6.04
76	7.84	7.37	6.41	5.88	6.15	6.71
78	8.83	8.28	7.14	6.49	6.78	7.43
80	9.92	9.28	7.95	7.15	7.45	8.21
82	11.1	10.4	8.8	7.9	8.2	9.0
84	12.4	11.6	9.8	8.6	8.9	9.9
86	13.8	12.9	10.8	9.5	9.8	10.9
88	15.4	14.3	11.9	10.4	10.6	11.9
90	17.1	15.8	13.2	11.3	11.6	12.9

Table D.7. Axle Load Equivalency Factors for Flexible Pavements, Single Axles and p_t of 3.0

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0008	.0009	.0006	.0003	.0002	.0002
4	.004	.008	.006	.004	.002	.002
6	.014	.030	.028	.018	.012	.010
8	.035	.070	.080	.055	.040	.034
10	.082	.132	.168	.132	.101	.086
12	.173	.231	.296	.260	.212	.187
14	.332	.388	.468	.447	.391	.358
16	.594	.633	.695	.693	.651	.622
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.60	1.53	1.41	1.38	1.44	1.51
22	2.47	2.29	1.96	1.83	1.97	2.16
24	3.67	3.33	2.69	2.39	2.60	2.96
26	5.29	4.72	3.65	3.08	3.33	3.91
28	7.43	6.56	4.88	3.93	4.17	5.00
30	10.2	8.9	6.5	5.0	5.1	6.3
32	13.8	12.0	8.4	6.2	6.3	7.7
34	18.2	15.7	10.9	7.8	7.6	9.3
36	23.8	20.4	14.0	9.7	9.1	11.0
38	30.6	26.2	17.7	11.9	11.0	13.0
40	38.8	33.2	22.2	14.6	13.1	15.3
42	48.8	41.6	27.6	17.8	15.5	17.8
44	60.6	51.6	34.0	21.6	18.4	20.6
46	74.7	63.4	41.5	26.1	21.6	23.8
48	91.2	77.3	50.3	31.3	25.4	27.4
50	110.	94.	61.	37.	30.	32.

Table D.8. Axle Load Equivalency Factors for Flexible Pavements, Tandem Axles and p_t of 3.0

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0002	.0002	.0001	.0001	.0000	.0000
4	.001	.001	.001	.000	.000	.000
6	.003	.004	.003	.002	.001	.001
8	.006	.011	.009	.005	.003	.003
10	.011	.024	.020	.012	.008	.007
12	.019	.042	.039	.024	.017	.014
14	.031	.066	.068	.045	.032	.026
16	.049	.096	.109	.076	.055	.046
18	.075	.134	.164	.121	.090	.076
20	.113	.181	.232	.182	.139	.119
22	.166	.241	.313	.260	.205	.178
24	.238	.317	.407	.358	.292	.257
26	.333	.413	.517	.476	.402	.360
28	.457	.534	.643	.614	.538	.492
30	.616	.684	.788	.773	.702	.656
32	.817	.870	.956	.953	.896	.855
34	1.07	1.10	1.15	1.15	1.12	1.09
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.75	1.71	1.64	1.62	1.66	1.70
40	2.21	2.11	1.94	1.89	1.98	2.08
42	2.75	2.59	2.29	2.19	2.33	2.50
44	3.39	3.15	2.70	2.52	2.71	2.97
46	4.15	3.81	3.16	2.89	3.13	3.50
48	5.04	4.58	3.70	3.29	3.57	4.07
50	6.08	5.47	4.31	3.74	4.05	4.70
52	7.27	6.49	5.01	4.24	4.57	5.37
54	8.65	7.67	5.81	4.79	5.13	6.10
56	10.2	9.0	6.7	5.4	5.7	6.9
58	12.0	10.6	7.7	6.1	6.4	7.7
60	14.1	12.3	8.9	6.8	7.1	8.6
62	16.3	14.2	10.2	7.7	7.8	9.5
64	18.9	16.4	11.6	8.6	8.6	10.5
66	21.8	18.9	13.2	9.6	9.5	11.6
68	25.1	21.7	15.0	10.7	10.5	12.7
70	28.7	24.7	17.0	12.0	11.5	13.9
72	32.7	28.1	19.2	13.3	12.6	15.2
74	37.2	31.9	21.6	14.8	13.8	16.5
76	42.1	36.0	24.3	16.4	15.1	17.9
78	47.5	40.6	27.3	18.2	16.5	19.4
80	53.4	45.7	30.5	20.1	18.0	21.0
82	60.0	51.2	34.0	22.2	19.6	22.7
84	67.1	57.2	37.9	24.6	21.3	24.5
86	74.9	63.8	42.1	27.1	23.2	26.4
88	83.4	71.0	46.7	29.8	25.2	28.4
90	92.7	78.8	51.7	32.7	27.4	30.5

Table D.9. Axle Load Equivalency Factors for Flexible Pavements, Triple Axles and p_t of 3.0

Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0004	.0003	.0002	.0001	.0001
6	.001	.001	.001	.001	.000	.000
8	.003	.004	.002	.001	.001	.001
10	.005	.008	.005	.003	.002	.002
12	.007	.014	.010	.006	.004	.003
14	.011	.023	.018	.011	.007	.006
16	.016	.035	.030	.018	.013	.010
18	.022	.050	.047	.029	.020	.017
20	.031	.069	.069	.044	.031	.026
22	.043	.090	.097	.065	.046	.039
24	.059	.116	.132	.092	.066	.056
26	.079	.145	.174	.126	.092	.078
28	.104	.179	.223	.168	.126	.107
30	.136	.218	.279	.219	.167	.143
32	.176	.265	.342	.279	.218	.188
34	.226	.319	.413	.350	.279	.243
36	.286	.382	.491	.432	.352	.310
38	.359	.456	.577	.524	.437	.389
40	.447	.543	.671	.626	.536	.483
42	.550	.643	.775	.740	.649	.593
44	.673	.760	.889	.865	.777	.720
46	.817	.894	1.014	1.001	.920	.865
48	.984	1.048	1.152	1.148	1.080	1.030
50	1.18	1.23	1.30	1.31	1.26	1.22
52	1.40	1.43	1.47	1.48	1.45	1.43
54	1.66	1.66	1.66	1.66	1.66	1.66
56	1.95	1.92	1.86	1.85	1.88	1.91
58	2.28	2.21	2.09	2.06	2.13	2.20
60	2.66	2.54	2.34	2.28	2.39	2.50
62	3.08	2.92	2.61	2.52	2.66	2.84
64	3.56	3.33	2.92	2.77	2.96	3.19
66	4.09	3.79	3.25	3.04	3.27	3.58
68	4.68	4.31	3.62	3.33	3.60	4.00
70	5.34	4.88	4.02	3.64	3.94	4.44
72	6.08	5.51	4.46	3.97	4.31	4.91
74	6.89	6.21	4.94	4.32	4.69	5.40
76	7.78	6.98	5.47	4.70	5.09	5.93
78	8.76	7.83	6.04	5.11	5.51	6.48
80	9.84	8.75	6.67	5.54	5.96	7.06
82	11.0	9.8	7.4	6.0	6.4	7.7
84	12.3	10.9	8.1	6.5	6.9	8.3
86	13.7	12.1	8.9	7.0	7.4	9.0
88	15.3	13.4	9.8	7.6	8.0	9.6
90	16.9	14.8	10.7	8.2	8.5	10.4

Table D.10. Axle Load Equivalency Factors for Rigid Pavements, Single Axles and p_t of 2.0

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002
4	.002	.002	.002	.002	.002	.002	.002	.002	.002
6	.011	.010	.010	.010	.010	.010	.010	.010	.010
8	.035	.033	.032	.032	.032	.032	.032	.032	.032
10	.087	.084	.082	.081	.080	.080	.080	.080	.080
12	.186	.180	.176	.175	.174	.174	.173	.173	.173
14	.353	.346	.341	.338	.337	.336	.336	.336	.336
16	.614	.609	.604	.601	.599	.599	.598	.598	.598
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.55	1.56	1.57	1.58	1.58	1.59	1.59	1.59	1.59
22	2.32	2.32	2.35	2.38	2.40	2.41	2.41	2.41	2.42
24	3.37	3.34	3.40	3.47	3.51	3.53	3.54	3.55	3.55
26	4.76	4.69	4.77	4.88	4.97	5.02	5.04	5.06	5.06
28	6.58	6.44	6.52	6.70	6.85	6.94	7.00	7.02	7.04
30	8.92	8.68	8.74	8.98	9.23	9.39	9.48	9.54	9.56
32	11.9	11.5	11.5	11.8	12.2	12.4	12.6	12.7	12.7
34	15.5	15.0	14.9	15.3	15.8	16.2	16.4	16.6	16.7
36	20.1	19.3	19.2	19.5	20.1	20.7	21.1	21.4	21.5
38	25.6	24.5	24.3	24.6	25.4	26.1	26.7	27.1	27.4
40	32.2	30.8	30.4	30.7	31.6	32.6	33.4	34.0	34.4
42	40.1	38.4	37.7	38.0	38.9	40.1	41.3	42.1	42.7
44	49.4	47.3	46.4	46.6	47.6	49.0	50.4	51.6	52.4
46	60.4	57.7	56.6	56.7	57.7	59.3	61.1	62.6	63.7
48	73.2	69.9	68.4	68.4	69.4	71.2	73.3	75.3	76.8
50	88.0	84.1	82.2	82.0	83.0	84.9	87.4	89.8	91.7

Table D.11. Axle Load Equivalency Factors for Rigid Pavements, Tandem Axles and p_t of 2.0

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
4	.0006	.0005	.0005	.0005	.0005	.0005	.0005	.0005	.0005
6	.002	.002	.002	.002	.002	.002	.002	.002	.002
8	.006	.006	.005	.005	.005	.005	.005	.005	.005
10	.014	.013	.013	.012	.012	.012	.012	.012	.012
12	.028	.026	.026	.025	.025	.025	.025	.025	.025
14	.051	.049	.048	.047	.047	.047	.047	.047	.047
16	.087	.084	.082	.081	.081	.080	.080	.080	.080
18	.141	.136	.133	.132	.131	.131	.131	.131	.131
20	.216	.210	.206	.204	.203	.203	.203	.203	.203
22	.319	.313	.307	.305	.304	.303	.303	.303	.303
24	.454	.449	.444	.441	.440	.439	.439	.439	.439
26	.629	.626	.622	.620	.618	.618	.618	.618	.618
28	.852	.851	.850	.850	.850	.849	.849	.849	.849
30	1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.14	1.14
32	1.48	1.48	1.49	1.50	1.51	1.51	1.51	1.51	1.51
34	1.90	1.90	1.93	1.95	1.96	1.97	1.97	1.97	1.97
36	2.42	2.41	2.45	2.49	2.51	2.52	2.53	2.53	2.53
38	3.04	3.02	3.07	3.13	3.17	3.19	3.20	3.20	3.21
40	3.79	3.74	3.80	3.89	3.95	3.98	4.00	4.01	4.01
42	4.67	4.59	4.66	4.78	4.87	4.93	4.95	4.97	4.97
44	5.72	5.59	5.67	5.82	5.95	6.03	6.07	6.09	6.10
46	6.94	6.76	6.83	7.02	7.20	7.31	7.37	7.41	7.43
48	8.36	8.12	8.17	8.40	8.63	8.79	8.88	8.93	8.96
50	10.00	9.69	9.72	9.98	10.27	10.49	10.62	10.69	10.73
52	11.9	11.5	11.5	11.8	12.1	12.4	12.6	12.7	12.8
54	14.0	13.5	13.5	13.8	14.2	14.6	14.9	15.0	15.1
56	16.5	15.9	15.8	16.1	16.6	17.1	17.4	17.6	17.7
58	19.3	18.5	18.4	18.7	19.3	19.8	20.3	20.5	20.7
60	22.4	21.5	21.3	21.6	22.3	22.9	23.5	23.8	24.0
62	25.9	24.9	24.6	24.9	25.6	26.4	27.0	27.5	27.7
64	29.9	28.6	28.2	28.5	29.3	30.2	31.0	31.6	31.9
66	34.3	32.8	32.3	32.6	33.4	34.4	35.4	36.1	36.5
68	39.2	37.5	36.8	37.1	37.9	39.1	40.2	41.1	41.6
70	44.6	42.7	41.9	42.1	42.9	44.2	45.5	46.6	47.3
72	50.6	48.4	47.5	47.6	48.5	49.9	51.4	52.6	53.5
74	57.3	54.7	53.6	53.6	54.6	56.1	57.7	59.2	60.3
76	64.6	61.7	60.4	60.3	61.2	62.8	64.7	66.4	67.7
78	72.5	69.3	67.8	67.7	68.6	70.2	72.3	74.3	75.8
80	81.3	77.6	75.9	75.7	76.6	78.3	80.6	82.8	84.7
82	90.9	86.7	84.7	84.4	85.3	87.1	89.6	92.1	94.2
84	101.	97.	94.	94.	95.	97.	99.	102.	105.
86	113.	107.	105.	104.	105.	107.	110.	113.	116.
88	125.	119.	116.	116.	116.	118.	121.	125.	128.
90	138.	132.	129.	128.	129.	131.	134.	137.	141.

Table D.12. Axle Load Equivalency Factors for Rigid Pavements, Triple Axles and p_t of 2.0

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
6	.0010	.0009	.0009	.0009	.0009	.0009	.0009	.0009	.0009
8	.002	.002	.002	.002	.002	.002	.002	.002	.002
10	.005	.005	.005	.005	.005	.005	.005	.005	.005
12	.010	.010	.009	.009	.009	.009	.009	.009	.009
14	.018	.017	.017	.016	.016	.016	.016	.016	.016
16	.030	.029	.028	.027	.027	.027	.027	.027	.027
18	.047	.045	.044	.044	.043	.043	.043	.043	.043
20	.072	.069	.067	.066	.066	.066	.066	.066	.066
22	.105	.101	.099	.098	.097	.097	.097	.097	.097
24	.149	.144	.141	.139	.139	.138	.138	.138	.138
26	.205	.199	.195	.194	.193	.192	.192	.192	.192
28	.276	.270	.265	.263	.262	.262	.262	.262	.261
30	.364	.359	.354	.351	.350	.349	.349	.349	.349
32	.472	.468	.463	.460	.459	.458	.458	.458	.458
34	.603	.600	.596	.594	.593	.592	.592	.592	.592
36	.759	.758	.757	.756	.755	.755	.755	.755	.755
38	.946	.947	.949	.950	.951	.951	.951	.951	.951
40	1.17	1.17	1.18	1.18	1.18	1.18	1.18	1.18	1.19
42	1.42	1.43	1.44	1.45	1.46	1.46	1.46	1.46	1.46
44	1.73	1.73	1.75	1.77	1.78	1.78	1.79	1.79	1.79
46	2.08	2.07	2.10	2.13	2.15	2.16	2.16	2.16	2.17
48	2.48	2.47	2.51	2.55	2.58	2.59	2.60	2.60	2.61
50	2.95	2.92	2.97	3.03	3.07	3.09	3.10	3.11	3.11
52	3.48	3.44	3.50	3.58	3.63	3.66	3.68	3.69	3.69
54	4.09	4.03	4.09	4.20	4.27	4.31	4.33	4.35	4.35
56	4.78	4.69	4.76	4.89	4.99	5.05	5.08	5.09	5.10
58	5.57	5.44	5.51	5.66	5.79	5.87	5.91	5.94	5.95
60	6.45	6.29	6.35	6.53	6.69	6.79	6.85	6.88	6.90
62	7.43	7.23	7.28	7.49	7.69	7.82	7.90	7.94	7.97
64	8.54	8.28	8.32	8.55	8.80	8.97	9.07	9.13	9.16
66	9.76	9.46	9.48	9.73	10.02	10.24	10.37	10.44	10.48
68	11.1	10.8	10.8	11.0	11.4	11.6	11.8	11.9	12.0
70	12.6	12.2	12.2	12.5	12.8	13.2	13.4	13.5	13.6
72	14.3	13.8	13.7	14.0	14.5	14.9	15.1	15.3	15.4
74	16.1	15.5	15.4	15.7	16.2	16.7	17.0	17.2	17.3
76	18.2	17.5	17.3	17.6	18.2	18.7	19.1	19.3	19.5
78	20.4	19.6	19.4	19.7	20.3	20.9	21.4	21.7	21.8
80	22.8	21.9	21.6	21.9	22.6	23.3	23.8	24.2	24.4
82	25.4	24.4	24.1	24.4	25.0	25.8	26.5	26.9	27.2
84	28.3	27.1	26.7	27.0	27.7	28.6	29.4	29.9	30.2
86	31.4	30.1	29.6	29.9	30.7	31.6	32.5	33.1	33.5
88	34.8	33.3	32.8	33.0	33.8	34.8	35.8	36.6	37.1
90	38.5	36.8	36.2	36.4	37.2	38.3	39.4	40.3	40.9

Table D.13. Axle Load Equivalency Factors for Rigid Pavements, Single Axles and p_t of 2.5

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002
4	.003	.002	.002	.002	.002	.002	.002	.002	.002
6	.012	.011	.010	.010	.010	.010	.010	.010	.010
8	.039	.035	.033	.032	.032	.032	.032	.032	.032
10	.097	.089	.084	.082	.081	.080	.080	.080	.080
12	.203	.189	.181	.176	.175	.174	.174	.173	.173
14	.376	.360	.347	.341	.338	.337	.336	.336	.336
16	.634	.623	.610	.604	.601	.599	.599	.599	.598
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.51	1.52	1.55	1.57	1.58	1.58	1.59	1.59	1.59
22	2.21	2.20	2.28	2.34	2.38	2.40	2.41	2.41	2.41
24	3.16	3.10	3.22	3.36	3.45	3.50	3.53	3.54	3.55
26	4.41	4.26	4.42	4.67	4.85	4.95	5.01	5.04	5.05
28	6.05	5.76	5.92	6.29	6.61	6.81	6.92	6.98	7.01
30	8.16	7.67	7.79	8.28	8.79	9.14	9.35	9.46	9.52
32	10.8	10.1	10.1	10.7	11.4	12.0	12.3	12.6	12.7
34	14.1	13.0	12.9	13.6	14.6	15.4	16.0	16.4	16.5
36	18.2	16.7	16.4	17.1	18.3	19.5	20.4	21.0	21.3
38	23.1	21.1	20.6	21.3	22.7	24.3	25.6	26.4	27.0
40	29.1	26.5	25.7	26.3	27.9	29.9	31.6	32.9	33.7
42	36.2	32.9	31.7	32.2	34.0	36.3	38.7	40.4	41.6
44	44.6	40.4	38.8	39.2	41.0	43.8	46.7	49.1	50.8
46	54.5	49.3	47.1	47.3	49.2	52.3	55.9	59.0	61.4
48	66.1	59.7	56.9	56.8	58.7	62.1	66.3	70.3	73.4
50	79.4	71.7	68.2	67.8	69.6	73.3	78.1	83.0	87.1

Table D.14. Axle Load Equivalency Factors for Rigid Pavements, Tandem Axles and p_t of 2.5

