10.2 REHABILITATION DESIGN CRITERIA

10.2.1 Basic Considerations in Establishment of Rehabilitation Criteria

As described in Section 10.1, problems in the existing bridges on the Study Road are broadly categorized into the following four:
a) Problems of standards
b) Problems of hydraulic regime
c) Structural deterioration
d) Lack of aseismicity

Basic considerations on how to cope with the problems are as follows:

a) Problems of Standards

Carriageway Width

Carriageway width of the existing bridges varies from 6.70m to 8.10m. In 86 bridges out of 125, carriageway is narrower than the DPWH standard width of 7.32m. Since every bridge has at least the standard width of the Pan-Philippine Highway of 6.70m, however, widening is not considered to be in urgent need except in the following case:

In case where approach roads on both sides are 4 or more-lane roads and traffic volume is quite high, the bridge is needed to be widened to 4 lanes to maintain a smooth flow of traffic avoiding bottleneck.

Sidewalk Width

Most bridges are substandard in sidewalk width, 112 bridges out of 125 having narrower sidewalk than the DPWH standard width of 0.76m. Sidewalks of less than 0.60m in width, in case where they are located in residential areas and many pedestrians pass thereon, are needed to be widened to secure safety of pedestrians and smooth passage of vehicles. In scarsely populated areas on the other hand, the widening of sidewalk is not considered to be in urgent need.

Load Limit

2 bridges are given a 10-ton load limit, 82 bridges 15-ton load limit, 2 bridges 18-ton load limit and the remaining 39 bridges 20-ton load limit which is the DPWH standard design load. The bridges with 10-ton load limit are needed to be reconstructed, while the bridges with 15- or 18-ton load limit are desirable to be also reconstructed but they are given lower priority. In this Study, only 10-ton load limit is used as one of the criteria for reconstruction.

b) Problems of Hydraulic Regime

Insufficient Freeboard

There are two cases in shortage of freeboard; bridge elevation being too low from the beginning and riverbed being raised due to sedimentation. In the former case, the bridge is needed to be raised by either whole reconstruction or heightening substructure and lifting or reconstructing superstructure. The latter way is not practical in this project because the bearing and structural capacity of the existing substructure is generally not enough to support the lifted superstructure and it is better to change the locations of substructure in most cases, and therefore, the former way will be applied. In case of raise of riverbed, either raise of bridge or dredging of riverbed sediment or both is selected depending on the river condition.

Insufficient Length of Bridge and Lateral Scour

Where approach road embankment encroaches on the stream, the bridge is needed to be extended by constructing additional span(s).

Where river bank is eroded due to meandering of the river at the upstream of bridge, remedial and protective measures are needed, such as spurdike, dredging, river bank protection, etc.

Local Scour

Where local scour is found at abutment slope or pier foundation, firm protective measures are needed to avoid damage by scour.

In most bridges, abutment slope is protected with grouted riprap but sometimes the protection is damaged. In such case, partial repair or total reconstruction is needed depending on the degree of damage. There is no bridge in which pier foundation is protected. If pier foundation is scoured, it is needed to be protected.

c) Structural Deterioration

Main Structures

If main structures, i.e., slab, girder and substructure, are deteriorated to the degree of dissatisfaction in their bearing and structural capacity, they are needed to be reconstructed. Only the portion in such condition is generally subject to reconstruction. However, girders are usually deteriorated to some degree when substructure supporting them is structurally defective and likewise slab is damaged when girders are defective. Therefore, reconstruction of girder will accompany reconstruction of slab and reconstruction of substructure will accompany reconstruction of girder and slab.

If main structures are damaged but still repairable, repair works such as partial reconstruction of damaged portion, crack sealing, partial replacement of steel member(s), etc. will be applied instead of reconstruction.

Other Components

Basic principles to cope with the damage of other components of bridge are as follows:

Railing : Partially or totally reconstructed depending on the degree of damage.
Slab overlay : (Re)constructed if existing overlay is deteriorated, or no overlay exists but it is needed to provide smooth riding surface or to protect reinforcing steel of slab.
Expansion joint: Replaced when slab is reconstructed.
Bearing : Replaced when girder is reconstructed, or bearing is seriously damaged to fail in its function even if girder is not reconstructed, especially for roller or rocker expansion bearing.
Drainage pipe : Replaced when slab is reconstructed.
Approach road embankment slope: If embankment slope is unprotected and eroded, it shall be protected. If embankment slope is already protected but the protection is seriously damaged, it shall be reconstructed.
Approach road embankment settlement: Approach slab shall be provided if settlement is significant.

Repair of only expansion joint or drainage pipe without reconstruction of slab is not taken up in this Study because no serious case is found in the existing bridges.

d) Lack of Aseismicity

No special aseismatic consideration is given to the existing bridges. It is, however, necessary to prevent a bridge from falling in order to maintain road traffic even in the occurrence of earthquake. From this point of view, falling prevention measures should be taken for as many bridges as possible. It is a good opportunity when a bridge is totally reconstructed. For the other bridges, priority should be determined depending on significance of impact when falling and difficulty in taking urgent restoration measures. Length of bridge is one of the determinative factors. Based on the above considerations, the following bridges are selected as the bridge to take falling prevention measures:

- bridges to be totally reconstructed irrespective of length
- bridges of 35m or more in length

Among various measures, the following are selected in this Study as a general rule, taking into consideration constructability and existing condition of bridges:

- Widening of bridge seat for concrete bridges and trusses.
- Installation of girder-to-abutment and girder-to-girder connection devices for steel bridges.

10.2.2 Bridge Rehabilitation Methods and Application Criteria

Based on the considerations described in Section 10.2.1, bridge rehabilitation methods are selected for this Project as follows (see Table 10.2-1 for brief description of each method and its application criteria):

A. Total Reconstruction	1. Total Reconstruction of Bridge
B. Partial Reconstruction	2. Reconstruction of Entire Slab of Span 3. Reconstruction of All Girders of Span 4. Reconstruction of Substructure
C. Widening	5. Widening of Carriageway or Construction of Additional Bridge 6. Widening of Sidewalk
D. Extension	7. Construction of Additional Span
E. Major Repair	8. Partial or Total Reconstruction of Railing 9. Partial Reconstruction of Slab 10. Reconstruction of Concrete Girder 11. Replacement of Steel Girder/Member 12. Replacement of Bearing 13. Repair of Bridge Seat 14. Reinforcement of Pier 15. Reinforcement of Foundation
F. Minor Repair	16. Repair of Slab 17. Repair of Concrete Girder 18. Repainting of Steel Girder/Member 19. Repair of Substructure 20. Provision/Reconstruction of Slab Overlay
G. Protection from Scour	21. Repair of Abutment Slope Protection 22. Provision/Reconstruction of Abutment Slope Protection 23. Provision/Reconstruction of Pier Foundation Protection 24. Provision/Reconstruction of River Bank Protection
H. Approach Road Protection	25. Provision/Reconstruction of Approach Road Embankment Slope Protection 26. Provision of Approach Slab
I. River Control	27. Provision of Spurdike 28. Dredging
J. Aseismatic Protection	29. Widening of Bridge Seat 30. Provision of Mechanical Connection Device

Note: Methods 16 to 21, referred to as the minor works, should be done by the DPWH District Offices as maintenance work. Therefore, the bridges which need only the minor works will not be included in the rehabilitation project, expecting the District Offices' proper maintenance operation. For the bridges including both minor works and any other work, however, the minor works will be included in the scope of work of the rehabilitation project.

TABLE 10.2-1 BRIDGE REHABILITATION METHODS AND THEIR APPLICATION CRITERIA

(1/8)

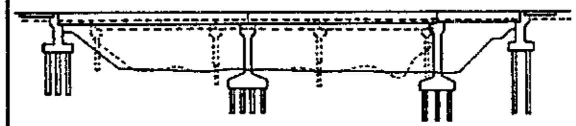
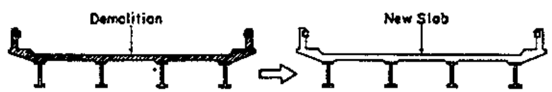
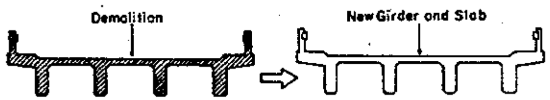
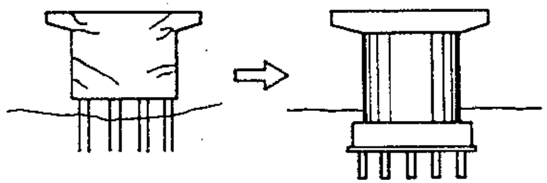
Category	Rehabilitation Method	Sample Illustration	Description of Method	Criteria for Application
A. Total Reconstruction	1. Total Reconstruction of Bridge		Totally reconstruct a bridge providing sufficient waterway opening and aseismicity. Take protection measures against scour as necessary.	o All substructures are inadequate in their structural capacities, being obviously settled or tilted or concrete being seriously cracked and spalled and reinforcing steel being exposed and rusted. o Girders of all spans meet the conditions to apply Method 3 and substructure is not sound to be used as is. o Load limit is below 15 tons. o Because of low elevation of girders, freeboard is insufficient and bridge is in danger of submergence during high-water.
B. Partial Reconstruction	2. Reconstruction of Entire Slab of Span		Reconstruct entire slab of span(s) in problem.	o In most part of slab, wide cracks are found on both top and bottom surfaces, often, reinforcing steel being exposed and rusted or concrete block falling off.
	3. Reconstruction of All Girders of Span		Reconstruct all girders of span(s) in problem. Reconstruction of slab will be accompanied.	o Half or more concrete girders have shearing or bending cracks for lack of structural capacity. o Half or more steel girders are seriously deformed for lack of structural capacity or loss of cross-sectional area due to rust.
	4. Reconstruction of Substructure		Reconstruct substructure in problem. Usually reconstruction of slab and girders of the related span(s) will be accompanied.	o A certain substructure is inadequate in its structural capacity, being obviously settled or tilted or concrete being seriously cracked and spalled and reinforcing steel exposed and rusted.

TABLE 10.2-1 BRIDGE REHABILITATION METHODS AND THEIR APPLICATION CRITERIA

(2/8)

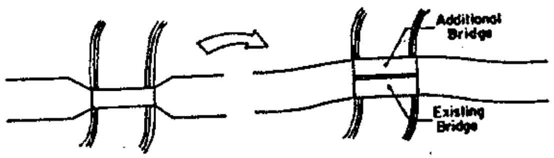
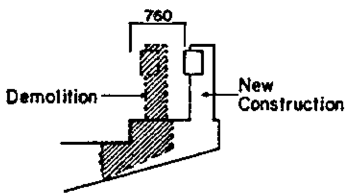
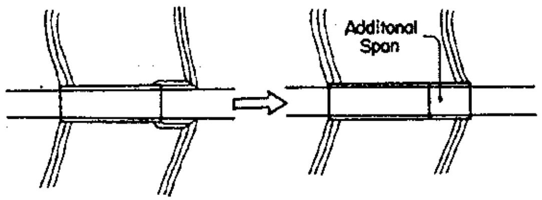
Category	Rehabilitation Method	Sample Illustration	Description of Method	Criteria for Application
C. Widening	5. Widening of Carriageway or Construction of Additional Bridge		Demolish existing sidewalk and railing on one or both sides(s), widen substructure if necessary and construct additional girders and slab, or construct another bridge adjacent to and parallel with the existing bridge.	o Number of lanes is less than that of approach road on each side and traffic volume is high.
	6. Widening of Sidewalk		Demolish existing sidewalk and railing, widen substructure if necessary, construct additional girders if necessary, and construct new sidewalk and railing.	o Bridge is located in residential area and has less than 60cm wide sidewalk.
D. Extension	7. Construction of Additional Span		Take necessary measures to convert the existing abutment into pier or reconstruck it , and construct substructure and superstructure of additional span(s).	o Approach road embankment encroaches on waterway causing flooding upstream and erosion of approach road embankment.

TABLE 10.2-1 BRIDGE REHABILITATION METHODS AND THEIR APPLICATION CRITERIA

(3/8)

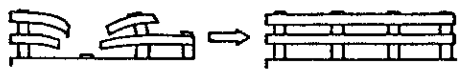
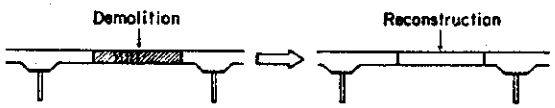
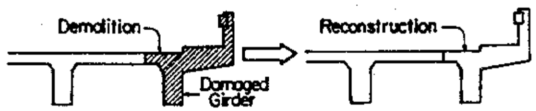
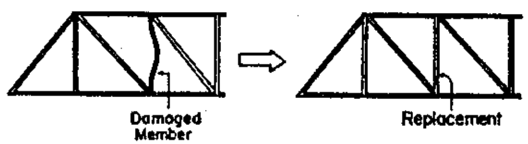
Category	Rehabilitation Method	Sample Illustration	Description of Method	Criteria for Application
E. Major Repair	8. Partial or Total Reconstruction of Railing		Demolish existing railing partially or totally depending on the degree of damage and reconstruct it.	o Railing is damaged and endangers traffic and pedestrians.
	9. Partial Reconstruction of Slab		Demolish damaged portion of slab and reconstruct it.	o In a part of slab, wide cracks are found on both top and bottom surfaces, often, reinforcing steel being exposed and rusted or concrete block falling off.
	10. Reconstruction of Concrete Girder		Demolish damaged girder(s) and reconstruct them. Partial or total reconstruction of supported slab will be accompanied.	o A certain concrete girder has shearing or bending cracks for lack of structural capacity.
	11. Replacement of Steel Girder/ Member		Replace damaged girder(s)/member(s).	o A certain steel girder/member is deformed or thickly rusted.

TABLE 10.2-1 BRIDGE REHABILITATION METHODS AND THEIR APPLICATION CRITERIA

(4/8)

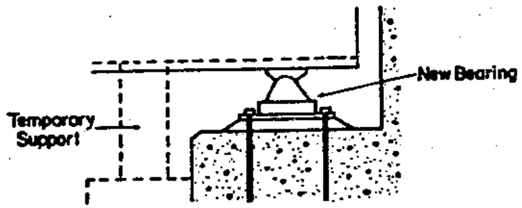
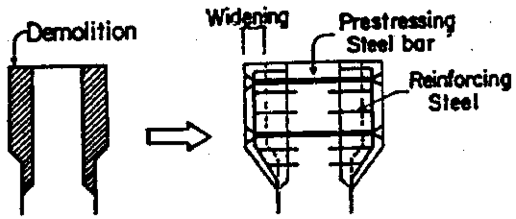
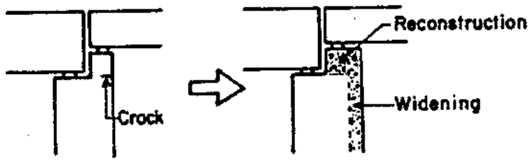
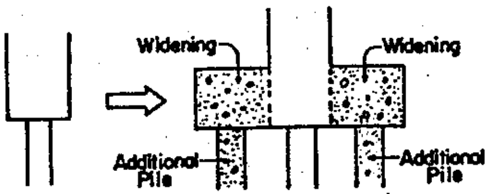
Category	Rehabilitation Method	Sample Illustration	Description of Method	Criteria for Application
E. Major Repair (continued)	12. Replacement of Bearing		Provide temporary support in the vicinity of the bearing, jack up superstructure evenly, demolish and reinforce bridge seat, and install new bearing. If the width of bridge seat is insufficient from the aseismatic point of view, widen it.	o Bearing, especially roller or rocker expansion bearing, is seriously damaged to fail in its function and induce stresses in superstructure and substructure.
	13. Repair of Bridge Seat		Seal cracks by injecting them with low viscosity epoxy or demolish damaged portion as the case may be (usually temporary support is needed in the latter case), and widen bridge seat in the same manner as Method 28.	o Concrete at bridge seat is cracked or spalled.
	14. Reinforcement of Pier		Provide temporary support of related girders, demolish damaged portion of pier, and place reinforcing steel and concrete to widen the existing pier.	o Pier is seriously damaged, especially at top portion of pier supporting girders with different depth between neighboring girders, and needs to be strengthened.
	15. Reinforcement of Foundation		Widen footing with piles if necessary.	o Bearing capacity of foundation is insufficient or will be insufficient due to reconstruction of superstructure.

TABLE 10.2-1 BRIDGE REHABILITATION METHODS AND THEIR APPLICATION CRITERIA

(5/8)

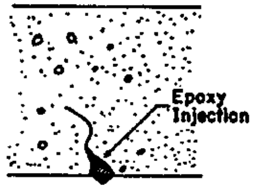
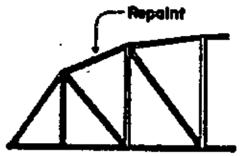
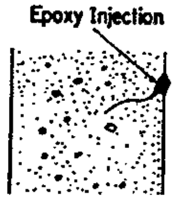
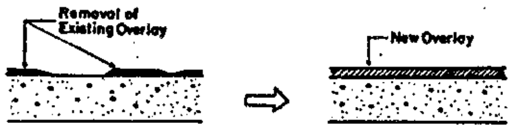
Category	Rehabilitation Method	Sample Illustration	Description of Method	Criteria for Application
F. Minor Repair	16. Repair of Slab		Seal cracks by injecting them with low viscosity epoxy.	o Concrete slab is cracked or spalled but reinforcing steel is neither seriously deformed nor rusted.
	17. Repair of Concrete Girder		Seal cracks by injecting them with low viscosity epoxy.	o Concrete girder is cracked or spalled but reinforcing steel is neither seriously deformed nor rusted.
	18. Repainting of Steel Girder/ Member		Repaint all steel members.	o Steel girder/member is rusty but not structurally deteriorated.
	19. Repair of Substructure		Seal cracks by injecting them with low viscosity epoxy.	o Substructure concrete is cracked or spalled but reinforcing steel is neither seriously deformed nor rusted.
	20. Provision/ Reconstruction of Slab Overlay		Remove overlay if exists, and place asphalt overlay.	o Existing concrete overlay is considerably cracked or spalled. o Existing asphalt overlay is considerably cracked, distorted or disintegrated. o No overlay exists but it is considered to be needed in order to provide smooth riding surface or to protect reinforcing steel of slab.

TABLE 10.2-1 BRIDGE REHABILITATION METHODS AND THEIR APPLICATION CRITERIA

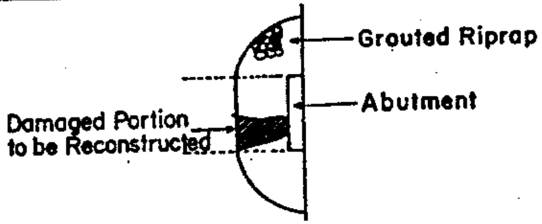
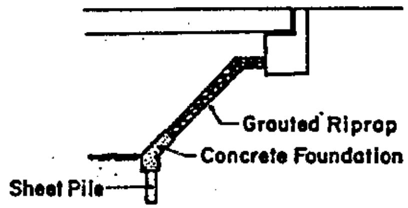
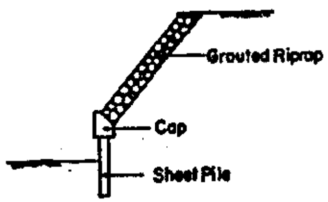
Category	Rehabilitation Method	Sample Illustration	Description of Method	Criteria for Application
G. Protection from Scour	21. Repair of Abutment Slope Protection		Remove damaged portion of existing abutment slope protection and reconstruct it.	o Abutment slope protection is damaged and/or its foundation is scoured. But the damage is still repairable.
	22. Provision/ Reconstruction of Abutment Slope Protection		Remove abutment slope protection if exists, and (re)construct the protection with grouted riprap, concrete pitching, gabion, or so on.	o Abutment slope is protected but the protection is seriously damaged and its foundation is scoured. o Abutment slope is not protected, being exposed to scour.
	23. Provision/ Reconstruction of Pier Foundation Protection		Remove pier foundation protection if exists, and (re)construct the protection with stone or concrete pitching, concrete block, gabion or so on.	o Pier foundation, unprotected or protected but seriously damaged, is scoured.
	24. Provision/ Reconstruction of River Bank Protection		Remove river bank protection if exists, and (re)construct the protection with grouted riprap, concrete block, concrete crib, sheet pile, gabion or so on, to the extent within which bridge and/or approach road is affected when river bank is damaged.	o River bank, unprotected or protected but seriously damaged, is scoured or in danger of being scoured due to the effect of meandering stream.

TABLE 10.2-1 BRIDGE REHABILITATION METHODS AND THEIR APPLICATION CRITERIA

(7/8)

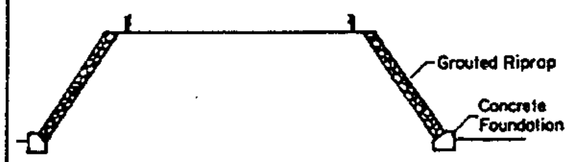
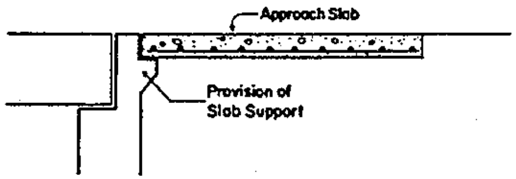
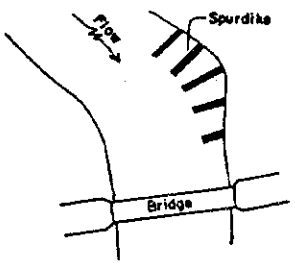
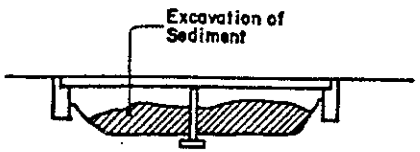
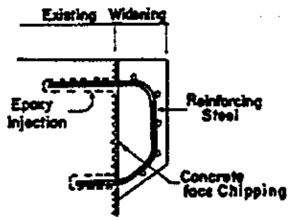
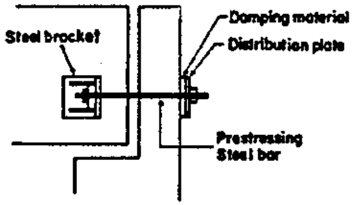
Category	Rehabilitation Method	Sample Illustration	Description of Method	Criteria for Application
H. Approach Road Protection	25. Provision/ Reconstruction of Approach Road Embankment Slope Protection		Remove approach road embankment slope protection if exists, and (re)construct the protection with grouted riprap, concrete block concrete crib, concrete retaining wall or so on.	o Approach road embankment slope, unprotected or protected but seriously damaged, is eroded or scoured.
	26. Provision of Approach Slab		Provide slab support on parapet of the existing abutment (reconstruct parapet if necessary) and construct reinforced concrete approach slab.	o Approach road embankment sinks by 20cm or more at the embankment end.
I. River Control	27. Provision of Spurdike		Construct spurdike with stone masonry, concrete block, gabion or so on to protect river bank and approach road by changing river flow direction.	o Control of river flow direction is considered to be needed in order to protect river bank and bridge approach.
	28. Dredging		Excavate riverbed sediment to recover freeboard.	o Riverbed rises due to sedimentation and consequently freeboard is insufficient and superstructure is in danger of submergence during high-water.

TABLE 10.2-1 BRIDGE REHABILITATION METHODS AND THEIR APPLICATION CRITERIA

(8/8)

Category	Rehabilitation Method	Sample Illustration	Description of Method	Criteria for Application
J. Aseismatic Protection	29. Widening of Bridge Seat		Widen bridge seat to provide allowance for displacement of superstructure, by inserting reinforcing steel and/or prestressing steel bar into the existing concrete body and placing concrete.	o This is applied to all concrete bridges and steel trusses of 35m or more in length.
	30. Provision of Mechanical Connection Device		Install device for connecting girder with substructure or adjacent girder to prevent superstructure from falling.	o This is applied to all steel girder bridges of 35m or more in length.

10.3 PRELIMINARY DESIGN

10.3.1 Identification of Bridges for Rehabilitation

In accordance with the rehabilitation criteria described in Section 10.2, the bridges needing rehabilitation are identified as shown in Table 10.3-1.

As mentioned in Section 10.2.2, the bridges needing only minor works (Methods 16-21) are proposed to be treated by the DPWH District Offices as maintenance work and therefore not included in the rehabilitation project.

Number of bridges identified is as follows:

- Total Reconstruction: 8 bridges
- Rehabilitation other than Total Reconstruction: 81 bridges
- Maintenance: 28 bridges (not included in the rehabilitation project)

Note: 1) Panaytay Bridge (No. 4-13) is presently given a load limit of 10 tons which is one of the criteria for total reconstruction. However, the load limit was originally 15 tons and it was changed to 10 tons when superstructure was seriously deteriorated and bailey bridge was built on the bridge supported by the existing substructure. From such background and the fact that the substructure is judged to be still sound, reconstruction of only superstructure is proposed for this bridge.

2) Total reconstruction of Gov. Miranda Bridge (No. 5-21) is required to form a part of countermeasures against flood of the Liboganon River which is discussed in detail in Section 12.3).

10.3.2 Preliminary Design

The geotechnical and soils investigation undertaken at the selected bridge sites is presented in Appendix 10.1 and design precedents of previous/on-going rehabilitation projects are presented in Appendix 10.2.

Design principles are described hereunder.

a) Total Reconstruction

Preliminary design of total reconstruction of bridges are outlined as follows:

<u>Specifications</u>

The following specifications are applied:
- Design Guidelines, Criteria and Standards for Public Works and Highways, DPWH
- Standard Specifications for Highway Bridges, 15th Edition, AASHTO, 1992

TABLE 10.3 - 1 BRIDGES IDENTIFIED FOR REHABILITATION

(1/2)

REHABILITATION METHOD APPLIED	BRIDGE NUMBER / BRIDGE NAME	1-01 Lipata	1-02 Lamintao	1-03 Kinabutan I	1-04 Kinabutan II	1-05 Malico	1-06 Cagbayoc	1-07 Reyes	1-08 Mabuhay	1-09 Payao	1-10 Timamana	1-11 Motorpool	1-12 Pingaping	1-13 Marga	1-14 Tubod	1-15 Siana	1-16 Magpayang I	1-17 Magpayang II	1-18 Pongtod	1-19 Alimpatayan	1-20 Alipao	1-21 Baloran	1-22 Candiis	1-23 Togbongon	1-24 Magtiaco	1-25 San Pedro
A. TOTAL RECONSTRUCTION	1. Total Reconstruction of Bridge																									
B. PARTIAL RECONSTRUCTION	2. Reconstruction of Entire Slab of Span																	●						●		
	3. Reconstruction of All Girders of Span																							●		
	4. Reconstruction of Substructure																									
C. WIDENING	5. Widening of Carriageway or Const. of Additional Bridge																									
	6. Widening of Sidewalk																									
D. EXTENSION	7. Construction of Additional Span																									
E. MAJOR REPAIR	8. Partial or Total Reconstruction of Railing																									
	9. Partial Reconstruction of Slab																									●
	10. Reconstruction of Concrete Girder																									
	11. Replacement of Steel Girder / Member																									
	12. Replacement of Bearing																									
	13. Repair of Bridge Seat																									
	14. Reinforcement of Pier																									
	15. Reinforcement of Foundation																									
F. MINOR REPAIR	16. Repair of Slab			●		●	●			●			●	●	●	●	●			●		●			●	
	17. Repair of Concrete Girder												●	●		●	●				●	●				
	18. Repainting of Steel Girder / Member	●	●	●	●										●					●			●		●	●
	19. Repair of Substructure																									
	20. Provision / Reconstruction of Slab Overlay			●									●	●	●		●								●	
G. PROTECTION FROM SCOUR	21. Repair of Abutment Slope Protection		●							●					●	●					●					
	22. Provision / Reconstruction of Abutment Slope Protection								●											●		●				
	23. Provision / Reconstruction of Pier Foundation Protection																								●	
	24. Provision / Reconstruction of River Bank Protection								●									●	●							●
H. APPROACH ROAD PROTECTION	25. Provision/ Reconst. of Approach Road Embank. Slope Protection																							●	●	●
	26. Provision of Approach Slab	●			●	●																			●	
I. RIVER CONTROL	27. Provision of Spurdike																									●
	28. Dredging																			●						●
J. ASEISMATIC PROTECTION	29. Widening of Bridge Seat								●										●							●
	30. Provision of Mechanical Connection Device				●																				●	
CATEGORY	Total Reconstruction																									
	Rehabilitation Other Than Total Reconstruction	●			●	●			●									●	●	●		●		●	●	●
	Maintenance		●	●			●			●			●	●	●	●	●				●		●			

REHABILITATION METHOD APPLIED	BRIDGE NUMBER / BRIDGE NAME	2-01 Mamkas	2-02 Lambog	2-03 Taytay-Oyos	2-04 Jaliobong	2-05 New Camalig	2-06 Baliguian	2-07 Sayadion	2-08 Puyo	2-09 Bangonay	2-10 Paypay	2-11 Jagupit	2-12 Guinoyoran	2-13 Tagmamarkay	2-14 Sta. Ana	2-15 Calo-oy	2-16 Minusuang	2-17 Maraput	2-18 Comagascas	2-19 Cabadbaran	2-20 Pandanon	2-21 Sanghan	2-22 Capudlosan	2-23 Humilog	2-24 Mina-ano	2-25 Panaytayon
A. TOTAL RECONSTRUCTION	1. Total Reconstruction of Bridge																					●				
B. PARTIAL RECONSTRUCTION	2. Reconstruction of Entire Slab of Span		●	●							●								●					●		
	3. Reconstruction of All Girders of Span																									
	4. Reconstruction of Substructure																									
C. WIDENING	5. Widening of Carriageway or Const. of Additional Bridge																									
	6. Widening of Sidewalk										●															●
D. EXTENSION	7. Construction of Additional Span																									
E. MAJOR REPAIR	8. Partial or Total Reconstruction of Railing																									
	9. Partial Reconstruction of Slab																				●					
	10. Reconstruction of Concrete Girder																									
	11. Replacement of Steel Girder / Member																									
	12. Replacement of Bearing																									
	13. Repair of Bridge Seat				●									●												
	14. Reinforcement of Pier																									
	15. Reinforcement of Foundation																									
F. MINOR REPAIR	16. Repair of Slab	●			●			●				●	●		●		●	●	●	●	●		●		●	●
	17. Repair of Concrete Girder	●		●	●		●						●	●			●							●		
	18. Repainting of Steel Girder / Member								●	●					●											
	19. Repair of Substructure	●																								
	20. Provision / Reconstruction of Slab Overlay	●			●			●	●			●	●			●	●		●	●	●		●		●	●
G. PROTECTION FROM SCOUR	21. Repair of Abutment Slope Protection							●							●		●	●	●							●
	22. Provision / Reconstruction of Abutment Slope Protection									●												●				
	23. Provision / Reconstruction of Pier Foundation Protection								●						●					●						
	24. Provision / Reconstruction of River Bank Protection	●						●	●	●										●		●				
H. APPROACH ROAD PROTECTION	25. Provision/ Reconst. of Approach Road Embank. Slope Protection		●							●										●						
	26. Provision of Approach Slab	●						●	●	●	●											●	●	●		
I. RIVER CONTROL	27. Provision of Spurdike																									
	28. Dredging											●	●		●											
J. ASEISMATIC PROTECTION	29. Widening of Bridge Seat	●				●					●									●						
	30. Provision of Mechanical Connection Device								●	●					●											
CATEGORY	Total Reconstruction																					●				
	Rehabilitation Other Than Total Reconstruction	●	●	●	●	●		●	●	●	●	●	●	●	●				●	●	●		●	●		●
	Maintenance						●									●	●	●							●	

REHABILITATION METHOD APPLIED	BRIDGE NUMBER / BRIDGE NAME	3-01 Agay	3-02 Minalum	3-03 Ngilan	3-04 Los Angeles	3-05 Taguibo	3-06 Dalipdipan	3-07 Ampayon	4-01 Afga	4-02 Hupas	4-03 Wawa	4-04 Bayanacon	4-05 Mambutay	4-06 Andanan
A. TOTAL RECONSTRUCTION	1. Total Reconstruction of Bridge													
B. PARTIAL RECONSTRUCTION	2. Reconstruction of Entire Slab of Span			●	●		●	●	●		●	●	●	
	3. Reconstruction of All Girders of Span								●					
	4. Reconstruction of Substructure													
C. WIDENING	5. Widening of Carriageway or Const. of Additional Bridge													
	6. Widening of Sidewalk													
D. EXTENSION	7. Construction of Additional Span													
E. MAJOR REPAIR	8. Partial or Total Reconstruction of Railing													
	9. Partial Reconstruction of Slab									●				●
	10. Reconstruction of Concrete Girder													
	11. Replacement of Steel Girder / Member										●			
	12. Replacement of Bearing										●			
	13. Repair of Bridge Seat													
	14. Reinforcement of Pier													
	15. Reinforcement of Foundation													
F. MINOR REPAIR	16. Repair of Slab	●				●							●	●
	17. Repair of Concrete Girder						●		●					
	18. Repainting of Steel Girder / Member	●	●			●					●			
	19. Repair of Substructure													
	20. Provision / Reconstruction of Slab Overlay	●				●								●
G. PROTECTION FROM SCOUR	21. Repair of Abutment Slope Protection							●	●	●			●	●
	22. Provision / Reconstruction of Abutment Slope Protection					●	●							
	23. Provision / Reconstruction of Pier Foundation Protection										●			●
	24. Provision / Reconstruction of River Bank Protection	●				●							●	
H. APPROACH ROAD PROTECTION	25. Provision/ Reconst. of Approach Road Embank. Slope Protection													
	26. Provision of Approach Slab							●						
I. RIVER CONTROL	27. Provision of Spurdike					●								
	28. Dredging	●		●	●					●				
J. ASEISMATIC PROTECTION	29. Widening of Bridge Seat					●					●	●		●
	30. Provision of Mechanical Connection Device					●				●	●			
CATEGORY	Total Reconstruction													
	Rehabilitation Other Than Total Reconstruction	●		●	●	●	●	●	●	●	●	●	●	●
	Maintenance		●											

TABLE 10.3 - 1 BRIDGES IDENTIFIED FOR REHABILITATION

(2/2)

REHABILITATION METHOD APPLIED	BRIDGE NUMBER / BRIDGE NAME	4-07 Taglatawan	4-08 Sinadjap	4-09 Bayugan Relief	4-10 Bayugan	4-11 Maytibog	4-12 Labao	4-13 Panaytay	4-14 Sianib	4-15 Awa	4-16 Gibong	4-17 Patin-ay I	4-18 Patin-ay II	4-19 Hubang	4-20 Adlayan	4-21 Tagconayon	4-22 Bayugan II	4-23 Anagasian	4-24 Lagcogengan	4-25 Tagbayagan	4-26 Sulibao	4-27 Padigusan	4-28 Lahi	4-29 Wasian	4-30 Boan	4-31 Bayugan III	4-32 Ko-o	4-33 Singanan	4-34 Bunawan	4-35 Simulao	4-36 Magalibobo	4-37 Onoman	4-38 Langkilaan
A. TOTAL RECONSTRUCTION	1. Total Reconstruction of Bridge																		●	●													
B. PARTIAL RECONSTRUCTION	2. Reconstruction of Entire Slab of Span	●	●	●	●	●	●	●	●			●	●	●										●									
	3. Reconstruction of All Girders of Span	●		●	●	●		●	●			●												●									
	4. Reconstruction of Substructure																							●									
C. WIDENING	5. Widening of Carriageway or Const. of Additional Bridge	●																															
	6. Widening of Sidewalk																																
D. EXTENSION	7. Construction of Additional Span																																
E. MAJOR REPAIR	8. Partial or Total Reconstruction of Railing																												●				
	9. Partial Reconstruction of Slab														●								●					●	●				
	10. Reconstruction of Concrete Girder																																
	11. Replacement of Steel Girder / Member																																
	12. Replacement of Bearing																																
	13. Repair of Bridge Seat																																
	14. Reinforcement of Pier										●																						
	15. Reinforcement of Foundation																							●									
F. MINOR REPAIR	16. Repair of Slab										●					●	●	●				●			●	●	●	●	●	●			
	17. Repair of Concrete Girder		●				●				●		●		●	●	●				●	●	●			●	●	●	●				
	18. Repainting of Steel Girder / Member																																
	19. Repair of Substructure																																
	20. Provision / Reconstruction of Slab Overlay															●	●	●				●			●	●	●	●	●	●			
G. PROTECTION FROM SCOUR	21. Repair of Abutment Slope Protection	●							●			●		●							●					●				●			
	22. Provision / Reconstruction of Abutment Slope Protection		●		●	●		●					●						●	●					●								●
	23. Provision / Reconstruction of Pier Foundation Protection																													●			
	24. Provision / Reconstruction of River Bank Protection								●	●			●		●									●									
H. APPROACH ROAD PROTECTION	25. Provision/ Reconst. of Approach Road Embank. Slope Protection		●									●		●																			
	26. Provision of Approach Slab																	●	●	●				●									
I. RIVER CONTROL	27. Provision of Spurdike																																
	28. Dredging																																
J. ASEISMATIC PROTECTION	29. Widening of Bridge Seat		●		●				●		●										●								●				
	30. Provision of Mechanical Connection Device									●																				●			●
CATEGORY	Total Reconstruction																		●	●													
	Rehabilitation Other Than Total Reconstruction	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●			●		●	●	●			●	●	●			●
	Maintenance															●	●					●				●	●						

REHABILITATION METHOD APPLIED	BRIDGE NUMBER / BRIDGE NAME	5-01 Maitum	5-02 Pasian	5-03 Haguimitan	5-04 Gabanan	5-05 Buay	5-06 Liboton	5-07 Kalaw	5-08 Tina	5-09 Banlag	5-10 Olaycon	5-11 Bankerohan	5-12 Guyon	5-13 Tigbawan	5-14 Casangay	5-15 Nabunturan	5-16 Pongtod	5-17 Linda	5-18 Mawab	5-19 Tagmanok	5-20 Liboganon	5-21 Gov. Miranda	5-22 Tuganay	5-23 Ising	5-24 Lasang	6-01 Bunawan	6-02 Ilang	6-03 Awad	6-04 Panacan	6-05 Davao River	6-06 Pangi	TOTAL
A. TOTAL RECONSTRUCTION	1. Total Reconstruction of Bridge				●				●	●											●	●										8
B. PARTIAL RECONSTRUCTION	2. Reconstruction of Entire Slab of Span							●										●					●			●						31
	3. Reconstruction of All Girders of Span																															10
	4. Reconstruction of Substructure																															1
C. WIDENING	5. Widening of Carriageway or Const. of Additional Bridge															●																2
	6. Widening of Sidewalk																												●			3
D. EXTENSION	7. Construction of Additional Span																															0
E. MAJOR REPAIR	8. Partial or Total Reconstruction of Railing					(Under Reconstruction by DPWH)																(See Chapter 7)										1
	9. Partial Reconstruction of Slab										●													●								10
	10. Reconstruction of Concrete Girder										●									●				●								3
	11. Replacement of Steel Girder / Member																															1
	12. Replacement of Bearing																															1
	13. Repair of Bridge Seat																									●						3
	14. Reinforcement of Pier																															1
	15. Reinforcement of Foundation										●													●								3
F. MINOR REPAIR	16. Repair of Slab						●						●		●			●	●	●							●					48
	17. Repair of Concrete Girder			●			●							●																		33
	18. Repainting of Steel Girder / Member							●																●		●						19
	19. Repair of Substructure							●																								2
	20. Provision / Reconstruction of Slab Overlay						●											●	●	●							●					38
G. PROTECTION FROM SCOUR	21. Repair of Abutment Slope Protection			●			●							●																		26
	22. Provision / Reconstruction of Abutment Slope Protection				●				●	●	●	●					●				●	●										24
	23. Provision / Reconstruction of Pier Foundation Protection				●																									●	●	10
	24. Provision / Reconstruction of River Bank Protection																															18
H. APPROACH ROAD PROTECTION	25. Provision/ Reconst. of Approach Road Embank. Slope Protection			●							●											●										12
	26. Provision of Approach Slab				●				●	●											●	●										22
I. RIVER CONTROL	27. Provision of Spurdike																															2
	28. Dredging																									●						10
J. ASEISMATIC PROTECTION	29. Widening of Bridge Seat							●															●		●	●				●	●	23
	30. Provision of Mechanical Connection Device		●																							●						13
CATEGORY	Total Reconstruction				●				●	●											●	●										8
	Rehabilitation Other Than Total Reconstruction		●	●				●			●	●				●	●	●		●			●	●	●	●			●	●	●	81
	Maintenance						●						●	●	●				●								●					28

• Highway Drainage Guidelines, AASHTO, 1992

Location

There are two cases; same location as and adjacent to the original bridge. In the former case, the construction of a detour bridge is needed during construction and in the latter case, the existing bridge is used until the completion of new bridge and the road is re-aligned later. Unless the road alignment, river condition and roadside environment do not accept the re-alignment, the latter case is adopted taking advantage of being generally less costly and giving no disturbance to the traffic during construction.

Length and Height

Sufficient waterway opening should be provided. Size of waterway opening is determined based on hydrological analysis. Bridge length and height are determined depending on the maximum flood water level (MFWL), freeboard and depth of girders as shown in Figure 10.3-1. Freeboard (vertical clearance between MFWL and the bottom of the lowest member of the superstructure) shall not be less than 1.50m for stream carrying debris and 1.00m for others.

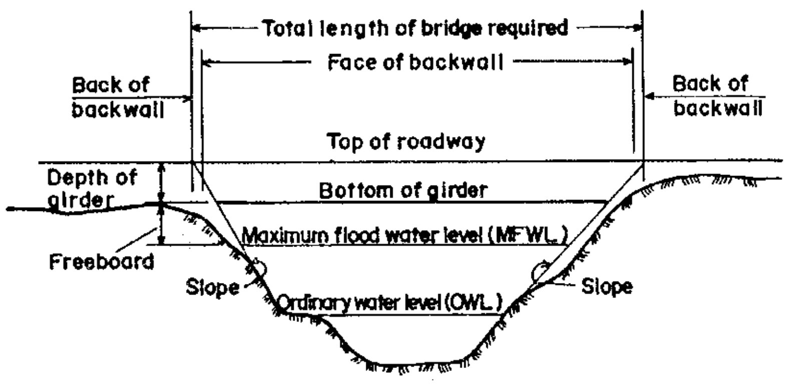


FIGURE 10.3-1 DETERMINATION OF BRIDGE LENGTH AND HEIGHT

Width

Width shall be as shown in Table 10.3-2.

TABLE 10.3-2 WIDTH OF BRIDGE

Item	Width	Application	Base of Determination
Carriage-way	7.32m (2 lanes)	Standard	According to " Standard Drawings for Roads and Bridges, Bureau of Design, DPWH "
	14.00m (4 lanes)	Where approach roads on both sides are 4 or more-lane roads and traffic volume is quite high	Adding the standard carriageway width of the Pan-Philippine Highway of 6.70m to the standard carriageway width of 2-lane bridge of 7.32m
Sidewalk	0.76m	Standard	According to " Standard Drawings for Roads and Bridges, Bureau of Design, DPWH "
	1.50m	In the busy area with many pedes-trians	Almost double standard width

Load

Design load shall be HS20.

Superstructure

As for material, there are two choices; concrete or steel. Concrete was selected in this Study, taking into account the availability of local material and less maintenance requirement. Bridge type was determined depending on the span length as follows:

- RC Slab : Span length 4 to 8m
- RC Deck Girder : Span length 8 to 18m
- PC Deck Girder : Span length 18 to 40m

For multi-span bridge, continuous spans were used as much as possible from the aseismatic point of view.

Substructure

Reinforced concrete abutment of rectangular wall type and reinforced concrete pier of elliptic wall type were applied.

Foundation

Either spread footing or pile foundation was selected depending on the soil condition. Pier foundation was designed to be placed below riverbed taking the allowance for scour into account.

Other Considerations

Other considerations to be given in the design are as follows:

- Provision of approach slab
  In most of existing bridges, there is a bump between bridge and approach road caused by settlement of approach road embankment. Approach slab is provided to prevent such bump.

- Bridge falling prevention measures
  As preventive measures of a bridge from falling even in the worst case, the bridge seat is made wide enough to provide allowance for displacement of girder.

- Protection from scour/erosion
  Protection of abutment slope, pier foundation, river bank and approach road embankment slope are taken into consideration in the design as necessary depending on the river morphology. River control measures are also incorporated in the design if necessary.

Design of the total reconstruction bridges is outlined in Table 10.3-3.

TABLE 10.3-3 OUTLINE OF TOTAL RECONSTRUCTION BRIDGES

Bridge No.	Bridge Name	Description of Existing Bridge	Justification of Reconstruction	Outline of New Bridge
2-21	Sanghan	2-Span RC Deck Girder Length = 12.00 + 12.00 = 24.00m	Abuments settled excessively. Shear cracks in girders. Wide cracks in slab.	1-span PC deck girder (l = 24.00m) with approach slab & river bank protection.
4-24	Lagcogangan	1-Span RC Slab 1-Span RC Deck Girder 1-Span RC Slab Length = 6.00+9.90+6.27 = 22.17m	Piers settled and tilted exces- sively on leftside. Medium cracks in girders. Cracks & spalls in slab.	1-span PC deck girder (l = 22.00m) with approach slab.
4-25	Tagbayagan	3-Span RC Deck Girder Length = 9.92+9.92+10.00 = 29.84m	Substructure has differential settlement. All girders fractured at support. Cracks & spalls in slab.	1-span PC deck girder (l = 30.00m) with approach slab.
5-04	Gabanan	3-Span RC Deck Girder Length = 14.90+14.90+15.00 = 44.80m	Cracks through support at six girder ends. Cracks & spalls in slab. Substructure also deteriorated.	3-span continuous RC deck girder (l = 13.50+18.00+13.50 = 45.00m) with approach slab.
5-08	Tina	3-Span RC Deck Girder Length = 9.65+12.00+9.80 = 31.45m	Bridge submerges because of low elevation.	1-span PC deck girder (l = 32.00m) with approach slab. Bridge elevation is raised by 3.0m.
5-09	Banlag	3-Span RC Deck Girder Length = 6.10+14.95+6.05 = 27.10m	Bridge submerges because of low elevation.	1-span PC deck girder (l = 28.00m) with approach slab. Bridge elevation is raised by 3.0m.
5-20	Liboganon	3-Span RC Deck Girder Length = 10.00+12.00+10.00 = 32.00m	Load limit is 10 tons. Girders are cracked through support at 10 locations.	1-span PC deck girder (l = 32.00m) with approach slab.
5-21	Gov. Miranda	1-Span RC Box Girder 2-Span Through Truss 1-Span RC Box Girder Length= 23.15+49.60+49.60 +23.15 = 145.50m	Low elevation. Encroachment of approach road embankment on the flood plain. (see Section 7.2.3 3))	10-span PC deck girder (l=500m) with approach slab. Bridge elevation is raised by 1.7m.

2) Rehabilitation other than Total Reconstruction

The same standards as used in the total reconstruction design is basically applied to the design of rehabilitation works such as partial reconstruction, widening, extension, repair, protection and provision of aseismatic measures. Substandard items, if any in the existing bridge, shall be upgraded taking the opportunity of undertaking such rehabilitation works that the upgrading can be done at the same time, e.g.:

- When reconstructing a slab in which existing width is substandard, the deficit in width is corrected unless girders and substructure will not be able to bear the increased load.

- When reconstructing girders, the standard design load is used in their design even if the existing bridge is designed for lower load. Substructure, especially foundation, is needed to be incidentally strengthened as the case may be.

CHAPTER 11

SLOPE PROTECTION

11.1 PRESENT CONDITION OF SLOPES

There are two types of slope failures. One is the slopes which have failed, but have not been restored/protected by sufficient measures since occurrence of slope failure (hereinafter referred to as "failed slopes"). The other is the slopes which have potential of failure though they have not failed yet (hereinafter referred to as "potential slopes"). Potential slopes were further categorized into "high" and "low" potential slopes. Criteria to determine "high" or "low" potential of slopes are shown in Appendix 11.1.

97 slopes were identified as failed/potential slopes along the Study Road (see Figure 11.1-1), of which 71 are the failed slopes and 26 are the potential slopes (19 low potential slopes and 7 high potential slopes). Table 11.1-1 shows the number of failed/potential slopes by type of disaster. (Since the Slope Inventory Survey was conducted in May 1994, restoration works have been implemented for seven slopes. Restoration measures taken for those slopes were reviewed and it was concluded that 1) two slopes (Nos. 4-32 and 5-03) were well restored and requires no additional work, and 2) remaining five slopes were restored in an incomplete manner and supplemental or improving works are still needed. Consequently, number of the failed slopes decreased by 2.)

From the topographic reason, Agusan del Sur has a highest number of failed/potential slopes amounting to 43 slopes, while Davao City has a lowest number amounting to 4. Agusan del Sur also has the highest density of 0.315 slope per km, followed by Butuan City having a density of 0.265 slope per km.. The average density of the Study Road is 0.240 sloper per km.

Embankment slope failure is predominant amounting to 64 slopes or 66% of total number of slopes, followed by cut slope failure amounting to 19 slopes or 20%. Others are few. The road alignment was relatively well selected and natural slopes at mountain sides were not cut during construction, therefore, cut slope failures were not observed frequently. Although number of embankment slope failures is high, most of them are small in magnitude and were mostly caused by inadequate surface water drainage.

Characteristics of slope failures by type are as follows:

Cut Slope Failures (including failures of mountainside natural slopes)

Disaster and potential slopes are mostly distributed in the sections in Surigao del Norte, Agusan del Norte and Davao del Norte, and in Davao City Diversion Road. The disaster slopes located in Surigao del Norte and Agusan del Norte are composed of igneous rock, mainly andesite, while those in the southern sections are composed of Tertiary rocks such as sandstone, mudstone and

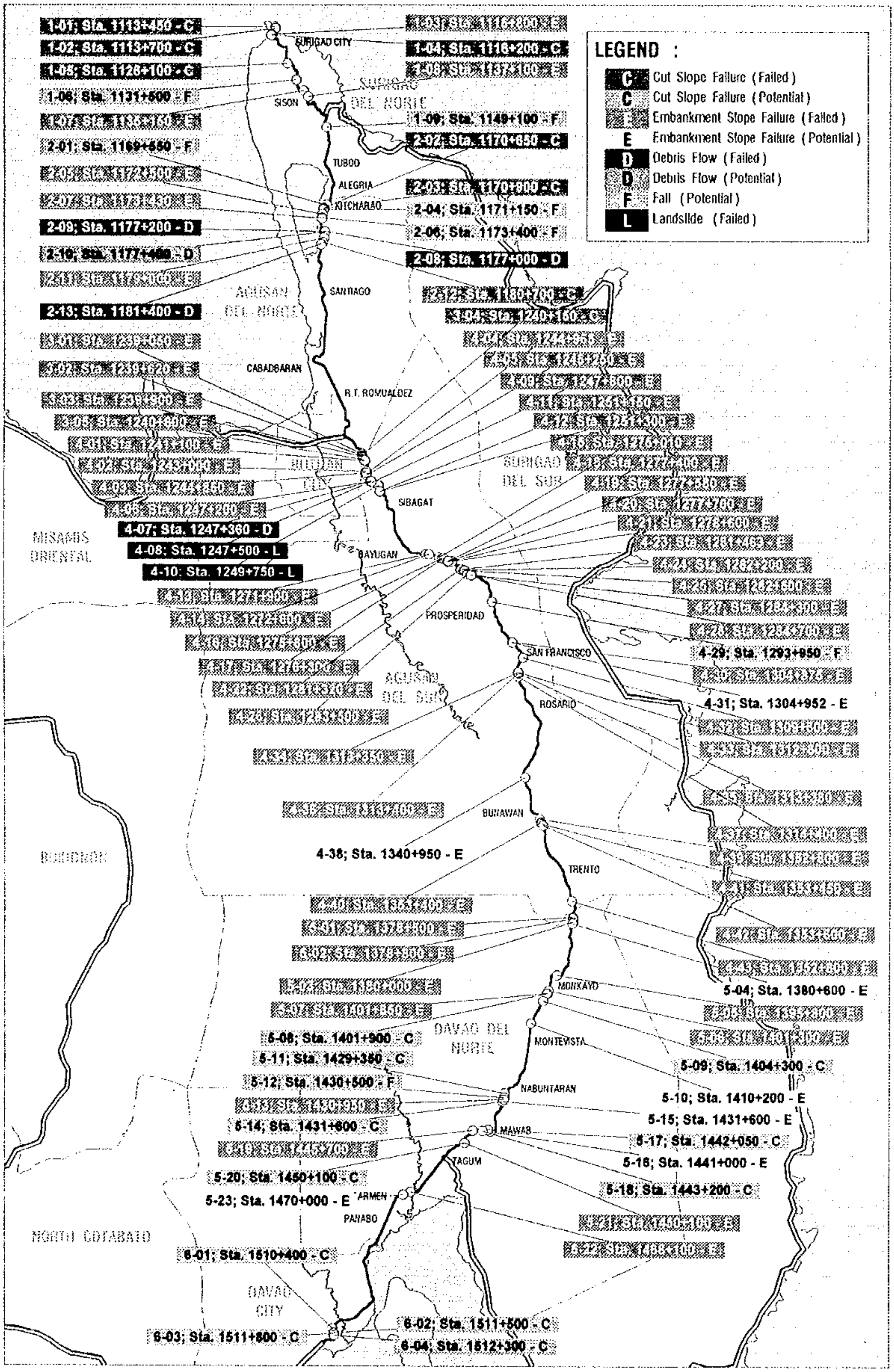


FIGURE 11.1 - 1 LOCATION OF DISASTER SPOTS

TABLE 11.1-1 NUMBER OF FAILED/POTENTIAL SLOPES

Section	Failed/Potential		Type of Disaster: Cut Slope Failure	Embank. Slope Failure	Debris Flow	Fall	Land-slide	Total
Surigao del Norte (1113+397~1167+592)	Failed Slope		4	3	-	-	-	7
		Low	-	-	-	2	-	2
	Potential Slope	High	-	-	-	-	-	-
		Sub-total	-	-	-	2	-	2
	Total		4	3	-	2	-	9
Agusan del Norte (1167+592~1221+985)	Failed Slope		3	3	3	-	-	9
		Low	-	-	-	3	-	3
	Potential Slope	High	-	-	1	-	-	1
		Sub-total	-	-	1	3	-	4
	Total		3	3	4	3	-	13
Butuan City (1221+985~1240+696)	Failed Slope		1	4	-	-	-	5
		Low	-	-	-	-	-	-
	Potential Slope	High	-	-	-	-	-	-
		Sub-total	-	-	-	-	-	-
	Total		1	4	-	-	-	5
Agusan del Sur (1240+696~1376+830)	Failed Slope		-	37	1	-	2	40
		Low	-	-	-	1	-	1
	Potential Slope	High	-	2	-	-	-	2
		Sub-total	-	2	-	1	-	3
	Total		-	39	1	1	2	43
Davao del Norte (1376+830~1482+101)	Failed Slope		-	10	-	-	-	10
		Low	7	1	-	1	-	9
	Potential Slope	High	-	4	-	-	-	4
		Sub-total	7	5	-	1	-	13
	Total		7	15	-	1	-	23
Davao City (1482+101~1515+949)	Failed Slope		-	-	-	-	-	-
		Low	4	-	-	-	-	4
	Potential Slope	High	-	-	-	-	-	-
		Sub-total	4	-	-	-	-	4
	Total		4	-	-	-	-	4
Total	Failed Slope		8	57	4	-	2	71 1)
		Low	11	1	-	7	-	19
	Potential Slope	High	-	6	1	-	-	7
		Sub-total	11	7	1	7	-	26
	Total		19	64	5	7	2	97

Note: 1) Seven slopes have been restored after the conduct of the slope inventory survey, two slopes in satisfactory manner, but five slopes still require additional protection works.

tuff, and/or gravely or sandy soil that were produced from the heavily weathered Tertiary rocks. In the north of Davao del Norte where the Study Road crosses the Philippine Fault, rocks are remarkably weathered. Rocks, especially Tertiary sandstone and mudstone are generally weathered by repeated rain and sunshine. Weathering of rocks in the Study Area has been accelerated under the notably varied meteorological condition.

Slopes are mostly inclined at an angle of 30 degrees or more regardless of their height. Since there are no slope protection works on unstable slopes with steep gradient, surface failures have been often occurred. Although such surface failures have not affected the road traffic because of wide road shoulders and small in scale, there is a possibility that deep failures with large scale caused by heavily weathered rocks might occur in future.

Embankment Slope Failures (including failures of valley side natural slopes)

Most embankment slope failures are located at the road sections crossing vales. Due to the insufficient capacity or lack of cross drainage facilities, the embankments are oftenly overflowed during heavy rain. Surface failures of embankments at such locations are mostly caused by overflows. There are seven embankment slopes constructed on the inclined ground. Slope failures in such embankments are usually caused by decrease of shear strength of fill due to groundwater seepage into the embankments.

Many embankment slopes face rivers or are located on the valley side of road sections in mountainous areas. Failures in the slopes facing rivers were caused or are to be caused by river flow. Slopes located on the valley side are mostly composed of soils which are easily eroded, failures occurred due to lack of drainage facilities.

Debris Flows

Debris flows are mostly located the Section near km. 1177 in Agusan del Norte. Debris deposited on the side of a hill that has no vegetation were sometimes washed down by floods. Although slopes are away from the road, debris oftenly reach up to the roadway.

Falls

Falls are mostly located in Surigao del Norte and Agusan del Norte where the road passes through the eastern tip of the Diwata Cordillera. Slopes are mainly composed of limestone with developed cracks and joints. Although slopes have relatively low height of 15 meters or less, their grades ranging from 80 to 90 degrees are quite sharp. Fallen rocks usually do not reach to the carriageway, therefore, impact of fall to road traffic is negligible.

Landslides

Landslides were seen at two locations (km. 1247+500 and km. 1249+500) both in Agusan del Sur where the road crosses the Philippine Fault. Slopes are composed of mudstone. It was not ascertained what kind of external force induced the landslides; earthquake, embankments constructed near top of the slopes, or the like. As the main scarp is observed in each slope, there is a possibility that the slides are still in progress.

11.2 SLOPE PROTECTION DESIGN CRITERIA

11.2.1 Criteria for Selection of Slopes To Be Protected

Slopes to be protected under this project was selected in accordance with the following criteria:

- Failed slopes
- Slopes with high potential

Low potential slopes were excluded from the project because of low possibility of occurrence and low impact on road traffic, even if it occurs.