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
4	.0006	.0006	.0005	.0005	.0005	.0005	.0005	.0005	.0005
6	.002	.002	.002	.002	.002	.002	.002	.002	.002
8	.007	.006	.006	.005	.005	.005	.005	.005	.005
10	.015	.014	.013	.013	.012	.012	.012	.012	.012
12	.031	.028	.026	.026	.025	.025	.025	.025	.025
14	.057	.052	.049	.048	.047	.047	.047	.047	.047
16	.097	.089	.084	.082	.081	.081	.080	.080	.080
18	.155	.143	.136	.133	.132	.131	.131	.131	.131
20	.234	.220	.211	.206	.204	.203	.203	.203	.203
22	.340	.325	.313	.308	.305	.304	.303	.303	.303
24	.475	.462	.450	.444	.441	.440	.439	.439	.439
26	.644	.637	.627	.622	.620	.619	.618	.618	.618
28	.855	.854	.852	.850	.850	.850	.849	.849	.849
30	1.11	1.12	1.13	1.14	1.14	1.14	1.14	1.14	1.14
32	1.43	1.44	1.47	1.49	1.50	1.51	1.51	1.51	1.51
34	1.82	1.82	1.87	1.92	1.95	1.96	1.97	1.97	1.97
36	2.29	2.27	2.35	2.43	2.48	2.51	2.52	2.52	2.53
38	2.85	2.80	2.91	3.03	3.12	3.16	3.18	3.20	3.20
40	3.52	3.42	3.55	3.74	3.87	3.94	3.98	4.00	4.01
42	4.32	4.16	4.30	4.55	4.74	4.86	4.91	4.95	4.96
44	5.26	5.01	5.16	5.48	5.75	5.92	6.01	6.06	6.09
46	6.36	6.01	6.14	6.53	6.90	7.14	7.28	7.36	7.40
48	7.64	7.16	7.27	7.73	8.21	8.55	8.75	8.86	8.92
50	9.11	8.50	8.55	9.07	9.68	10.14	10.42	10.58	10.66
52	10.8	10.0	10.0	10.6	11.3	11.9	12.3	12.5	12.7
54	12.8	11.8	11.7	12.3	13.2	13.9	14.5	14.8	14.9
56	15.0	13.8	13.6	14.2	15.2	16.2	16.8	17.3	17.5
58	17.5	16.0	15.7	16.3	17.5	18.6	19.5	20.1	20.4
60	20.3	18.5	18.1	18.7	20.0	21.4	22.5	23.2	23.6
62	23.5	21.4	20.8	21.4	22.8	24.4	25.7	26.7	27.3
64	27.0	24.6	23.8	24.4	25.8	27.7	29.3	30.5	31.3
66	31.0	28.1	27.1	27.6	29.2	31.3	33.2	34.7	35.7
68	35.4	32.1	30.9	31.3	32.9	35.2	37.5	39.3	40.5
70	40.3	36.5	35.0	35.3	37.0	39.5	42.1	44.3	45.9
72	45.7	41.4	39.6	39.8	41.5	44.2	47.2	49.8	51.7
74	51.7	46.7	44.6	44.7	46.4	49.3	52.7	55.7	58.0
76	58.3	52.6	50.2	50.1	51.8	54.9	58.6	62.1	64.8
78	65.5	59.1	56.3	56.1	57.7	60.9	65.0	69.0	72.3
80	73.4	66.2	62.9	62.5	64.2	67.5	71.9	76.4	80.2
82	82.0	73.9	70.2	69.6	71.2	74.7	79.4	84.4	88.8
84	91.4	82.4	78.1	77.3	78.9	82.4	87.4	93.0	98.1
86	102.	92.	87.	86.	87.	91.	96.	102.	108.
88	113.	102.	96.	95.	96.	100.	105.	112.	119.
90	125.	112.	106.	105.	106.	110.	115.	123.	130.

Table D.15. Axle Load Equivalency Factors for Rigid Pavements, Triple Axles and p_t of 2.5

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
6	.001	.001	.001	.001	.001	.001	.001	.001	.001
8	.003	.002	.002	.002	.002	.002	.002	.002	.002
10	.006	.005	.005	.005	.005	.005	.005	.005	.005
12	.011	.010	.010	.009	.009	.009	.009	.009	.009
14	.020	.018	.017	.017	.016	.016	.016	.016	.016
16	.033	.030	.029	.028	.027	.027	.027	.027	.027
18	.053	.048	.045	.044	.044	.043	.043	.043	.043
20	.080	.073	.069	.067	.066	.066	.066	.066	.066
22	.116	.107	.101	.099	.098	.097	.097	.097	.097
24	.163	.151	.144	.141	.139	.139	.138	.138	.138
26	.222	.209	.200	.195	.194	.193	.192	.192	.192
28	.295	.281	.271	.265	.263	.262	.262	.262	.262
30	.384	.371	.359	.354	.351	.350	.349	.349	.349
32	.490	.480	.468	.463	.460	.459	.458	.458	.458
34	.616	.609	.601	.596	.594	.593	.592	.592	.592
36	.765	.762	.759	.757	.756	.755	.755	.755	.755
38	.939	.941	.946	.948	.950	.951	.951	.951	.951
40	1.14	1.15	1.16	1.17	1.18	1.18	1.18	1.18	1.18
42	1.38	1.38	1.41	1.44	1.45	1.46	1.46	1.46	1.46
44	1.65	1.65	1.70	1.74	1.77	1.78	1.78	1.78	1.79
46	1.97	1.96	2.03	2.09	2.13	2.15	2.16	2.16	2.16
48	2.34	2.31	2.40	2.49	2.55	2.58	2.59	2.60	2.60
50	2.76	2.71	2.81	2.94	3.02	3.07	3.09	3.10	3.11
52	3.24	3.15	3.27	3.44	3.56	3.62	3.66	3.68	3.68
54	3.79	3.66	3.79	4.00	4.16	4.26	4.30	4.33	4.34
56	4.41	4.23	4.37	4.63	4.84	4.97	5.03	5.07	5.09
58	5.12	4.87	5.00	5.32	5.59	5.76	5.85	5.90	5.93
60	5.91	5.59	5.71	6.08	6.42	6.64	6.77	6.84	6.87
62	6.80	6.39	6.50	6.91	7.33	7.62	7.79	7.88	7.93
64	7.79	7.29	7.37	7.82	8.33	8.70	8.92	9.04	9.11
66	8.90	8.28	8.33	8.83	9.42	9.88	10.17	10.33	10.42
68	10.1	9.4	9.4	9.9	10.6	11.2	11.5	11.7	11.9
70	11.5	10.6	10.6	11.1	11.9	12.6	13.0	13.3	13.5
72	13.0	12.0	11.8	12.4	13.3	14.1	14.7	15.0	15.2
74	14.6	13.5	13.2	13.8	14.8	15.8	16.5	16.9	17.1
76	16.5	15.1	14.8	15.4	16.5	17.6	18.4	18.9	19.2
78	18.5	16.9	16.5	17.1	18.2	19.5	20.5	21.1	21.5
80	20.6	18.8	18.3	18.9	20.2	21.6	22.7	23.5	24.0
82	23.0	21.0	20.3	20.9	22.2	23.8	25.2	26.1	26.7
84	25.6	23.3	22.5	23.1	24.5	26.2	27.8	28.9	29.6
86	28.4	25.8	24.9	25.4	26.9	28.8	30.5	31.9	32.8
88	31.5	28.6	27.5	27.9	29.4	31.5	33.5	35.1	36.1
90	34.8	31.5	30.3	30.7	32.2	34.4	36.7	38.5	39.8

Table D.16. Axle Load Equivalency Factors for Rigid Pavements, Single Axles and p_t of 3.0

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0003	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002
4	.003	.003	.002	.002	.002	.002	.002	.002	.002
6	.014	.012	.011	.010	.010	.010	.010	.010	.010
8	.045	.038	.034	.033	.032	.032	.032	.032	.032
10	.111	.095	.087	.083	.081	.081	.080	.080	.080
12	.228	.202	.186	.179	.176	.174	.174	.174	.173
14	.408	.378	.355	.344	.340	.337	.337	.336	.336
16	.660	.640	.619	.608	.603	.600	.599	.599	.599
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.46	1.47	1.52	1.55	1.57	1.58	1.58	1.59	1.59
22	2.07	2.06	2.18	2.29	2.35	2.38	2.40	2.41	2.41
24	2.90	2.81	3.00	3.23	3.38	3.47	3.51	3.53	3.54
26	4.00	3.77	4.01	4.40	4.70	4.87	4.96	5.01	5.04
28	5.43	4.99	5.23	5.80	6.31	6.65	6.83	6.93	6.98
30	7.27	6.53	6.72	7.46	8.25	8.83	9.17	9.36	9.46
32	9.59	8.47	8.53	9.42	10.54	11.44	12.03	12.37	12.56
34	12.5	10.9	10.7	11.7	13.2	14.5	15.5	16.0	16.4
36	16.0	13.8	13.4	14.4	16.2	18.1	19.5	20.4	21.0
38	20.4	17.4	16.7	17.7	19.8	22.2	24.2	25.6	26.4
40	25.6	21.8	20.6	21.5	23.8	26.8	29.5	31.5	32.9
42	31.8	26.9	25.3	26.0	28.5	32.0	35.5	38.4	40.3
44	39.2	33.1	30.8	31.3	33.9	37.9	42.3	46.1	48.8
46	47.8	40.3	37.2	37.5	40.1	44.5	49.8	54.7	58.5
48	57.9	48.6	44.8	44.7	47.3	52.1	58.2	64.3	69.4
50	69.6	58.4	53.6	53.1	55.6	60.6	67.6	75.0	81.4

Table D.17. Axle Load Equivalency Factors for Rigid Pavements, Tandem Axles and p_t of 3.0

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
4	.0007	.0006	.0005	.0005	.0005	.0005	.0005	.0005	.0005
6	.003	.002	.002	.002	.002	.002	.002	.002	.002
8	.008	.006	.006	.006	.005	.005	.005	.005	.005
10	.018	.015	.013	.013	.013	.012	.012	.012	.012
12	.036	.030	.027	.026	.026	.025	.025	.025	.025
14	.066	.056	.050	.048	.047	.047	.047	.047	.047
16	.111	.095	.087	.083	.081	.081	.081	.080	.080
18	.174	.153	.140	.135	.132	.131	.131	.131	.131
20	.260	.234	.217	.209	.205	.204	.203	.203	.203
22	.368	.341	.321	.311	.307	.305	.304	.303	.303
24	.502	.479	.458	.447	.443	.440	.440	.439	.439
26	.664	.651	.634	.625	.621	.619	.618	.618	.618
28	.859	.857	.853	.851	.850	.850	.850	.849	.849
30	1.09	1.10	1.12	1.13	1.14	1.14	1.14	1.14	1.14
32	1.38	1.38	1.44	1.47	1.49	1.50	1.51	1.51	1.51
34	1.72	1.71	1.80	1.88	1.93	1.95	1.96	1.97	1.97
36	2.13	2.10	2.23	2.36	2.45	2.49	2.51	2.52	2.52
38	2.62	2.54	2.71	2.92	3.06	3.13	3.17	3.19	3.20
40	3.21	3.05	3.26	3.55	3.76	3.89	3.95	3.98	4.00
42	3.90	3.65	3.87	4.26	4.58	4.77	4.87	4.92	4.95
44	4.72	4.35	4.57	5.06	5.50	5.78	5.94	6.02	6.06
46	5.68	5.16	5.36	5.95	6.54	6.94	7.17	7.29	7.36
48	6.80	6.10	6.25	6.93	7.69	8.24	8.57	8.76	8.86
50	8.09	7.17	7.26	8.03	8.96	9.70	10.17	10.43	10.58
52	9.57	8.41	8.40	9.24	10.36	11.32	11.96	12.33	12.54
54	11.3	9.8	9.7	10.6	11.9	13.1	14.0	14.5	14.8
56	13.2	11.4	11.2	12.1	13.6	15.1	16.2	16.9	17.3
58	15.4	13.2	12.8	13.7	15.4	17.2	18.6	19.5	20.1
60	17.9	15.3	14.7	15.6	17.4	19.5	21.3	22.5	23.2
62	20.6	17.6	16.8	17.6	19.6	22.0	24.1	25.7	26.6
64	23.7	20.2	19.1	19.9	22.0	24.7	27.3	29.2	30.4
66	27.2	23.1	21.7	22.4	24.6	27.6	30.6	33.0	34.6
68	31.1	26.3	24.6	25.2	27.4	30.8	34.3	37.1	39.2
70	35.4	29.8	27.8	28.2	30.6	34.2	38.2	41.6	44.1
72	40.1	33.8	31.3	31.6	34.0	37.9	42.3	46.4	49.4
74	45.3	38.1	35.2	35.4	37.7	41.8	46.8	51.5	55.2
76	51.1	42.9	39.5	39.5	41.8	46.1	51.5	56.9	61.3
78	57.4	48.2	44.3	44.0	46.3	50.7	56.6	62.7	67.9
80	64.3	53.9	49.4	48.9	51.1	55.8	62.1	68.9	74.9
82	71.8	60.2	55.1	54.3	56.5	61.2	67.9	75.5	82.4
84	80.0	67.0	61.2	60.2	62.2	67.0	74.2	82.4	90.3
86	89.0	74.5	67.9	66.5	68.5	73.4	80.8	89.8	98.7
88	98.7	82.5	75.2	73.5	75.3	80.2	88.0	97.7	107.5
90	109.	91.	83.	81.	83.	88.	96.	106.	117.

Table D.18. Axle Load Equivalency Factors for Rigid Pavements, Triple Axles and p_t of 3.0

Axle Load (kips)	Slab Thickness, D (inches)								
	6	7	8	9	10	11	12	13	14
2	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
4	.0004	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003
6	.001	.001	.001	.001	.001	.001	.001	.001	.001
8	.003	.003	.002	.002	.002	.002	.002	.002	.002
10	.007	.006	.005	.005	.005	.005	.005	.005	.005
12	.013	.011	.010	.009	.009	.009	.009	.009	.009
14	.023	.020	.018	.017	.017	.016	.016	.016	.016
16	.039	.033	.030	.028	.028	.027	.027	.027	.027
18	.061	.052	.047	.045	.044	.044	.043	.043	.043
20	.091	.078	.071	.068	.067	.066	.066	.066	.066
22	.132	.114	.104	.100	.098	.097	.097	.097	.097
24	.183	.161	.148	.143	.140	.139	.139	.138	.138
26	.246	.221	.205	.198	.195	.193	.193	.192	.192
28	.322	.296	.277	.268	.265	.263	.262	.262	.262
30	.411	.387	.367	.357	.353	.351	.350	.349	.349
32	.515	.495	.476	.466	.462	.460	.459	.458	.458
34	.634	.622	.607	.599	.595	.594	.593	.592	.592
36	.772	.768	.762	.758	.756	.756	.755	.755	.755
38	.930	.934	.942	.947	.949	.950	.951	.951	.951
40	1.11	1.12	1.15	1.17	1.18	1.18	1.18	1.18	1.18
42	1.32	1.33	1.38	1.42	1.44	1.45	1.46	1.46	1.46
44	1.56	1.56	1.64	1.71	1.75	1.77	1.78	1.78	1.78
46	1.84	1.83	1.94	2.04	2.10	2.14	2.15	2.16	2.16
48	2.16	2.12	2.26	2.41	2.51	2.56	2.58	2.59	2.60
50	2.53	2.45	2.61	2.82	2.96	3.03	3.07	3.09	3.10
52	2.95	2.82	3.01	3.27	3.47	3.58	3.63	3.66	3.68
54	3.43	3.23	3.43	3.77	4.03	4.18	4.27	4.31	4.33
56	3.98	3.70	3.90	4.31	4.65	4.86	4.98	5.04	5.07
58	4.59	4.22	4.42	4.90	5.34	5.62	5.78	5.86	5.90
60	5.28	4.80	4.99	5.54	6.08	6.45	6.66	6.78	6.84
62	6.06	5.45	5.61	6.23	6.89	7.36	7.64	7.80	7.88
64	6.92	6.18	6.29	6.98	7.76	8.36	8.72	8.93	9.04
66	7.89	6.98	7.05	7.78	8.70	9.44	9.91	10.18	10.33
68	8.96	7.88	7.87	8.66	9.71	10.61	11.20	11.55	11.75
70	10.2	8.9	8.8	9.6	10.8	11.9	12.6	13.1	13.3
72	11.5	10.0	9.8	10.6	12.0	13.2	14.1	14.7	15.0
74	12.9	11.2	10.9	11.7	13.2	14.7	15.8	16.5	16.9
76	14.5	12.5	12.1	12.9	14.5	16.2	17.5	18.4	18.9
78	16.2	13.9	13.4	14.2	15.9	17.8	19.4	20.5	21.1
80	18.2	15.5	14.8	15.6	17.4	19.6	21.4	22.7	23.5
82	20.2	17.2	16.4	17.2	19.1	21.4	23.5	25.1	26.1
84	22.5	19.1	18.1	18.8	20.8	23.4	25.8	27.6	28.8
86	25.0	21.2	19.9	20.6	22.6	25.5	28.2	30.4	31.8
88	27.6	23.4	21.9	22.5	24.6	27.7	30.7	33.2	35.0
90	30.5	25.8	24.1	24.6	26.8	30.0	33.4	36.3	38.3

Axle Load	Traffic Equivalency Factor		Number of Axles		A18 Kip EAL's
Single Axles	P = 2.5, SN = 5				
Under 3,000	0.0002	X	0	=	0.000
3,000 - 6,999	0.0050	X	1	=	0.005
7,000 - 7,999	0.0320	X	6	=	0.192
8,000 - 11,999	0.0870	X	144	=	12.528
12,000 - 15,999	0.3600	X	16	=	5.760
26,000 - 29,999	5.3890	X	1	=	5.3890
Tandem Axle Groups					
Under 6,000	0.0100	X	0	=	0.000
6,000 - 11,993	0.0100	X	14	=	0.140
12,000 - 17,999	0.0440	X	21	=	0.924
18,000 - 23,999	0.1480	X	44	=	6.512
24,000 - 29,999	0.4260	X	42	=	17.892
30,000 - 32,000	0.7530	X	44	=	33.132
32,001 - 32,500	0.8850	X	21	=	18.585
32,501 - 33,999	1.0020	X	101	=	101.202
34,000 - 35,999	1.2300	X	43	=	52.890
18 Kip EAL's for all trucks wieghed				=	255.151

$$\text{Truck Load Factor} = \frac{\text{18 Kip EAL's for all trucks weighed}}{\text{Number of trucks weighed 165}} = \frac{255.151}{165} = 1.5464$$

Figure D.1. Computation of the Truck Load Factor for 5 Axle or Greater Trucks on Flexible Pavements with an SN = 5 and a Terminal Serviceability of 2.5

within the axle load intervals indicated. The ESAL's by axle load intervals is summed to give a total ESAL's for 165 trucks of this type which were weighed. The truck load factor is found to be 1.5464. A similar set of calculations can be made for each truck classification included in the W-4 tables.

It should be noted that this truck load factor was based on an assumed terminal serviceability of 2.5 and a structural number (SN) of 5.0. In most cases, such an assumption will provide information sufficiently accurate for design purposes. When more accuracy is required, it will be necessary to recalculate the truck load factor with the new equivalency factors as previously discussed.

When information is not available directly from weigh station loadings, it is necessary to use representative values for each of the various truck classifications. No adjustments can be made for serviceability or thicknesses using this alternate. This method is likely to be the one used most often.

The work sheet in Table D.19 may be used to calculate ESAL's using truck load factors obtained directly or based on representative values furnished by the design agency.

The first column (A) represents the base year daily volume counts of each vehicle type taken from data collected at classification count stations representative of the design location.

The second column (B) indicates the growth factor assigned to each of the various vehicle types. The calculations should take into account the fact that growth factors normally vary from one vehicle type to another. Table D.20 provides appropriate multipliers for a given growth rate and design period. Any growth factor selected should reflect consideration of the variables mentioned in Section D.1.