A total of 76 slopes composing of 69 failed slopes and seven high potential slopes were selected for the project.

11.2.2 Selection of Protection Works

Generally Applicable Protection Works

Type of protection work must be selected in due consideration of causes as well as type of slope failure. Table 11.2-1 shows slope protection works generally applicable to each type of slope failure by cause.

Comparative Study of Selected Slopes

To determine the appropriate protection measures, many factors should be considered such as meteorological, topographical and geological conditions, economical aspect, constructability, impact on traffic during construction, etc.. In some cases, two or more works should be combined. In order to find the optimum solution, comparative study of alternative protection works was made for the selected slopes which are considered typical of each type of disaster. A summary of comparative study is shown in Table 11.2-2. The results of comparative study of each selected slope are shown in Tables 11.2-3 to 11.2-7.

TABLE 11.2-1 GENERALLY APPLICABLE SLOPE PROTECTION WORKS TO EACH TYPE OF SLOPE FAILURE (1/4)

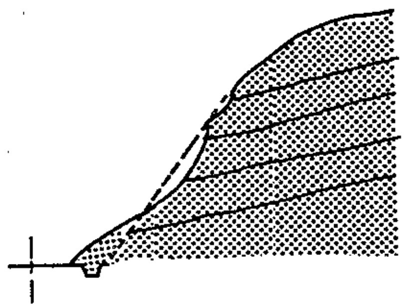
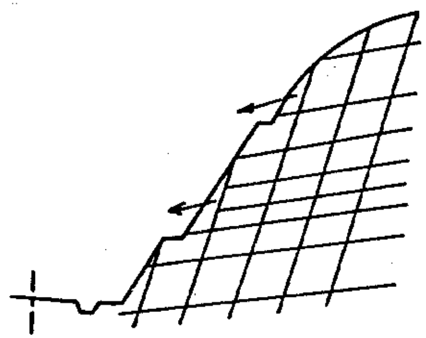
TYPE OF DISASTER	CAUSE OF DISASTER	ILLUSTRATION	APPLICABLE WORKS
CUT SLOPE FAILURE	Failure of highly weathered layer due to drying up or erosion by surface water.		a) Re-cutting with stable gradient b) Protection works: - Concrete spraying - Concrete crib - Anchor work - Wattling c) Catch Work: - Concrete catch wall
	Failure of slope due to developed cracks.		a) Recutting with stable gradient b) Protection Works: - Concrete spraying - Concrete crib - Anchor work c) Catch Work: - Concrete catch wall

TABLE 11.2-1 GENERALLY APPLICABLE SLOPE PROTECTION WORKS TO EACH TYPE OF SLOPE FAILURE

(2/4)

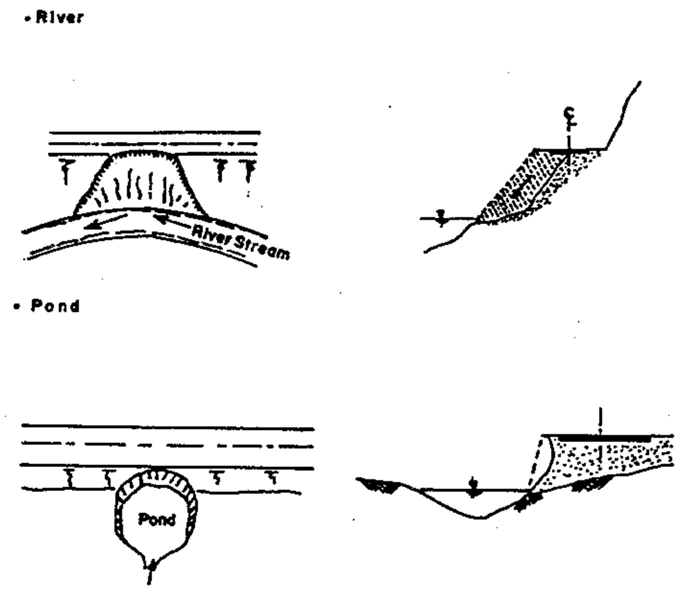
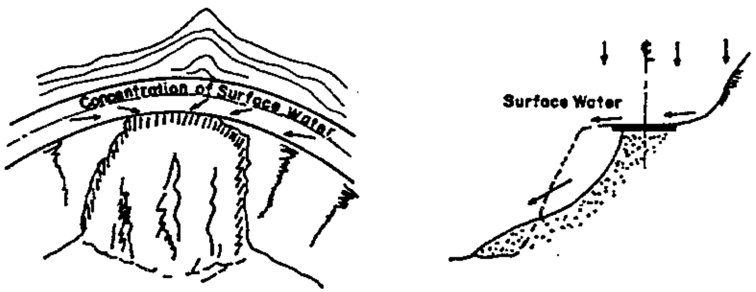
TYPE OF DISASTER	CAUSE OF DISASTER	ILLUSTRATION	APPLICABLE WORKS
EMBANKMENT SLOPE FAILURE	Failure of slope caused by scour due to effect of river stream, or due to rising/lowering of pond water level.		a) Retaining Walls: - Gabion wall - Concrete wall b) Protection works: - Grouted riprap - Concrete crib - Concrete pitching - Cylinder gabion
	Failure caused by erosion due to concentrated surface water, especially on curved or sagged portion.		a) Retaining Wall: - Concrete wall b) Protection Works: - Grouted riprap - Concrete crib - Concrete pitching - Concrete pavement of shoulder c) Drainage Works: - Vertical ditch - Water channel - RCPC/RCBC

TABLE 11.2-1 GENERALLY APPLICABLE SLOPE PROTECTION WORKS TO EACH TYPE OF SLOPE FAILURE (3/4)

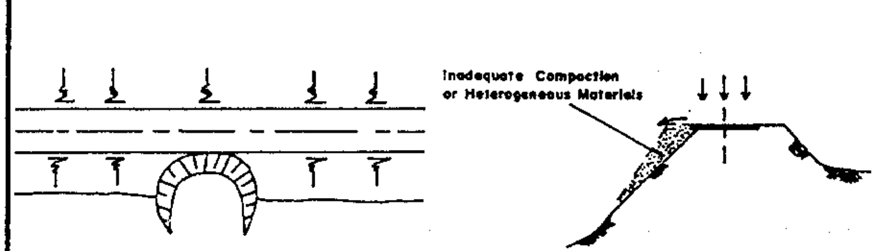
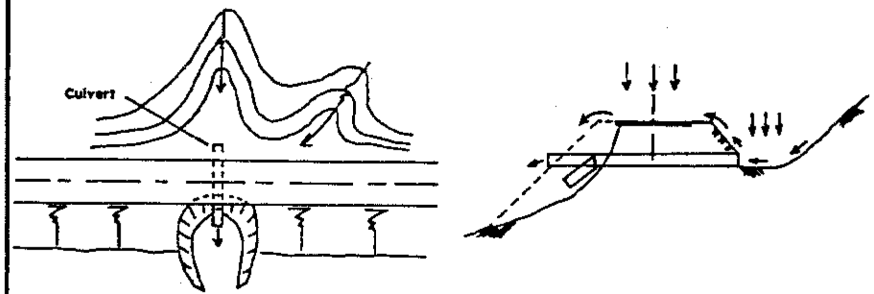
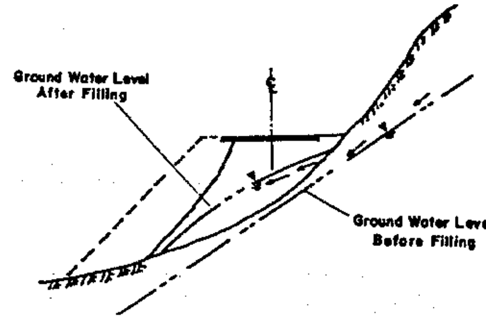
TYPE OF DISASTER	CAUSE OF DISASTER	ILLUSTRATION	APPLICABLE WORKS
EMBANKMENT SLOPE FAILURE	Failure due to inadequate compaction of embankment or use of heterogeneous materials.		a) Earth Work: - Re-filling b) Retaining Wall: - Concrete wall c) Protection Works: - Grouted riprap - Concrete crib - Concrete pitching - Concrete pavement of shoulder d) Drainage Works: - Vertical ditch - Water channel
	Failure of embankment at valley due to inadequate capacity or lack of cross drainage.		a) Retaining Walls: - Concrete wall - Stone masonry wall b) Protection Works: - Grouted riprap - Concrete crib - Concrete pitching - Concrete pavement of shoulder - Gabion foot protection c) Drainage Works: - Vertical ditch - Water channel - RCPC/RCBC
	Failure of embankment in mountainous area due to effect of groundwater permeating the embankment.		a) Retaining Wall: - Concrete wall b) Protection Works: - Grouted riprap - Concrete crib - Gabion foot protection c) Drainage Works: - Vertical ditch - Water channel - Subsurface drainer - Horizontal drain hole - RCPC/RCBC

TABLE 11.2-1 GENERALLY APPLICABLE SLOPE PROTECTION WORKS TO EACH TYPE OF SLOPE FAILURE (4/4)

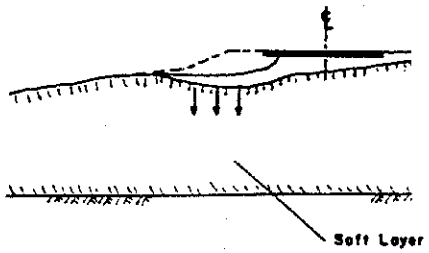
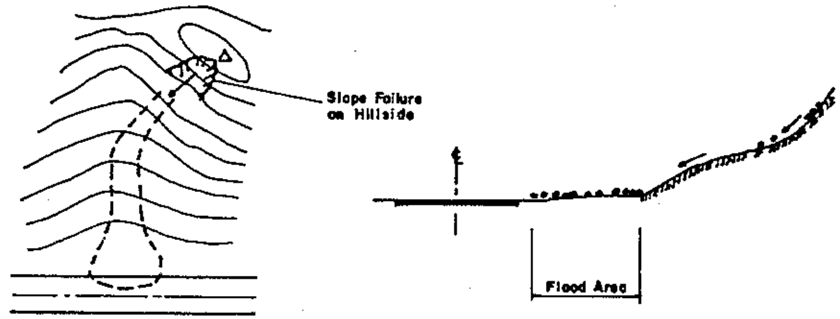
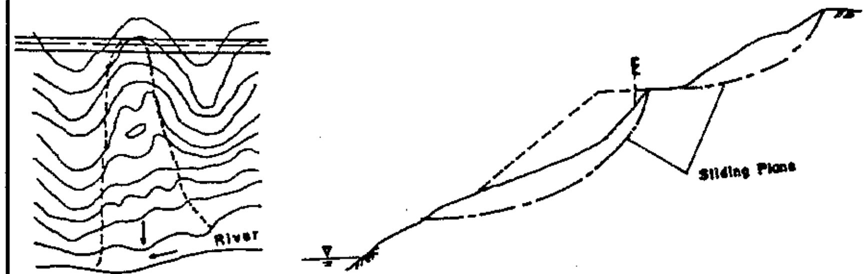
TYPE OF DISASTER	CAUSE OF DISASTER	ILLUSTRATION	APPLICABLE WORKS
EMBANKMENT SLOPE FAILURE	Failure due to settlement of embankment constructed on the soft ground.		a) Earth Work: - Replacement - Counterweight filling - Earth removal b) Protection Works: - Grouted riprap - Gabion foot protection
DEBRIS FLOW	Flow of debris. Debris supplied by hillside slope failures carried down by stream.		a) Retaining Wall: - Gabion wall b) Hillside Works: - Vegetation or Afforestation - Water channel c) Avoiding Problem: - Bridge - RCBC
LANDSLIDE	Movement along sliding plane in cohesive soil layer induced by the raise of groundwater level.		a) Earth Works: - Counterweight filling - Earth removal b) Structural Works: - Gabion wall - Piling - Anchor work c) Drainage Works: - Subsurface drainer - Horizontal drain hole

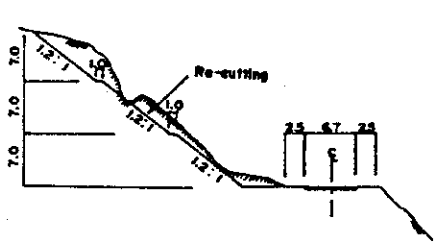
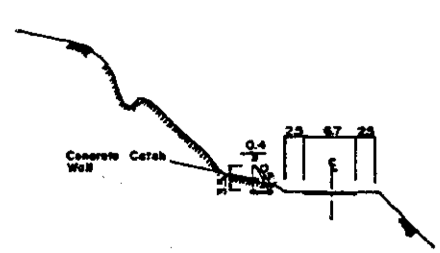
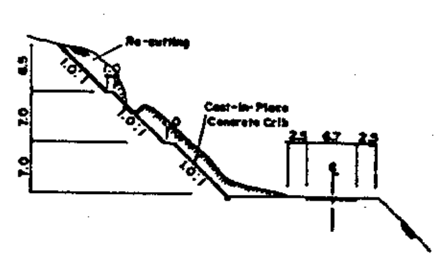
TABLE 11.2-2 SUMMARY OF COMPARATIVE STUDY

Slope No.	Station	Type of Disaster	Major Causes	Alternative Work	Evaluation	Table Referred
2-12	1180+700	Cut Slope Failure	Highly weathered layer	1. Re-cutting 2. Concrete Catch Wall 3. Combinational of Rec-cutting and Concrete Crib	○ △ △	Table 11.2-3
1-3	1115+800	Embankment Slope Failure	Effect of groundwater	1. Combination of Subsurface Drainer and Gravity Type Concrete Wall 2. Combination of Subsurface Drainer and Grouted Riprap 3. Combination of Subsurface Drainer and Supported Type Concrete Wall	○ △ △	Table 11.2-4
5-2	1378+800	Embankment Slope Failure	Concentration of surface water, Pipe culvert not functioning due to clogging at inlet	1. Combination of Grouted Riprap, Gravity Type Concrete Wall, Gabion Foot Protection, RCPC & Vertical Ditch 2. Combination of Grouted Riprap, Supported Type Conc. Wall, Gabion Foot Protection, RCPC & Vertical Ditch 3. Combination of Grouted Riprap, Gabion Wall, RCPC & Vertical Ditch	○ △ △	Table 11.2-5
4-08 (A)	1247+500	Landslide	Movement along sliding plane in cohesive soil layer (valley side)	1. Counterweight Filling 2. Piling 3. Combination of Piling and Horizontal Drain Hole	○ × ×	Table 11.2-6
4-08 (B)	1247+500	Landslide	Movement along sliding plane in cohesive soil layer (hill side)	1. Earth Removal 2. Piling 3. Combination of Piling and Horizontal Drain Hole	○ × ×	Table 11.2-7

Note:
○ Recommended.
△ Recommendable but not preferred.
× Not Recommended.

TABLE 11.2-3 COMPARISON OF COUNTERMEASURES FOR CUT SLOPE FAILURE (2-12, 1180+700)

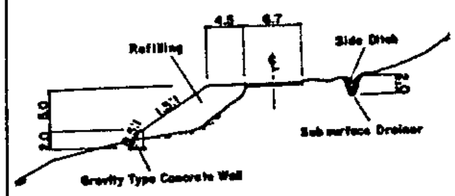
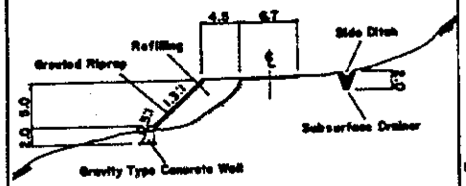
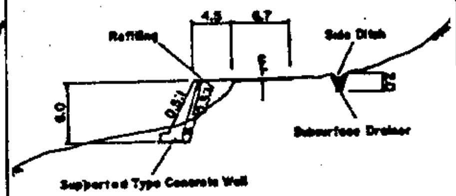
Major cause of disaster: Highly weathered layer

		Alternative - 1 Re-Cutting	Alternative - 2 Concrete Catch Wall	Alternative - 3 Re-Cutting + Concrete Crib
Cross-section				
Description of Works		Remove surface soil and form the slope with a stable gradient (1.2:1).	Construct catch wall instead of protection of slope itself, since there is enough open space between the edge of road and the toe of slope.	Form slope with a steeper gradient (1.0:1) than Alternative-1 and protect it with concrete cribs.
Evaluation	Technical Aspect	Construction is easy because only earthwork is required.	Construction is quite easy because all works are only on roadside. Frequent maintenance is required to remove the debris accumulating on the back of catch wall.	Volume of earth work is lower than that in Alternative-1. Concrete work at high place is required.
	Economical Aspect	Construction Cost - Recutting of Soft Rock 2,100 cu.m. x P380/cu.m. = P 0.798 million - Vegetation (Seeding) 726 sq.m. x P22/sq.m. = P 0.016 million Total P 0.816 million (100%) Construction cost is slightly higher than that of Alternative-2. No maintenance cost is required.	Construction Cost - Concrete Catch Wall 179 cu.m. x P4,000/cu.m. = P 0.716 million - Structural Excavation 149 cu.m. x P280/cu.m. = P 0.042 million - Foundation Fill 73 cu.m. x P380/cu.m. = P 0.028 million Total P 0.786 million (96%) Construction cost is the lowest. However, maintenance cost is required to remove debris every time when slope failure occurs.	Construction Cost - Recutting of Soft Rock 1,900 cu.m. x P380/cu.m. = P 0.722 million - Cast-in-place Concrete Crib 670 sq.m. x P2,100/sq.m. = P 1.407 million Total P 2.129 million (261%) Construction cost is the highest.
	Overall Evaluation	○	△	△

Note: ○ : Recommended.
△ : Recommended but not preferred.

TABLE 11.2-4 COMPARISON OF COUNTERMEASURES FOR EMBANKMENT SLOPE FAILURE (1-3, 1115+800)

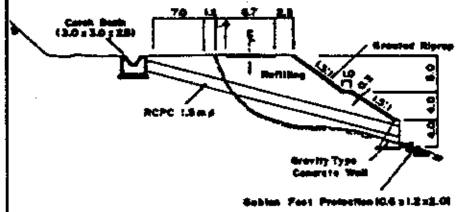
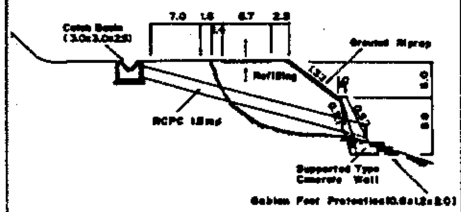
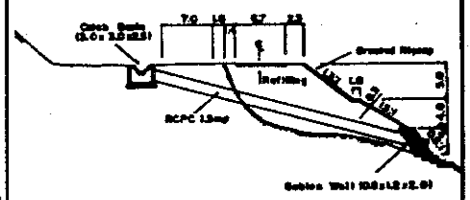
Major cause of disaster: Effect of groundwater

		Alternative - 1	Alternative - 2	Alternative - 3
		Subsurface Drainer + Gravity Type Concrete Wall	Subsurface Drainer + Grouted Riprap	Subsurface Drainer + Supported Type Concrete Wall
Cross-section				
Description of Works		Construct embankment with a stable gradient (1.5:1) and provide a gravity type concrete wall at the toe of embankment. Provide side ditch and subsurface drainer on the mountain side of the road to lower the groundwater level.	Construct embankment with a steeper grade (1.3:1) than Alternative-1 and protect it with grouted riprap. Provide side ditch and subsurface drainer on the mountain side of the road to lower the groundwater level.	Construct supported type concrete wall. Provide side ditch and subsurface drainer on the mountain side of the road to lower the groundwater level.
Evaluation	Technical Aspect	Structural work is minimum. Construction is easy.	Earth work volume is lower than that in Alternative-1. However, it takes longer time because of riprap construction.	Construction of concrete wall takes time.
	Economical Aspect	Construction Cost - Refilling 1,340 cu.m. x P380/cu.m. = P 0.509 million - Gravity Type Concrete Wall 81 cu.m. x P4,000/cu.m. = P 0.324 million - Side Ditch 90m. x P3,100/m. = P 0.279 million - Subsurface Drainer 90m. x P1,050/m. = P 0.095 million - Excavation and Fill for Wall 45cu.m. x P473/cu.m. = P 0.021 million Total P 1.228 million (100%) Construction cost is the lowest.	Construction Cost - Refilling 935 cu.m. x P380/cu.m. = P 0.355 million - Gravity Type Concrete Wall 72 cu.m. x P4,000/cu.m. = P 0.288 million - Grouted Riprap 157 cu.m. x P1,500/cu.m. = P 0.236 million - Side Ditch 90 m. x P3,100/m. = P 0.279 million - Subsurface Drainer 90m. x P1,050/m. = P 0.095 million - Excavation and Fill for Wall 40cu.m. x P532/cu.m. = P 0.021 million Total P 1.274 million (104%) Construction cost is slightly higher than that of Alternative-1.	Construction Cost - Refilling 408 cu.m. x P380/cu.m. = P 0.155 million - Supported Type Concrete Wall 267 cu.m. x P4,000/cu.m. = P 1.068 million - Side Ditch 90 m. x P3,100/m. = P 0.279 million - Subsurface Drainer 90 m. x P1,050/m. = P 0.095 million - Excavation and Fill for Wall 55 cu.m. x P2,860/cu.m. = P 0.157 million Total P 1.754 million (143%) Construction cost is the highest.
	Overall Evaluation	○	△	△

Note: ○ : Recommended.
△ : Recommendable, but not preferred.

TABLE 11.2-5 COMPARISON OF COUNTERMEASURES FOR EMBANKMENT SLOPE FAILURE (5-2, 1378+800)

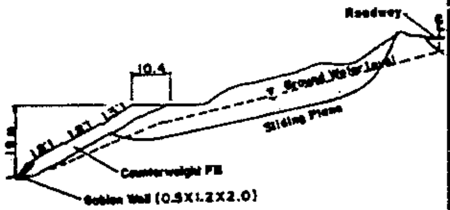
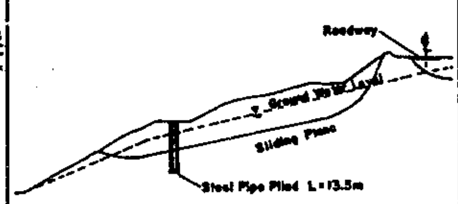
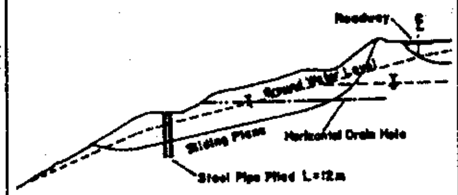
Major cause of disaster: Concentration of surface water, Pipe culvert not functioning due to clogging at inlet

		Alternative - 1	Alternative - 2	Alternative - 3
		Drainage Work + Gravity Type Concrete Wall + Grouted Riprap	**Drainage Work +Supported Type Concrete Wall + Grouted Riprap**	**Drainage Work + Gabion Wall + Grouted Riprap**
Cross-section				
Description of Works		After refilling, protect the slope with grouted riprap and provide gravity type concrete wall at the toe of slope to assure the stability of embankment. Replace RCPC with the one wth sufficient capacity.	Same as Alternative-1 except provision of supported type concrete wall instead of gravity type concrete wall to reduce the earth work volume.	Same as Alternative-1 except provision of gabion wall instead of gravity type concrete wall to simplify the construction work.
Evaluation	Technical Aspect	Construction is easy.	Earth work volume is lower than that in Alternative-1. However, it takes longer time because of more structural work.	Construction period is the shortest.
	Economical Aspect	Construction Cost - Refilling 4,175 cu.m. x P380/cu.m. = P 1.587 million - Recutting of Soil 137 cu.m. x P110/cu.m. = P 0.015 million - Gravity Type Concrete Wall 154 cu.m. x P4,000/cu.m. = P 0.615 million - Gabion Foot Protection 22 cu.m. x P3,400/cu.m. = P 0.073 million - Grouted Riprap 312 cu.m. x P1,500/cu.m. = P 0.468 million - RCPC 1.5m dia. 36m. x P11,500/m. = P 0.414 million - Vertical Ditch 28m. x P1,900/m. = P 0.053 million - Catch Basin (for RCPC, 3x3x2.5) P23,500 + P79,700 = P 0.103 million - Excavation and Fill for Wall 54 cu.m. x P3,680/cu.m. = P 0.199 million Total P 3.527 million (100%) Construction cost is the lowest.	Construction Cost - Refilling 3,450 cu.m. x P380/cu.m. = P 1.311 million - Recutting of Soil 137 cu.m. x P110/cu.m. = P 0.015 million - Supported Type Concrete Wall 434 cu.m. x P4,000/cu.m. = P 1.735 million - Gabion Foot Protection 22 cu. m. x P3,400/cu.m. = P 0.073 million - Grouted Riprap 229 cu.m. x P1,500/cu.m. = P 0.344 million - RCPC 1.5m dia. 32m. x P11,500/m. = P 0.368 million - Vertical Ditch 28m. x P1,900/m. = P 0.053 million - Catch Basin (for RCPC, 3x3x2.5) P23,500 + P79,700 = P 0.103 million - Excavation and Fill for Wall 49 cu.m. x P6,135/cu.m. = P 0.301 million Total P 4.303 million (122%) Construction cost is the highest.	Construction Cost - Refilling 4,270 cu.m. x P380/cu.m. = P 1.623 million - Recutting of Soil 137 cu.m. x P110/cu.m. = P 0.015 million - Gabion Wall 404 cu.m. x P3,400/cu.m. = P 1.374 million - Grouted Riprap 312 cu.m. x P1,500/cu.m. = P 0.468 million - RCPC 1.5m dia. 38m. x P11,500/m. = P 0.437 million - Vertical Ditch 28m. x P1,900/m. = P 0.053 million - Catch Basin (for RCPC, 3x3x2.5) P23,500 + P79,700 = P 0.103 million Total P 4.073 million (115%) Construction cost is slightly higher than that of Alternative-1.
	Overall Evaluation	○	△	△

Note: ○ : Recommended.
△ : Recommended but not preferred.

TABLE 11.2-6 COMPARISON OF COUNTERMEASURES FOR LANDSLIDE (4-8 (A), 1247 + 500)

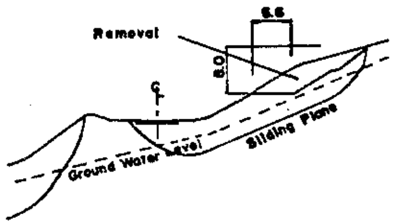
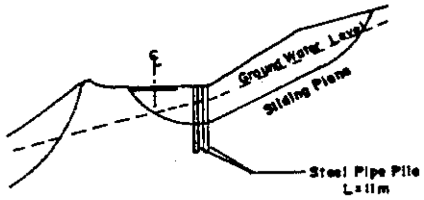
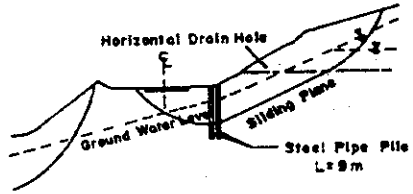
Major cause of disaster: Movement along sliding plane in cohesive soil layer (valley side)

		Alternative - 1 Counterweight filling	Alternative - 2 Piling	Alternative - 3 Piling + Horizontal Drain Hole
Cross-section				
Description of Works		Construct counterweight fill at foot portion of slope to resist sliding force. Place gabion wall at the toe of fill to prevent a rise of groundwater level taking advantage of permeability of gabion.	Bore holes using large-diameter boring machine and install steel pipe piles at the lower portion of sliding mass to resist the sliding force.	In addition to the piling similar to Alternative-2 but using smaller and shorter piles, install horizontal drain holes to drain groundwater and lower its level.
Evaluation	Technical Aspect	Construction site is distant from road (about 100m), needing temporary road for construction.	Same as Alternative-1. in addition, large-diameter boring machine is not commonly used in the Philippines.	Same as Alternative-2. Furthermore, horizontal boring machine is seldom used in the Philippines.
	Economical Aspect	Construction Cost - Counterweight Filling 15,200 cu.m. x P265/cu.m. = P 4.028 million - Gabion Wall 792cu.m. x P3,400/cu.m. = P 2.693 million Total P 6.721 million (100%) Construction cost is the lowest.	Construction Cost - Piling (Steel Pipe Pile 558.8 dia.) 13.5m. x 51 pcs. x P70,000/m. = P 48.195 million Total P 48.195 million (717%) Construction cost is much higher than Alternative-1.	Construction Cost - Horizontal Drain Hole 48m. x 15 pcs. x P7,500/m. = P 5.400 million - Piling (Steel Pipe Pile 406.4 dia.) 12m. x 70 pcs. x P52,500/m. = P 44.100 million Total P 49.500 million (736%) Construction cost is the highest.
	Overall Evaluation	○	✕	✕

Note: ○ : Recommended.
✕ : Not Recommended

TABLE 11.2-7 COMPARISON OF COUNTERMEASURES FOR LANDSLIDE (4-8 (B), 1247+500)

Major cause of disaster: Movement along sliding plane in cohesive soil layer (hill side)

		Alternative - 1	Alternative - 2	Alternative - 3
		Earth Removal	Piling	Piling + Horizontal Drain Hole
Cross-section				
Description of Works		Remove head portion of sliding mass to reduce sliding force.	Bore holes using large-diameter boring machine and install steel pipe piles at the lower portion of sliding mass to resist the sliding force.	In addition to the piling similar to Alternative-2 but using smaller and shorter piles, install horizontal drain holes to drain ground-water and lower its level.
Evaluation	Technical Aspect	Construction is easy because construction site is close to the road and only earth work is required.	Large-diameter boring machine is not commonly used in the Philippines.	Horizontal boring machine is seldom used in the Philippines.
	Economical Aspect	Construction Cost - Re-cutting of softrock 1,500 cu.m. x P380/cu.m. = P 0.570 million Total P 0.570 million (100%) Construction cost is the lowest.	Construction Cost - Piling (Steel Pipe Pile 558.8 dia.) 11.0m. x 37 pcs. x P70,000/m. = P 28.490 million Total P 28.490 million (4,998%) Construction cost is the highest.	Construction Cost - Horizontal Drain Hole 23m. x 11 pcs. x P7,500/m. = P 1.898 million - Piling (Steel Pipe Pile 355.6dia.) 9.0m. x 22 pcs. x P45,000/m. = P 8.910 million Total P 10.800 million (1,896%) Construction cost is much higher than Alternative-1.
	Overall Evaluation	○	×	×

Note: ○ : Recommended
× : Not Recommended

11.3 PRELIMINARY DESIGN

Locations of topographic survey and geotechnical investigation undertaken for the preliminary design are presented in Appendix 11.2. Design precedents of previous/on-going rehabilitation projects are shown in Appendix 11.3.