The third column (C) is basically a product of the first two columns multiplied again by 365. The result is the accumulated applications of specific vehicle types during the analysis period.

The fourth column (D) indicates the individual ESAL values for each of the vehicle types.

The fifth column (E) is an extension of columns (C) and (D) indicating the total ESAL's (by vehicle type) that might be applied to the sample section during the analysis period. The summation of these values then is the total 18-kip ESAL traffic that should be used for pavement structural design.

The number of equivalent axle loads derived using the procedure represents the total for all lanes and both directions of travel. This number must then be distributed by direction and by lanes, as discussed in Section D.1.

D.3 EXAMPLE ESAL CALCULATIONS

In order to illustrate more specifically how this procedure works, a number of sample calculations follow. Table D.21 shows the calculations of 18-kip ESAL's for a facility having traffic typical of a rural arterial. Data for this example comes from the W-2 and W-4 tables and are assumed to be representative of the design facility. In developing the Example 1 calculation, the following assumptions were made:

(1) Traffic volumes (for all vehicle types) will increase at a rate of 2 percent per year, compounded annually (as previously noted, a poor assumption).
(2) The axle weights of the various vehicle types will remain constant over the analysis period.
(3) Terminal serviceability (p_t) is 2.5.
(4) Analysis period is 20 years; since stage construction is not considered, the performance period is also 20 years.
(5) Slab thickness (D) is equal to 9 inches.

From the W-2 table, the number of passenger cars (5,925) is entered in Column A, followed by the number for buses (35). From the W-4 table, the total number of vehicles counted is used for the balance of the Column A entries, using only the numbers for the current year's data. For this example, 1,135 panel and pickup trucks, 3 other two-axle/four-tire trucks, 372 two-axle/six-tire trucks, etc., have been entered to complete Column A.

Table D.20 provides the criteria for selection of values for Column B. For the 20-year analysis period and the fixed growth factor of 2 percent per year for all vehicle types, a value of 24.30 is obtained. Multiplying Column A by Column B and then multiplying this number by 365 to annualize it, Column C can be completed.

Returning to the W-4 tables, summary information is provided for the average ESAL's per 1,000 trucks weighed. For this example, under panel and pickup trucks, the value is 12.2 ESAL per 1,000 trucks, or 0.0122 per vehicle. The W-4 table will provide similar information for each truck classification shown in Table D.21.

Finally, by multiplying the numbers in Column C by the values in Column D, Column E can be completed. The summation of the numbers in Column E, then, is the total design 18-kip ESAL value. In the first example, it has been predicted that this sample section will experience 43.8 million 18-kip ESAL applications over the next 20 years assuming only a 2-percent annual growth in traffic with no change in axle

Table D.19. Worksheet for Calculating 18-kip Equivalent Single Axle Load (ESAL) Applications

Location ____________________

Analysis Period = __________ **Years**

Assumed SN or D = __________

Vehicle Types	**Current Traffic (A)**	**Growth Factors (B)**	**Design Traffic (C)**	**E.S.A.L. Factor (D)**	**Design E.S.A.L. (E)**
Passenger Cars Buses					
Panel and Pickup Trucks Other 2-Axle/4-Tire Trucks 2-Axle/6-Tire Trucks 3 or More Axle Trucks All Single Unit Trucks					
3 Axle Tractor Semi-Trailers 4 Axle Tractor Semi-Trailers 5+ Axle Tractor Semi-Trailers All Tractor Semi-Trailers					
5 Axle Double Trailers 6+ Axle Double Trailers All Double Trailer Combos					
3 Axle Truck-Trailers 4 Axle Truck-Trailers 5+ Axle Truck-Trailers All Truck-Trailer Combos					
All Vehicles				**Design E.S.A.L.**	

Table D.20. Traffic Growth Factors*

Analysis Period Years (n)	Annual Growth Rate, Percent (g)							
	No Growth	2	4	5	6	7	8	10
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.02	2.04	2.05	2.06	2.07	2.08	2.10
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	3.31
4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	6.11
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	7.72
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	9.49
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	11.44
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	13.58
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	15.94
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	18.53
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	21.38
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	24.52
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	27.97
15	15.0	17.29	20.02	21.58	23.28	25.13	27.15	31.77
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	35.95
17	17.0	20.01	23.70	25.84	28.21	30.84	33.75	40.55
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	45.60
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	51.16
20	20.0	24.30	29.78	33.06	36.79	41.00	45.76	57.28
25	25.0	32.03	41.65	47.73	54.86	63.25	73.11	98.35
30	30.0	40.57	56.08	66.44	79.06	94.46	113.28	164.49
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	271.02

*Factor $= \frac{(1 + g)^n - 1}{g}$, where $g = \frac{\text{rate}}{100}$ and is not zero. If annual growth rate is zero, the growth factor is equal to the analysis period.

NOTE: The above growth factors multiplied by the first year traffic estimate will give the total volume of traffic expected during the analysis period.

Table D.21. Worksheet for Calculating 18-kip Equivalent Single Axle Load (ESAL) Applications

Location Example 1

Analysis Period = 20 **Years**

Assumed SN or D = 9″

Vehicle Types	Current Traffic (A)	Growth Factors (B)	Design Traffic (C)	E.S.A.L. Factor (D)	Design E.S.A.L. (E)
		2%			
Passenger Cars	5,925	24.30	52,551,787	.0008	42,041
Buses	35	24.30	310,433	.6806	211,280
Panel and Pickup Trucks	1,135	24.30	10,066,882	.0122	122,816
Other 2-Axle/4-Tire Trucks	3	24.30	26,609	.0052	138
2-Axle/6-Tire Trucks	372	24.30	3,299,454	.1890	623,597
3 or More Axle Trucks	34	24.30	301,563	.1303	39,294
All Single Unit Trucks					
3 Axle Tractor Semi-Trailers	19	24.30	168,521	.8646	145,703
4 Axle Tractor Semi-Trailers	49	24.30	434,606	.6560	285,101
5+ Axle Tractor Semi-Trailers	1,880	24.30	16,674,660	2.3719	39,550,626
All Tractor Semi-Trailers					
5 Axle Double Trailers	103	24.30	913,559	2.3187	2,118,268
6+ Axle Double Trailers	0	24.30			
All Double Trailer Combos					
3 Axle Truck-Trailers	208	24.30	1,844,856	.0152	28,042
4 Axle Truck-Trailers	305	24.30	2,705,198	.0152	41,119
5+ Axle Truck-Trailers	125	24.30	1,108,688	.5317	589,489
All Truck-Trailer Combos					
All Vehicles	10,193		90,406,816	Design E.S.A.L.	43,772,314

APPENDIX-J

DESIGN FORM FOR DRAINAGE

Drainage Channel Lining Design Form

Project: ___________________________________

Station:________________________ To station:________________ Date:____________________

Drainage Area:________________________________ha Designer:________________

Hydrologic Computation:

Design Flow: Q ___________________________ m3/sec.

Channel Slope: So= ________________________

Max Top width:____________________________ m

Channel Description

Lining	d_{max}	B	A	R	V	Q= AV	T	Remarks

Drainage Channel Lining Design Form Date__________________

Sheet No.__________________

Project No.__________________

Storm Sewer Design Compulations

Computed By__________________

Design Storm__________________

"n"__________________

Location of Pipe		Diff in Level	Length (m)	Pipe Stope	Velocity (m/sec)	Time of flow(min)	Time of Conc. (min)	Rainfall intensity (mm/hr)	Area		Flow	Pipe Dia. (mm)	Flow / Capacity	Velocity / Full Velocity	Velocity (m/sec)	Remarks
From	To								Total(m)	Cumulative(m)						

APPENDIX-K

INTENSITY DURATION FREQUENCY CURVE (IDF CURVE)

ATTAPEU STATION

Station Name: Attapeu
Station Code:18020000

Year	Annual	Rank(m)
1992	1829.1	1
1993	2029.7	2
1994	2923.8	3
1995	1831.7	4
1996	3266.8	5
1997	2183.6	6
1998	1407.6	7
1999	2140.7	8
2000	2268.4	9
2001	2609.2	10
2002	2433.4	11
2003	2701.0	12
2004	1954.4	13
2005	2549.4	14
2006	2726.8	15
2007	2231.8	16
2008	1890.5	17
2009	2042.4	18
2010	1195.1	19
2011	2314.6	20
2012	1893.5	21
2013	2267.1	22
2014	2241.3	23
2015	1504.0	24
Mean	2184.83	
STD	478.08	

Yn= Mean Reduce of Bubell variate (see table)
Ytr= depend on Tr of the year
Sx = Standard Deviation
Sn= Reduce Standard Deviation
n : Number of the year
m : Ranging number

1. $X_{Tr} = X + KSx$ $K = (Y_{Tr} - Yn)/S_n$
2. $X_{Tr} = X + C.Ytr$ $C = Sx/Sn$, $\bar{X} = X - (Sx/Sn) x Y_n$

Tr: Retun Period 5,10,25,50,100,

n= 37
Yn = 0.5309
Sx = 478.08
Sn = 1.0316
C = Sx/Sn ⟹ 463.440

X = 2184.83

$\hat{\bar{X}} = X - (Sx/Sn) x Y_n$

$\hat{X}$ = 1938.7871

$$X_{Tr} = \bar{X} + C.\,Y_{Tr}$$

Y(5):	1.4999	X_{Tr}= 1352.544+212.493xY_{Tr}	2633.90 mm
Y(10):	2.2502	X_{Tr}= 1352.544+212.493xY_{Tr}	2981.62 mm
Y(25):	3.1985	X_{Tr}= 1352.544+212.493xY_{Tr}	3421.10 mm
Y(50):	3.9019	X_{Tr}= 1352.544+212.493xY_{Tr}	3747.08 mm
Y(100):	4.6001	X_{Tr}= 1352.544+212.493xY_{Tr}	4070.66 mm

Station Name: Attapeu
Station Code:18020000

Year	dailymaxiRR	Rank(m)
1992	81.0	1
1993	139.8	2
1994	141.7	3
1995	77.2	4
1996	399.3	5
1997	91.4	6
1998	97.5	7
1999	175.0	8
2000	128.4	9
2001	121.2	10
2002	88.6	11
2003	132.0	12
2004	102.4	13
2005	160.4	14
2006	150.0	15
2007	193.0	16
2008	210.5	17
2009	187.7	18
2010	78.0	19
2011	94.6	20
2012	119.9	21
2013	187.3	22
2014	112.1	23
2015	95.0	24
Mean	140.17	
STD	68.07	

Yn= Mean Reduce of Bubell variate (see table)

Ytr= depend on Tr of the year
Sx = Standard Deviation
Sn= Reduce Standard Deviation
n : Number of the year
m : Ranging number

n= 37
Yn = 0.5309
Sx = 68.07
Sn = 1.0316
C = Sx/Sn ⟹ 65.989

1. $X_{Tr} = \bar{X}+KSx$ $K=(Y_{Tr}-Yn)/S_n$
2. $X_{Tr} = \hat{X}+C.Ytr$ $C = Sx/Sn$, $\hat{X} = \bar{X}-(Sx/Sn)x\,Y_n$

Tr: Retun Period 5,10,25,50,100,

$\bar{X}$ = 140.17

$\hat{X} = \bar{X}-(Sx/Sn)x\,Y_n$

$\hat{X}$ = 105.13299

$$X_{Tr} = \hat{X}+C.\,Y_{Tr}$$

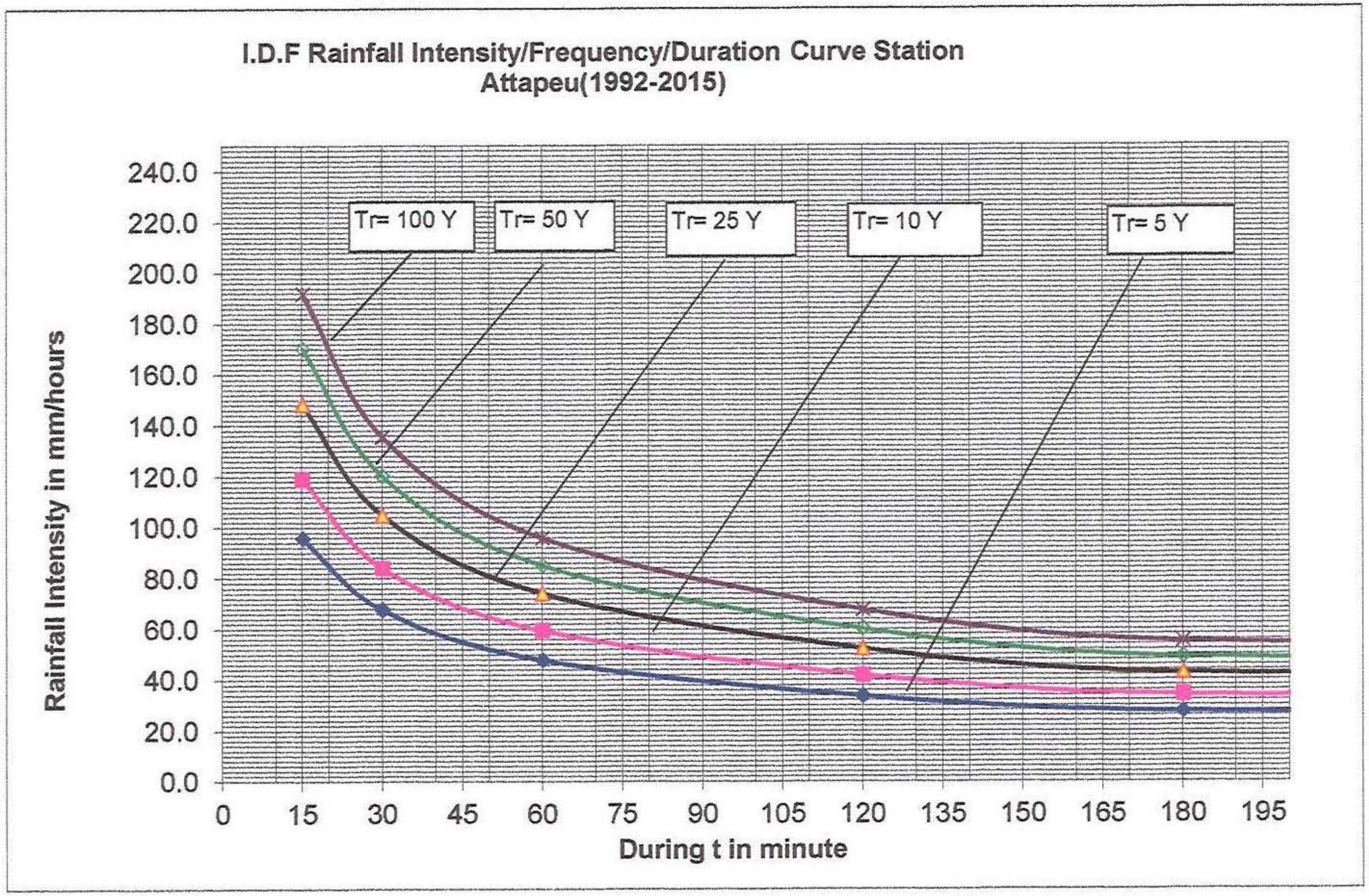
Y(5):	1.4999	X_{Tr}= 86.122+29.1860xY_{Tr}	**204.11 mm**
Y(10):	2.2502	X_{Tr}= 86.122+29.1860xY_{Tr}	**253.62 mm**
Y(25):	3.1985	X_{Tr}= 86.122+29.1860xY_{Tr}	**316.20 mm**
Y(50):	3.9019	X_{Tr}= 86.122+29.1860xY_{Tr}	**362.62 mm**
Y(100):	4.6001	X_{Tr}= 86.122+29.1860xY_{Tr}	**408.69 mm**

Station Name: Attapeu

	15'	30'	60'	120'	180'	1440'
Tr=5	83.3	58.9	41.7	29.5	24.1	8.5
Tr=10	103.5	73.2	51.8	36.6	29.9	10.6
Tr=25	129.1	91.3	64.5	45.6	37.3	13.2
Tr=50	148.0	104.7	74.0	52.3	42.7	15.1
Tr=100	166.8	118.0	83.4	59.0	48.2	17.0

+15%

	15	30	60	120	180	1440
Tr=5	95.8	67.8	47.9	33.9	27.7	9.8
Tr=10	119.1	84.2	59.5	42.1	34.4	12.2
Tr=25	148.5	105.0	74.2	52.5	42.9	15.2
Tr=50	170.2	120.4	85.1	60.2	49.1	17.4
Tr=100	191.9	135.7	95.9	67.8	55.4	19.6


I.D.F Rainfall Intensity/Frequency/Duration Curve Station
Attapeu(1992-2015)
Tr= 100 Y
Tr= 50 Y
Tr= 25 Y
Tr= 10 Y
Tr= 5 Y
Rainfall Intensity in mm/hours
240.0
220.0
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
15
30
45
60
75
90
105
120
135
150
165
180
195
During t in minute

APPENDIX-L

CAPACITY OF PIPE BOX CULVERTS AT DIFFERENT SLOPES

Capacity of Pipe Culverts at Different Slopes (m^3/s) n=0.015

Slope (%)	Diameter (cm)											
	75			90			105			120		
	Single	Double	Triple	Single	Double	Triple	Single	Double	Triple	Single	Double	Triple
0.5	0.5	1	1.5	0.9	1.8	2.7	1.4	2.8	4.2	1.9	3.8	5.7
0.6	0.54	1.08	1.62	1	2	3	1.5	3	4.5	2	4	6
0.7	0.58	1.16	1.74	1.05	2.1	3.15	1.6	3.2	4.8	2.2	4.4	6.6
0.8	0.62	1.24	1.86	1.1	2.2	3.3	1.7	3.4	5.1	2.4	4.8	7.2
0.9	0.66	1.32	1.98	1.15	2.3	3.45	1.8	3.6	5.4	2.55	5.1	7.65
1	0.71	1.42	2.13	1.3	2.6	3.9	1.9	3.8	5.7	2.7	5.4	8.1
1.1	0.74	1.48	2.22	1.34	2.68	4.02	1.98	3.96	5.94	2.81	5.62	8.43
1.2	0.77	1.54	2.31	1.38	2.76	4.14	2.06	4.12	6.18	2.92	5.84	8.76
1.3	0.8	1.6	2.4	1.42	2.84	4.26	2.14	4.28	6.42	3.03	6.06	9.09
1.4	0.85	1.7	2.55	1.46	2.92	4.38	2.22	4.44	6.66	3.14	6.28	9.42
1.5	0.89	1.78	2.67	1.5	3	4.5	2.3	4.6	6.9	3.25	6.5	9.75
1.6	0.93	1.86	2.79	1.56	3.12	4.68	2.38	4.76	7.14	3.34	6.68	10.02
1.7	0.97	1.94	2.91	1.62	3.24	4.86	2.46	4.92	7.38	3.43	6.86	10.29
1.8	1.02	2.04	3.06	1.68	3.36	5.04	2.54	5.08	7.62	3.52	7.04	10.56
1.9	1.06	2.12	3.18	1.74	3.48	5.22	2.62	5.24	7.86	3.61	7.22	10.83
2	1.1	2.2	3.3	1.8	3.6	5.4	2.7	5.4	8.1	3.7	7.4	11.1