Preliminary design of the protection works for 76 slopes was carried out applying the appropriate types of work which were selected based on the comparative study described in Section 11.2.2. Protection works applied to each slope are listed in Table 11.3-1.

TABLE 11.3-1 SLOPE PROTECTION WORKS APPLIED TO EACH SLOPE

(1/2)

TYPE OF COUNTERMEASURE	SLOPE NUMBER	1-01	1-02	1-03	1-04	1-05	1-07	1-08	2-02	2-03	2-05	2-07	2-08	2-09	2-10	2-11	2-12	2-13	3-01	3-02	3-03	3-04	3-05	4-01	4-02	4-03	4-04	4-05	4-06	4-07	4-08	4-09	4-10	4-11	4-12	4-13	4-14	4-15	4-16	4-17
	SECTION	Surigao del Norte							Agusan del Norte										Butuan City					Agusan del Sur																
	KM.	1113+450	1113+700	1115+800	1116+200	1126+100	1135+150	1137+100	1170+650	1170+900	1172+500	1173+430	1177+000	1177+200	1177+400	1179+000	1180+700	1181+400	1239+200	1239+620	1239+900	1240+150	1240+600	1241+100	1243+000	1244+850	1244+965	1245+250	1247+200	1247+360	1247+500	1247+800	1249+750	1251+150	1251+300	1271+900	1272+600	1275+010	1275+800	1276+300
	TYPE OF DISASTER	C - F	C - F	E - F	C - F	C - F	E - F	E - F	C - F	C - F	E - F	E - F	D - FL	D - FL	D - FL	E - F	C - F	D - FL	E - F	E - F	E - F	C - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	D - FL	L - SL	E - F	L - SL	E - F	E - F	E - F	E - F	E - F	E - F	E - F
	CAUSE OF DISASTER	8	8	5	8	7	1	1	7	7	3	1	9	9	9	5	7	9	1	5	4	7	4	4	2	2	4	2	2	9	10	4	10	2	5	3	3	6	5	5
EARTHWORK	Re-filling			●			●	●			●	●				●			●	●	●		●		●	●	●	●	●			●		●		●	●	●	●	●
	Re-cutting		●														●			●		●																		
	Counterweight Filling																														●									
	Earth Removal																														●		●					●		
	Embankment												●	●	●																									
RETAINING WALL	Gravity Type Concrete Wall			●							●					●				●	●		●		●		●		●			●		●						
	Supported Type Concrete Wall																						●	●																
	Stone Masonry Wall																				●																			
	Gabion Wall																		●												●									●
PROTECTION WORK	Vegetation																●																							●
	Grouted Riprap							●			●	●				●				●	●				●	●		●	●					●			●	●	●	
	Concrete Spraying	●	●			●																																		
	Concrete Crib																					●																		
	Cylinder Gabion						●																																	
CATCH WORK	Gabion Catch Wall												●	●				●																						
	Concrete Catch Wall				●				●	●																														
FOOT PROTECTION	Gabion Foot Protection																			●	●		●	●								●						●		
PAVEMENT WORK	Concrete Pavement												●	●	●																									
	Concrete Pavement of Shoulder										●										●		●	●		●		●	●					●						
DRAINAGE WORK	Side Ditch			●			●				●		●	●		●	●	●	●							●				●	●		●		●			●		●
	Vertical Ditch						●				●						●											●	●		●		●	●	●			●		
	Water Channel						●	●		●	●		●	●		●					●		●			●				●							●			
	R C P C						●	●								●					●		●	●		●						●			●		●			
	R C B C												●	●	●					●																				
	Subsurface Drainer			●																																				●

TYPE OF DISASTER : E - F (Embankment Slope Failure), C - F (Cut Slope Failure), D - FL (Debris Flow), L - SL (Landslide)

CAUSE OF FAILURE : 1. Facing River, 2. Concentration of Surface Water, 3. Inadequate Compaction, 4. Inadequate Drainage Facility, 5. Groundwater, 6. Settlement due to Soft Ground, 7. Weathered Layer, 8. Developed Crack in Rock, 9. Flow of Debris, 10. Movement along sliding plane in Cohesive Soil Layer

TABLE 11.3-1 SLOPE PROTECTION WORKS APPLIED TO EACH SLOPE

(2/2)

TYPE OF COUNTERMEASURE	SECTION	Agusan del Sur																								Davao del Norte													TOTAL
	SLOPE NUMBER	4-18	4-19	4-20	4-21	4-22	4-23	4-24	4-25	4-26	4-27	4-28	4-30	4-31	4-33	4-34	4-35	4-36	4-37	4-38	4-39	4-40	4-41	4-42	4-43	5-01	5-02	5-04	5-05	5-06	5-07	5-10	5-13	5-16	5-19	5-21	5-22	5-23	
	KM.	1277+400	1277+580	1277+700	1278+600	1281+320	1281+463	1282+200	1282+500	1283+500	1284+300	1284+700	1304+875	1304+952	1312+800	1313+350	1313+380	1313+400	1314+400	1340+950	1352+800	1353+400	1353+450	1353+600	1372+800	1378+500	1378+800	1380+600	1395+800	1401+300	1401+850	1410+200	1430+950	1441+000	1445+700	1450+100	1468+100	1469+925	
	TYPE OF DISASTER	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	E - F	
	CAUSE OF DISASTER	3	3	3	6	3	3	3	3	3	5	4	3	3	3	3	3	3	3	1	4	1	1	1	5	4	4	1	3	1	1	1	1	1	2	5	1	1	
EARTHWORK	Re-filling		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●	●	●	55
	Re-cutting																										●							●					6
	Counterweight Filling																																						1
	Earth Removal				●																																		4
	Embankment																																						3
RETAINING WALL	Gravity Type Concrete Wall		●					●				●									●	●	●				●					●			●		●		21
	Supported Type Concrete Wall	●																												●	●			●					6
	Stone Masonry Wall																																●						2
	Gabion Wall																			●					●														5
PROTECTION WORK	Vegetation																																						2
	Grouted Riprap			●	●	●		●		●	●	●			●	●	●		●					●			●		●	●	●				●	●		●	33
	Concrete Spraying																																						3
	Concrete Crib																																						1
	Cylinder Gabion																											●											2
CATCH WORK	Gabion Catch Wall																																						3
	Concrete Catch Wall																																						3
FOOT PROTECTION	Gabion Foot Protection				●							●									●	●	●	●			●			●	●	●	●	●			●	●	20
PAVEMENT WORK	Concrete Pavement																																						3
	Concrete Pavement of Shoulder	●		●											●																								11
DRAINAGE WORK	Side Ditch	●			●	●	●			●	●								●						●	●				●						●			27
	Vertical Ditch	●								●	●								●						●	●	●									●			18
	Water Channel																																						12
	R C P C											●									●	●	●				●									●			16
	R C B C																																						4
	Subsurface Drainer																																						2

TYPE OF DISASTER : E - F (Embankment Slope Failure), C - F (Cut Slope Failure), D - FL (Debris Flow), L - SL (Landslide)
CAUSE OF FAILURE : 1. Facing River, 2. Concentration of Surface Water, 3. Inadequate Compaction, 4. Inadequate Drainage Facility, 5. Groundwater, 6. Settlement due to Soft Ground, 7. Weathered Layer, 8. Developed Crack in Rock, 9. Flow of Debris, 10. Movement along sliding plane in Cohesive Soil Layer

CHAPTER 12

COUNTERMEASURES AGAINST FLOOD

12.1 PRESENT CONDITION OF FLOOD SECTIONS

12.1.1 Identification of Flood Sections

18 sections are identified as flood-prone sections along the Study Road. Location of the identified sections are shown in Figure 12.1-1 while nature of flood is summarized in Table 12.1-1. Detailed description of each flood section is presented in Appendix 12.1.

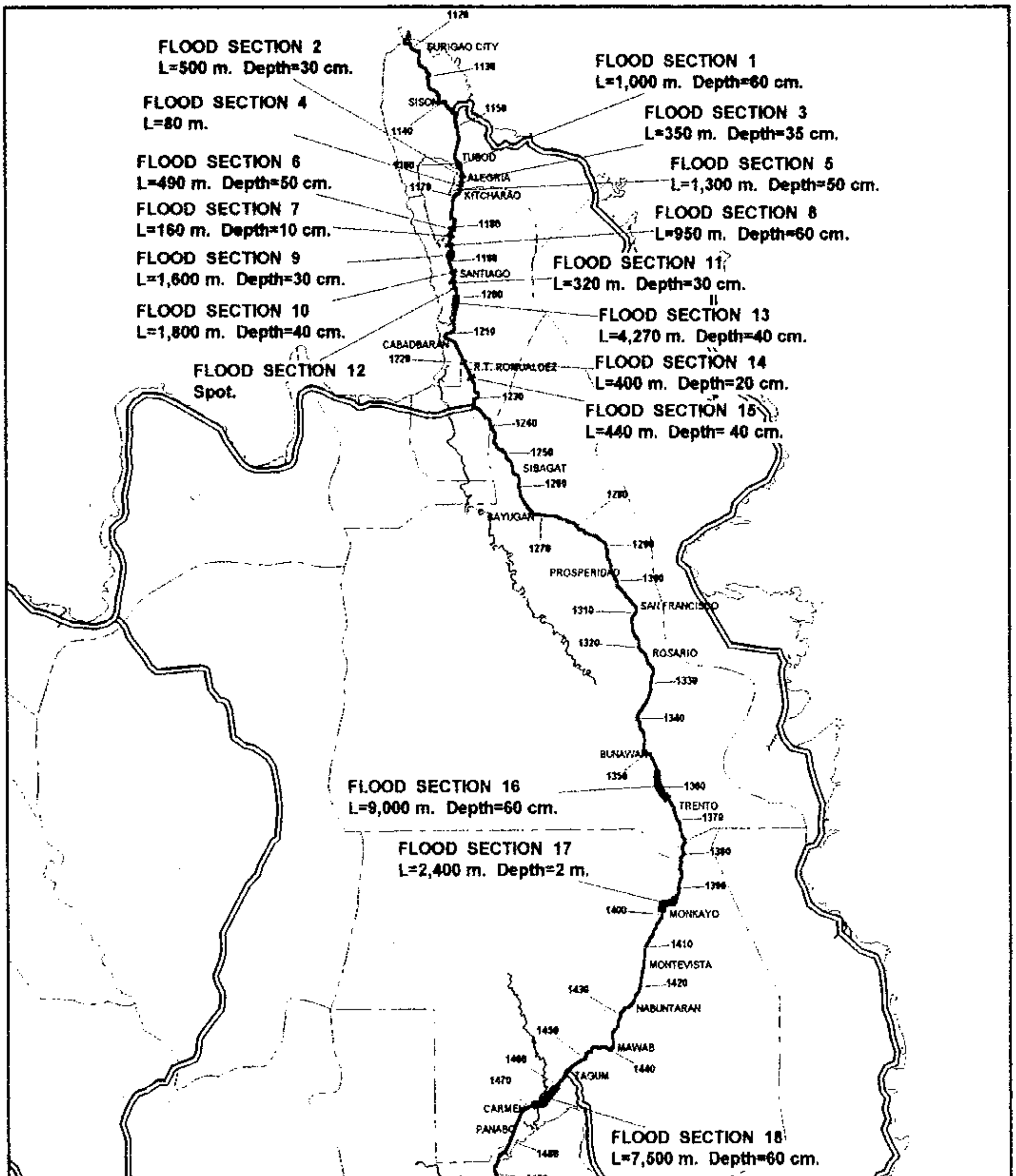


FIGURE 12.1-1 LOCATION OF FLOOD SECTION

TABLE 12.1-1 SUMMARY OF FLOOD SECTIONS (1/2)

NO.	LOCATION	NATURE OF FLOOD DEPTH	DURATION	FREQUENCY	TRAFFIC DISTURBANCE	DAMAGE TO THE ROAD	TOPOGRAPHY	CAUSE OF FLOOD	SEVERITY OF FLOOD	ROADSIDE DEVELOPT	FLOOD TYPE 1)
1	1160+700 ~ 1161+700 L = 1,000m Alipao, Surigao del Norte	60cm	6 hrs.	3/year	Impassable to all types of vehicles	Mud and debris deposit on the road. Shoulder scoured at 1161+250.	Mountain Foot	Flood water from mountain slopes. No significant water channel is present.	A	Low	I
2	1163+600 ~ 1164+100 L = 500m Candiis, Surigao del Norte	30cm	4 hrs.	3/year	Passable only to buses and trucks.	Mud deposits on the road surface.	Mountain Foot	Flood water from mountain slopes. No significant water channel is present.	B	Low	I
3	1164+750 ~ 1165+100 L = 350m Matiaco, Surigao del Norte	35cm	12 hrs.	2/year	Passable only to buses and trucks.	No significant road damage. Residential houses along the road are also inundated.	Alluvial Fan	Overflow from Legaspi River.	A	Medium	III
4	1165+800 ~ 1165+880 L = 80m San Pedro, Surigao del Norte	No flood	N/A	N/A	N/A	Embankment of approach road to San Pedro Bridge is severely scoured for about 80m.	Alluvial Fan	Flood water of San Pedro River directly hit approach dike of San Pedro Bridge.	-	Medium	III
5	1166+600 ~ 1167+900 L = 1,300m Alegria, Surigao del Norte	50cm	12 hrs.	2/year	Impassable to all vehicles for 6 hrs.	Shoulder scoured at 1166+600, +800, 1167+250, +500. Pavement collapsed at 1166+600.	Alluvial Fan	Overflow from Legaspi River.	A	High	III
6	1182+100 ~ 1182+590 L = 490m Baliguian, Agusan del Norte	30cm	4 hrs.	2/year	Passable only to buses and trucks.	Shoulder scoured at 1182+350~400.	Alluvial Fan	Overflow from Baliguian River.	B	High	III
7	1183+100 ~ 1183+260 L = 160m Baliguian, Agusan del Norte	10cm	3 hrs.	1/2 years	Passable with care.	Mudflow occurs over 50m. Existing box culvert subsided. Shoulder is scoured at the box culvert.	Alluvial Fan	Overflow from Sayadion River.	C	Low	III
8	1184+250 ~ 1185+200 L = 950m Toliago, Agusan del Norte	60cm	6 hrs.	2/year	Impassable to all types of vehicle.	Mud and debris deposit on the road surface. Shoulder washed out for 90m.	Mountain Foot	Flood water from mountain slopes. No significant water channel.	A	Low	I
9	1187+600 ~ 1189+200 L = 1,600m Bangonay, Agusan del Norte	30cm	6 hrs.	1/year	Passable only to buses and trucks.	Road damage is not significant. Huge amount of drift woods stuck below Bangonay Bridge during storm.	Alluvial Fan	Overflow form Puyo River.	A	Low	III
10	1192+000 ~ 1193+800 L = 1,800m Santiago, Agusan del Norte	40cm	6 hrs.	2/year	Impassable to all types of vehicle.	Mud and debris deposit on the road Shoulder scoured over 60m.	Mountain Foot	Flood water from mountain slope. No significant water channel is present.	A	High	I

Note: 1) Refer to Section 12.1.2 as to FLOOD TYPE

TABLE 12.1-1 SUMMARY OF FLOOD SECTIONS (2/2)

NO.	LOCATION	NATURE OF FLOOD				DAMAGE TO THE ROAD	TOPOGRAPHY	CAUSE OF FLOOD	SEVERITY OF FLOOD	ROADSIDE DEVELOPT	FLOOD TYPE 1)
		DEPTH	DURATION	FREQUENCY	TRAFFIC DISTURBANCE						
11	1196+400 ~ 1196+720 L = 320m Jagupit, Agusan del Norte	25cm	4 hrs.	3/year	Passable only to buses and trucks.	Jagupit River is heavily silted. No clearance below Jagupit Bridge.	Alluvial Fan	Overflow from Jagupit River.	B	Low	III
12	1197+571 Guinoyoran, Agusan del Norte	No flood	N/A	N/A	N/A	Embankment of approach road to Guinoyoran Bridge is severely scoured for about 18m.	Alluvial Fan	Water channel of Guinoyoran River shifted its course and hit approach road to the bridge.	-	Low	III
13	1199+600 ~ 1203+870 L = 4,270m Sta. Ana, Agusan del Norte	40cm	6 hrs.	2/year	Impassable to all types of vehicle.	Road washed out at 1200+000, 1202+250, and 1203+250.	Alluvial Fan	Overflow from Tagmamarkay River, Kinahiloan River and Maniswag River.	A	Medium	III
14	1219+700 ~ 1220+100 L = 400m Agay, Agusan del Norte	15cm	6 hrs.	3/year	Passable with care.	Box and pipes are frequently overflowed. Shoulder washed out. Pavement frequently collapsed at 1220+000.	Flood plain	Lowland area.	C	Medium	II
15	1224+200 ~ 1224+640 L = 440m Los Angeles, Butuan City	30cm	10 hrs.	2/year	Passable only to buses and trucks.	Road damage is not significant. Agay River is heavily silted.	Flood plain	Overflow from Agay River. Lowland area.	B	Medium	II
16	1355+200 ~ 1364+200 L = 9,000m Trento, Agusan del Sur	60cm	48 hrs.	1/5 years	Impassable to all types of vehicles at 1356+450.	No significant road damage.	Flood plain	Overflow from Simulao River.	A	High	IV
17	1393+400 ~ 1398+300 L = 2,400m Monkayo, Davao del Norte	2.0m	3 days	1/5 years	Impassable to all types of vehicle.	Monkayo town proper totally submerged under flood water.	Flood plain	Overflow from Agusan River.	A	High	IV
18	1460+500 ~ 1468+000 L = 7,500m Tagum, Davao del Norte	60cm	24 hrs.	1/year	Impassable to all types of vehicle.	Shoulder severely scoured for about 1,600m.	Flood plain	Overflow from Liboganon River.	A	Medium	IV

Note: 1) Refer to Section 12.1.2 as to FLOOD TYPE

12.1.2 Classification of Flood Sections

Flood sections along the Study Road are classified into four types based on the cause of flood as follows:

Type I : Flood caused by surface run-off from mountain slope.

Type II : Flood caused by rise of water level in lowland area. Flood water comes from various rivers.

Type III : Flood caused by overflow from river due to siltation and aggradation of river at alluvial fan.

Type IV : Flood caused by overflow from river due to gentle river bed slope and meandering of river channel.

Magnitude of flood along the road is further aggravated by the following road conditions.

- Absence of adequate capacity of drainage facilities along the road such as side ditch, RCPC and RCBC.
- Low elevation of road surface compared with adjacent area.

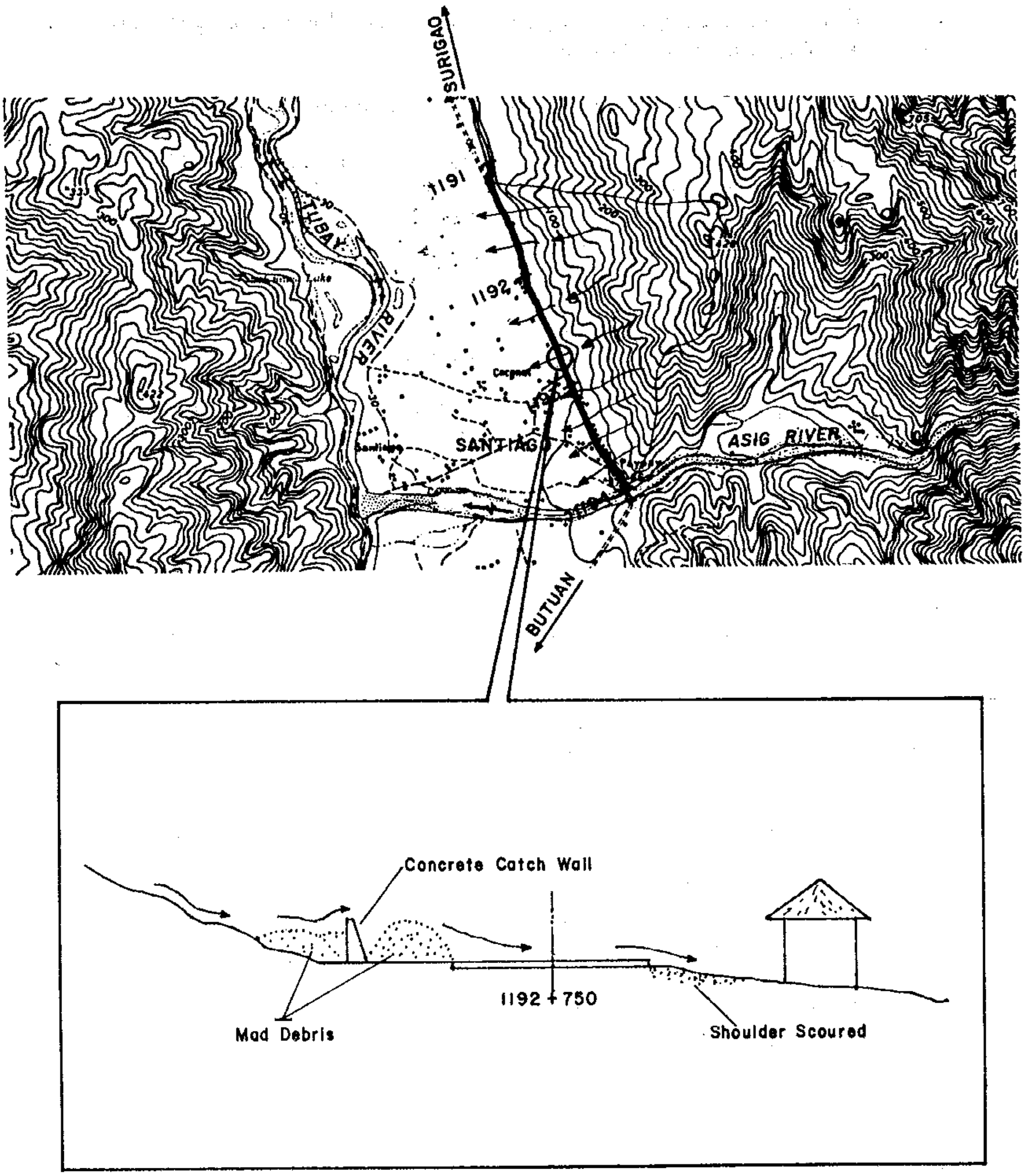
Nature of each flood type observed at the field is discussed in detail below.

1) Type I Flood

This type of flood is often observed along the road section passing at foot of mountain as shown in Figure 12.1-2.

Although no marked stream channel is observed along the mountain slope, fairly large amount of surface run-off occurs during downpour. If soil composition of the slope is loose and not covered by thick vegetation, significant amount of mud and debris flow also occurs. Catchment area of this type of flood is quite small, normally less than 2 km^2, but it has short time of concentration and thus quite sensitive to short but high intensity rainfall. Characteristics of this type of flood are:

- Short flood duration but fairly high flood magnitude.
- High flood velocity.
- Mud/debris flow accompanied.



FLOOD SECTION 10 SANTIAGO, AGUSAN DEL NORTE

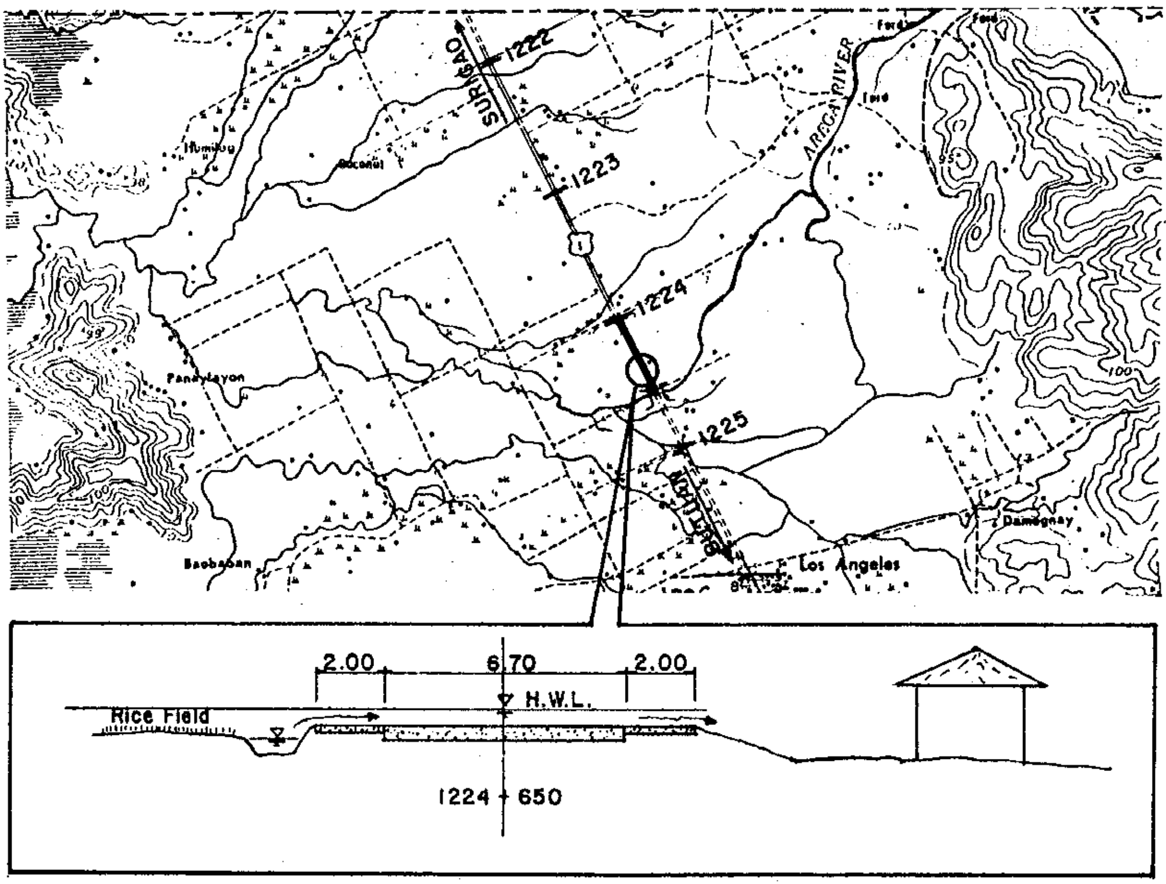
FIGURE 12.1-2 SAMPLE OF TYPE I FLOOD

2) Type II Flood

Type II flood is observed along the road sections traversing lowland area, where numerous creeks run across the area. Usually it is difficult to identify single source of flood water because numerous number of rivers from different origin with different drainage area flow across the area. See Figure 12.1-3.

Characteristics of Type II flood are:

- Flood duration is long.
- Magnitude of flood along the road is largely dependent on the elevation of the road.
- Velocity of flood water is low.
- Damage to the road structure is not serious.



FLOOD SECTION 15 LOS ANGELES, BUTUAN CITY

FIGURE 12.1-3 SAMPLE OF TYPE II FLOOD

3) Type III Flood

Type III flood is observed along the road sections traversing through the middle of alluvial fan. The rivers tend to split into several substreams at tip of the alluvial fan and spread over entire stretch of the area. The alluvial channels exhibit a natural instability which results in continuous shifting of the stream through erosion and deposition.

As shown in Figure 12.1-4, the stream channel of Kinahilom River has shifted southward by 2 km over 50 years period. It is therefore difficult to determine a location of permanent drainage structures to be constructed. Though bridges are constructed at best fit location, excessive siltation in the river may totally clog-up bridge opening like Jagupit Bridge, or water flow as a result of change in its course may hit and damage approch road like Guinoyoran Bridge. Characteristics of Type III flood are:

- Location and magnitude of flood change yearly.
- Relatively short flood period.
- Relatively high flood velocity.
- Debris flow always accompanied.
- Damage to the road structure is high.
- Periodic dredging of the river and drainage channel is required to mitigate flood.