Capacity of Box Culverts at Different Slopes (m^3/s)									
								n = 0.017	
Slope(%)	Span(m)	Height(m)							
		1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0.5	1.00	2.00	3.24	4.52	5.80	7.09	8.39	9.69	10.99
	1.50	3.55	5.90	8.33	10.81	13.32	15.84	18.37	20.91
	2.00	5.24	8.88	12.70	16.62	20.60	24.62	28.68	32.75
	2.50	7.03	12.08	17.46	23.02	28.70	34.45	40.26	46.11
	3.00	8.88	15.45	22.52	29.88	37.44	45.12	52.89	60.74
	3.50	10.77	18.94	27.81	37.11	46.69	56.47	66.39	76.42
	4.00	12.70	22.52	33.28	44.62	56.36	68.39	80.62	93.01
	4.50	14.65	26.17	38.89	52.38	66.39	80.79	95.47	110.37
	5.00	16.62	29.88	44.62	60.33	76.72	93.61	110.86	128.41
	6.00	20.60	37.44	56.36	76.72	98.11	120.26	142.99	166.18
0.6	1.00	2.19	3.55	4.95	6.35	7.77	9.19	10.61	12.04
	1.50	3.89	6.46	9.13	11.84	14.59	17.35	20.12	22.91
	2.00	5.74	9.72	13.91	18.20	22.57	26.98	31.41	35.87
	2.50	7.70	13.24	19.13	25.22	31.44	37.74	44.11	50.51
	3.00	9.72	16.93	24.67	32.73	41.01	49.42	57.94	66.54
	3.50	11.80	20.75	30.46	40.65	51.14	61.86	72.73	83.72
	4.00	13.91	24.67	36.45	48.88	61.74	74.92	88.32	101.89
	4.50	16.05	28.67	42.60	57.38	72.73	88.50	104.59	120.91
	5.00	18.20	32.73	48.88	66.09	84.05	102.54	121.45	140.66
	6.00	22.57	41.01	61.74	84.05	107.47	131.73	156.64	182.04
0.7	1.00	2.37	3.84	5.34	6.86	8.39	9.93	11.46	13.01
	1.50	4.20	6.98	9.86	12.79	15.75	18.74	21.74	24.74
	2.00	6.20	10.50	15.02	19.66	24.38	29.14	33.93	38.75
	2.50	8.31	14.30	20.66	27.24	33.96	40.77	47.64	54.56
	3.00	10.50	18.28	26.65	35.36	44.29	53.38	62.59	71.87
	3.50	12.74	22.41	32.90	43.90	55.24	66.81	78.56	90.43
	4.00	15.02	26.65	39.37	52.80	66.69	80.92	95.39	110.05
	4.50	17.33	30.97	46.01	61.97	78.56	95.60	112.97	130.59
	5.00	19.66	35.36	52.80	71.39	90.78	110.76	131.18	151.93
	6.00	24.38	44.29	66.69	90.78	116.08	142.29	169.19	196.63
0.8	1.00	2.53	4.10	5.71	7.34	8.97	10.61	12.26	13.90
	1.50	4.49	7.46	10.54	13.67	16.84	20.03	23.24	26.45
	2.00	6.63	11.23	16.06	21.02	26.06	31.15	36.27	41.42
	2.50	8.89	15.28	22.09	29.12	36.30	43.58	50.93	58.33
	3.00	11.23	19.54	28.48	37.80	47.35	57.07	66.91	76.83
	3.50	13.62	23.96	35.17	46.94	59.06	71.43	83.98	96.67
	4.00	16.06	28.48	42.09	56.44	71.30	86.51	101.98	117.65
	4.50	18.53	33.11	49.19	66.25	83.98	102.20	120.77	139.61
	5.00	21.02	37.80	56.44	76.32	97.05	118.41	140.23	162.42
	6.00	26.06	47.35	71.30	97.05	124.10	152.11	180.87	210.20
0.9	1.00	2.68	4.35	6.06	7.78	9.52	11.26	13.00	14.75
	1.50	4.76	7.91	11.18	14.50	17.86	21.25	24.65	28.06
	2.00	7.03	11.91	17.03	22.30	27.64	33.04	38.47	43.94
	2.50	9.43	16.21	23.43	30.89	38.50	46.22	54.02	61.87
	3.00	11.91	20.73	30.21	40.09	50.22	60.53	70.97	81.49
	3.50	14.45	25.41	37.31	49.78	62.64	75.76	89.07	102.53
	4.00	17.03	30.21	44.64	59.87	75.62	91.75	108.16	124.79
	4.50	19.65	35.11	52.18	70.27	89.08	108.39	128.09	148.08
	5.00	22.30	40.09	59.87	80.94	102.93	125.59	148.74	172.28
	6.00	27.64	50.22	75.62	102.93	131.63	161.34	191.84	222.96
1.0	1.00	2.83	4.59	6.39	8.20	10.03	11.87	13.70	15.54
	1.50	5.02	8.34	11.78	15.29	18.83	22.40	25.98	29.58
	2.00	7.41	12.55	17.96	23.50	29.13	34.82	40.55	46.31
	2.50	9.94	17.09	24.69	32.56	40.59	48.72	56.94	65.21
	3.00	12.55	21.85	31.85	42.26	52.94	63.81	74.80	85.90
	3.50	15.23	26.78	39.33	52.47	66.03	79.86	93.89	108.08
	4.00	17.96	31.85	47.06	63.10	79.71	96.72	114.02	131.54
	4.50	20.72	37.01	55.00	74.07	93.90	114.26	135.02	156.09
	5.00	23.50	42.26	63.10	85.32	108.50	132.38	156.79	181.59
	6.00	29.13	52.94	79.71	108.50	138.75	170.07	202.22	235.02

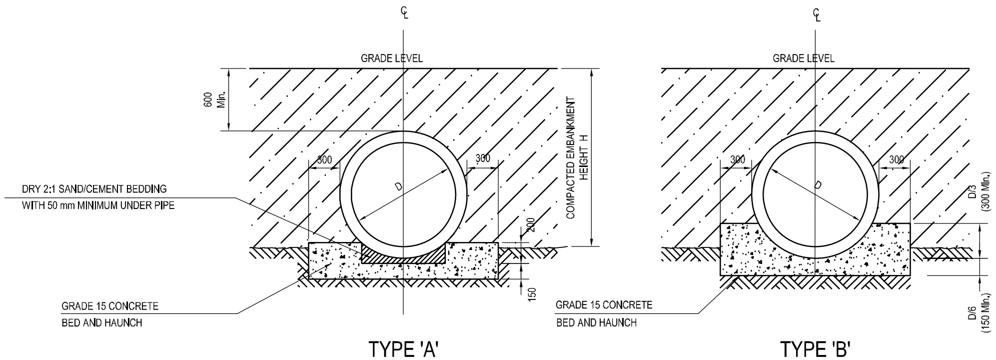
Capacity of Box Culverts at Different Slopes (m^3/s)									
Slope(%)	Span(m)							n = 0.017	
		Height(m)							
		1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
1.1	1.00	2.97	4.81	6.70	8.60	10.52	12.44	14.37	16.30
	1.50	5.26	8.74	12.36	16.03	19.75	23.49	27.25	31.02
	2.00	7.77	13.17	18.83	24.65	30.56	36.52	42.53	48.57
	2.50	10.42	17.92	25.90	34.15	42.57	51.10	59.72	68.40
	3.00	13.17	22.92	33.40	44.32	55.53	66.92	78.46	90.09
	3.50	15.98	28.09	41.24	55.04	69.25	83.76	98.48	113.36
	4.00	18.83	33.40	49.36	66.18	83.60	101.44	119.58	137.96
	4.50	21.73	38.82	57.68	77.69	98.48	119.83	141.61	163.71
	5.00	24.65	44.32	66.18	89.49	113.80	138.84	164.44	190.46
	6.00	30.56	55.53	83.60	113.80	145.52	178.37	212.09	246.49
1.2	1.00	3.10	5.03	7.00	8.99	10.99	13.00	15.01	17.03
	1.50	5.49	9.13	12.91	16.75	20.63	24.54	28.46	32.40
	2.00	8.12	13.75	19.67	25.75	31.92	38.15	44.42	50.73
	2.50	10.89	18.72	27.05	35.66	44.46	53.38	62.38	71.44
	3.00	13.75	23.94	34.89	46.29	57.99	69.90	81.94	94.10
	3.50	16.69	29.34	43.08	57.48	72.33	87.48	102.85	118.40
	4.00	19.67	34.89	51.55	69.13	87.32	105.95	124.90	144.09
	4.50	22.69	40.55	60.25	81.14	102.86	125.16	147.91	170.99
	5.00	25.75	46.29	69.13	93.47	118.86	145.02	171.75	198.93
	6.00	31.92	57.99	87.32	118.86	151.99	186.30	221.52	257.45
1.3	1.00	3.22	5.23	7.28	9.35	11.44	13.53	15.62	17.72
	1.50	5.72	9.51	13.43	17.43	21.47	25.54	29.62	33.72
	2.00	8.45	14.31	20.47	26.80	33.22	39.71	46.24	52.80
	2.50	11.33	19.48	28.15	37.12	46.27	55.55	64.92	74.36
	3.00	14.31	24.91	36.31	48.18	60.36	72.75	85.29	97.94
	3.50	17.37	30.54	44.84	59.83	75.28	91.05	107.05	123.23
	4.00	20.47	36.31	53.66	71.95	90.88	110.27	130.00	149.97
	4.50	23.62	42.20	62.71	84.46	107.06	130.27	153.95	177.97
	5.00	26.80	48.18	71.95	97.28	123.71	150.94	178.76	207.05
	6.00	33.22	60.36	90.88	123.71	158.19	193.91	230.56	267.96
1.4	1.00	3.35	5.43	7.56	9.71	11.87	14.04	16.21	18.39
	1.50	5.93	9.87	13.94	18.09	22.28	26.50	30.74	34.99
	2.00	8.77	14.85	21.25	27.81	34.47	41.21	47.98	54.80
	2.50	11.76	20.22	29.22	38.52	48.02	57.65	67.37	77.16
	3.00	14.85	25.85	37.68	50.00	62.64	75.50	88.51	101.64
	3.50	18.02	31.69	46.53	62.09	78.12	94.49	111.10	127.88
	4.00	21.25	37.68	55.68	74.67	94.32	114.44	134.90	155.63
	4.50	24.51	43.79	65.07	87.64	111.10	135.19	159.76	184.69
	5.00	27.81	50.00	74.67	100.96	128.38	156.64	185.51	214.87
	6.00	34.47	62.64	94.32	128.38	164.17	201.23	239.27	278.07
1.5	1.00	3.46	5.62	7.82	10.05	12.29	14.53	16.78	19.04
	1.50	6.14	10.21	14.43	18.72	23.06	27.43	31.82	36.22
	2.00	9.08	15.38	21.99	28.78	35.68	42.65	49.67	56.72
	2.50	12.17	20.93	30.24	39.87	49.71	59.68	69.74	79.87
	3.00	15.38	26.76	39.00	51.76	64.84	78.15	91.62	105.20
	3.50	18.66	32.80	48.16	64.27	80.87	97.81	114.99	132.37
	4.00	21.99	39.00	57.64	77.29	97.63	118.45	139.64	161.10
	4.50	25.37	45.33	67.36	90.72	115.00	139.94	165.37	191.17
	5.00	28.78	51.76	77.29	104.50	132.89	162.13	192.02	222.41
	6.00	35.68	64.84	97.63	132.89	169.93	208.29	247.66	287.83

Capacity of Box Culverts at Different Slopes (m^3/s)									
								n = 0.017	
		Height(m)							
Slope(%)	Span(m)	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
1.6	1.00	3.58	5.80	8.08	10.38	12.69	15.01	17.33	19.66
	1.50	6.34	10.55	14.90	19.34	23.82	28.33	32.86	37.41
	2.00	9.37	15.88	22.71	29.73	36.85	44.05	51.30	58.58
	2.50	12.57	21.61	31.23	41.18	51.34	61.63	72.03	82.49
	3.00	15.88	27.64	40.28	53.45	66.97	80.71	94.62	108.65
	3.50	19.27	33.88	49.74	66.38	83.52	101.01	118.77	136.71
	4.00	22.71	40.28	59.53	79.82	100.83	122.34	144.22	166.38
	4.50	26.20	46.82	69.57	93.69	118.77	144.53	170.79	197.44
	5.00	29.73	53.45	79.82	107.93	137.25	167.45	198.32	229.70
	6.00	36.85	66.97	100.83	137.25	175.50	215.12	255.79	297.27
1.7	1.00	3.69	5.98	8.33	10.70	13.08	15.47	17.87	20.27
	1.50	6.54	10.87	15.36	19.93	24.55	29.20	33.87	38.56
	2.00	9.66	16.37	23.41	30.64	37.99	45.41	52.88	60.38
	2.50	12.96	22.28	32.19	42.45	52.92	63.53	74.24	85.03
	3.00	16.37	28.49	41.52	55.10	69.03	83.19	97.53	112.00
	3.50	19.86	34.92	51.27	68.42	86.09	104.12	122.42	140.92
	4.00	23.41	41.52	61.36	82.28	103.93	126.10	148.66	171.50
	4.50	27.01	48.26	71.71	96.58	122.43	148.97	176.04	203.51
	5.00	30.64	55.10	82.28	111.25	141.47	172.60	204.42	236.77
	6.00	37.99	69.03	103.93	141.47	180.90	221.74	263.66	306.42
1.8	1.00	3.79	6.16	8.57	11.01	13.46	15.92	18.38	20.85
	1.50	6.73	11.19	15.81	20.51	25.26	30.05	34.86	39.68
	2.00	9.94	16.84	24.09	31.53	39.09	46.72	54.41	62.13
	2.50	13.33	22.93	33.13	43.68	54.45	65.37	76.39	87.49
	3.00	16.84	29.32	42.73	56.70	71.03	85.61	100.36	115.25
	3.50	20.44	35.93	52.76	70.40	88.58	107.14	125.97	145.00
	4.00	24.09	42.73	63.14	84.66	106.94	129.76	152.97	176.47
	4.50	27.79	49.66	73.79	99.38	125.97	153.29	181.15	209.41
	5.00	31.53	56.70	84.66	114.47	145.57	177.61	210.35	243.63
	6.00	39.09	71.03	106.94	145.57	186.15	228.17	271.30	315.31
1.9	1.00	3.90	6.32	8.80	11.31	13.83	16.35	18.89	21.43
	1.50	6.91	11.49	16.24	21.07	25.96	30.87	35.81	40.77
	2.00	10.22	17.30	24.75	32.40	40.16	48.00	55.90	63.84
	2.50	13.70	23.55	34.04	44.88	55.94	67.16	78.49	89.89
	3.00	17.30	30.12	43.90	58.25	72.97	87.95	103.11	118.40
	3.50	21.00	36.92	54.21	72.33	91.01	110.08	129.42	148.98
	4.00	24.75	43.90	64.87	86.98	109.87	133.32	157.16	181.31
	4.50	28.55	51.02	75.81	102.10	129.43	157.49	186.11	215.15
	5.00	32.40	58.25	86.98	117.61	149.56	182.48	216.11	250.31
	6.00	40.16	72.97	109.87	149.56	191.25	234.42	278.74	323.95
2.0	1.00	4.00	6.49	9.03	11.60	14.19	16.78	19.38	21.98
	1.50	7.09	11.79	16.66	21.62	26.63	31.68	36.74	41.83
	2.00	10.48	17.75	25.39	33.24	41.20	49.25	57.35	65.50
	2.50	14.05	24.17	34.92	46.04	57.40	68.91	80.53	92.23
	3.00	17.75	30.90	45.04	59.76	74.87	90.24	105.79	121.48
	3.50	21.54	37.88	55.61	74.21	93.38	112.94	132.78	152.85
	4.00	25.39	45.04	66.55	89.24	112.73	136.78	161.24	186.02
	4.50	29.30	52.34	77.78	104.75	132.79	161.59	190.95	220.74
	5.00	33.24	59.76	89.24	120.67	153.45	187.22	221.73	256.81
	6.00	41.20	74.87	112.73	153.45	196.22	240.51	285.98	332.36

Capacity of Box Culverts at Different Slopes (m^3/s)									
								n = 0.017	
		Height(m)							
Slope(%)	Span(m)	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
2.1	1.00	4.10	6.65	9.26	11.89	14.54	17.19	19.86	22.53
	1.50	7.27	12.08	17.07	22.15	27.29	32.46	37.65	42.86
	2.00	10.74	18.19	26.02	34.06	42.22	50.47	58.77	67.11
	2.50	14.40	24.76	35.78	47.18	58.81	70.61	82.52	94.50
	3.00	18.19	31.67	46.15	61.24	76.72	92.46	108.40	124.48
	3.50	22.07	38.81	56.99	76.04	95.68	115.73	136.06	156.62
	4.00	26.02	46.15	68.19	91.45	115.51	140.16	165.22	190.61
	4.50	30.02	53.64	79.70	107.34	136.07	165.58	195.66	226.19
	5.00	34.06	61.24	91.45	123.65	157.24	191.84	227.20	263.16
	6.00	42.22	76.72	115.51	157.24	201.06	246.45	293.04	340.57
2.2	1.00	4.19	6.81	9.47	12.17	14.88	17.60	20.33	23.06
	1.50	7.44	12.37	17.47	22.67	27.93	33.22	38.54	43.87
	2.00	10.99	18.62	26.63	34.86	43.21	51.65	60.15	68.69
	2.50	14.74	25.35	36.62	48.29	60.20	72.27	84.46	96.73
	3.00	18.62	32.41	47.24	62.68	78.52	94.64	110.95	127.41
	3.50	22.59	39.73	58.33	77.83	97.93	118.45	139.27	160.31
	4.00	26.63	47.24	69.80	93.60	118.23	143.45	169.11	195.10
	4.50	30.73	54.90	81.57	109.87	139.27	169.47	200.27	231.52
	5.00	34.86	62.68	93.60	126.55	160.94	196.35	232.55	269.35
	6.00	43.21	78.52	118.23	160.94	205.79	252.25	299.94	348.58
2.3	1.00	4.29	6.96	9.69	12.44	15.21	17.99	20.78	23.57
	1.50	7.61	12.64	17.87	23.18	28.56	33.97	39.40	44.85
	2.00	11.24	19.04	27.23	35.64	44.18	52.81	61.50	70.24
	2.50	15.07	25.92	37.45	49.38	61.55	73.89	86.36	98.90
	3.00	19.04	33.14	48.30	64.09	80.29	96.77	113.45	130.27
	3.50	23.10	40.62	59.64	79.58	100.13	121.11	142.40	163.91
	4.00	27.23	48.30	71.37	95.70	120.89	146.68	172.91	199.48
	4.50	31.42	56.13	83.41	112.34	142.40	173.28	204.77	236.72
	5.00	35.64	64.09	95.70	129.40	164.55	200.77	237.78	275.40
	6.00	44.18	80.29	120.89	164.55	210.42	257.92	306.68	356.42
2.4	1.00	4.38	7.11	9.89	12.71	15.54	18.38	21.23	24.08
	1.50	7.77	12.92	18.25	23.68	29.17	34.70	40.25	45.82
	2.00	11.48	19.45	27.82	36.41	45.14	53.95	62.83	71.75
	2.50	15.40	26.47	38.25	50.44	62.88	75.48	88.21	101.03
	3.00	19.45	33.85	49.34	65.47	82.02	98.85	115.89	133.07
	3.50	23.60	41.49	60.92	81.29	102.29	123.72	145.46	167.44
	4.00	27.82	49.34	72.90	97.76	123.49	149.83	176.63	203.77
	4.50	32.09	57.34	85.20	114.75	145.46	177.01	209.17	241.81
	5.00	36.41	65.47	97.76	132.18	168.09	205.08	242.89	281.33
	6.00	45.14	82.02	123.49	168.09	214.94	263.47	313.27	364.08
2.5	1.00	4.47	7.25	10.10	12.97	15.86	18.76	21.67	24.58
	1.50	7.93	13.18	18.63	24.17	29.77	35.41	41.08	46.76
	2.00	11.72	19.85	28.39	37.16	46.07	55.06	64.12	73.23
	2.50	15.71	27.02	39.04	51.48	64.17	77.04	90.03	103.11
	3.00	19.85	34.55	50.35	66.82	83.71	100.89	118.28	135.82
	3.50	24.08	42.35	62.18	82.97	104.40	126.27	148.46	170.89
	4.00	28.39	50.35	74.41	99.78	126.03	152.92	180.27	207.98
	4.50	32.75	58.52	86.96	117.12	148.46	180.66	213.49	246.80
	5.00	37.16	66.82	99.78	134.91	171.56	209.31	247.90	287.13
	6.00	46.07	83.71	126.03	171.56	219.38	268.90	319.73	371.59