4) Type IV Flood

Type IV flood is observed along the road sections passing through flood plain of big river whose drainage area is large but river bed slope is quite flat. During the storm, swell of flood water spills out to adjacent area and inundate quite wide stretch of area along the river for long time. See Figure 12.1-5.

Characteristics of Type IV flood are:

- Flooded area is quite large.
- Duration of flood is long.
- Velocity of flood is low except during subsidence.
- Damage to the road structure is not serious but traffic disturbance is quite severe.
- Mud/debris flow rarely accompanied.

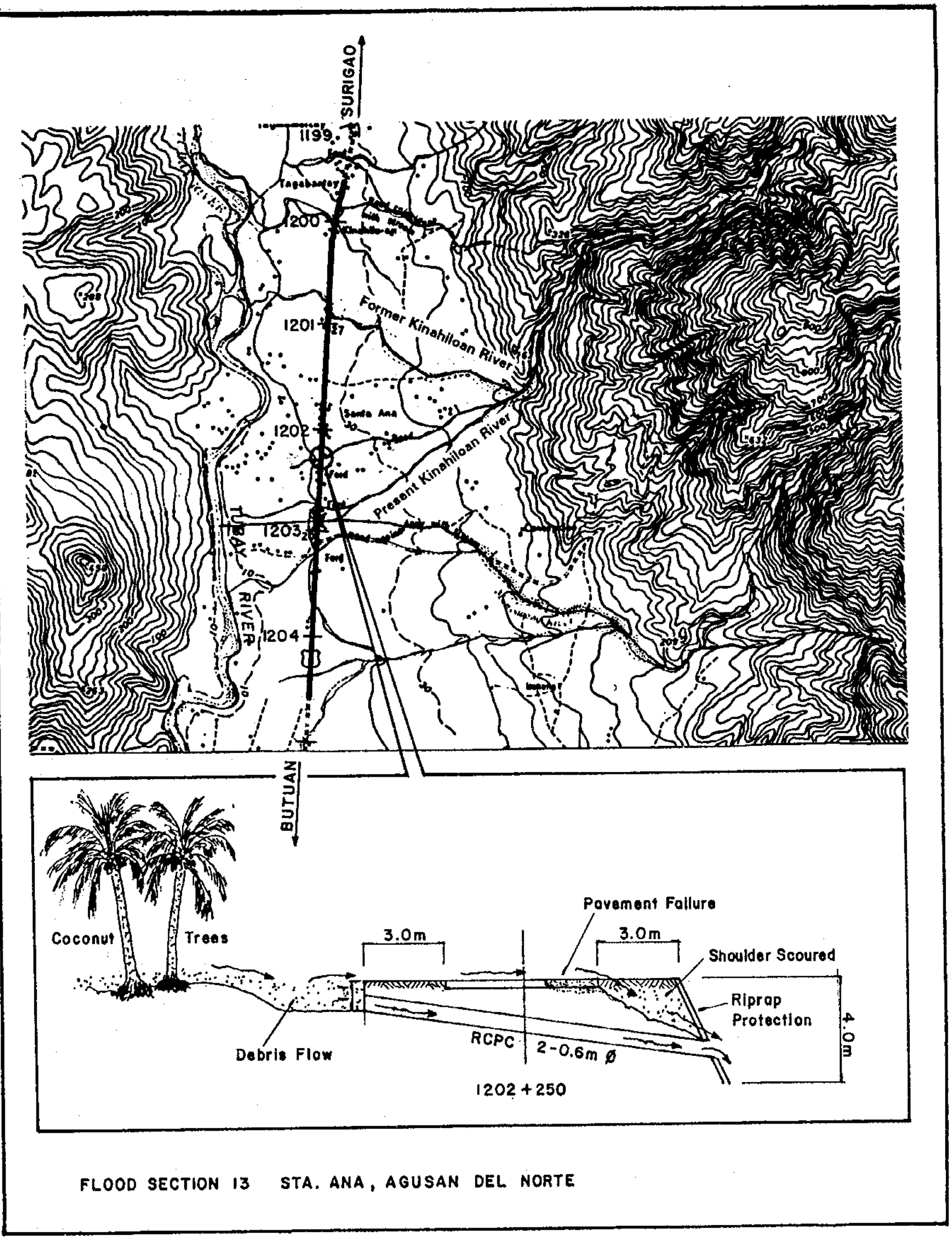
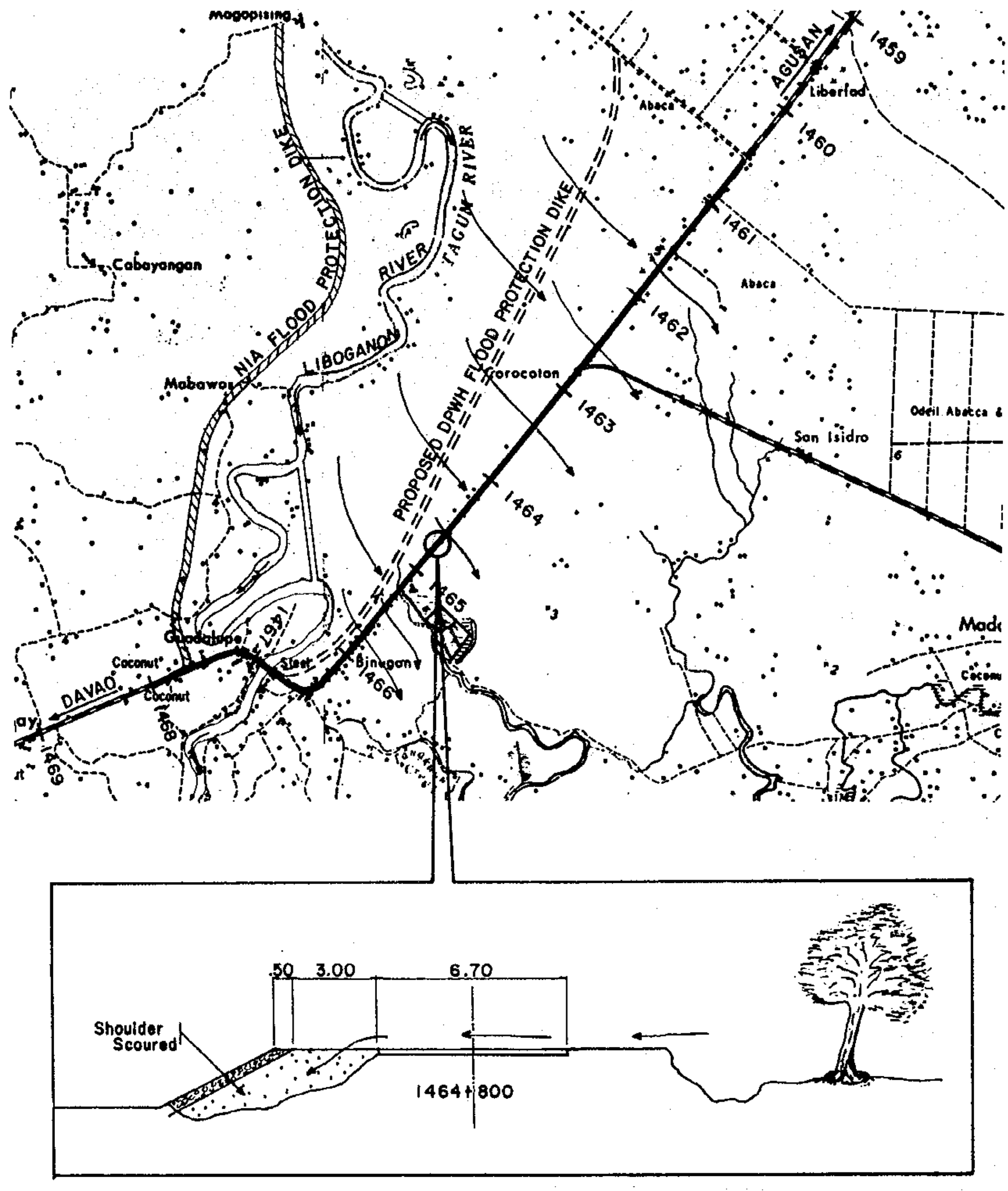


FIGURE 12.1-4 SAMPLE OF TYPE III FLOOD



FLOOD SECTION 18 TAGUM, DAVAO DEL NORTE

FIGURE 12.1-5 SAMPLE OF TYPE IV FLOOD

12.2. COUNTERMEASURES DESIGN CRITERIA

12.2.1 Types of Countermeasures

There are two types of principal countermeasures for flood prevention and protection:

- Countermeasures along the road to protect the road.
- Countermeasures along a river to prevent flood water spilling out.

The following three countermeasures are proposed as countermeasure along the road:

Countermeasure - 1: Protect the road against flood water (Flood protection)
Countermeasure - 2: Install flood interception canal (Flood prevention)
Countermeasure - 3: Raise the road elevation above floodwater level (Flood prevention)

Illustrative description of each countermeasure along the road is presented in Table 12.2-1.

Countermeasures along the river are selected taking into account characteristics of the rivers along the study road. The following four countermeasures are proposed:

Countermeasure - 4: Dredge the river (Flood prevention)
Countermeasure - 5: Construct Sabo dam (Flood prevention)
Countermeasure - 6: Construct flood protection dike (Flood prevention)
Countermeasure - 7: Provide cut-off channel (Flood prevention)

Table 12.2-2 presents illustrative description of countermeasures along the river.

12.2.2 Selection Criteria of Countermeasures

1) Evaluation of Severity of Flood

Severity of flood is widely dependent on flood depth, duration and frequency. For the purpose of selection of countermeasures for flood sections, severity of flood is assessed based on the criteria as shown in Table 12.2-3.

TABLE 12.2-1 COUNTERMEASURES ALONG ROAD

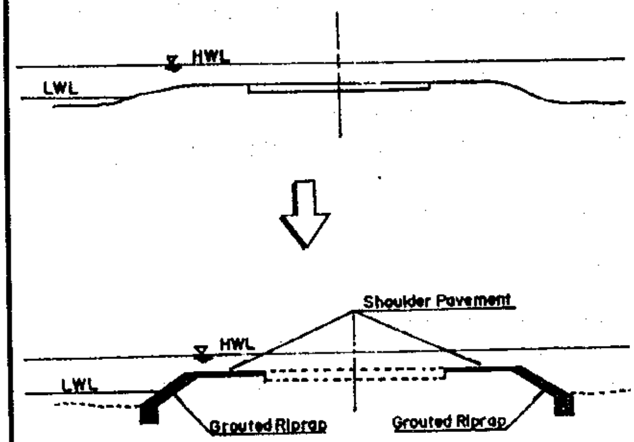
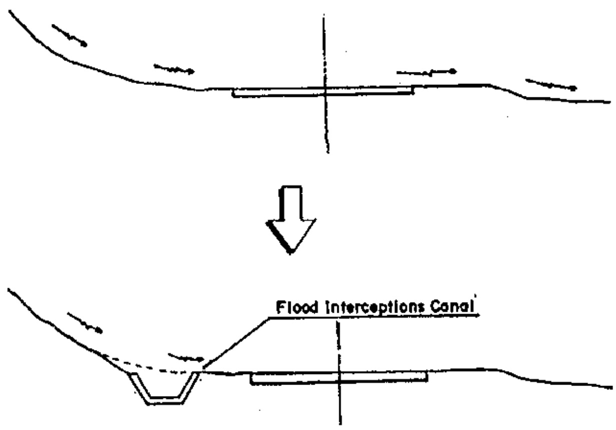
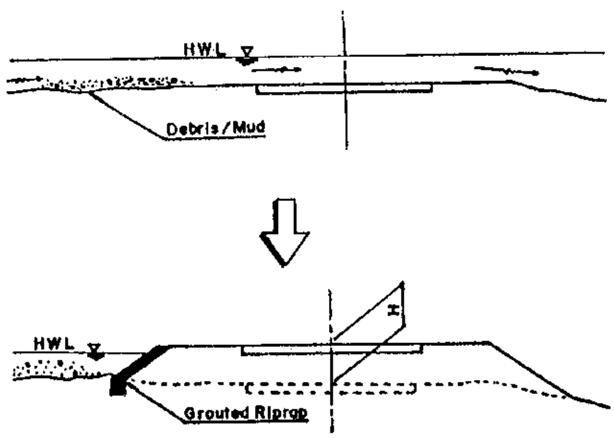
Sample Illustration	Description of Method	Application Criteria
COUNTERMEASURE 1 Protection of Road 	- Protect the road with grouted riprap and shoulder pavement. - Adequate capacity of side ditch and cross drainage facilities shall be installed.	- Flood elevation is not so high. - No mud/debris flow. - Suitable to urbanized area. - Suitable to area where flood interception canal doesn't work properly.
COUNTERMEASURE 2 Flood Interception Canal 	- Install adequate capacity of flood interception canal. - Size of canal is dependent on flood discharge and distance to convey flood water. - Grouted riprap and shoulder pavement may be provided if there still be possibility of overflow. - Cross drainage facility such as RCPC, RCBC shall be installed at proper location.	- Flood depth is not so deep. - No mud/debris flow accompanied. - Suitable to urbanized area. - Periodic dredging of canal is required.
COUNTERMEASURE 3 Raise of Road 	- Raise the road above expected high water level. - Height of embankment is dependent on elevation of flood water. - Embankment slope exposed to flood water may be protected by grouted riprap. - Cross drainage facility such as RCPC, RCBC shall be installed at proper location.	- Flood elevation is high. - Mud/debris flow accompanied. - Suitable to not urbanized area.

TABLE 12.2-2 COUNTERMEASURES ALONG RIVER

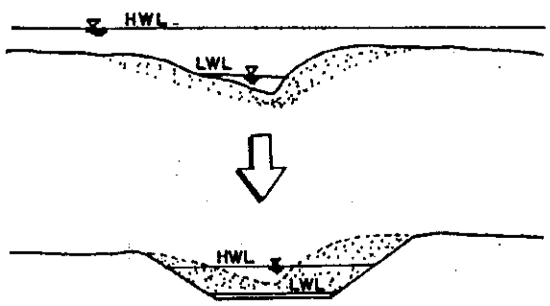
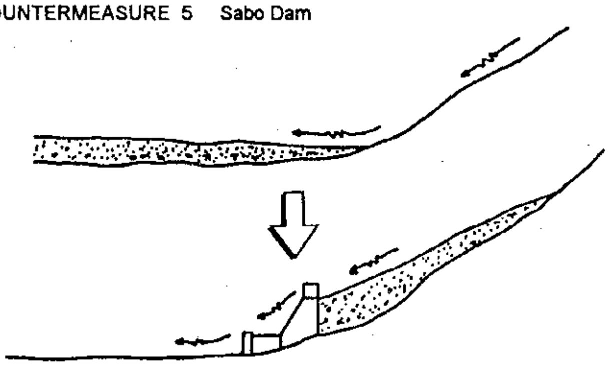
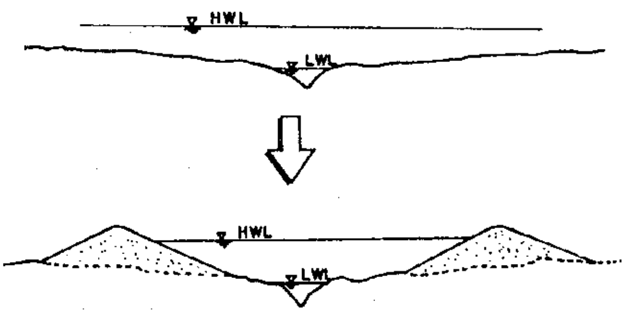
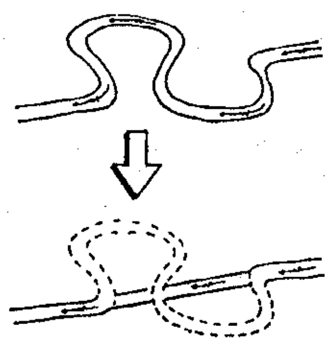
Sample Illustration	Description of Method	Application Criteria
COUNTERMEASURE 4 Riverbed Dredging 	- Remove sediments on the river by excavation. - Dimension of river is determined based on amount of discharge and nature of river channel.	- Applicable to rivers in alluvial fan which exhibits excessive sedimentation and aggradation of riverbed. - Periodic dredging is required to maintain stream steady.
COUNTERMEASURE 5 Sabo Dam 	- Construct sabo dam at top of an alluvial fan. - Exact location and size of dam shall be determined by experienced engineer after thorough investigation.	- Applicable to middle or minor rivers in alluvial fan. - Additional sabo dam may be required at upstream when downstream dam is filled with sediments.
COUNTERMEASURE 6 Dike 	- Construct earth dike high enough to prevent flood water spilling-out. - Embankment slope may be protected by grouted riprap if velocity of flood is high.	- Applicable to rivers in flat plain. - Rivers whose surrounding area has economically high value.
COUNTERMEASURE 7 Cut-off Channel 	- Straighten river channel at meandering section by introducing man-made canal.	- Applicable to rivers in flat plain whose water course meanders significantly.

TABLE 12.2-3 CRITERIA FOR ASSESSMENT OF FLOOD SEVERITY

Flood Depth	Duration	Return Period				
		Less than 2 years	2 ~ 5 years	5 ~ 10 years	10 ~ 15 years	More than 15 years
Less than 15cm (passable to all types of vehicle with care)	Any	B	C	D	D	D
15~30cm (passable to bus and truck only)	Less than 5 hrs.	B	B	C	D	D
	5 hrs. or more	A	B	B	C	D
30cm or more (Impassable to all types of vehicle)	Less than 5 hrs.	A	A	B	B	B
	5 hrs. or more	A	A	A	B	B

A: High
B: Medium
C: Low
D: Negligible

2) Selection Criteria of Countermeasures

Criteria for Selection of Road or River Countermeasures

There is no defined water channel in the catchment area of Type I Flood, while several number of creeks exist in affected area of Type II Flood. Since it is difficult to identify water channel that may be a source of flood water or Types I and II Flood, countermeasures are limited to protection works along the road.

On the otherhand, source of flood water is readily determined for Type III and IV Flood. Countermeasures for Types III and IV Flood, may be either along the road or a river.

Basically countermeasures along the road shall be selected for all types of flood but adoption of countermeasures along the river shall be considered under the following circumstances:

- Flood damage other than the road is also serious, and it is economically worth to protect vicinity area as well as the road itself.

- It is obvious that countermeasure along the river is technically and economically superior than countermeasure along the road.

Criteria for Selection of Countermeasures along the Road

Countermeasure along the road is selected based on severity of flood and roadside development. The basic criteria for selection of countermeasure along the road is as follows:

a) Severity of flood is A or B, and
Roadside development is high · · · · · · Countermeasure 2

b) Severity of flood is A or B, and
Roadside development is low · · · · · · Countermeasure 3

c) Severity of flood is C · · · · · · · · · · · Countermeasure 1

d) Severity of flood is D · · · · · · · · · · · Do Nothing

General application criteria of each countermeasure is presented in Tables 12.2-1 and 12.2-2.

Selection of Countermeasures

Based on above criteria, countermeasure for each flood section was selected. A comparative study was carried out for the sections whose countermeasures were not easily determined.

12.2.3 Comparative Study

Comparative study was carried out for flood sections 13, 17 and 18 to determine the optimum solution.

1) Flood Section 13 (Sta. Ana, Agusan del Norte)

Vicinity of flood section 13 is illustrated in Figure 12.2-1. The following three countermeasures were proposed for comparison:

Alternative - 1 (Countermeasure 1): Protect the road with shoulder pavement and grouted riprap.

Alternative - 2 (Countermeasure 3): Raise the road above flood level.

Alternative - 3 (Countermeasure 4, 5, 6): Control flood with river dredging, sabo dam, and flood protection dike.

The result of comparison is presented in Table 12.2-4. Based on the comparative study, Alternative-2 was adopted.

2) Flood Section 17 (Monkayo, Davao del Norte)

Vicinity of flood section 17 is illustrated in Figure 12.2-2. The flood around the area is reportedly caused by chalking of flow at 2.5 km downstream of Kalaw Bridge where river meanders for about 1.9 km westward and return to a point some 70m away from starting point of long turn and similar turn follows again. This series of extreme meanders causes backflow up to Kalaw bridge and inundates Monkayo area. Kalaw bridge with a length of 111m and 8.6m clearance below bridge is reportedly overtopped by flood water by 1~2m. Monkayo town proper is submerged under flood water by 2m whenever strong storm hit the area.

The following three countermeasures were studied.

Alternative - 1 (Countermeasure 6, 7): Cut-off channel between extreme meanders and flood protection dike at the lowest area.

Alternative - 2 (Countermeasure 6): Flood protection dike to protect the road and surrounding area.

Alternative - 3 (Countermeasure 3): Raise the road elevation by constructing new road (Monkayo Bypass) along higher portion.

The result of comparison is shown in Table 12.2-5. Based thereon, Alternative-3 was adopted.

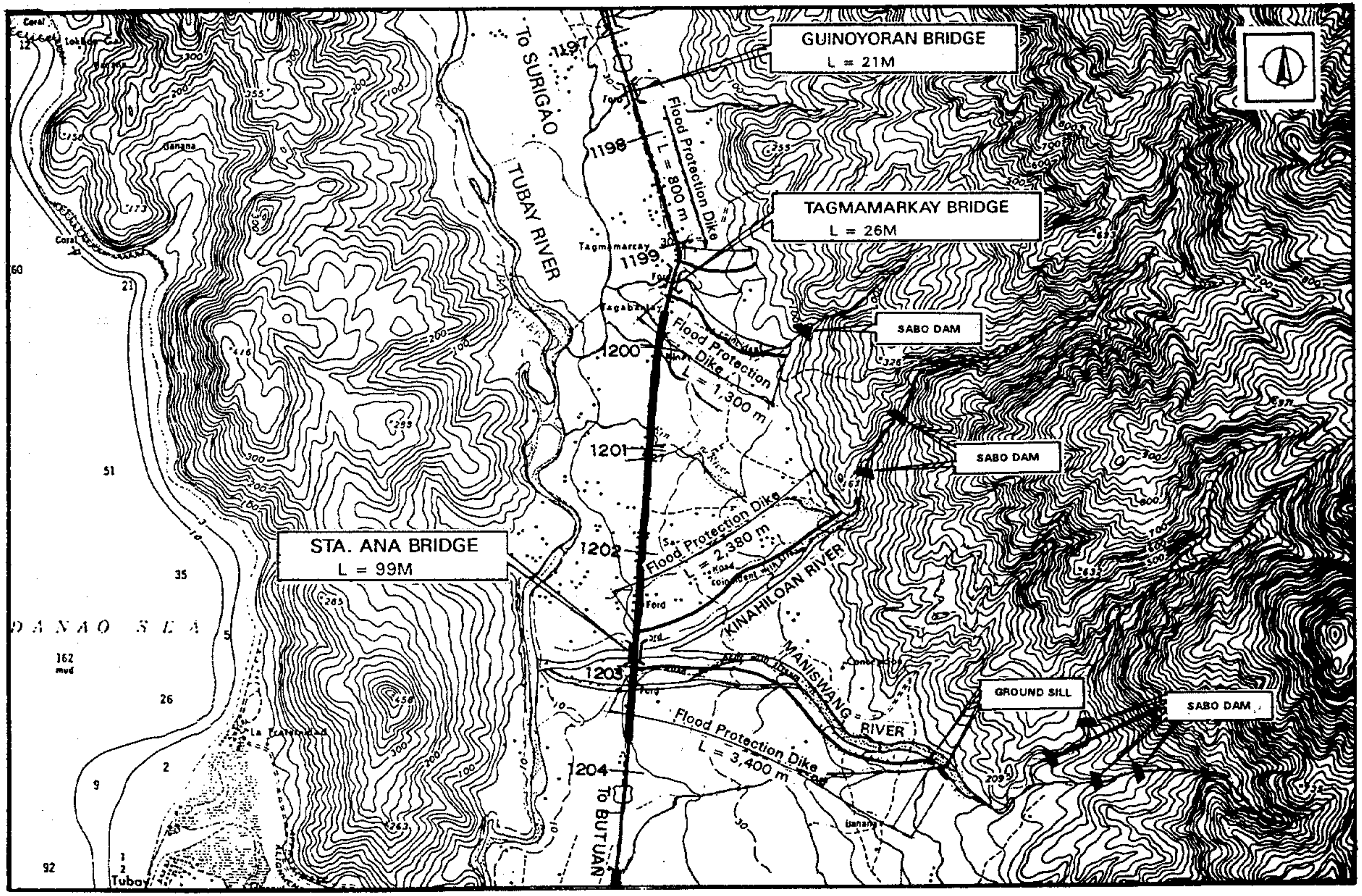
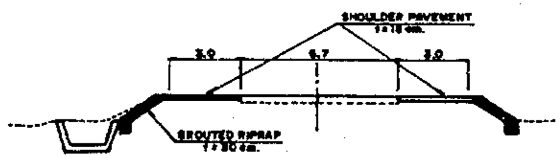


FIGURE 12.2-1 LOCATION MAP OF FLOOD SECTION 13 Sta. Ana, Agusan del Norte with Location of flood control measures in Alternative-3

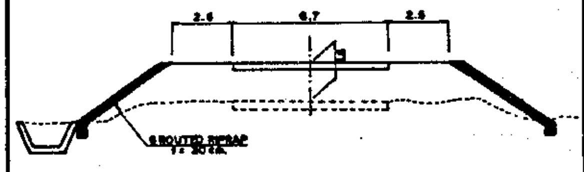
TABLE 12.2-4 COMPARATIVE TABLE OF COUNTERMEASURES

FLOOD SECTION 13: STA. ANA, AGUSAN DEL NORTE Depth: 40cm, Duration: 6 hrs. Frequency: 2/year

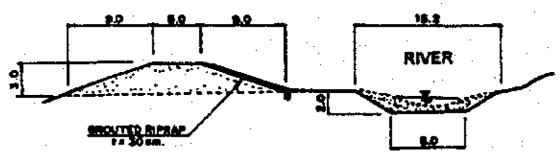
ALTERNATIVE - 1		ALTERNATIVE - 2		ALTERNATIVE - 3	
COUNTERMEASURE 1 Protection of Road	Cost (MP)	COUNTERMEASURE 3 Raising the Road above flood level	Cost (MP)	COUNTERMEASURE 4, 5, 6 Flood control	Cost (MP)
o Shoulder pavement L = 4,300m	16.4	o Raise the Road L = 4,300m	44.6	o River Dredging 8,840m	28.4
o Riprap protection L = 4,300m	6.5	o Riprap protection L = 4,300m	6.8	o Protection Dike 8,380m	130.5
o Box Culvert 4 locations	6.3	o Box Culvert 4 locations	6.3	o Sabo Dam 7 locations	11.1
o Pipe Culvert 5 locations	1.4	o Pipe Culvert 5 locations	1.4	o Ground Sill 2 locations	3.0
o Side Ditch L = 4,271m	27.8	o Side Ditch L = 4,271m	27.8	o Pipe Culvert 5 locations	1.4
(Excluding Engineers' Facilities) TOTAL	58.3	(Excluding Engineers' Facilities) TOTAL	86.9	(Excluding Engineers' Facilities) TOTAL	174.4



PROTECTION OF ROAD



RAISING OF ROAD



RIVER DREDGING AND PROTECTION DIKE
(Location is shown in FIG. 7.2-1)

Alternative - 1		Evaluation	Alternative - 2		Evaluation	Alternative - 3		Evaluation
Construction cost is low.	○	△	Construction is not high.	○	○	Cost is quite high.	×	△
Road is flooded.	×		Road is not flooded.	○		Road is not flooded.	○	
Road is protected.	○		Road is protected.	○		Periodic dredging is required.	×	
Surrounding area is flooded.	×		Surrounding area is flooded.	×		Surrounding area is not flooded.	○	

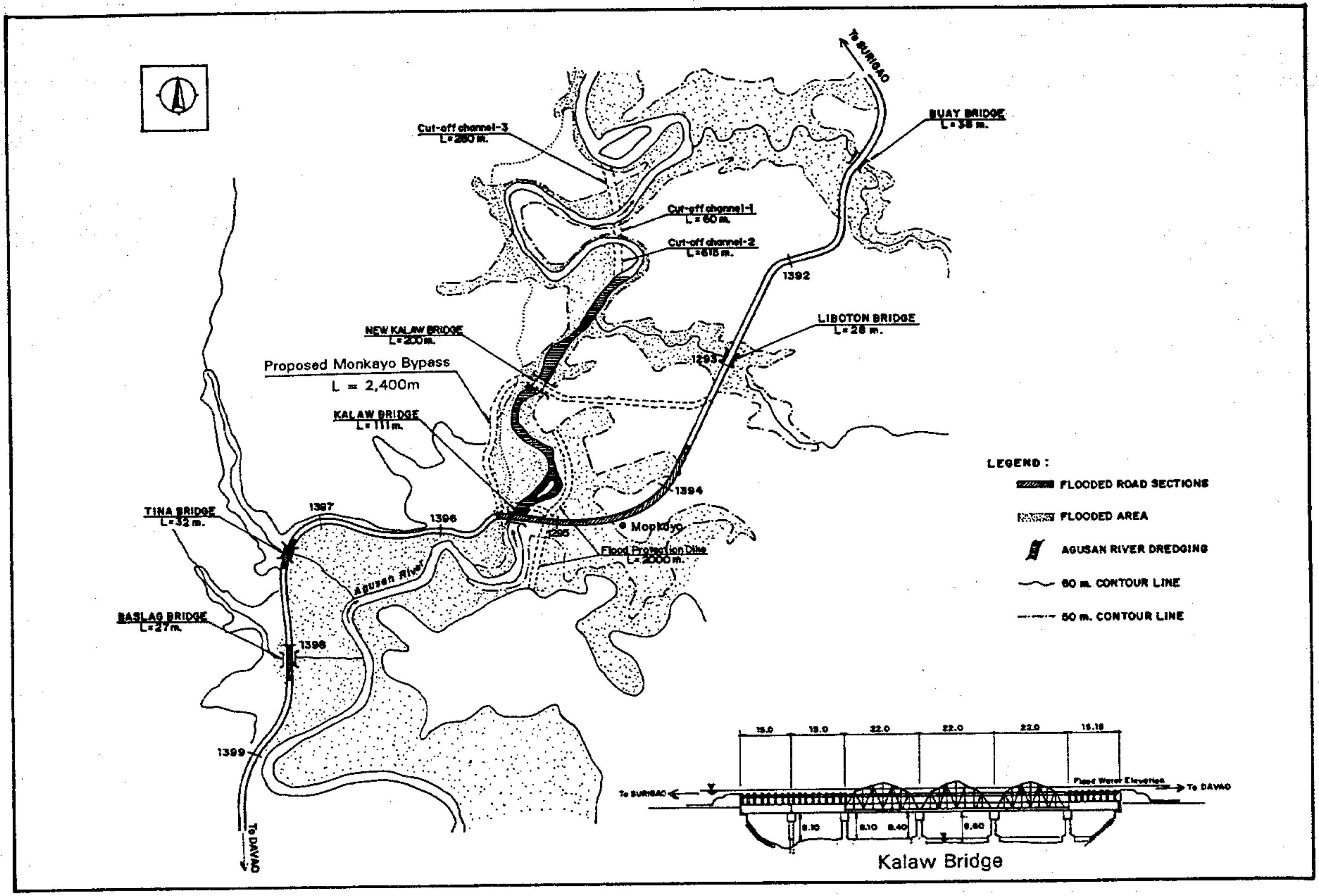


FIGURE 12.2-2 LOCATION MAP OF FLOOD SECTION 17 Monkayo, Davao del Norte with Location of proposed Monkayo Bypass in Alternative-3

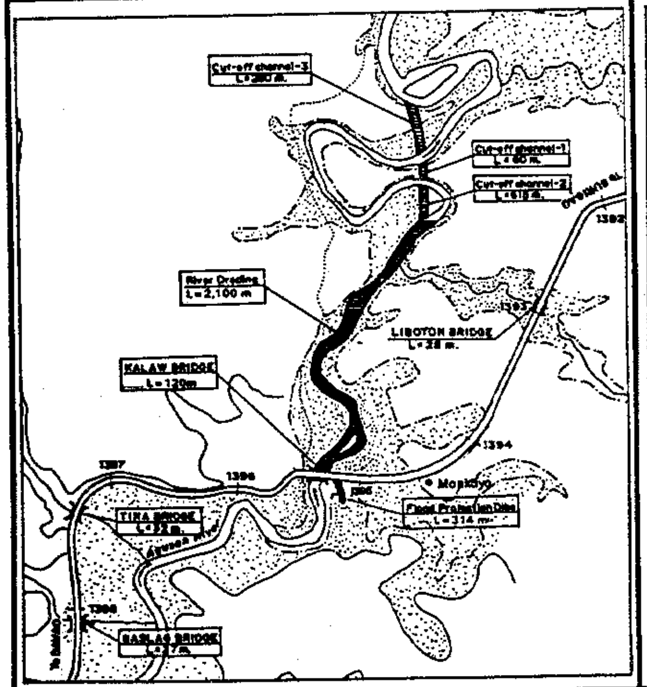
TABLE 12.2-5 COMPARATIVE TABLE OF COUNTERMEASURES

FLOOD SECTION 17: MONKAYO, DAVAO DEL NORTE

Depth: 2m Duration: 3 days Frequency: Once/5 years

ALTERNATIVE - 1

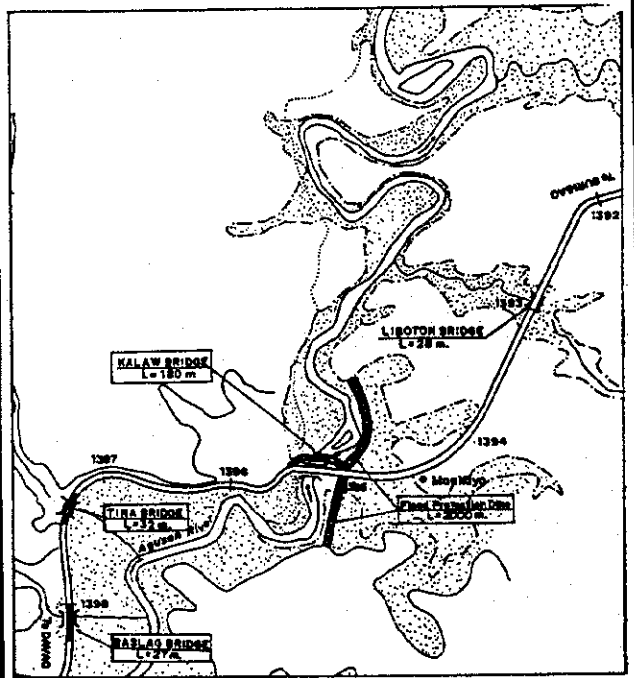
COUNTERMEASURE 7, 6 Cut-off Channel & Flood Protection Dike		Cost (MP)
FLOOD CONTROL		
o Cut-off Channel	L = 1,020m	288.9
o Agusan River Dredging	L = 2,100m	9.0
o Diking H = 2.5m	L = 317m	1.3
Sub-total		299.2
KALAW BRIDGE RECONSTRUCTION		
o Kalaw Bridge	L = 120m	36.0
o Approach Road	L = 400m	4.0
Sub-total		40.0
(Excluding Engineer's Facilities) TOTAL		339.2



		Evaluation
Cost is quite high.	x	△
Effects on downstream is not known.	x	
Road is not flooded.	O	

ALTERNATIVE - 2

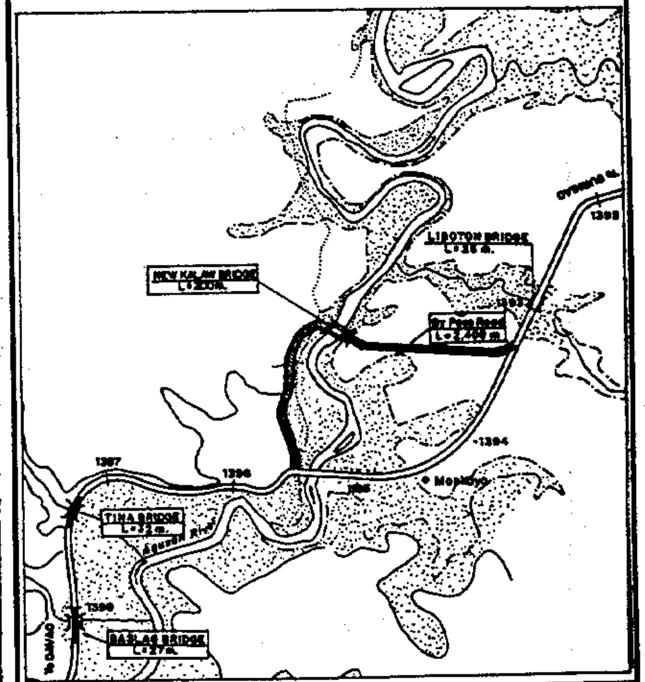
COUNTERMEASURE 6 Flood Protection Dike		Cost (MP)
FLOOD PROTECTION DIKE		
o Diking H = 8.0m	L = 2,000m	157.4
KALAW BRIDGE RECONSTRUCTION		
o Kalaw Bridge	L = 180m	54.0
o Approach Road	L = 400m	9.7
Sub-total		63.7
RAISING ROAD/BRIDGES		
o Tina Bridge	L = 32m	8.0
o Banlag Bridge	L = 27m	7.3
o Approach Road	L = 791m	8.8
Sub-total		24.1
(Excluding Engineer's Facilities) TOTAL		245.2



		Evaluation
Cost is high.	x	△
Damage due to dike failure is serious.	x	
Road is not flooded.	O	

ALTERNATIVE - 3

COUNTERMEASURE 3 Bypass Construction		Cost (MP)
NEW KALAW BRIDGE & BYPASS		
o New Kalaw Bridge	L = 200m	64.0
o Bypass Road	L = 2,400m	30.5
Sub-total		94.5
RAISING ROAD/BRIDGES		
o Tina Bridge	L = 32m	8.0
o Banlag Bridge	L = 27m	7.3
o Approach Road	L = 791m	8.8
Sub-total		24.1
(Excluding Engineer's Facilities) TOTAL		118.6



		Evaluation
Cost is not high.	O	O
Road is not flooded.	O	
Surrounding area is flooded.	X	

3) Flood Section 18

Vicinity of flood section 18 is illustrated in Figure 12.2-3. Western side of Liboganon River is protected by the dike constructed by National Irrigation Administration (NIA) in 1989. DPWH is currently constructing the protection dike along Eastern bank of the river, but some 6.2 km is still not protected. Area without protection dike is flooded yearly.

Alternative - 1 (Countermeasure 1): Protect road with shoulder pavement and grouted riprap.

Alternative - 2 (Countermeasure 6): Flood protection dike.

The result of comparison is shown in Table 12.2-6. In view of continuation of the DPWH plan of dike construction, the adoption of Alternative-2 is considered to be reasonable, although it costs very high. To refrain from immoderate investment at one time, stage construction is proposed as follows:

Stage - 1 :	Flood protection dike upstream	L=6,200m	P 52.3M
	Bridge between dikes	L= 500m	203.1
	Cut-off channel	L= 650m	21.1
	Approach Road including Embankment Slope Protection	L=1,050m	16.7
		Total	P293.2M*
Stage - 2 :	Flood protection dike (DPWH downstream)	L=7,300m	P 43.5M
	Flood protection dike (NIA downstream)	L=7,200m	43.0
		Total	P 86.5M*

*: Excluding Engineer's Facilities

Stage-1 is proposed to be included in this project and Stage-2 is expected to be implemented later.

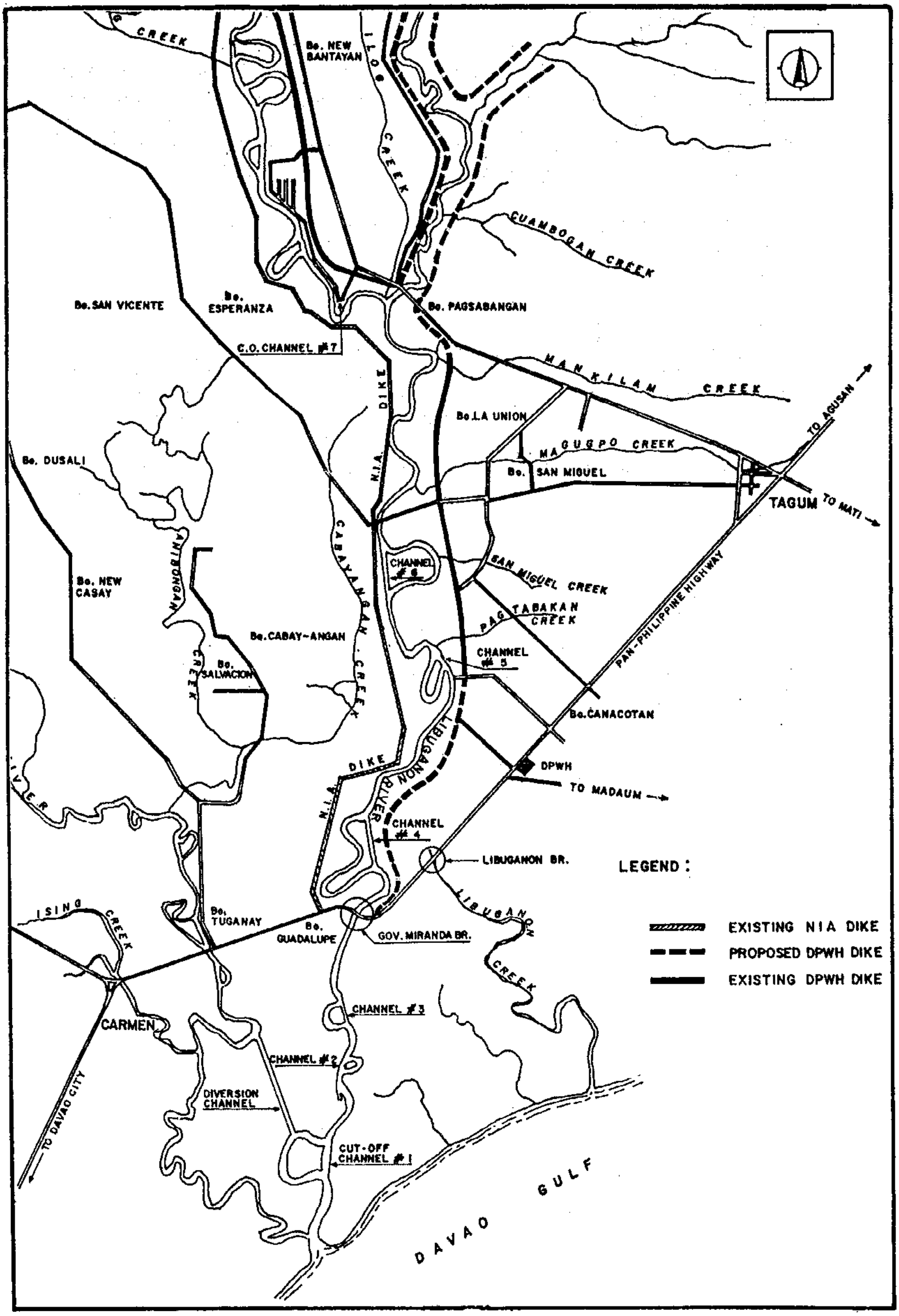


FIGURE 12.2-3 LOCATION MAP OF FLOOD SECTION 18 Tagum, Davao del Norte

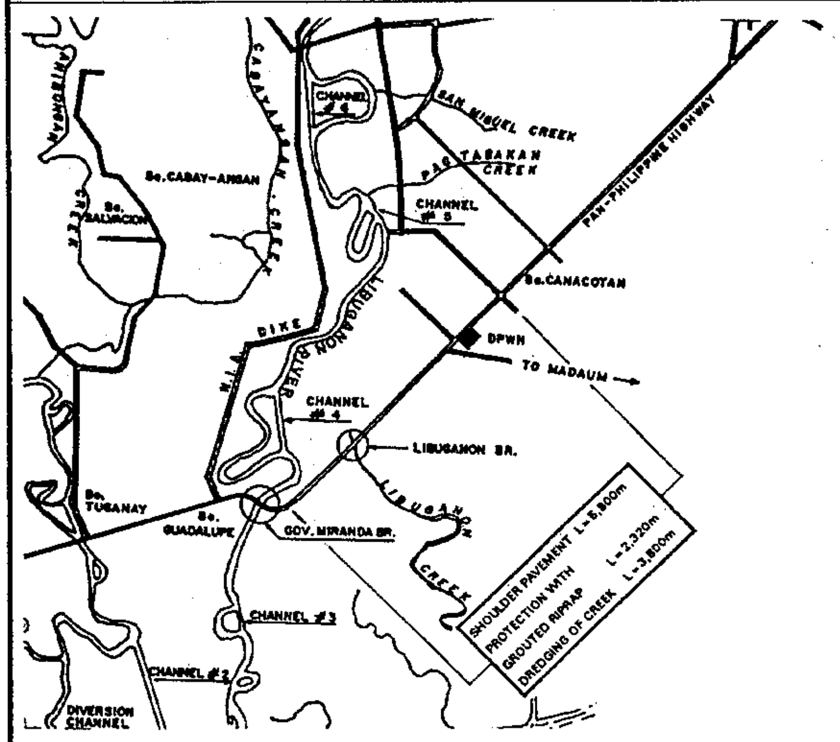
TABLE 12.2-6 COMPARATIVE TABLE OF COUNTERMEASURES

FLOOD SECTION 18: TAGUM, DAVAO DEL NORTE | Depth: 60cm | Duration: 24 hrs. | Frequency: 1/year

ALTERNATIVE - 1

Countermeasure - 1
Protect Road, with shoulder pavement & Grouted Riprap

			Cost (MP)
Shoulder pavement	L = 5,800m	(1460+500~1466+400)	22.1
Grouted Riprap	L = 2,320m	(1462+600~1464+920)	6.7
Dredging Creek	L = 3,800m	(1460+500~1464+300)	2.4
(Excluding Engineers' Facilities)		Total	31.2

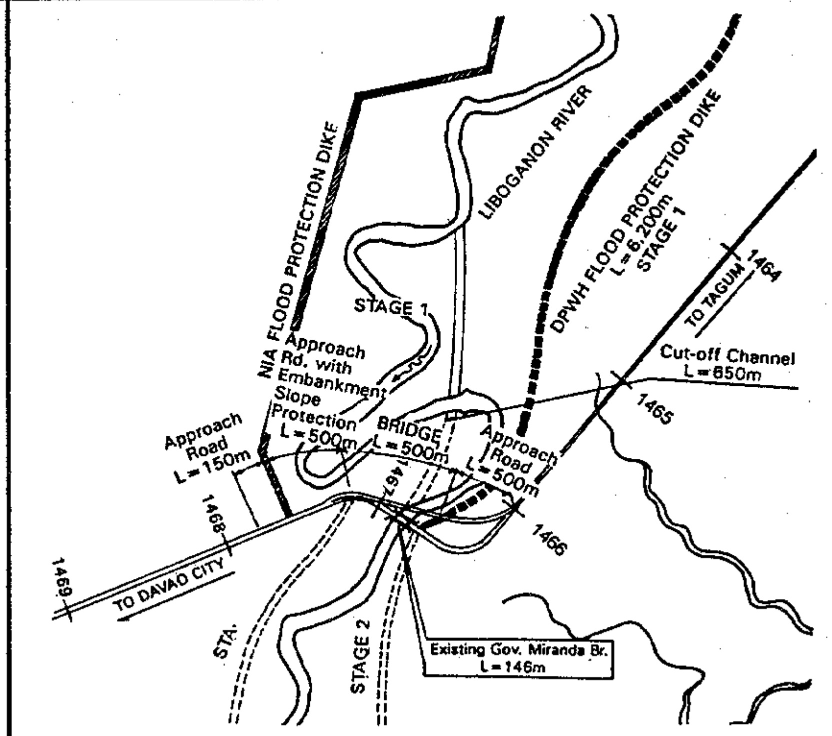


	Evaluation
Road is still flooded: X Cost is not high: O Surrounding area still flooded: X	△

ALTERNATIVE - 2

Countermeasure - 6
Construct flood protection dike along river

		Cost (MP)
Flood protection dike (DPWH upstream)	L = 6,200m	52.3
Flood protection dike (DPWH downstream)	L = 7,300m	43.5
Flood protection dike (NIA downstream)	L = 7,200m	42.0
Bridge	L = 500m	203.1
Approach Road including Embank. Slope Prot.	L = 1,050m	16.7
Cut-off Channel	L = 650m	21.1
(Excluding Engineers' Facilities)	Total	378.7



	Evaluation
Road is not flooded: O Cost is quite high: X Surrounding area is not flooded: O	△

12.2.4 Selected Countermeasures

Based on the above criteria and the result of comparative study, countermeasure on each flood section was determined as shown in Table 12.2-7.

TABLE 12.2-7 SELECTED COUNTERMEASURES (1/2)

FLOOD SECTION	COUNTERMEASURE	SELECTION CRITERIA
1	Countermeasure 3 (Raising the Road)	Severity of flood is A, Roadside development is low.
2	Countermeasure 1 (Protection of the Road)	Severity of flood is B.
3	Countermeasure 6 (Flood protection dike)	Severity of flood is A. Roadside development is medium. Flood around the area is easily controlled by constructing flood protection dike.
4	Countermeasure 4 (Dredging the river), and Embankment protection	No flood so far but road may be washed out by flood water if dredging the river and embankment protection is not carried out.
5	Countermeasure 2 (Flood Interception Canal)	Severity of flood is A. Roadside development is high.
6	Countermeasure 2 (Flood Interception Canal)	Severity of flood is B. Roadside development is high.
7	Countermeasure 1 (Protection of the Road)	Severity of flood is C.
8	Countermeasure 3 (Raising the Road)	Severity of flood is A. Roadside development is low.
9	Countermeasure 3 (Raising the Road)	Severity of flood is A. Roadside development is low.
10	Countermeasure 2 (Flood Interception Canal)	Severity of flood is A. Roadside development is high.
11	Countermeasure 3 (Raising the Road), and Countermeasure 4 (Dredging the River)	Severity of flood is B. Raising the road is proposed to improve local depression of the road surface. Dredging the river is proposed because opening of Jagupit bridge is totally clogged.
12	Countermeasure 4 (Dredging the River)	No flood so far but road may be washed out if dredging of the river is not carried out.
13	Countermeasure 3 (Raising the Road)	Severity of flood is A. Roadside development is medium. Raising the road is proposed based on the comparative study.

TABLE 12.2-7 SELECTED COUNTERMEASURES (2/2)

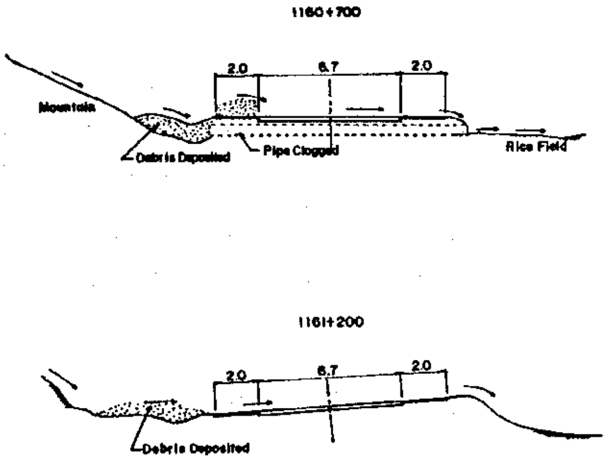
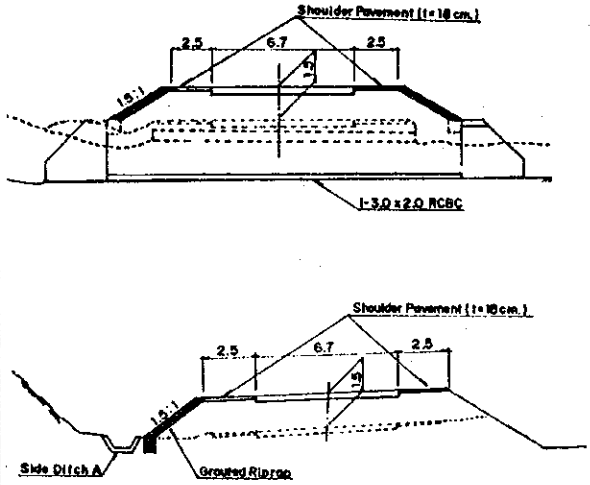
FLOOD SECTION	COUNTERMEASURE	SELECTION CRITERIA
14	Countermeasure 3 (Raising the Road)	Severity of flood is B. Roadside development is medium. Existing condition of PCC pavement is bad. Total reconstruction of PCC pavement by raising the road surface.
15	Countermeasure 3 (Raising the Road), and Countermeasure 4 (River dredging)	Severity of flood is B. Roadsite development is medium. Agay river is heavily silted, it is safe to raise the road to provide against the future aggravation of flooded condition.
16	Countermeasure 3 (Raising the Road)	Severity of flood is A. Roadside development is high. Flood interception canal does not work properly.
17	Construction of Bypass Road	Based on the comparative study, construction of bypass road is proposed to avoid low elevation area.
18	Countermeasure 6 (Flood protection dike), Countermeasure 7 (Cut-off Channel), and Bridge Reconstruction	Based on the comparative study, construction of flood protection dike is proposed.

12.3 PRELIMINARY DESIGN

Preliminary design was carried out adopting the countermeasures selected in Section 12.2. Table 12.3-1 presents summary of preliminary design of each flood section. Detailed description of preliminary design is presented in Appendix 12.1.

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (1/9)

FLOOD SECTION: 1 Location: 1160+700~1161+7000 L = 1,000m

Existing Condition	Proposed Countermeasure
FLOOD TYPE I 	COUNTERMEASURE 3 (Raising the Road) 
Depth : 60cm Duration : 6 hrs. Frequency : 3/year Traffic : Impassable to all vehicles Mud and debris deposit on the road. Existing side canal is buried by debris. Shoulder is scoured at 1161 + 250	Raise the road by 1.5m L = 1,200m (1160+600~1161+800) RCBC 1.30 x 2.0 at 1160.7 RCPC 1.22 dia. 9 Locations Side ditch Type A L = 1,200m Excavation of Creek L = 60m

FLOOD SECTION: 2 Location: 1163+600~1164+100 L = 500m

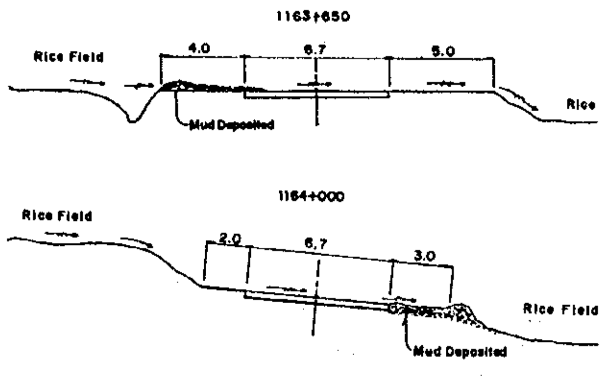
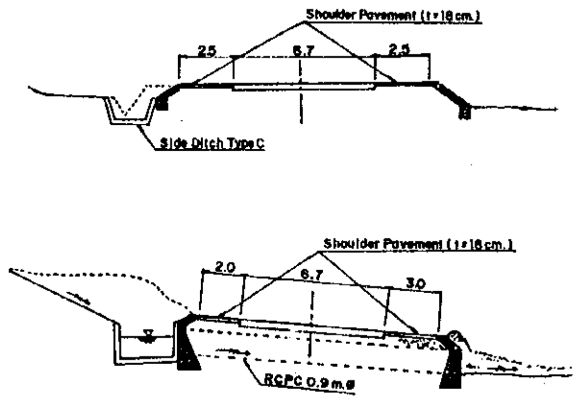
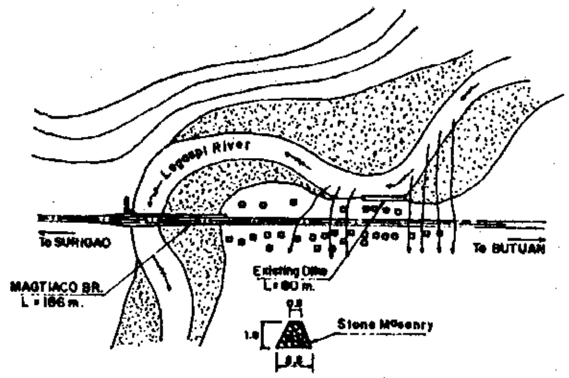
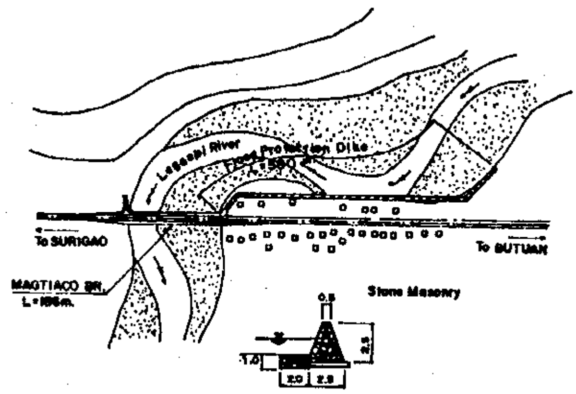
Existing Condition	Proposed Countermeasure
FLOOD TYPE I 	COUNTERMEASURE 2 (Flood Interception Canal) 
Depth : 30cm Duration : 4 hrs. Frequency : 3/year Traffic : Passable to bus & truck Mud deposits on the road surface. Only one cross drainage pipe at 1163+900. Existing earth canal is heavily silted.	Install side ditch Type C L = 590m (1163+510~1164+100) Shoulder pavement L = 500m Riprap protection (both side) L = 500m RCPC 1.22 dia. 4 Locations RCPC 1.91 dia. 1 Location

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (2/9)

FLOOD SECTION: 3 Location: 1164+750~1165+100 L = 350m

Existing Condition	Proposed Countermeasure
FLOOD TYPE III 	COUNTERMEASURE 6 (Flood protection dike) 
Depth : 35cm Duration : 12 hrs. Frequency : 2/year Traffic : Passable to bus & truck Water in Legaspi river overflows to the road during flood. Residential house along the road are also inundated.	Flood protection dike along the river L = 580m H = 2.5m