APPENDIX-M

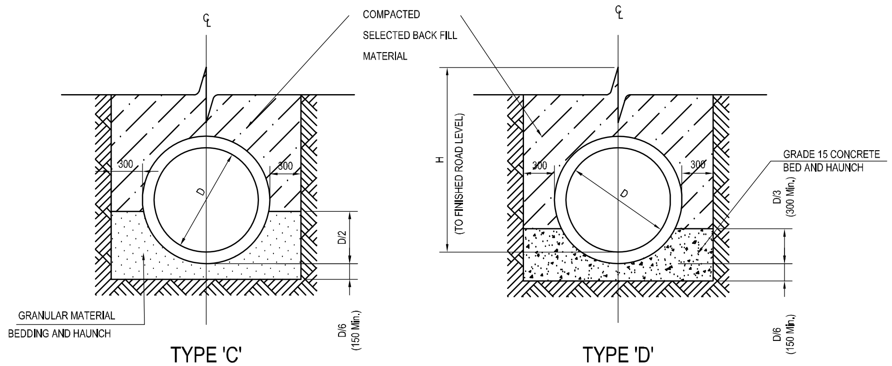
TYPICAL DRAWING OF PIPE/BOX CULVERTS



TYPE 'A'
(H⩽4 m)

TYPE 'B'
(4 m⩽H⩽8m)

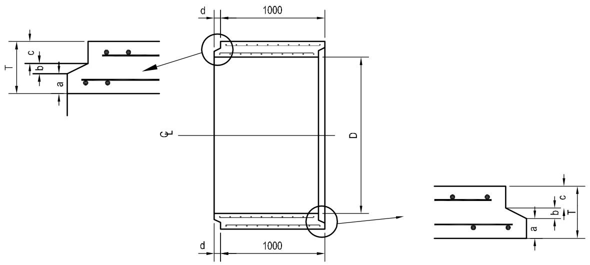
BEDDING FOR PIPES THROUGH EMBANKMENTS



TYPE 'C'
(H⩽4 m)

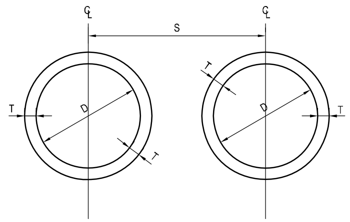
TYPE 'D'
(4 m⩽H⩽8m)

BEDDING FOR PIPES IN CUT TRENCHES



TONGUE AND GROOVE TYPE

INSIDE DIAMETER (D) mm	WALL THICKNESS (D) mm	PIPE AND DETAILS (mm) TONGUE & GROOVE TYPE			
		a	b	c	d
1000	110	43	20	47	45
1200	125	48	25	52	50
1500	150	57	30	63	60

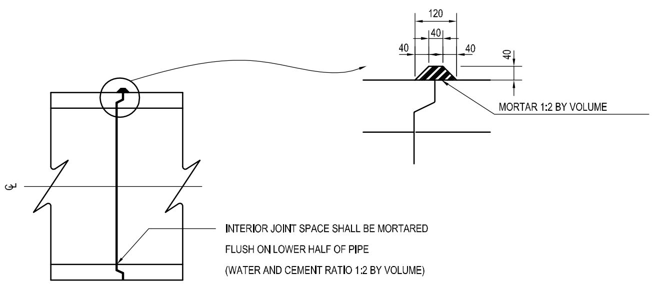


INTERNAL DIAMETER	1000	1200	1500
SPACING, S	1700	1900	2250

MULTIPLE PIPE CULVERTS

PIPE DETAILS

INSIDE DIAMETER	WALL THICKNESS	CIRCULAR REINFORCEMENT (cm2/m)		D-LOAD TO PRODUCE A 0.3 mm CRACK	D-LOAD TO PRODUCE ULTIMATE LOAD	CONCRETE STRENGTH AT 28 DAYS	MAXIMUM SPACING OF BARS	REINFORCING STEEL BAR YIELD STRESS	MAXIMUM H
(D) mm	(T) mm	INNER CAGE	OUTER CAGE	(mm)	(kN/m)	(MPa)	(mm)	(MPa)	(m)
1000	110	8.6	4.6	100	150	26	100	275	9.00
1200	125	10.7	5.9	120	180	26	100	275	9.00
1500	150	13.2	7.2	150	225	40	100	275	9.00

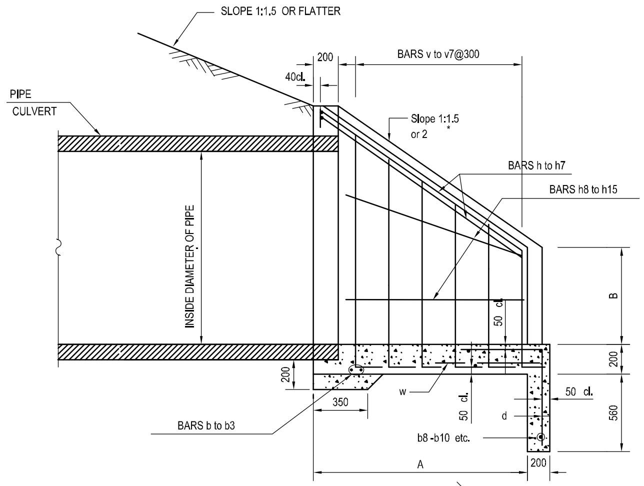


CONNECTION DETAILS

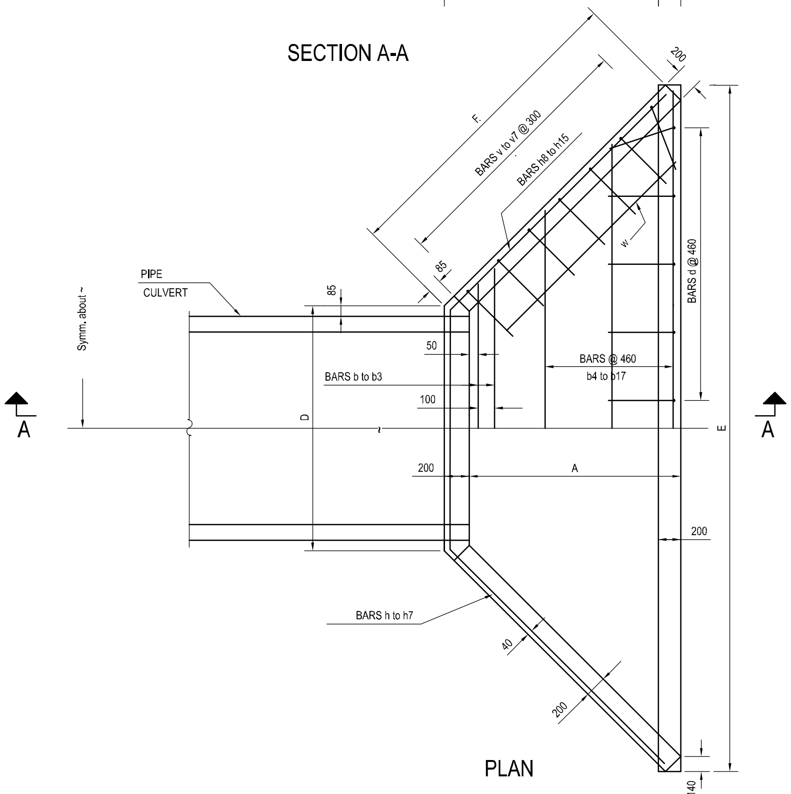
NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE INDICATED.
2. FOR EMBANKMENT HEIGHTS GREATER THAN 8 METRES A FULL CONCRETE SURROUND OF THICKNESS D/3 (MINIMUM 300) SHALL BE PROVIDED.
3. CONCRETE COVER SHALL BE 25 MM.

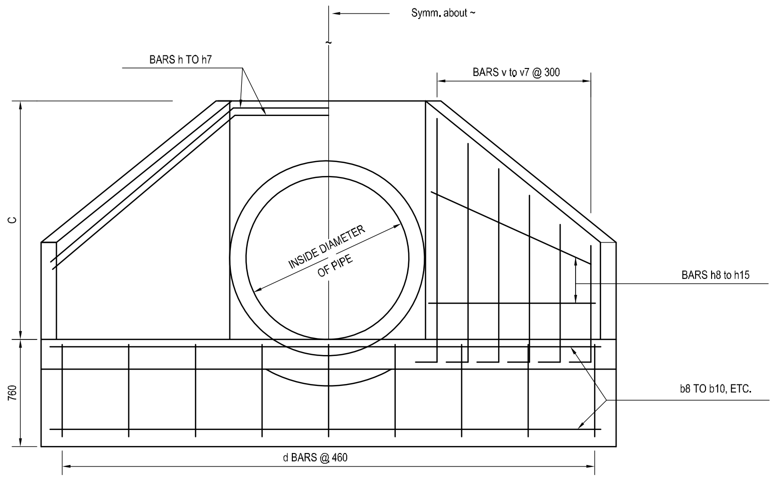
LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE PIPE CULVERT (PIPE AND BEDDING DETAILS)		DESIGNED					NOT TO SCALE	
			CHECKED						
			APPROVED						



SECTION A-A



PLAN



END ELEVATION

DIMENSIONS AND QUANTITIES

NOMINAL INSIDE DIAMETER OF PIPE	SLOPE OF FILL	DIMENSIONS						CONCRETE 2 END SECS.	REINFORCEMENT BARS 2 END SECS.
		A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	F (mm)	(m^3)	(kg)
1000	1:1.5	1010	6600	1330	1480	3630	1520	3,7	180
1000	1:2	1350	6600	1330	1480	4290	1990	4,7	220
1200	1:1.5	1140	7400	1500	1650	4050	1700	4,4	200
1200	1:2	1520	7400	1500	1650	4820	2240	5,8	250
1500	1:1.5	1400	8900	1830	2000	4910	2060	6,1	280
1500	1:2	1880	8900	1830	2000	5880	2740	8,3	350

NOTES:

1. IF EMBANKMENT SLOPE ABOVE HEADWALL. IS FLATTER THAN 1:2, PROVIDE WINGS FOR 1:2 SLOPE.
2. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SHOWN.
3. CONCRETE SHALL BE GRADE 25 MPA.
4. REINFORCING STEEL SHALL BE DEFORMED BARS GRADE 60.
5. CONCRETE COVER SHALL BE AS SHOWN ON THE DRAWINGS.

LAO PEOPLE'S DEMOCRATIC REPUBLIC
MINISTRY OF PUBLIC WORKS AND TRANSPORT

PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
DRAWING TITLE PIPE CULVERT INLET AND OUTLET STRUCTURE 1 CELL (SHEET 1 OF 2)		DESIGNED					NOT TO SCALE	
		CHECKED						
		APPROVED						

SIZES OF STRAIGHT BARS

BAR MARK	BAR SIZE (mm)	LENGTH (m)
b	16	1.90
b1	16	2.06
b2	16	2.21
b3	16	2.44
b4	16	2.51
b5	16	2.74
b6	16	3.05
b7	16	3.20
b8	16	3.43
b9	16	3.66
b10	12	3.96
b11	12	4.11
b12	12	4.34

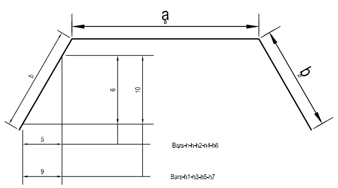
BAR MARK	BAR SIZE (mm)	LENGTH (m)
b13	12	4.57
b14	12	4.72
b15	12	5.03
b16	12	5.18
b17	12	5.79
h8	12	1.45
h9	12	1.90
h10	12	1.60
h11	12	2.20
h12	12	1.83
h13	12	2.44
h14	12	1.98
h15	12	2.67
w	12	1.22

DIMENSIONS OF BENT BARS

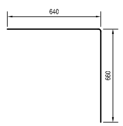
16 mm bars v TO v7			16 mm bars h TO h7			
BARS	c (mm)	TOTAL LENGTH (m)	BARS	a (mm)	b (mm)	TOTAL LENGTH (m)
v	1830	2.44	h	1420	1570	4.56
v1	1680	2.29	h_1	1420	2030	5.48
v2	1520	2.13	h_2	1600	1790	5.18
v3	1370	1.98	h_3	1600	2290	6.18
v4	1220	1.83	h_4	1780	2010	5.78
v5	1070	1.68	h_5	1780	2540	6.86
v6	9200	1.53	h_6	1960	2180	6.32
v7	6100	1.22	h_7	1960	2830	7.59

BARS IN ONE END SECTION

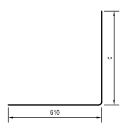
1000 PIPE				1200 PIPE				1500 PIPE			
SLOPE				SLOPE				SLOPE			
1:1.5		1:2		1:1.5		1:2		1:1.5		1:2	
BARS	No.	BARS	No.	BARS	No.	BARS	No.	BARS	No.	BARS	No.
d	8	d	9	d	9	d	10	d	11	d	13
b	2	b	2	b1	2	b1	2	b3	2	b3	2
b5	1	b4	1	b7	1	b6	1	b7	1	b7	1
b8	2	b8	1	b10	2	b10	1	b11	1	b11	1
		b11	2			b14	2	b14	2	b15	1
										b17	2
h	2	h1	2	h2	2	h1	2	h6	2	h7	2
h8	4	h9	4	h10	4	h9	4	h14	4	h15	4
v3	2	v3	2	v2	2	v2	2	v	2	v	4
v4	2	v4	2	v3	2	v3	4	v1	2	v1	2
v5	2	v5	4	v4	2	v4	2	v2	2	v2	2
v6	2	v6	2	v5	2	v5	2	v3	2	v3	4
v7	2	v7	2	v6	2	v6	4	v4	2	v4	2
								v_5	4	v5	4
w	2	w	2	w	2	w	2	w	2	w	2



BARS - h TO h7



BAR d

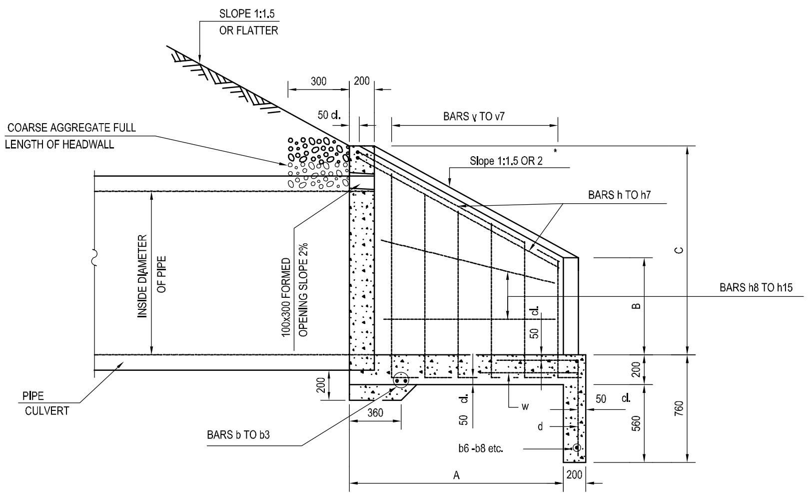


BARS v TO v7

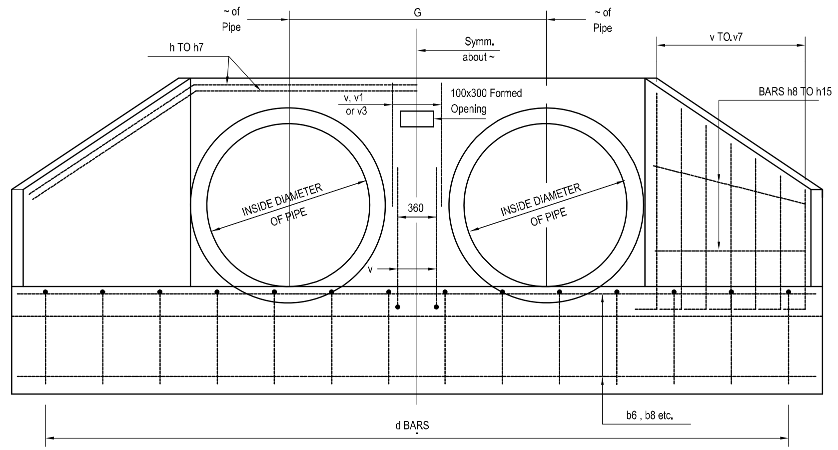
NOTE:

1 . ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SHOWN.

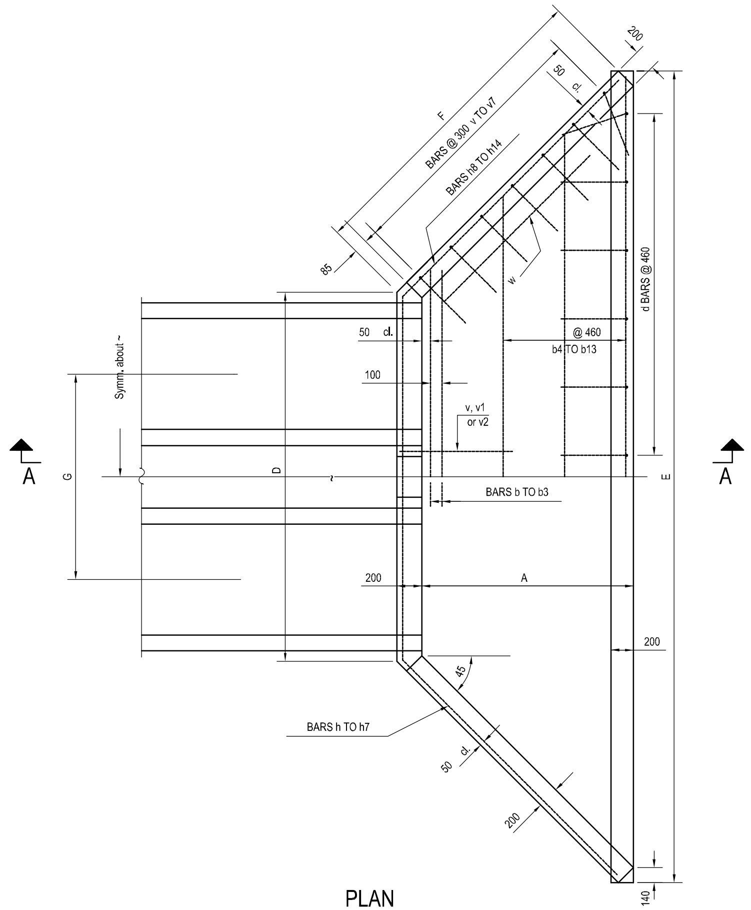
LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE PIPE CULVERT INLET AND OUTLET STRUCTURE 1 CELL (SHEET 2 OF 2)		DESIGNED CHECKED APPROVED					NOT TO SCALE	



SECTION A-A



END ELEVATION



PLAN

NOTES:

1. IF EMBANKMENT SLOPE ABOVE HEADWALL IS FLATTER THAN 1:2, PROVIDE WINGS FOR 1:2 SLOPE.
2. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SHOWN.

LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE PIPE CULVERT INLET AND OUTLET STRUCTURE 2 CELL (SHEET 1 OF 2)		DESIGNED					NOT TO SCALE	
			CHECKED						
			APPROVED						

DIMENSIONS AND QUANTITIES

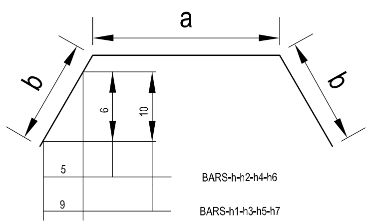
NOMINAL DIAMETER OF PIPE	SLOPE OF FILL	DIMENSIONS									QUANTITIES			
		FOR ALL MULTIPLES					2 PIPES		3 PIPES		2 PIPES		3 PIPES	
		A (mm)	B (mm)	C (mm)	F (mm)	G (mm)	D (mm)	E (mm)	D (mm)	E (mm)	CONCRETE 2 END SECTIONS (m^3)	REINFORCEMENT BARS 2 END SECTIONS (kg)	CONCRETE 2 END SECTIONS (m^3)	REINFORCEMENT BARS 2 END SECTIONS (kg)
1000	1:1.5	1010	660	1330	1520	1750	3230	5,38 m	4980	7130	5,4	250	7,1	300
1000	1:2	1350	660	1330	1990	1750	3230	6040	4980	7800	6,7	300	8,7	360
1200	1:1.5	1120	740	1500	1700	1930	3580	5980	5510	7910	6,4	280	8,5	340
1200	1:2	1520	740	1500	2240	1930	3580	6750	5510	8680	8,2	360	10,5	420
1500	1:1.5	1400	890	1830	2060	2290	4290	7200	6580	9490	8,9	370	11,7	440
1500	1:2	1880	890	1830	2740	2290	4290	8160	6580	10450	11,5	440	14,7	530

DIMENSIONS OF STRAIGHT BARS

BAR MARK	BAR SIZE	LENGTH (m) 2-PIPES	LENGTH (m) 3-PIPES	BAR MARK	BAR SIZE	LENGTH (m) 2-PIPES	LENGTH (m) 3-PIPES
b	12	3,58	5,33	h8	12	1,45	1,45
b1	16	3,96	5,87	h9	12	1,60	1,60
b2	16	4,27	6,32	h10	12	1,83	1,83
b3	16	4,65	6,94	h11	12	1,98	1,98
b4	16	4,42	6,25	h12	12	2,21	2,21
b5	16	4,95	7,01	h13	12	2,44	2,44
b6	16	5,26	7,32	h14	12	2,67	2,67
b7	16	5,49	7,47	w	12	1,22	1,22
b8	16	5,79	7,70				
b9	16	6,25	7,92				
b10	12	6,48	8,23				
b11	12	7,01	8,64				
b12	12	7,32	9,30				
b13	12	7,92	10,36				

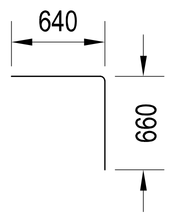
DIMENSIONS OF BENT BARS

16 mm-Bars V TO V7			16 mm-Bars h TO h7						
BARS	c (mm)	TOTAL LENGTH (m)	BARS	2-PIPES a (mm)	2-PIPES b (mm)	2-PIPES TOTAL LENGTH (m)	3-PIPES a (mm)	3-PIPES b (mm)	3-PIPES TOTAL LENGTH (m)
v	1830	2,44	h	3180	1570	6,32	4930	1570	8,07
v1	1680	2,29	h1	3180	2030	7,24	1930	2030	8,99
v2	1520	2,13	h2	3530	1780	7,09	5460	1800	9,06
v3	1370	1,98	h3	3530	2310	8,15	5460	2300	10,06
v4	1220	1,83	h4	3870	1980	7,83	6000	2000	10,0
v5	1070	1,68	h5	3870	2510	8,89	6000	2530	11,06
v6	9100	1,52	h6	4240	2180	8,60	6530	2180	10,89
v7	7600	1,37	h7	4240	2790	9,82	6530	2830	12,19

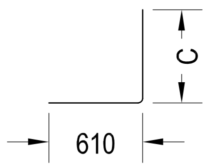


16 mm BARS - h TO h7

BEND IN FIELD
ONE REQUIRED IN EACH HEADWALL



16mm BARS d

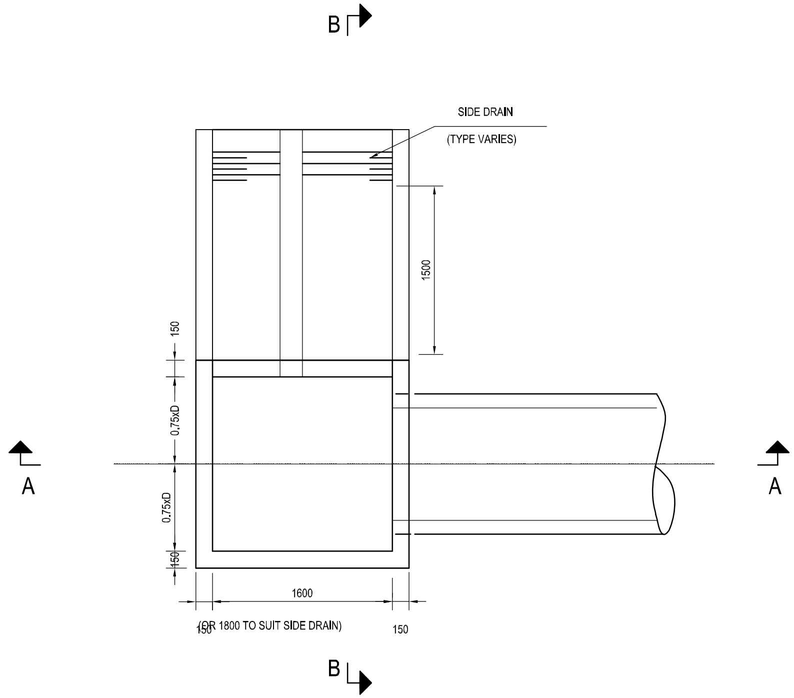


16 MM BARS v TO v7

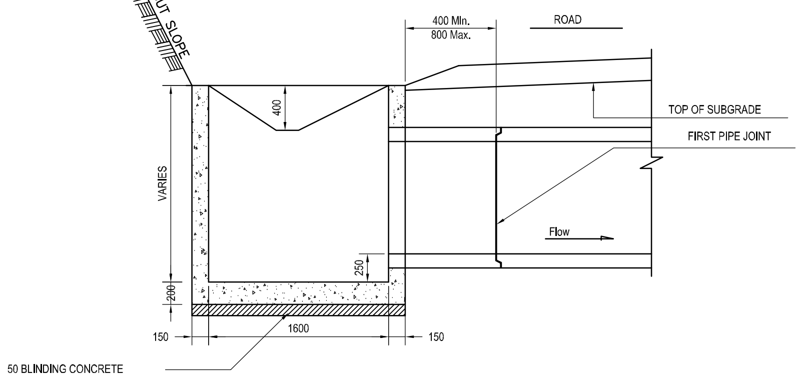
NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SHOWN.

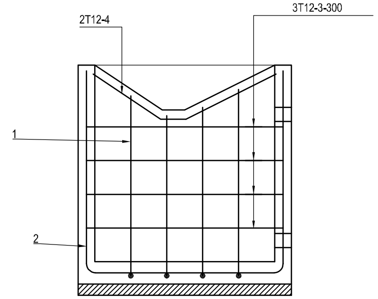
LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE PIPE CULVERT INLET AND OUTLET STRUCTURE 2 CELL (SHEET 2 OF 2)		DESIGNED CHECKED APPROVED					NOT TO SCALE	



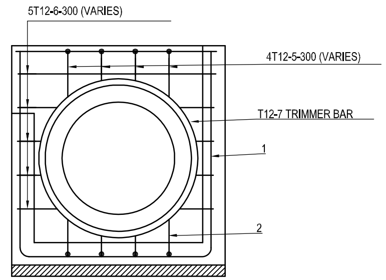
LAYOUT PLAN



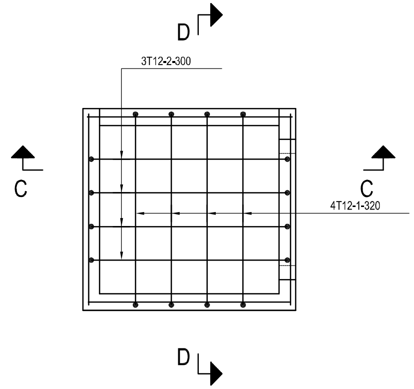
SECTION A-A



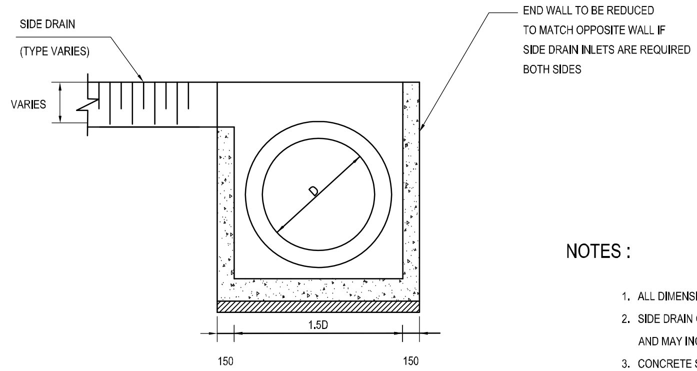
SECTION C-C



SECTION D-D



R.C. PLAN

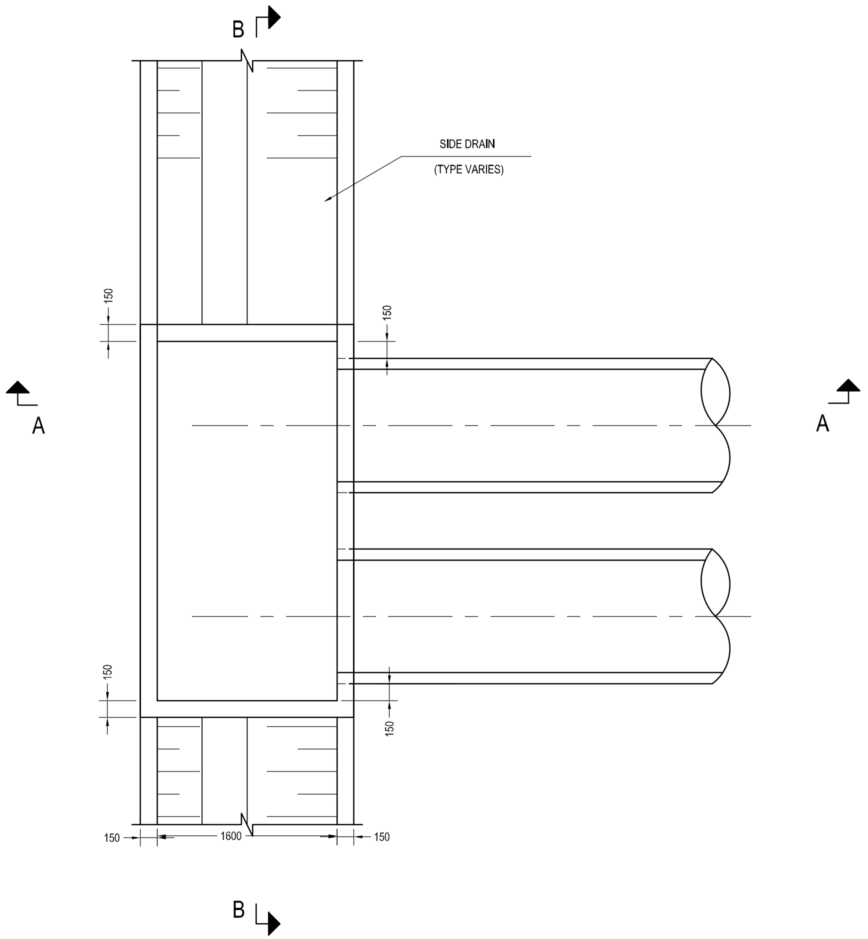


SECTION B-B

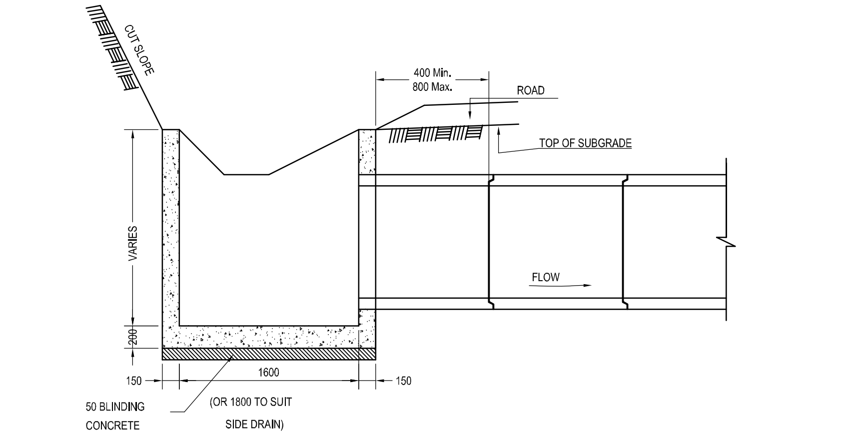
NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE INDICATED.
2. SIDE DRAIN OUTLET LOCATION WILL VARY ACCORDING TO SITE CONDITIONS. AND MAY INCLUDE 2No. SIDE DRAINS.
3. CONCRETE SHALL BE GRADE 25 MPA.
4. CONCRETE COVER SHALL BE 50 MM.
3. REINFORCING STEEL SHALL BE DEFORMED BARS GRADE 60.

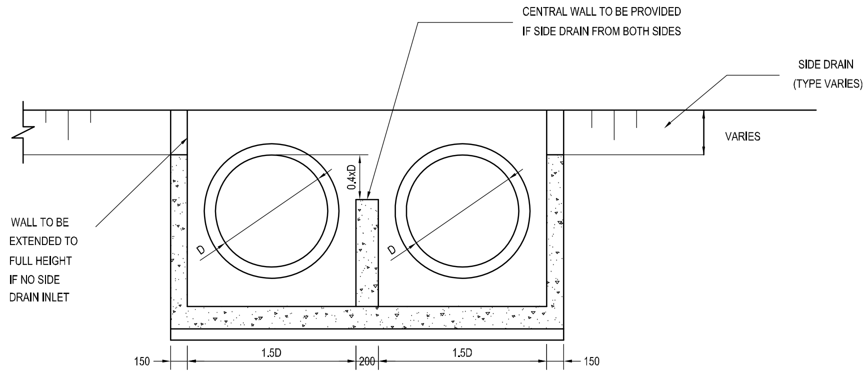
LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE PIPE CULVERTS DROP INLET DETAILS 1 CELL		DESIGNED					NOT TO SCALE	
			CHECKED						
			APPROVED						



PLAN



SECTION A-A



SECTION B-B

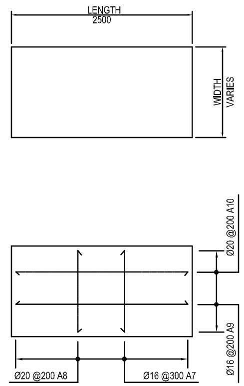
NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE INDICATED.
2. SIDE DRAIN OUTLET LOCATION WILL VARY ACCORDING TO SITE CONDITIONS.
3. AT LOCATIONS WHERE INSUFFICIENT SPACE IS AVAILABLE TO CONSTRUCT WING WALL TYPE INLETS A DOUBLE PIPE DROP INLET MAY BE USED AS DIRECTED BY ENGINEER ONLY. IN SUCH INSTANCES, A CIRCULAR OPENING OF 1000 DIAMETER SHALL BE INCLUDED THROUGH THE WALL OPPOSITE ONE OF THE OUTLET PIPES AND THE REINFORCEMENT CHANGED ACCORDINGLY. IT IS ANTICIPATED THAT THIS WILL ONLY BE REQUIRED AT A LIMITED NUMBER OF LOCATIONS THROUGH MOUNTAINOUS SECTIONS WHERE NATURAL WATERCOURSES DISCHARGE ACROSS THE ROAD FROM VERY STEEP SLOPES.
4. REINFORCEMENT FOR THE DROP INLET STRUCTURE SHALL BE SIMILAR TO SINGLE CELL AND AGREED WITH THE ENGINEER.

LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE PIPE CULVERTS DROP INLET DETAILS 2 CELL		DESIGNED					NOT TO SCALE	
			CHECKED						
			APPROVED						

BARREL DIMENSIONS AND QUANTITIES

CONCRETE						REINFORCEMENT																					
						BAR DIAMETER,SPACING AND LENGTH IN MILLIMETERS																					
SPAN	HEIGHT	TOP SLAB	BOTTOM SLAB	EXTERIOR WALL	VOLUME	BARS-A1			BARS-A2			BARS-B3			BARS-B4			BARS-B5			BARS-B6			NUMBER OF SPACER BARS Ø12 @300			WEIGHT
S mm	H mm	T mm	B mm	WE mm	CUM, PER,m	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	TOP	BOTTOM	EACH WALL	KG / M
FILL COVER 1,5m OR LESS																											
1000	1000	200	200	200	1,01	12	300	1320	16	150	1320	12	300	1520	12	300	1270	12	300	1140	12	300	1430	10	10	12	86,00
1500	1000	250	250	200	1,40	12	200	1820	16	150	1820	12	300	1980	12	300	1320	12	300	1400	12	300	1730	14	14	12	128,50
1500	1500	250	250	200	1,60	16	200	1820	16	150	1820	12	300	2230	12	300	1820	12	300	1650	12	300	1730	14	14	16	148,00
2000	1000	250	250	200	1,65	16	150	2320	20	175	2320	12	300	2230	12	300	1320	12	300	1550	12	300	1980	18	18	12	153,50
2000	1500	250	250	200	1,85	16	150	2320	20	175	2320	12	200	2420	12	300	1820	12	200	1780	12	300	1940	18	18	16	170,50
2000	2000	250	250	200	2,05	16	150	2320	20	175	2320	12	200	2830	12	300	2310	12	200	1970	12	300	3820	18	18	24	200,00
2500	1000	275	275	200	2,04	16	150	2820	20	150	2820	12	300	2510	12	300	1350	12	300	1730	12	300	2260	20	20	12	206,00
2500	1500	275	275	200	2,24	16	150	2820	20	150	2820	12	200	2760	12	200	1840	12	200	1920	12	200	2260	20	20	16	208,00
2500	2000	275	275	200	2,44	16	250	2820	20	150	2820	12	200	3110	12	300	2335	12	200	2145	12	300	3820	22	22	24	222,00
2500	2500	275	275	200	2,64	16	250	2820	20	150	2820	12	200	3260	12	300	2850	12	200	2420	12	300	2260	20	20	32	218,00
3000	1000	275	275	200	2,32	16	175	3320	20	150	3320	12	200	2760	12	200	1350	12	200	1820	12	200	2510	24	24	12	216,50
3000	1500	300	300	200	2,69	16	175	3320	20	150	3320	12	200	3030	12	200	1870	12	200	2150	12	200	2530	24	24	16	266,50
3000	2000	300	300	200	2,89	16	200	3320	20	150	3320	12	200	3380	12	300	2360	12	200	2320	12	300	4420	24	24	24	260,00
3000	2500	300	300	200	3,09	16	200	3320	20	150	3320	12	200	3630	12	300	2860	12	200	2570	12	300	5170	24	24	32	282,50
3000	3000	300	300	200	3,29	16	200	3320	20	150	3320	12	200	3880	12	300	3360	12	200	2820	12	300	5170	24	24	36	293,50
FILL COVER 1.50 m TO 3.00 m																											
1000	1000	200	200	200	1,01	12	300	1320	12	250	1320	12	300	1520	12	300	1270	12	300	1140	12	300	1430	10	10	12	77,00
1500	1000	250	250	200	1,40	12	200	1820	16	200	1820	12	300	1980	12	300	1320	12	300	1340	12	300	1730	14	14	12	95,50
1500	1500	250	250	200	1,60	12	275	1820	16	200	1820	12	300	2180	12	300	1770	12	300	1540	12	300	1680	14	14	16	111,00
2000	1000	250	250	200	1,65	16	175	2320	16	150	2320	12	300	2230	12	300	1320	12	300	1530	12	300	1820	18	18	12	139,00
2000	1500	250	250	200	1,85	16	200	2320	20	150	2320	16	225	2600	12	225	1820	16	225	1800	12	225	1980	18	18	16	208,00
2000	2000	250	250	200	2,05	16	200	2320	16	150	2320	16	225	2825	12	225	2310	16	225	2025	12	225	1970	18	18	24	179,00
2500	1000	275	275	200	2,04	16	250	2820	16	150	2820	12	300	2510	12	300	1350	12	300	1670	12	300	2260	20	20	12	151,00
2500	1500	275	275	200	2,24	16	250	2820	16	150	2820	16	200	2880	12	200	1850	16	200	1980	12	200	2260	20	20	16	230,00
2500	2000	275	275	200	2,44	16	250	2820	16	150	2820	16	250	3100	12	225	2335	16	250	2200	12	225	2245	20	20	24	195,00
2500	2500	275	275	200	2,64	16	250	2820	16	150	2820	16	150	3350	12	175	2835	16	150	2450	12	175	2245	20	20	32	256,00
3000	1000	300	300	200	2,49	20	175	3320	20	150	3320	16	300	2900	12	300	1370	16	300	1900	12	300	2530	24	24	12	230,50
3000	1500	300	300	200	2,69	20	200	3320	20	150	3320	16	200	3150	12	200	1870	16	200	2150	12	200	2530	24	24	16	262,00
3000	2000	300	300	200	2,89	20	200	3320	20	150	3320	16	250	3470	12	225	2335	16	250	2350	12	225	2495	24	24	24	269,50
3000	2500	300	300	200	3,09	20	150	3320	20	150	3320	16	150	3720	12	175	2835	16	150	2600	12	175	2495	24	24	32	350,00
3000	3000	300	300	200	3,29	20	150	3320	20	150	3320	16	200	3900	12	200	3370	16	200	2900	12	200	2530	24	24	36	349,50