FLOOD SECTION: 4 Location: 1165+800~1165+880 L = 80m

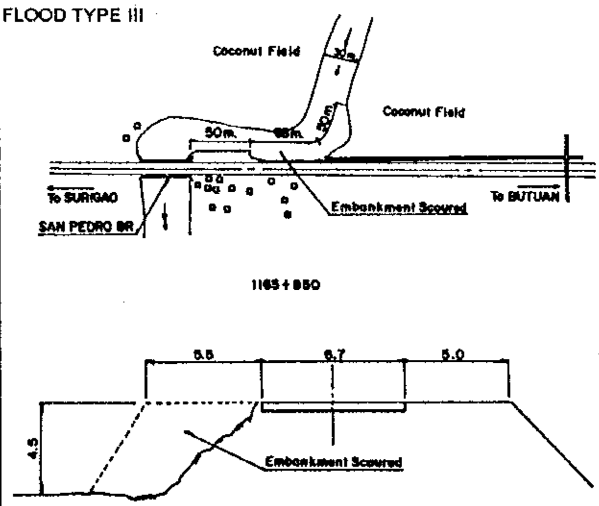
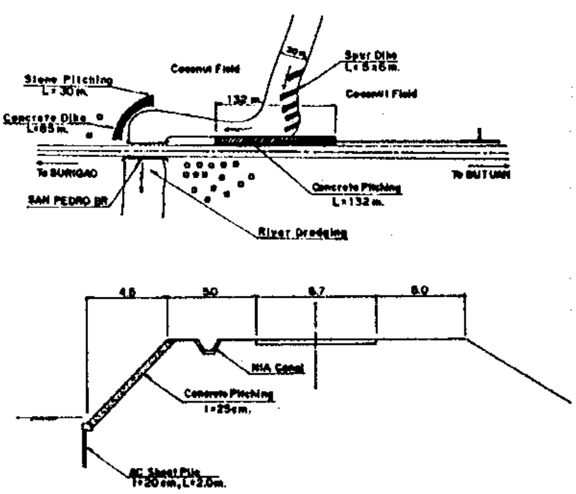
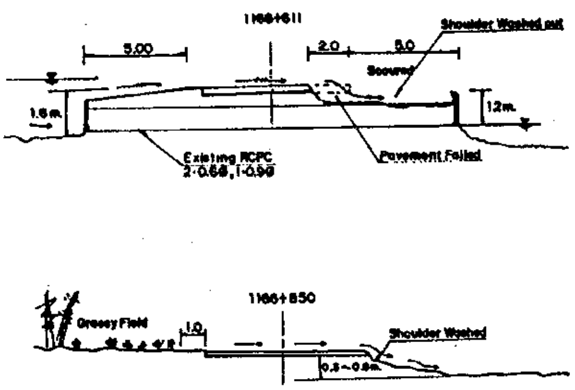
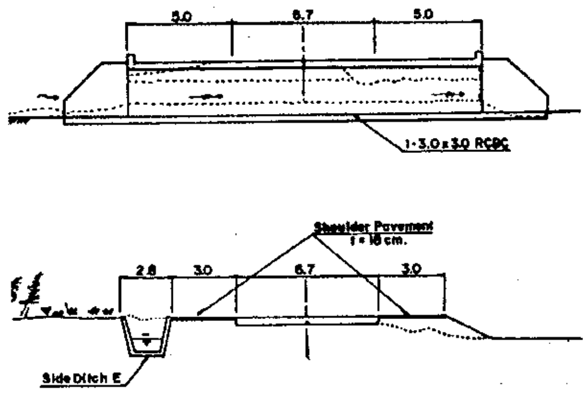
Existing Condition	Proposed Countermeasure
FLOOD TYPE III 	COUNTERMEASURE 4 + EMBANKMENT PROTECTION 
Embankment of bridge approach is scoured by flood water. Clearance below San Pedro bridge is only 1.3m	Dredging San Pedro River L = 400m Concrete pitching and sheet pile L = 132m Spurdike L = 30m Concrete dike L = 85m Stone pitching L = 30m

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (3/9)

FLOOD SECTION: 5 Location: 1166+600~1167+900 L = 1,300m

Existing Condition	Proposed Countermeasure
FLOOD TYPE III 	COUNTERMEASURE 2 (Flood Interception Canal) 
Depth : 50cm Duration : 12 hrs. Frequency : 2/year Traffic : Impassable to all vehicles Overflow of pipe always occurs at 1166+600, 1166+800, 1167+250, and 1167+500. Water spilled out form Legaspi river inundates the area.	Side Ditch Type E L = 1800m (1166+600~1167+900) Shoulder pavement L = 1,400m RCBC 2-3.0 x 2.0 2 Locations RCPC 1.22 dia. 4 Locations

FLOOD SECTION: 6 Location: 1182+100~1182+590 L = 490m

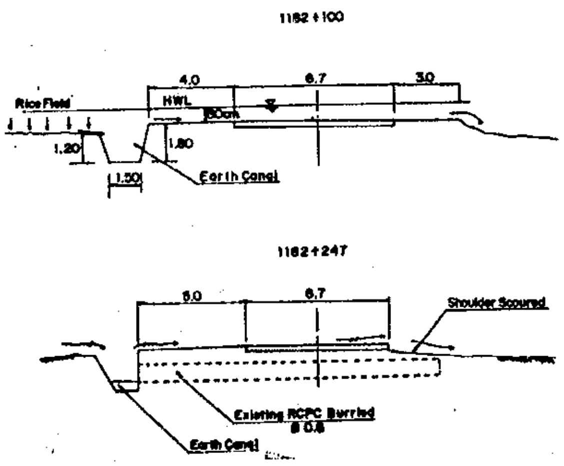
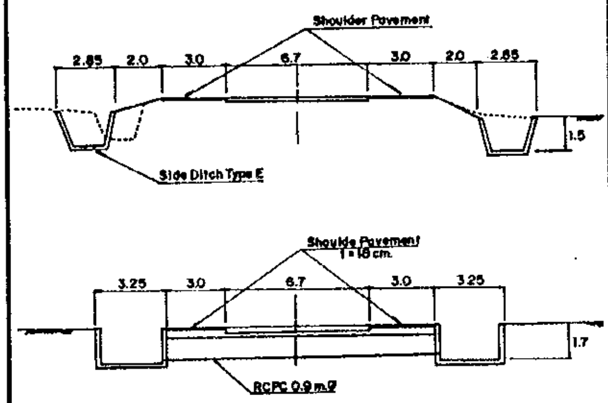
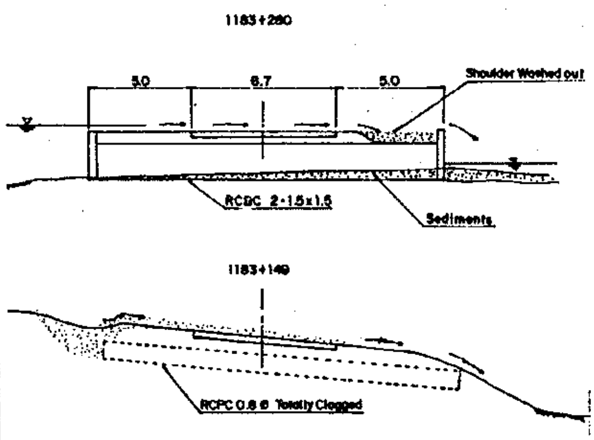
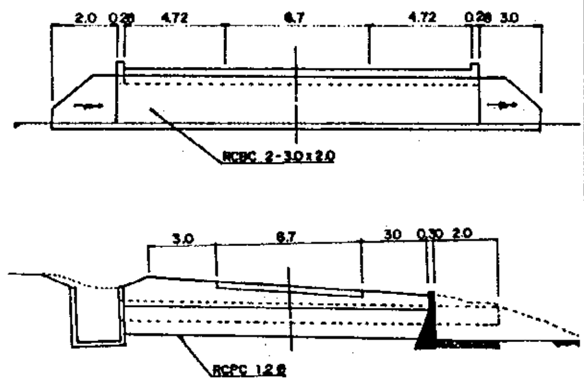
Existing Condition	Proposed Countermeasure
FLOOD TYPE III 	COUNTERMEASURE 2 (Flood Interception Canal) 
Depth : 30cm Duration : 4 hrs. Frequency : 2/year Traffic : Passable to bus & truck Flood water spilled out from Baliguian creek flows over the road. Existing cross drainage pipe are all crammed with clay.	Side Ditch Type E Both side L = 1,240m (1181+920~1182+550) Shoulder pavement L = 490m RCPC 1.07 dia. 5 Locations

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (4/9)

FLOOD SECTION: 7 Location: 1183+100~1183+260 L = 160m

Existing Condition	Proposed Countermeasure
FLOOD TYPE III 	COUNTERMEASURE 1 (Protect the road) 
Depth : 10cm Duration : 3 hrs. Frequency : 1/2 years Traffic : Passable with care Existing RCBC (2-1.5 x 1.5) subsided and overflowed , its shoulder washed out. Mudflow occurs at 1183+100~1183+150	Replace existing RCBC with new 1-3.0x2.0 RCBC. at 1183+240 RCPC 1.07 dia. at 1183+150.

FLOOD SECTION: 8 Location: 1184+250~1183+200 L = 950m

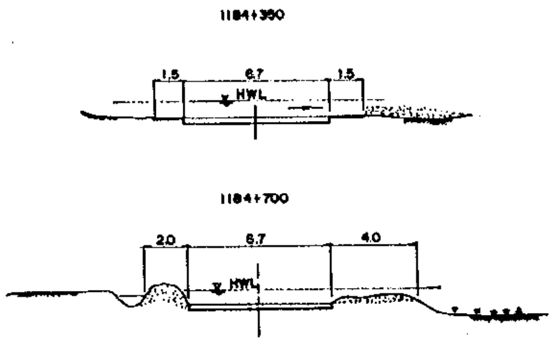
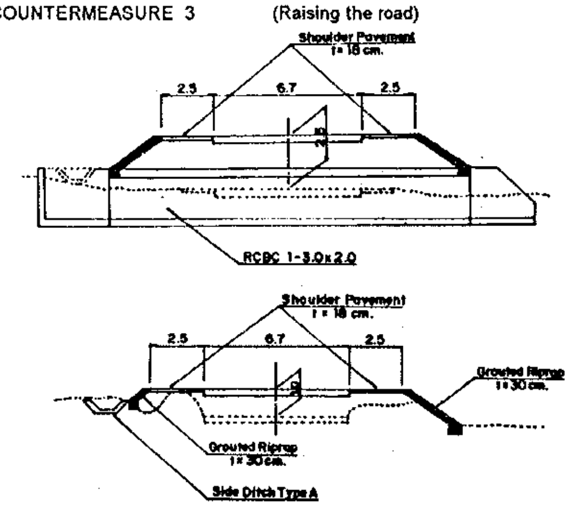
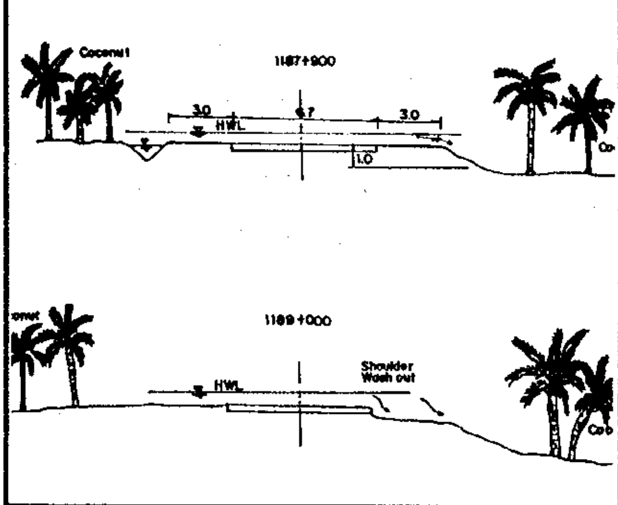
Existing Condition	Proposed Countermeasure
FLOOD TYPE I 	COUNTERMEASURE 3 (Raising the road) 
Depth : 60cm Duration : 6 hrs. Frequency : 2/year Traffic : Impassable to all vehicles Shoulder heavily scoured (both side) at 1184+360~1184+450 L = 90m Mud deposits between 1184+500~800	Raise the Road H = 1.5m L = 1,000m (1184+200~1185+200) Shoulder pavement L = 1,000m Riprap protection of Embankment (Both side) L = 1,000m RCBC 1-3.0 x 3.0 at 1184+300 RCPC 17 Locations Side Ditch type A L = 962m

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (5/9)

FLOOD SECTION: 9 Location: 1187+600~1189+200 L = 1,600m

Existing Condition

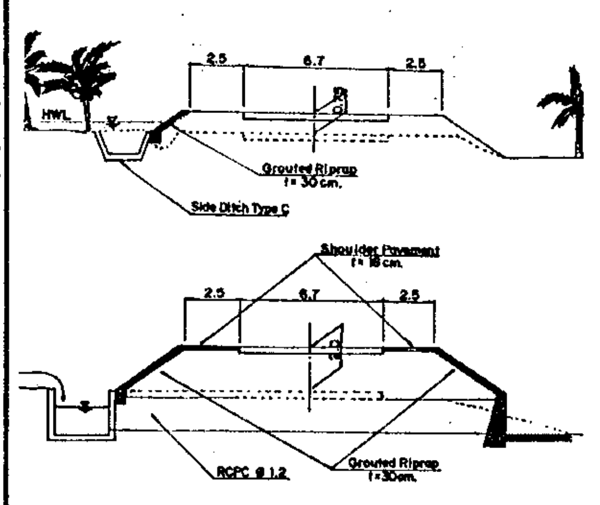
FLOOD TYPE III



Depth : 30cm Duration : 6 hrs.
Frequency : 1/year Traffic : Passable to bus & truck
Flood water in Puyo river spill out to adjacent area.
Frequently driftwood got stuck at Bangonay bridge
and narrowed bridge opening during storm.

Proposed Countermeasure

COUNTERMEASURE 3 (Raising the road)

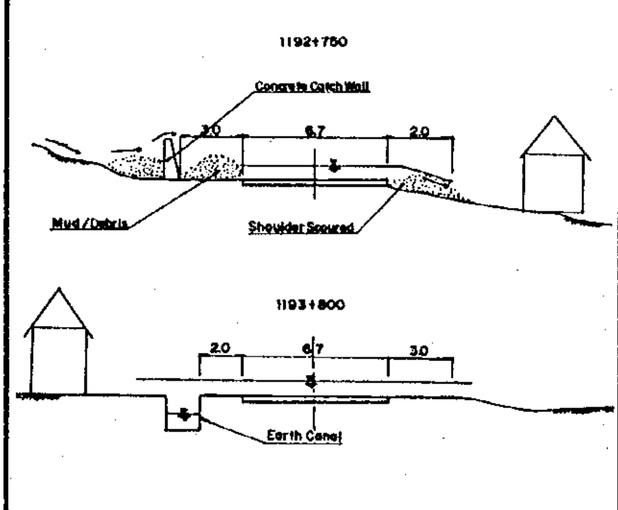


Raise the road by average 1.0m	L = 1,600m (1187+600~1189+200)
Riprap protection (upstream)	L = 1,600m
Side Ditch Type C	L = 1,567m
RCBC 1-3.0 x 2.0	at 1188+037
RCPC 1.22 dia.	12 Locations

FLOOD SECTION: 10 Location: 1192+000~1193+800 L = 1,800m

Existing Condition

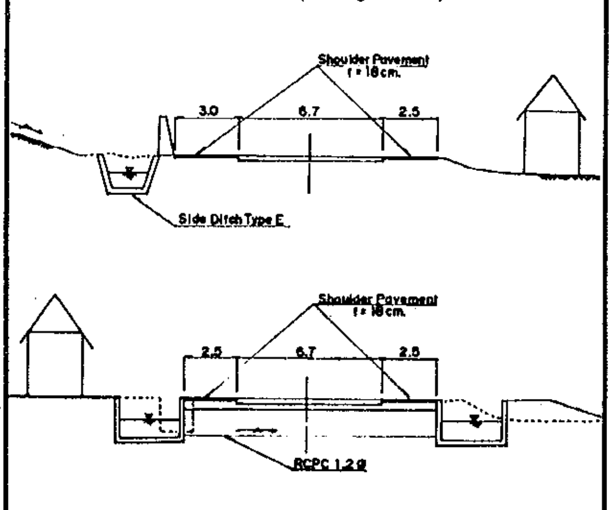
FLOOD TYPE I



Depth : 40cm Duration : 6 hrs.
Frequency : 2/year Traffic : Impassable to all vehicles
Huge amount of mud and debris flows over
the road between 1192+700~900.
Overflow always occur at 1192+700, 1193+100,
and 1193+550.

Proposed Countermeasure

COUNTERMEASURE 3 (Raising the road)



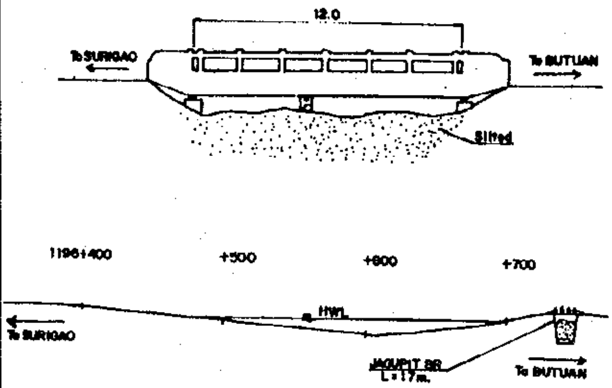
Flood Interception Canal (Type A, C & E)	
L = 2,700m (1191+900~1194+000)	
Shoulder pavement	L = 1,320m
RCPC 1.22 dia.	17 Locations
0.9 dia.	1 Location
Drainage Canal	L = 1,500m

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (6/9)

FLOOD SECTION: 11 Location: 1196+400~1196+720 L = 320m

Existing Condition

FLOOD TYPE III

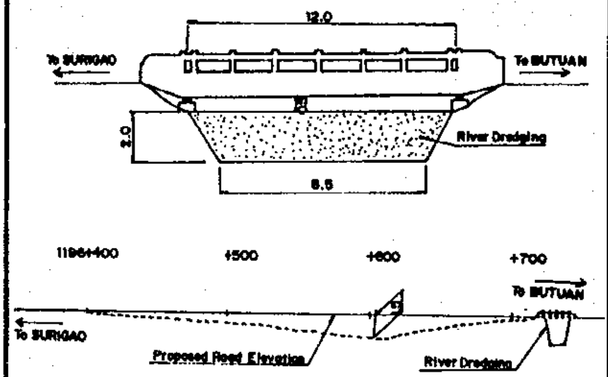


Depth	: 30cm	Duration	: 4 hrs.
Frequency	: 3/year	Traffic	: Close to passenger car

Jagupit river is heavily silted.
No clearance below Jagupit bridge.
Water of the river spills out to the adjacent area.

Proposed Countermeasure

COUNTERMEASURE 3 & 4 (Raising the road and dredging the river)

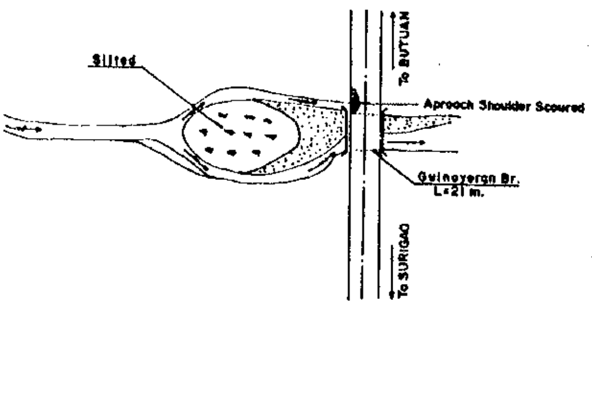


Raise the Road by 1.5m max.	L = 320m (1196 + 400 ~ 720)
Dredge Jagupit River	L = 2,260m
Construct Sabo dam	1 Location

FLOOD SECTION: 12 Location: 1197+556

Existing Condition

FLOOD TYPE III

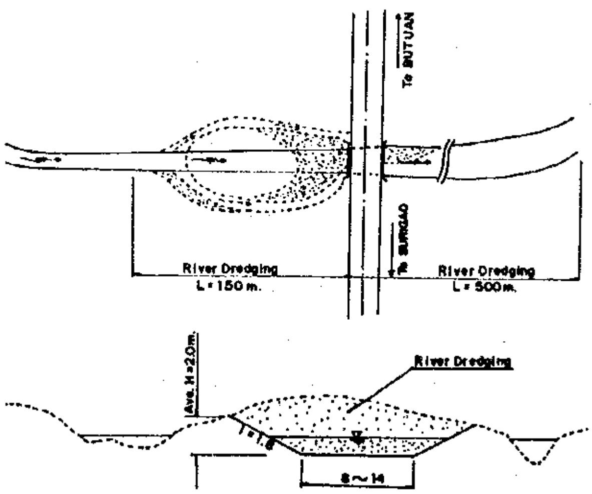


Embankment of the bridge approach scoured.	L = 15m
Pavement is destroyed (one lane)	L = 10m

River is silted and its waterway is distorted left and right.

Proposed Countermeasure

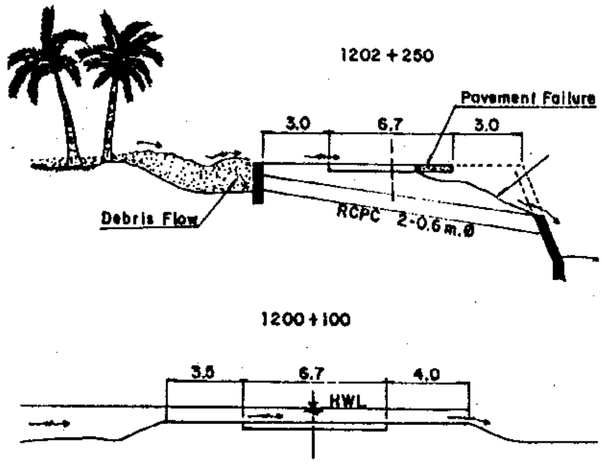
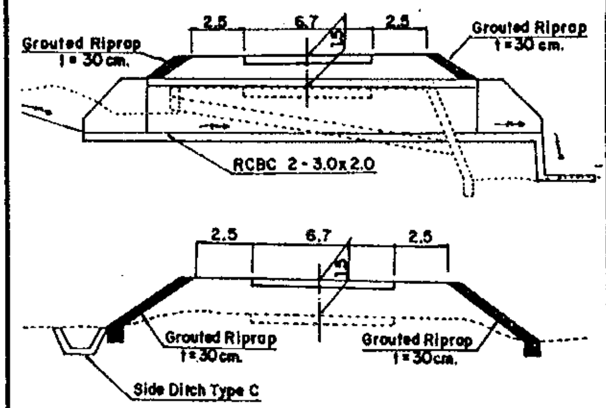
COUNTERMEASURE 4 (Dredging the river)



Dredge Guinoyoran River	L = 150m upstream
	L = 500m downstream

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (7/9)

FLOOD SECTION: 13 Location: 1199+600~1203+870 L = 4,270m

Existing Condition	Proposed Countermeasure
FLOOD TYPE III	COUNTERMEASURE 3 (Raising the road)
	
Depth : 40cm Duration : 6 hrs. Frequency : 2/year Traffic : Impassable to all vehicle Overflow from Kinahiloan river and Minuswag river. Road washed out at 1200+000, 1202+250 and 1203+250.	Raise the Road by ave. 1.5m L = 4,300m (1199+500~1203+900) Slope protection with grouted riprap L = 4,300m RCBC 2-3.0 x 2.0 4 Locations RCPC 2-1.22 dia. 5 Locations Side Ditch Type C 4,271m

FLOOD SECTION: 14 Location: 1219+700~1220+100 L = 400m

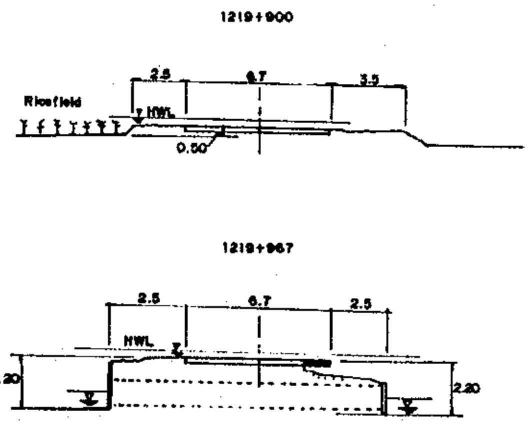
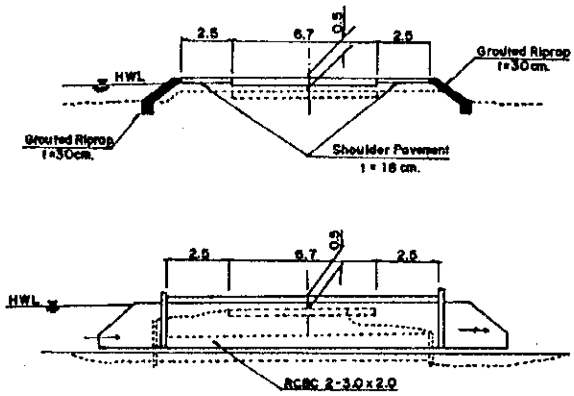
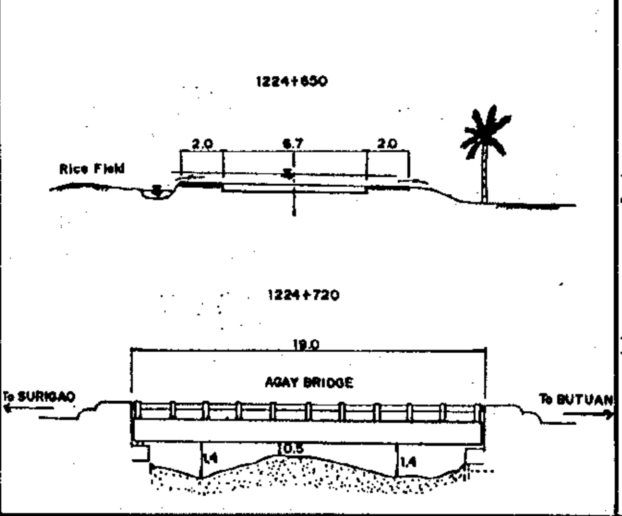
Existing Condition	Proposed Countermeasure
FLOOD TYPE II	COUNTERMEASURE 3 (Raising the road)
	
Depth : 15cm Duration : 6 hrs. Frequency : 3/year Traffic : Passable with care Box and pipe culverts are frequently overflowed. Shoulder washed out, pavement collapsed at 1219+967.	Raise the Road by 50cm L = 400m (1219+700~1220+100) Shoulder pavement L = 400m Slope protection with riprap L = 400m RCBC 2-3.0 x 2.0 at 1219+967

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (8/9)

FLOOD SECTION: 15 Location: 1224+200~1224+640 L = 440m

Existing Condition

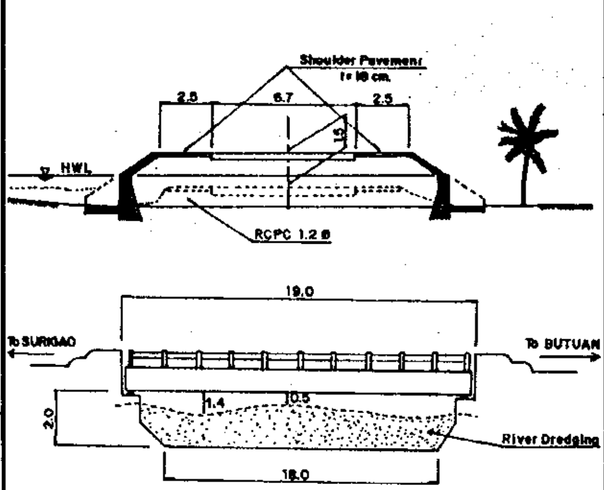
FLOOD TYPE II



Depth : 40cm Duration : 10 hrs.
Frequency : 2/year Traffic : Close to passenger car
Agay river is heavily silted, overflow from Agay river always occur.

Proposed Countermeasure

COUNTERMEASURE 3 (Raising the road)

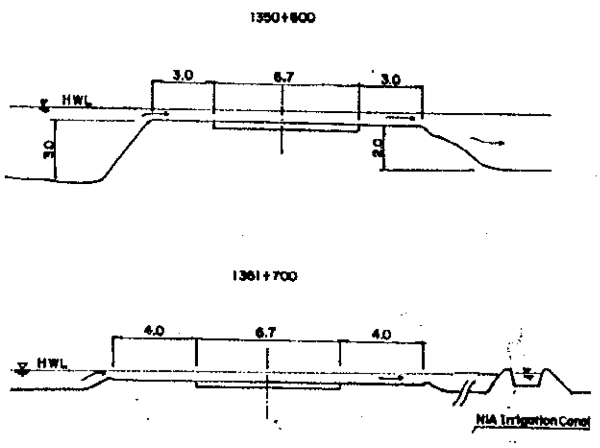


Raise the Road by 1.5m. max. L = 1,450m (1224+000~1225+470)
Dredge Agay River L = 500m
RCPC 1.22 dia. 2 Locations

FLOOD SECTION: 16 Location: 1355+200~1364+200 L = 9,000m

Existing Condition

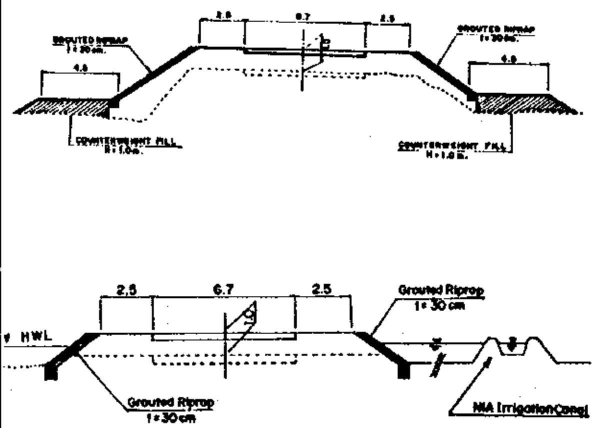
FLOOD TYPE III



Depth : 60cm Duration : 48 hrs.
Frequency : 1/5 yrs. Traffic : Impassable to all vehicles
Overflow from Simulao river.
Flood water is blocked by NIA irrigation dike.