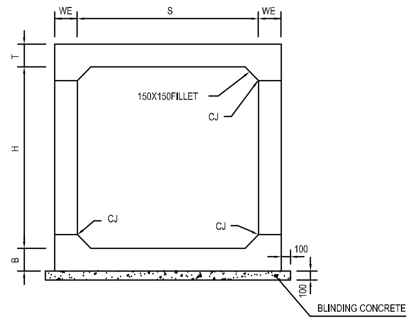


APPROACH SLAB

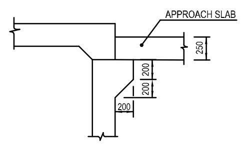
REINFORCEMENT AND CONCRETE FOR APPROACH SLAB						
BAR MARK	A-7	A-8	A-9	A-10	A-11	G-12
SIZE	16	20	16	20	16	16
LENGTH mm	VARIES	VARIES	2420	2420	VARIES	1290

NOTES

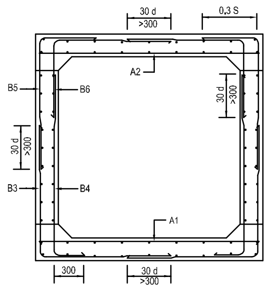
1. APPROACH SLAB SHALL ONLY BE USED WHERE THE COVER IS LESS THAN 0,60m.



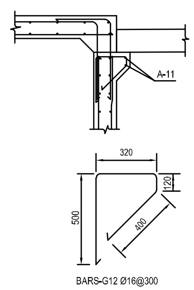
BARREL DIMENSIONS



APPROACH SLAB SUPPORT



BARREL REINFORCEMENT



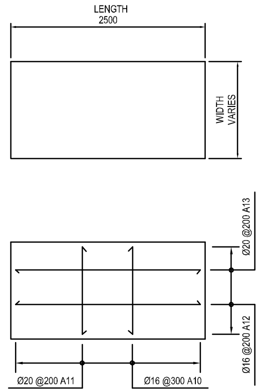
APPROACH SLAB SUPPORT REINFORCEMENT

LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE BOX CULVERT 1 CELL DIMENSION, REINFORCEMENT AND QUANTITY		DESIGNED CHECKED APPROVED					NOT TO SCALE	

BARREL DIMENSIONS AND QUANTITIES

FILL COVER 1.50m OR LESS

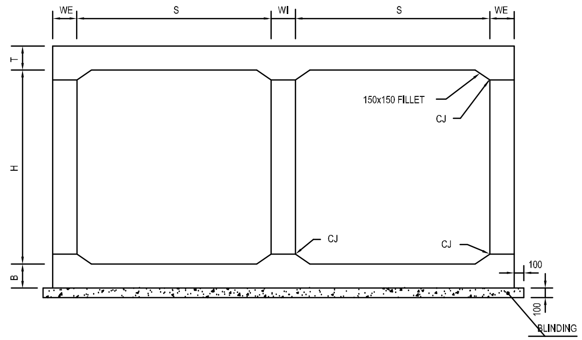
CONCRETE							REINFORCEMENT — BAR DIAMETER,SPACING AND LENGTH IN MILLIMETERS																															WEIGHT
SPAN	HEIGHT	TOP SLAB	BOTTOM SLAB	INTERIOR WALL	EXTERIOR WALL	VOLUME	BARS-A1			BARS-A2			BARS-A3			BARS-A4			BARS-B5			BARS-B6			BARS-B7			BARS-B8			BARS-B9			NUMBER OF SPACER BARS Ø12 @300			
S mm	H mm	T mm	B mm	WI mm	WE mm	CUM PER m	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	SIZE	SPACING	LENGTH	TOP	BOTTOM	EACH WALL	KG / M
2000	1000	250	250	200	200	2.99	12	300	3080	16	150	4520	12	300	4520	16	200	4520	12	300	1380	12	300	1490	12	300	1120	12	300	1380	12	300	1120	32	32	18	261.00
2000	1500	250	250	200	200	3.34	12	300	3080	16	150	4520	12	300	4520	16	200	4520	12	300	1880	12	300	1820	12	300	1120	12	300	1880	12	300	1120	32	32	32	284.00
2000	2000	250	250	200	200	3.68	12	300	3080	16	150	4520	12	300	4520	16	150	4520	12	300	2380	12	300	1990	12	300	1120	12	300	2380	12	300	1120	32	32	36	313.50
2500	1000	250	250	200	200	3.49	12	300	3580	16	175	5520	12	250	5520	16	150	5520	12	300	1380	12	300	1640	12	300	1120	12	300	1380	12	300	1120	38	38	18	303.50
2500	1500	250	250	200	200	3.84	12	300	3580	16	175	5520	12	250	5520	16	150	5520	12	300	1920	12	300	1970	12	300	1120	12	300	1920	12	300	1120	38	38	32	378.00
2500	2000	250	250	200	200	4.18	12	300	3080	16	150	4520	12	300	4520	16	150	4520	12	300	2380	12	200	2140	12	300	1120	12	200	2380	12	200	1120	32	32	36	350.50
2500	2500	250	250	200	200	4.53	12	280	3580	20	175	5520	12	225	5520	16	150	5520	12	250	2880	16	200	2450	12	250	1120	16	200	3000	16	200	1360	38	38	48	548.00
3000	1000	250	250	200	200	3.99	12	280	4080	20	175	6520	12	225	6520	16	150	6520	12	300	1380	12	200	1790	12	300	1120	12	200	1380	12	200	1120	38	38	18	386.50
3000	1500	250	250	200	200	4.34	12	200	4080	20	150	6520	16	300	6520	20	175	6520	12	250	1880	12	200	2040	12	250	1120	12	200	1880	12	200	1360	46	46	32	490.50
3000	2000	250	250	200	200	4.68	12	280	3580	20	175	6520	12	225	6520	16	150	6520	12	300	2380	12	200	2140	12	300	1120	12	200	2380	12	200	1120	38	38	36	433.50
3000	2500	250	250	200	200	5.03	12	200	4080	20	150	6520	16	300	6520	20	175	6520	12	250	2880	12	200	2600	12	250	1120	12	200	3000	12	200	1360	46	46	48	675.50
3000	3000	250	250	200	250	5.72	12	200	4130	20	150	6620	16	300	6620	20	175	6620	12	225	3380	16	175	2850	12	225	1120	16	175	3500	16	175	1360	46	46	54	629.50
3500	3500	300	300	250	250	7.59	16	300	4850	20	150	7670	16	300	7670	20	175	7670	12	225	3930	16	175	3300	12	225	1170	16	175	4050	16	175	1410	54	54	66	740.50
FILL COVER 1.50 TO 3.00m																																					
2000	1000	250	250	200	200	2.99	16	300	3200	16	225	4520	12	200	4520	16	200	4520	12	300	1380	12	300	1570	12	300	1120	12	300	1380	12	300	1120	32	32	18	269.50
2000	1500	250	250	200	200	3.34	16	300	3200	16	225	4520	12	200	4520	16	200	4520	12	300	1880	12	300	1820	12	300	1120	12	300	1880	12	300	1120	32	32	18	292.50
2000	2000	250	250	200	200	3.68	16	300	3200	16	200	4520	12	300	4520	16	200	4520	12	250	2380	12	200	1990	12	250	1120	12	200	2380	12	200	1120	32	32	36	310.50
2500	1000	250	250	200	200	3.49	16	300	3700	16	225	5520	16	200	5520	20	200	5520	12	300	1380	12	300	1640	12	300	1120	12	300	1380	12	300	1120	38	38	18	347.00
2500	1500	250	250	200	200	3.84	16	300	3700	16	225	5520	16	200	5520	20	200	5520	12	300	1920	12	300	1970	12	300	1120	12	300	1920	12	300	1120	38	38	32	329.00
2500	2000	250	250	200	200	4.18	16	300	3700	16	225	5520	12	300	5520	16	200	5520	12	250	2380	12	175	2140	12	250	1120	12	175	2380	12	175	1120	38	38	36	390.00
2500	2500	250	250	200	200	4.53	16	300	3700	16	225	5520	12	300	5520	16	200	5520	12	250	2880	16	175	2450	12	250	1120	16	175	3000	16	175	1120	38	38	48	516.50
3000	1000	250	250	200	200	3.99	16	220	4200	20	250	6520	16	300	6520	20	200	6520	12	250	1380	12	175	1790	12	250	1120	12	175	1380	12	175	1120	46	46	18	480.50
3000	1500	250	250	200	200	4.34	16	220	4200	20	250	6520	16	300	6520	20	200	6520	12	250	1880	12	175	2040	12	250	1120	12	175	1880	12	175	1120	46	46	32	522.00
3000	2000	250	250	200	200	4.68	16	220	4200	20	250	6520	16	300	6520	20	200	6520	12	250	2380	12	175	2140	12	250	1120	12	175	2380	12	175	1120	46	46	36	462.50
3000	2500	250	250	200	200	5.03	16	220	4200	20	250	6520	16	300	6520	20	200	6520	12	250	2880	12	175	2600	12	250	1120	12	175	3000	12	175	1120	46	46	48	666.00
3000	3000	250	250	200	250	5.72	16	220	4250	20	250	6620	16	300	6620	20	200	6620	16	300	3500	16	150	2850	16	300	1360	16	150	3500	16	150	1360	46	46	54	754.50
3500	3500	300	300	250	250	7.59	20	240	4970	20	225	7670	16	275	7670	20	150	7670	16	300	4050	16	150	3300	16	300	1410	16	150	4050	16	150	1410	54	54	66	969.00



APPROACH SLAB

REINFORCEMENT AND CONCRETE FOR APPROACH SLAB

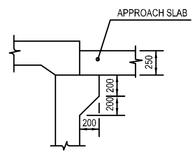
BAR MARK	A-10	A-11	A-12	A-13	A-14	G-15
SIZE mm	16	20	16	20	16	16
LENGTH mm	VARIES	VARIES	2420	2420	VARIES	1290



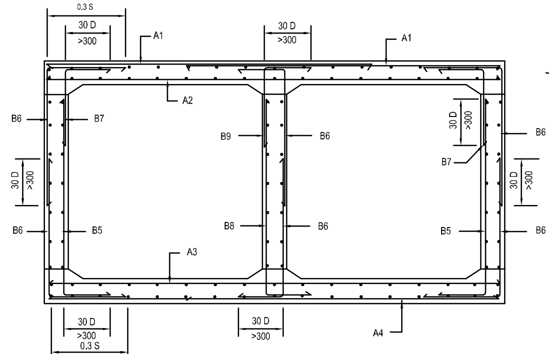
BARREL DIMENSIONS

NOTES

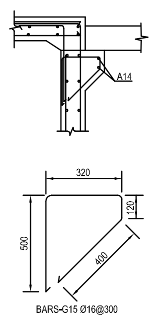
1. APPROACH SLAB SHALL ONLY BE USED WHERE THE COVER IS LESS THAN 0.60m.



APPROACH SLAB SUPPORT



BARREL REINFORCEMENT



APPROACH SLAB SUPPORT REINFORCEMENT

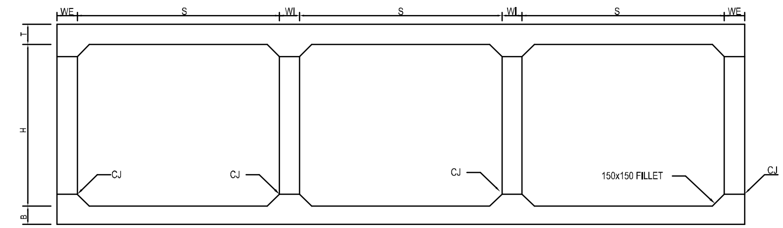
LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE		DESIGNED						
	BOX CULVERT 2 CELL DIMENSION, REINFORCEMENT AND QUANTITY		CHECKED					NOT TO SCALE	DR-032/2
			APPROVED						

BARREL DIMENSIONS AND QUANTITIES

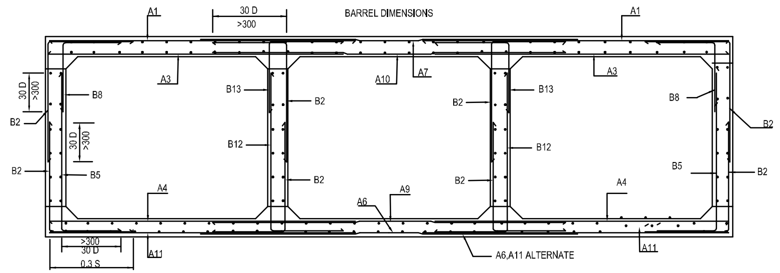
BAR DIAMETER,SPACING AND LENGTH IN MILLIMETERS

SPAN S mm	HEIGHT H mm	TOP SLAB T mm	BOTTOM SLAB B mm	INTERIOR WALL WI mm	EXTERIOR WALL WE mm	VOLUME CUM. PER.m	BARS-A1 SIZE	BARS-A1 SPACING	BARS-A1 LENGTH	BARS-B2 SIZE	BARS-B2 SPACING	BARS-B2 LENGTH	BARS-A3 SIZE	BARS-A3 SPACING	BARS-A3 LENGTH	BARS-A4 SIZE	BARS-A4 SPACING	BARS-A4 LENGTH	BARS-B5 SIZE	BARS-B5 SPACING	BARS-B5 LENGTH	BARS-A6 SIZE	BARS-A6 SPACING	BARS-A6 LENGTH	BARS-A7 SIZE	BARS-A7 SPACING	BARS-A7 LENGTH
FILL COVER 1.50m OR LESS																											
2000	1000	200	200	200	200	3.66	12	280	3030	12	300	1440	20	200	3610	16	200	2990	12	300	1330	16	300	3980	12	2800	3740
2000	1500	200	200	200	200	4.06	12	280	3030	12	225	1690	20	200	3610	16	200	2990	12	300	1830	16	300	3980	12	280	3740
2000	2000	200	250	200	200	4.80	12	280	3030	12	225	1990	20	200	3610	16	200	2990	12	300	2380	16	300	4080	12	280	3740
2500	1000	250	250	200	200	5.09	12	280	3580	12	300	1640	20	200	3610	16	200	3490	12	300	1380	16	300	4580	12	280	4340
2500	1500	250	250	200	200	5.49	12	280	3580	12	225	1890	20	200	3610	16	200	3490	12	300	1880	16	300	4580	12	280	4340
2500	2000	250	250	200	200	5.89	12	280	3580	12	250	2140	20	200	3610	16	200	3490	12	300	2380	16	300	4580	12	280	4340
2500	2500	250	250	200	200	6.29	12	280	3580	12	250	2390	20	200	3610	16	200	3490	12	250	2880	16	300	4580	12	280	4340
3000	1000	250	250	200	200	5.84	12	200	4080	12	300	1790	20	200	4110	16	200	3990	12	300	1380	16	300	5080	12	200	4840
3000	1500	250	250	200	200	6.24	12	200	4080	12	225	2040	20	200	4110	16	200	3990	12	300	1880	16	300	5080	12	200	4840
3000	2000	250	250	200	200	6.64	16	400	4200	16	250	2380	20	200	4110	16	150	3990	12	300	2410	16	300	5130	16	400	5130
3000	2500	250	250	200	200	7.04	16	400	4200	16	250	2600	20	200	4110	16	150	3990	12	250	2880	20	300	5320	16	400	5080
3000	3000	250	250	200	250	7.79	16	400	4250	16	200	2850	20	200	4160	16	150	4040	12	200	3380	20	300	5320	16	400	5080
FILL COVER 1.50m-3.00m																											
2000	1000	200	200	200	200	3.66	12	260	3030	12	300	1440	16	200	2990	16	250	2990	12	300	1330	16	300	4080	12	300	3840
2000	1500	200	200	200	200	4.06	12	260	3030	12	225	1690	16	200	2990	16	250	2990	12	300	1830	16	300	4080	12	260	3840
2000	2000	200	250	200	200	4.80	16	350	3150	16	250	2050	16	200	2990	12	150	2870	12	300	2380	16	300	4080	16	350	3980
2500	1000	250	250	200	200	5.09	16	300	3700	16	250	1700	16	175	3490	12	150	3370	12	300	1380	20	400	4820	16	300	4580
2500	1500	250	250	200	200	5.49	16	300	3700	12	225	1890	16	175	3490	16	250	3490	12	300	1880	16	300	4580	16	300	4580
2500	2000	250	250	200	200	5.89	16	300	3700	16	250	2200	16	175	3490	12	150	3370	12	300	2380	20	400	4820	16	300	4580
2500	2500	250	250	200	200	6.29	16	300	3700	16	175	2450	16	175	3490	12	150	3370	12	250	2880	20	350	4820	16	300	4580
3000	1000	275	275	200	200	6.33	16	300	4230	16	250	1880	16	150	3990	12	200	3870	12	300	1410	20	300	5370	16	300	5130
3000	1500	275	275	200	200	6.73	16	300	4230	12	225	2070	16	150	3990	16	200	3990	12	300	1910	16	280	5080	16	300	5080
3000	2000	275	275	200	200	7.13	16	300	4350	16	250	2380	16	150	3990	12	150	3870	12	300	2410	20	300	5370	16	300	5130
3000	2500	275	275	200	200	7.53	16	300	4230	16	175	2630	16	150	3990	12	150	3870	12	250	2910	20	300	5370	16	300	5130
3000	3000	275	275	200	275	8.46	16	300	4230	16	150	2880	16	150	4070	12	150	3950	12	200	3410	20	300	5370	16	300	5130

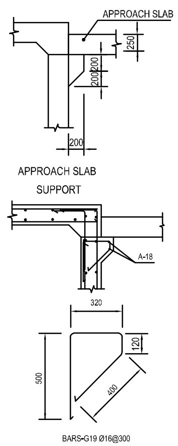
SPAN S mm	HEIGHT H mm	BARS-B8 SIZE	BARS-B8 SPACING	BARS-B8 LENGTH	BARS-A9 SIZE	BARS-A9 SPACING	BARS-A9 LENGTH	BARS-A10 SIZE	BARS-A10 SPACING	BARS-A10 LENGTH	BARS-A11 SIZE	BARS-A11 SPACING	BARS-A11 LENGTH	BARS-B12 SIZE	BARS-B12 SPACING	BARS-B12 LENGTH	BARS-B13 SIZE	BARS-B13 SPACING	BARS-B13 LENGTH	NUMBER OF SPACER BARS Ø12 @300 TOP	BOTTOM	EACH WALL	WEIGHT KG / M
FILL COVER 1.50m OR LESS																							
2000	1000	12	300	1070	16	200	3660	16	150	3660	16	300	3150	12	300	1330	12	300	1070	46	46	24	485.50
2000	1500	12	300	1070	16	200	3660	16	150	3660	16	300	3150	12	225	1830	12	225	1070	46	46	32	518.50
2000	2000	12	300	1070	16	200	3660	16	150	3660	16	300	3200	12	225	2380	12	225	1070	46	46	48	587.00
2500	1000	12	300	1120	16	200	4160	16	150	4160	16	300	3700	12	300	1380	12	300	1120	56	56	24	548.00
2500	1500	12	300	1120	16	200	4160	16	150	4160	16	300	3700	12	225	1880	12	225	1120	56	56	32	582.00
2500	2000	12	300	1120	16	200	4160	16	150	4160	16	300	3700	12	250	2380	12	250	1120	56	56	48	592.00
2500	2500	12	250	1120	16	200	4160	16	150	4160	16	300	3700	12	250	2880	12	250	1120	56	56	64	620.00
3000	1000	12	300	1120	16	200	4660	20	200	4900	16	300	4200	12	300	1380	12	300	1120	66	66	24	630.00
3000	1500	12	300	1120	16	200	4660	20	200	4900	16	300	4200	12	225	1880	12	225	1120	66	66	32	665.50
3000	2000	12	300	1150	16	150	4660	20	200	4900	16	300	4230	16	250	2530	16	250	1390	66	66	48	806.00
3000	2500	12	250	1120	16	150	4660	20	200	4900	20	300	4320	16	250	3000	16	250	1360	66	66	64	892.00
3000	3000	12	200	1120	16	150	4660	20	200	4900	20	300	4370	16	200	3000	16	200	1360	66	66	72	977.00
FILL COVER 1.50m-3.00m																							
2000	1000	12	300	1070	12	200	3420	12	200	3420	16	300	3150	12	300	1330	12	300	1070	46	46	24	396.00
2000	1500	12	200	1070	12	200	3420	12	200	3420	16	300	3150	12	225	1830	12	225	1070	46	46	32	434.50
2000	2000	12	200	1070	12	150	3420	12	200	3420	16	300	3200	16	250	2500	16	250	1310	46	46	48	537.00
2500	1000	12	300	1120	12	200	3920	12	200	3920	20	400	3580	16	250	1500	16	250	1360	56	56	24	568.50
2500	1500	12	200	1120	12	200	3920	12	200	3920	16	300	3700	12	225	1880	12	225	1120	56	56	32	494.50
2500	2000	12	200	1120	12	150	3920	12	200	3920	20	400	3820	16	250	2500	16	250	1360	56	56	48	647.00
2500	2500	12	175	1120	12	150	3920	12	200	3920	20	350	3820	16	175	3000	16	175	1360	56	56	64	774.50
3000	1000	12	300	1150	12	200	4920	12	200	4420	20	300	4110	16	250	1530	16	250	1390	66	66	24	657.00
3000	1500	12	200	1150	12	200	4420	12	200	4420	16	280	4200	12	225	1910	12	225	1150	66	66	32	577.00
3000	2000	12	200	1150	12	150	4420	12	200	4420	20	300	4350	16	250	2530	16	250	1390	66	66	48	766.50
3000	2500	12	175	1150	12	150	4420	12	200	4420	20	300	4350	16	175	3030	16	175	1390	66	66	64	889.00
3000	3000	12	175	1150	12	150	4420	12	200	4420	20	300	4420	16	150	3530	16	150	1390	66	66	72	999.00



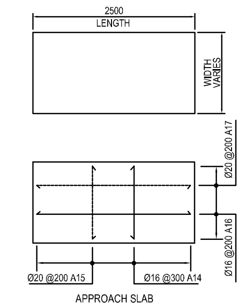
BARREL DIMENSIONS



BARREL REINFORCEMENT



APPROACH SLAB
SUPPORT REINFORCEMENT



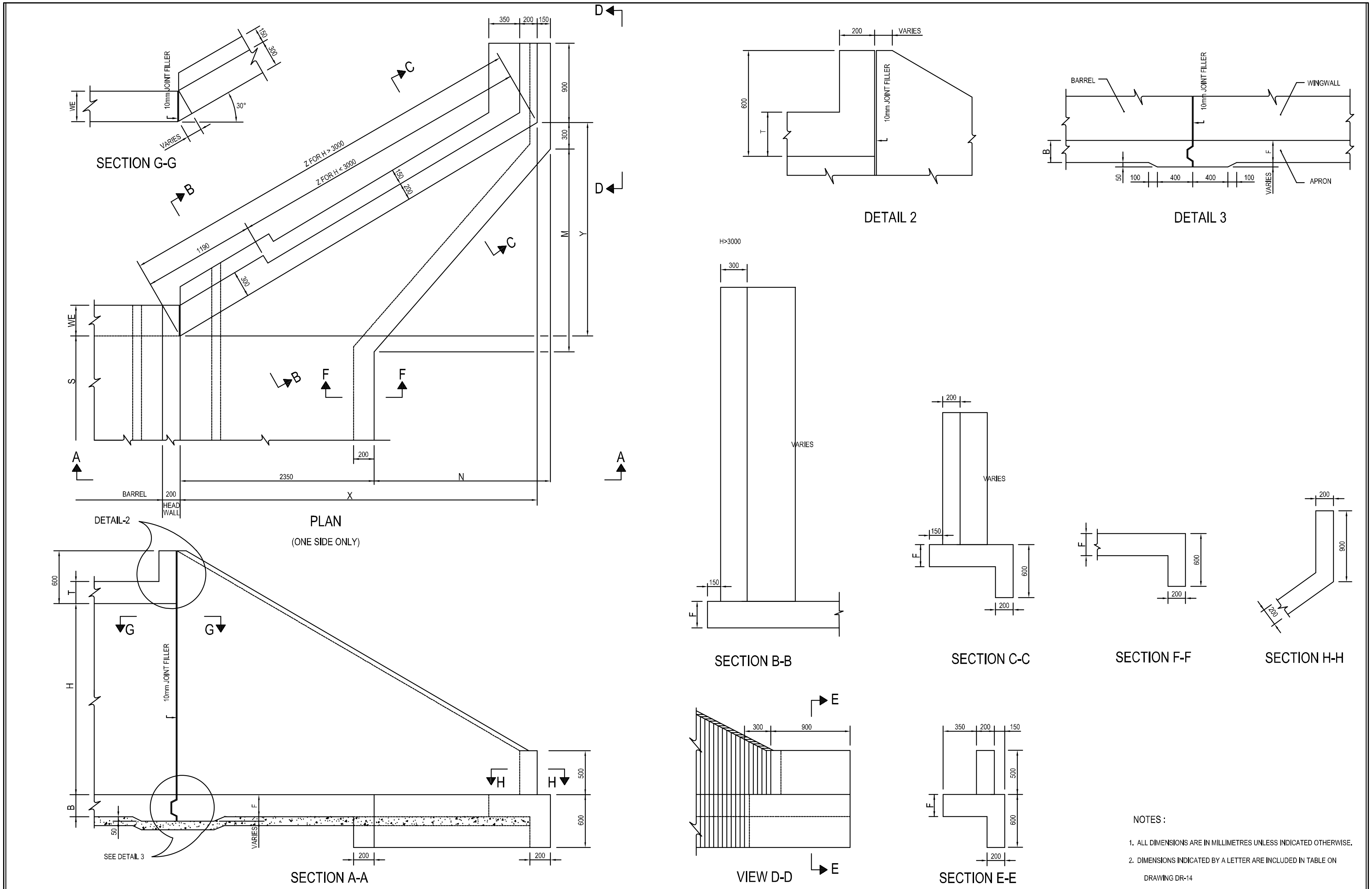
APPROACH SLAB

TABLE REINFORCEMENT AND CONCRETE FOR APPROACH SLAB						
BAR MARK	A-14	A-15	A-16	A-17	A-18	G-19
DIAMETER mm	16	20	16	20	16	16
LENGTH mm	VARIES	VARIES	2420	2420	VARIES	1290

NOTES

1. APPROACH SLAB SHALL ONLY BE USED WHERE THE COVER IS LESS THAN 0.60m.

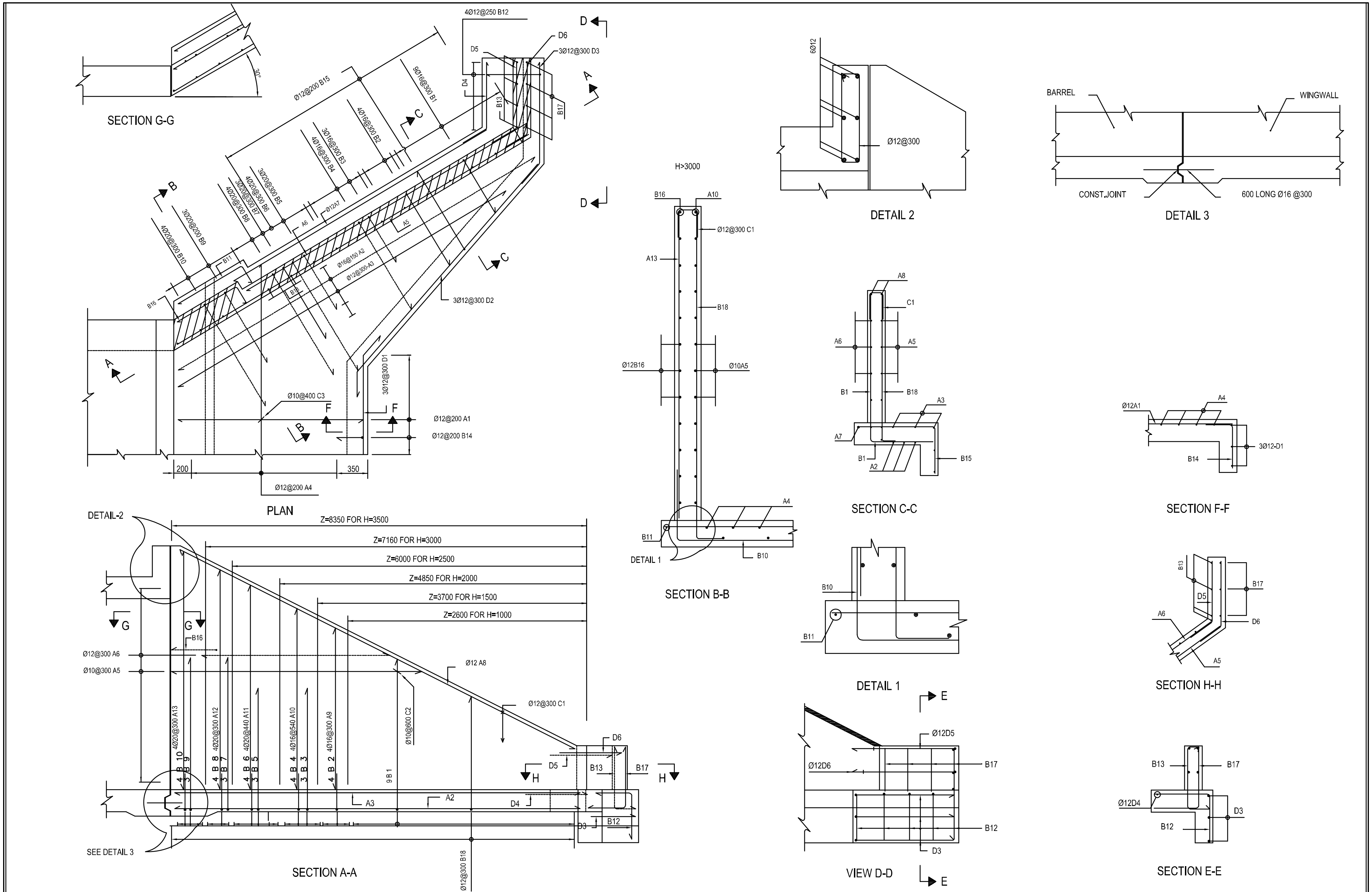
LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE		DESIGNED					NOT TO SCALE	
	BOX CULVERT 3 CELL DIMENSION, REINFORCEMENT AND QUANTITY		CHECKED						
			APPROVED						



NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS INDICATED OTHERWISE.
2. DIMENSIONS INDICATED BY A LETTER ARE INCLUDED IN TABLE ON DRAWING DR-14

LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE BOX CULVERT 1 CELL DIMENSION, REINFORCEMENT AND QUANTITY		DESIGNED					NOT TO SCALE	
			CHECKED						
			APPROVED						



LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No. / SCALE / DRAWING No.
	DRAWING TITLE BOX CULVERT WINGWALL REINFORCEMENT		DESIGNED				NOT TO SCALE
			CHECKED				
			APPROVED				

SUMMARY OF QUANTITIES FOR WINGWALL

TABLE OF WINGWALL DIMENSIONS AND QUANTITIES FOR SINGLE CELL BOX CULVERT

S	H	F	WI	WE	SLOPE 1:2					QUANTITIES		
					X	Y	Z	M	N	CONCRETE Grade 15	CONCRETE Grade 25	REINFORCEMENT
(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m3)	(m3)	(Tonne)
1.00	1.00	0.20		0.20	3.20	1.85	3.70	0.80	1.00	1.31	4.52	0.40
1.50	1.00	0.20		0.20	3.20	1.85	3.70	0.80	1.00	1.53	4.94	0.41
1.50	1.50	0.20		0.20	3.20	1.85	3.70	0.80	1.00	1.53	5.31	0.49
2.00	1.00	0.20		0.20	3.20	1.85	3.70	0.80	1.00	1.75	5.36	0.43
2.00	1.50	0.20		0.20	3.20	1.85	3.70	0.80	1.00	1.75	5.73	0.51
2.00	2.00	0.20		0.20	4.20	2.42	4.85	1.60	2.00	2.39	8.19	0.72
2.50	1.00	0.20		0.20	3.20	1.85	3.70	0.80	1.00	1.97	5.79	0.51
2.50	1.50	0.20		0.20	3.20	1.85	3.70	0.80	1.00	1.97	6.16	0.54
2.50	2.00	0.20		0.20	4.20	2.42	4.85	1.60	2.00	2.61	8.61	0.76
2.50	2.50	0.25		0.20	5.20	3.00	6.00	2.40	3.00	3.00	12.08	1.07
3.00	1.00	0.25		0.20	3.20	1.85	3.70	0.80	1.00	2.19	7.12	0.63
3.00	1.50	0.25		0.20	3.20	1.85	3.70	0.80	1.00	2.19	7.49	0.66
3.00	2.00	0.25		0.20	4.20	2.42	4.85	1.60	2.00	2.83	10.25	0.90
3.00	2.50	0.25		0.20	5.20	3.00	6.00	2.40	3.00	3.22	12.60	1.11
3.00	3.00	0.25		0.25	6.20	3.58	7.16	3.20	4.00	3.36	14.54	1.28
TABLE OF WINGWALL DIMENSIONS AND QUANTITIES FOR DOUBLE CELL BOX CULVERT												
2.00	1.00	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	2.72	7.23	0.63
2.00	1.50	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	2.72	7.60	0.67
2.00	2.00	0.20	0.20	0.20	4.20	2.42	4.85	1.60	2.00	3.36	10.06	0.88
2.50	1.00	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	3.16	8.08	0.71
2.50	1.50	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	3.16	8.45	0.74
2.50	2.00	0.20	0.20	0.20	4.20	2.42	4.85	1.60	2.00	3.80	10.90	0.96
2.50	2.50	0.25	0.20	0.20	5.20	3.00	6.00	2.40	3.00	4.19	14.87	1.30
3.00	1.00	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	3.60	8.93	0.78
3.00	1.50	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	3.60	9.30	0.81
3.00	2.00	0.20	0.20	0.20	4.20	2.42	4.85	1.60	2.00	4.25	11.75	1.03
3.00	2.50	0.25	0.20	0.20	5.20	3.00	6.00	2.40	3.00	4.64	15.90	1.39
3.00	3.00	0.25	0.20	0.25	6.20	3.58	7.16	3.20	4.00	4.81	17.95	1.57
3.50	3.50	0.25	0.25	0.25	7.20	4.20	8.35	4.00	5.00	5.25	20.85	1.83
TABLE OF WINGWALL DIMENSIONS AND QUANTITIES FOR TRIPPLE CELL BOX CULVERT												
2.00	1.00	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	3.69	9.10	0.80
2.00	1.50	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	3.69	9.47	0.83
2.00	2.00	0.20	0.20	0.20	4.20	2.42	4.85	1.60	2.00	4.33	11.92	1.05
2.50	1.00	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	4.35	10.37	0.91
2.50	1.50	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	4.35	10.74	0.94
2.50	2.00	0.20	0.20	0.20	4.20	2.42	4.85	1.60	2.00	5.00	13.19	1.16
2.50	2.50	0.25	0.20	0.20	5.20	3.00	6.00	2.40	3.00	5.39	17.66	1.55
3.00	1.00	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	5.01	11.64	1.02
3.00	1.50	0.20	0.20	0.20	3.20	1.85	3.70	0.80	1.00	5.01	12.01	1.05
3.00	2.00	0.20	0.20	0.20	4.20	2.42	4.85	1.60	2.00	5.66	14.46	1.27
3.00	2.50	0.25	0.20	0.20	5.20	3.00	6.00	2.40	3.00	6.05	19.21	1.68
3.00	3.00	0.25	0.20	0.25	6.20	3.58	7.16	3.20	4.00	6.24	21.30	1.87

LAO PEOPLE'S DEMOCRATIC REPUBLIC MINISTRY OF PUBLIC WORKS AND TRANSPORT	PROJECT NAME:	CONSULTANT		NAME	SIGNATURE	DATE	REVISION No.	SCALE	DRAWING No.
	DRAWING TITLE BOX CULVERT WINGWALL REINFORCEMENT		DESIGNED					NOT TO SCALE	DR-033/3
			CHECKED						
			APPROVED						