Proposed Countermeasure

COUNTERMEASURE 3 (Raising the road)



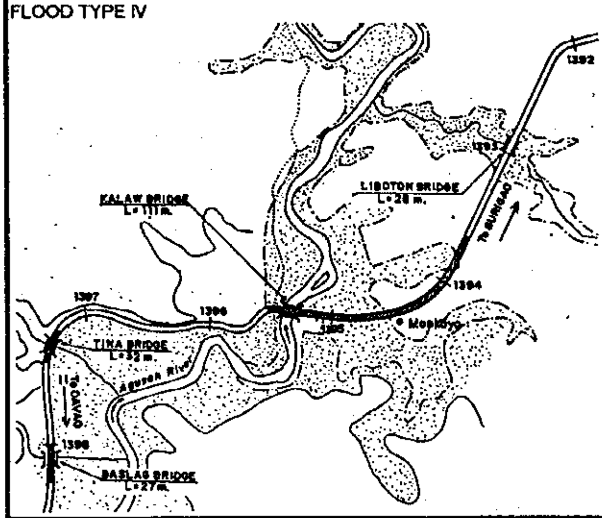
Raise the Road by 1.0m. L = 9,000m (1335+200~1364+200)
Embankment protection with riprap (Both side)
L = 9,000m
RCBC 2-3.0 x 3.0 at 1356+450
RCPC 0.9 dia., 1.22 dia., 1.52 dia. 62 Locations

TABLE 12.3-1 SUMMARY OF PRELIMINARY DESIGN (9/9)

FLOOD SECTION: 17 Location: 1393+400~1398+300 L = 2,400m

Existing Condition

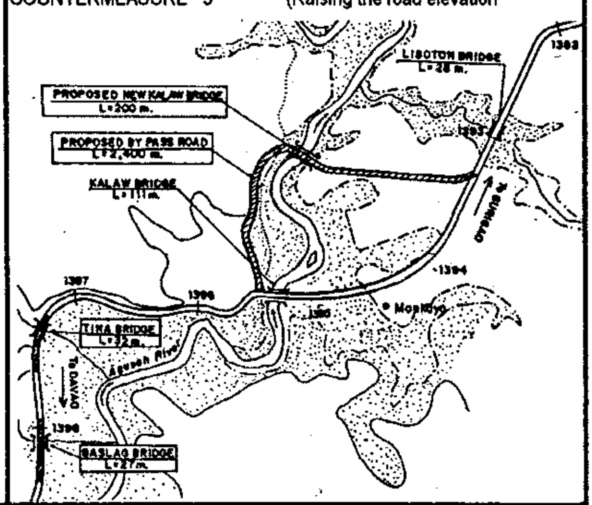
FLOOD TYPE IV



Depth : 2.0m Duration : 3 days
Frequency : 1/5 years Traffic : Impassable to all vehicles
Overflow from Agusan river.
Monkayo town proper totally submerged under flood water.

Proposed Countermeasure

COUNTERMEASURE 3 (Raising the road elevation

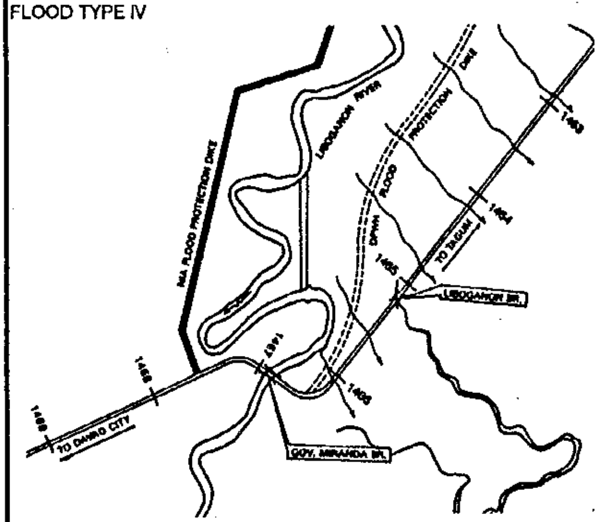


Construction of bypass road L = 2,200m
Construction of new Kalaw Bridge L = 200m
Raising the road L = 850m
Raising Tina Bridge L = 32m
Raising Banlag Bridge L = 27m

FLOOD SECTION: 18 Location: 1460+500~1468+000 L = 7,500m

Existing Condition

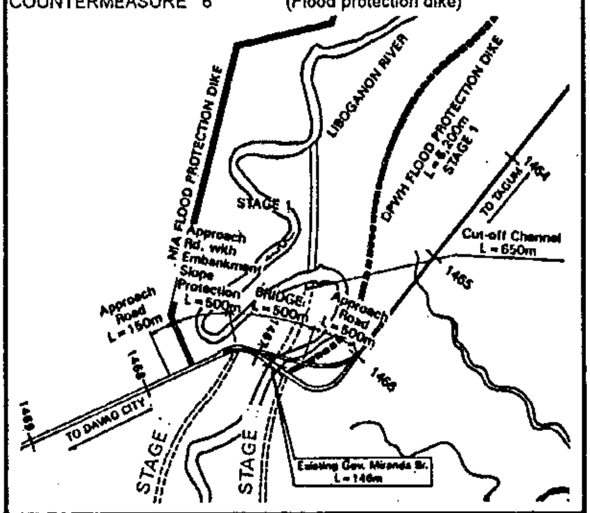
FLOOD TYPE IV



Depth : 60cm Duration : 24 hrs.
Frequency : 1/year Traffic : Impassable to all vehicles
Overflow from Liboganon river.
Shoulder severely scoured for 1,600m.

Proposed Countermeasure

COUNTERMEASURE 6 (Flood protection dike)



Stage I
- Flood protection dike (DPWH) L = 6,200m
- Bridge L = 500m
- Cut-off Channel L = 650m
- Approach Road Including Embankment slope protection L = 1,050m

Stage II
- Flood protection dike (Downstream) L = 14,500m

CHAPTER 13

DISTRIBUTION OF PROPOSED WORKS

13.1 DISTRIBUTION OF PROPOSED WORKS

A summary of proposed works is presented in Table 13.1-1. The project will rehabilitate/improve 54% of pavement, 59% of shoulder, 71% of bridges, 80% of failed/potential slopes and 100% of flood sections. Drainage system will be greatly improved with replacement of and additional side ditches, pipe culverts and box culverts.

Traffic safety facilities such as guard rails, pavement markings, regulatory/prohibitory signs, warning signs, informatory signs, etc. will be included in the Project.

Table 13.1-2 shows proposed works by province/city and Table 13.1-3 shows the same by road link.

TABLE 13.1-1 SUMMARY OF PROPOSED WORKS

	Existing (A)	Proposed Work (B)	B/A x 100
Pavement	398.1 km	213.9 km	54%
Shoulder	796.2 km	470.5 km	59%
Drainage			
- Side Ditch	71.0 km	148.2 km	-
- Subsurface	-	8.0 km	-
- RCPC	991	968	-
- RCBC	187	84	-
Bridges	125	89	71%
Failed/potential slopes	95	76	80%
Flood Sections	18	18	100%

TABLE 13.1-2 SUMMARY OF PROPOSED WORKS BY PROVINCE/CITY

Type of Work				Surigao del Norte (54.29 km)	Agusan del Norte (54.42 km)	Butuan City (18.90 km)	Agusan del Sur (136.45 km)	Davao del Norte (106.38 km)	Davao City (32.92 km)	Total (403.36 km)
Roadway Rehabilitation Works	Pavement Rehabilitation Works	1. PCC Reconstruction	(km)	6.66	14.18	3.60	57.42	25.50	-	107.36
		2. AC Overlay	(km)	-	-	-	53.10	41.75	-	94.85
		3. AC Reconstruction	(km)	-	-	-	10.67	1.00	-	11.67
		Total	(km)	6.66	14.18	3.60	121.19	68.25	-	213.88
	Shoulder Improvement Works	1. Gravel	(km)	10.22	22.86	4.80	187.80	104.55	-	330.23
		2. PCC	(km)	5.10	11.90	2.40	36.65	17.30	30.10	103.45
		3. AC	(km)	-	-	-	19.55	17.25	-	36.80
		Total	(km)	15.32	34.76	7.20	244.00	139.10	30.10	470.48
	Drainage Improvement Works	1. Side Ditch	(km)	3.50	11.00	-	62.66	41.11	29.89	148.16
		2. Subsurface	(km)	-	2.00	-	3.00	3.00	-	8.00
		3. RCPC Replacement	(ea.)	61	58	26	212	144	28	529
		4. Additional RCPC	(ea.)	11	42	6	176	122	82	439
		5. RCBC Replacement	(ea.)	1	15	5	39	14	-	74
		6. Additional RCBC	(ea.)	-	-	-	-	10	-	10
Bridge Rehabilitation Works		1. Total Reconstruction	(No.)	-	1	-	2	5	-	8
		2. Partial Reconstruction	(No.)	2	5	4	15	3	1	30
		3. Widening	(No.)	-	1	-	1	1	1	4
		4. Other Rehabilitation	(No.)	9	12	2	13	6	2	44
		5. Aseismatic Protection only	(No.)	-	1	-	-	2	-	3
		Total	(No.)	11	20	6	31	17	4	89
Slope Protection Works		1. Cut Slope Failure	(No.)	4	3	1	-	-	-	8
		2. Embankment Slope Failure	(No.)	3	3	4	38	13	-	61
		3. Debris Flow	(No.)	-	4	-	1	-	-	5
		4. Landslide	(No.)	-	-	-	2	-	-	2
		Total	(No.)	7	10	5	41	13	-	76
Countermeasure Works against Flood		1. Protection of Road	(Section)	1	1	-	-	-	-	2
		2. Flood Interception Canal	(Section)	1	2	-	-	-	-	3
		3. Raising of Road	(Section)	1	5	1	1	-	-	8
		4. Riverbed Dredging	(Section)	1	1	-	-	-	-	2
		5. Sabo Dam	(Section)	-	-	-	-	-	-	-
		6. Flood Protection Dike	(Section)	1	-	-	-	1	-	2
		7. Cut-off Channel	(Section)	-	-	-	-	-	-	-
		8. Bypass Road	(Section)	-	-	-	-	1	-	1
		Total	(Section)	5	9	1	1	2	-	18

TABLE 13.1-3 PROPOSED WORKS BY ROAD LINK (1/3)

Province / City	Link No.	Link Length (km)	Pavement Rehabilitation: PCC Recons-truction (km)	Pavement Rehabilitation: AC Overlay (km)	Pavement Rehabilitation: AC Recons-truction (km)	Pavement Rehabilitation: Total (km)	Shoulder Improvement: Gravel Shoulder (km)	Shoulder Improvement: PCC Shoulder (km)	Shoulder Improvement: AC Shoulder (km)	Shoulder Improvement: Total (km)	Drainage Improvement: Side Ditch (km)	Drainage Improvement: Subsurface Drainage (km)	Drainage Improvement: RCPC Replace-ment (ea.)	Drainage Improvement: Additional RCPC (ea.)	Drainage Improvement: RCBC Replace-ment (ea.)	Drainage Improvement: Additional RCBC (ea.)
Surigao del Norte	01	8.76	-	-	-	-	-	-	-	-	1.90	-	17	6	-	-
	02	24.02	4.27	-	-	4.27	7.54	-	-	7.54	1.60	-	21	5	-	-
	03	21.51	2.39	-	-	2.39	2.68	5.10	-	7.78	-	-	23	-	1	-
	Sub-Total	54.29	6.66			6.66	10.22	5.10		15.32	3.50		61	11	1	
Agusan del Norte	04 -1	22.36	9.44	-	-	9.44	14.38	8.70	-	23.08	11.00	2.00	24	36	4	-
	04 -2	20.86	2.21	-	-	2.21	4.42	-	-	4.42	-	-	24	-	5	-
	05	11.20	2.53	-	-	2.53	4.06	3.20	-	7.26	-	-	10	6	6	-
	Sub-Total	54.42	14.18			14.18	22.86	11.90		34.76	11.00	2.00	58	42	15	
Butuan City	06	10.93	-	-	-	-	-	-	-	-	-	-	18	-	4	-
	07	7.97	3.60	-	-	3.60	4.80	2.40	-	7.20	-	-	8	6	1	-
	Sub-Total	18.90	3.60			3.60	4.80	2.40		7.20			26	6	5	
Agusan del Sur	08 -1	13.27	12.98	-	-	12.98	16.76	9.20	-	25.96	13.50	3.00	32	45	4	-
	08 -2	15.05	10.50	-	-	10.50	17.30	5.40	-	22.70	2.70	-	22	9	2	-
	09	24.43	17.21	6.96	-	24.17	31.29	14.85	2.20	48.34	21.40	-	26	38	4	-
	10 -1	13.86	2.18	10.06	1.20	13.44	23.38	1.60	1.90	26.88	3.00	-	19	10	5	-
	10 -2	16.83	-	14.28	2.38	16.66	26.89	-	6.35	33.24	3.05	-	24	10	6	-
	11	25.59	-	18.77	6.59	25.36	43.42	-	7.30	50.72	10.71	-	49	36	11	-
	12 -1	14.78	2.06	3.03	0.50	5.59	9.38	-	1.80	11.18	3.00	-	10	10	2	-
	12 -2	12.64	12.49	-	-	12.49	19.38	5.60	-	24.98	5.30	-	30	18	5	-
	Sub-Total	136.45	57.42	53.10	10.67	121.19	187.80	36.65	19.55	244.00	62.66	3.00	212	176	39	
Davao del Norte	13	18.45	18.40	-	-	18.40	28.10	7.10	-	35.20	12.00	2.00	23	40	4	6
	14	29.50	-	16.18	0.40	16.58	33.16	-	-	33.16	11.16	-	55	37	10	2
	15	31.39	-	25.57	0.60	26.17	35.09	2.80	17.25	55.14	17.95	1.00	31	45	-	2
	16 -1	9.49	2.30	-	-	2.30	-	6.00	-	6.00	-	-	16	-	-	-
	16 -2	2.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	16 -3	15.04	4.80	-	-	4.80	8.20	1.40	-	9.60	-	-	19	-	-	-
	Sub-Total	106.38	25.50	41.75	1.00	68.25	104.55	17.30	17.25	139.10	41.11	3.00	144	122	14	10
Davao City	17	14.67	-	-	-	-	-	13.40	-	13.40	8.02	-	10	27	-	-
	18	18.25	-	-	-	-	-	16.70	-	16.70	21.87	-	18	55	-	-
	Sub-Total	32.92						30.10		30.10	29.89		28	82		
TOTAL		403.36	107.36	94.85	11.67	213.88	330.23	103.45	36.80	470.48	148.16	8.00	529	439	74	10

TABLE 13.1-3 PROPOSED WORKS BY ROAD LINK (2/3)

Province / City	Link No.	Link Length (km)	Bridge Rehabilitation Works (No. of Bridges)						Slope Protection Works (No. of Slopes)				
			Total Recon-struction	Partial Recon-struction	Widening	Other Rehabili-tation	Aseismatic Protection Only	Total	Cut Slope Failure	Embankment Slope Failure	Debris Flow	Landslide	Total
Surigao del Norte	01	8.76	-	-	-	3	-	3	3	1	-	-	4
	02	24.02	-	-	-	1	-	1	1	2	-	-	3
	03	21.51	-	2	-	5	-	7	-	-	-	-	-
	Sub-Total	54.29	-	2	-	9	-	11	4	3	-	-	7
Agusan del Norte	04 -1	22.36	-	2	-	5	1	8	3	3	4	-	10
	04 -2	20.86	-	2	-	5	-	7	-	-	-	-	-
	05	11.20	1	1	1	2	-	5	-	-	-	-	-
	Sub-Total	54.42	1	5	1	12	1	20	3	3	4	-	10
Butuan City	06	10.93	-	4	-	2	-	6	-	-	-	-	-
	07	7.97	-	-	-	-	-	-	1	4	-	-	5
	Sub-Total	18.90	-	4	-	2	-	6	1	4	-	-	5
Agusan del Sur	08 -1	13.27	-	1	-	-	-	1	-	9	1	2	12
	08 -2	15.05	-	3	-	2	-	5	-	-	-	-	-
	09	24.43	-	7	1	1	-	9	-	16	-	-	16
	10 -1	13.86	-	2	-	1	-	3	-	2	-	-	2
	10 -2	16.83	2	1	-	2	-	5	-	5	-	-	5
	11	25.59	-	1	-	4	-	5	-	1	-	-	1
	12 -1	14.78	-	-	-	2	-	2	-	4	-	-	4
	12 -2	12.64	-	-	-	1	-	1	-	1	-	-	1
	Sub-Total	136.45	2	15	1	13	-	31	-	38	1	2	41
Davao del Norte	13	18.45	1	1	-	1	1	4	-	3	-	-	3
	14	29.50	2	-	1	2	-	5	-	4	-	-	4
	15	31.39	-	1	-	2	-	3	-	4	-	-	4
	16 -1	9.49	1	-	-	-	-	1	-	-	-	-	-
	16 -2	2.51	1	-	-	-	-	1	-	2	-	-	2
	16 -3	15.04	-	1	-	1	1	3	-	-	-	-	-
	Sub-Total	106.38	5	3	1	6	2	17	-	13	-	-	13
Davao City	17	14.67	-	1	1	-	-	2	-	-	-	-	-
	18	18.25	-	-	-	2	-	2	-	-	-	-	-
	Sub-Total	32.92	-	1	1	2	-	4	-	-	-	-	-
TOTAL		403.36	8	30	4	44	3	89	8	61	5	2	76

TABLE 13.1-3 PROPOSED WORKS BY ROAD LINK (3/3)

Province / City	Link No.	Link Length (km)	Countermeasure Works Against Flood (No. of Sections and Km)								
			Protection of Road	Flood Interception Canal	Raising of Road	Riverbed Dredging	Sabo Dam	Flood Protection Dike	Cut-off Channel	Bypass Road	Total
Surigao del Norte	01	8.76	-	-	-	-	-	-	-	-	-
	02	24.02	-	-	-	-	-	-	-	-	-
	03	21.51	1 (0.50)	1 (1.30)	1 (1.00)	1 (0.08)	-	1 (0.35)	-	-	5 (3.23)
	Sub-Total	54.29	1 (0.50)	1 (1.30)	1 (1.00)	1 (0.08)	-	1 (0.35)			5 (3.23)
Agusan del Norte	04 -1	22.36	1 (0.16)	1 (0.49)	2 (2.55)	-	-	-	-	-	4 (3.20)
	04 -2	20.86	-	1 (1.80)	2 (4.59)	1 (0.02)	-	-	-	-	4 (6.41)
	05	11.20	-	-	1 (0.40)	-	-	-	-	-	1 (0.40)
	Sub-Total	54.42	1 (0.16)	2 (2.29)	5 (7.54)	1 (0.02)	-		-		9 (10.01)
Butuan City	06	10.93	-	-	1 (0.44)	-	-	-	-	-	1 (0.44)
	07	7.97	-	-	-	-	-	-	-	-	-
	Sub-Total	18.90	-	-	1 (0.44)	-	-		-		1 (0.44)
Agusan del Sur	08 -1	13.27	-	-	-	-	-	-	-	-	-
	08 -2	15.05	-	-	-	-	-	-	-	-	-
	09	24.43	-	-	-	-	-	-	-	-	-
	10 -1	13.86	-	-	-	-	-	-	-	-	-
	10 -2	16.83	-	-	-	-	-	-	-	-	-
	11	25.59	-	-	-	-	-	-	-	-	-
	12 -1	14.78	-	-	1 (9.00)	-	-	-	-	-	1 (9.00)
	12 -2	12.64	-	-	-	-	-	-	-	-	-
	Sub-Total	136.45	-	-	1 (9.00)	-	-	-	-	-	1 (9.00)
Davao del Norte	13	18.45	-	-	-	-	-	-	-	1 (2.40)	1 (2.40)
	14	29.50	-	-	-	-	-	-	-	-	-
	15	31.39	-	-	-	-	-	-	-	-	-
	16 -1	9.49	-	-	-	-	-	(5.00)	-	-	(5.00)
	16 -2	2.51	-	-	-	-	-	1 (2.50)	-	-	1 (2.50)
	16 -3	15.04	-	-	-	-	-	-	-	-	-
	Sub-Total	106.38	-	-	-	-	-	1 (7.50)	-	1 (2.40)	2 (9.90)
Davao City	17	14.67	-	-	-	-	-	-	-	-	-
	18	18.25	-	-	-	-	-	-	-	-	-
	Sub-Total	32.92	-	-	-	-	-	-	-	-	-
TOTAL		403.36	2 (0.66)	3 (3.59)	8 (17.98)	2 (0.10)	-	2 (7.85)	-	1 (2.40)	18 (32.58)

13.2 LOCATION OF PROPOSED WORKS

Locations of proposed works are presented in Figure 13.2-1.

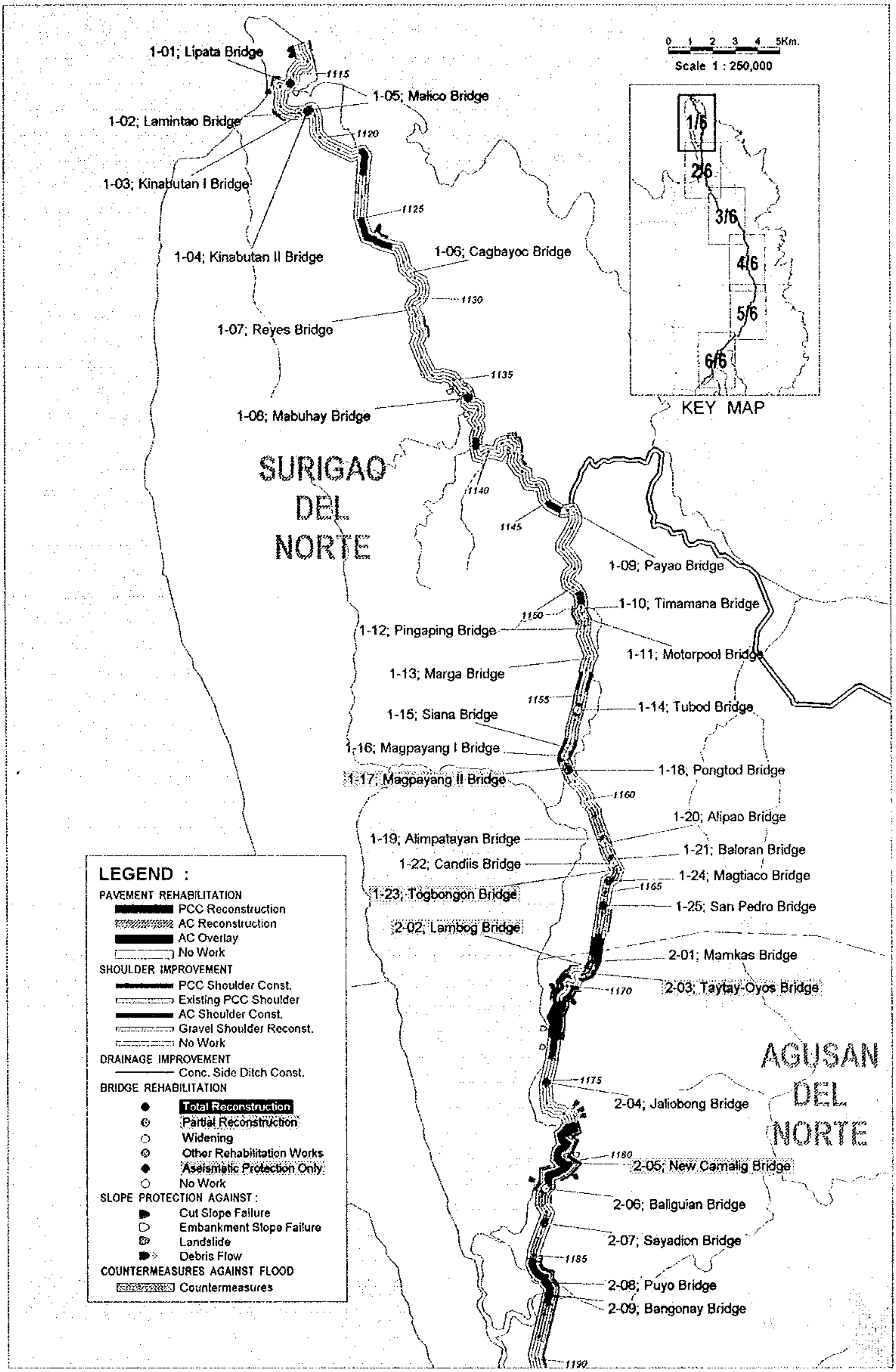


FIGURE 13.2 - 1 PROPOSED REHABILITATION WORKS (1/6)

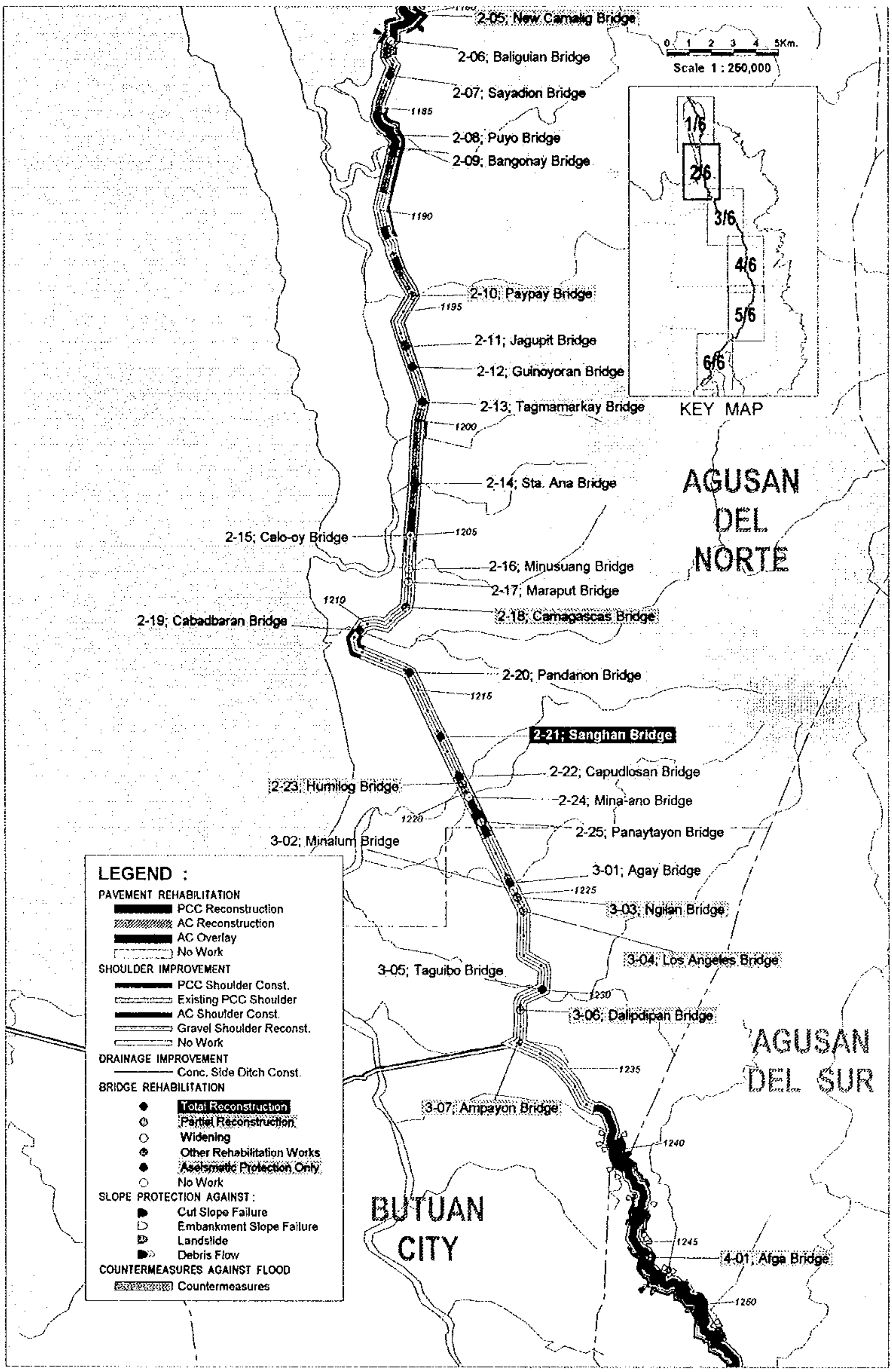


FIGURE 13.2 - 1 PROPOSED REHABILITATION WORKS (2/6)

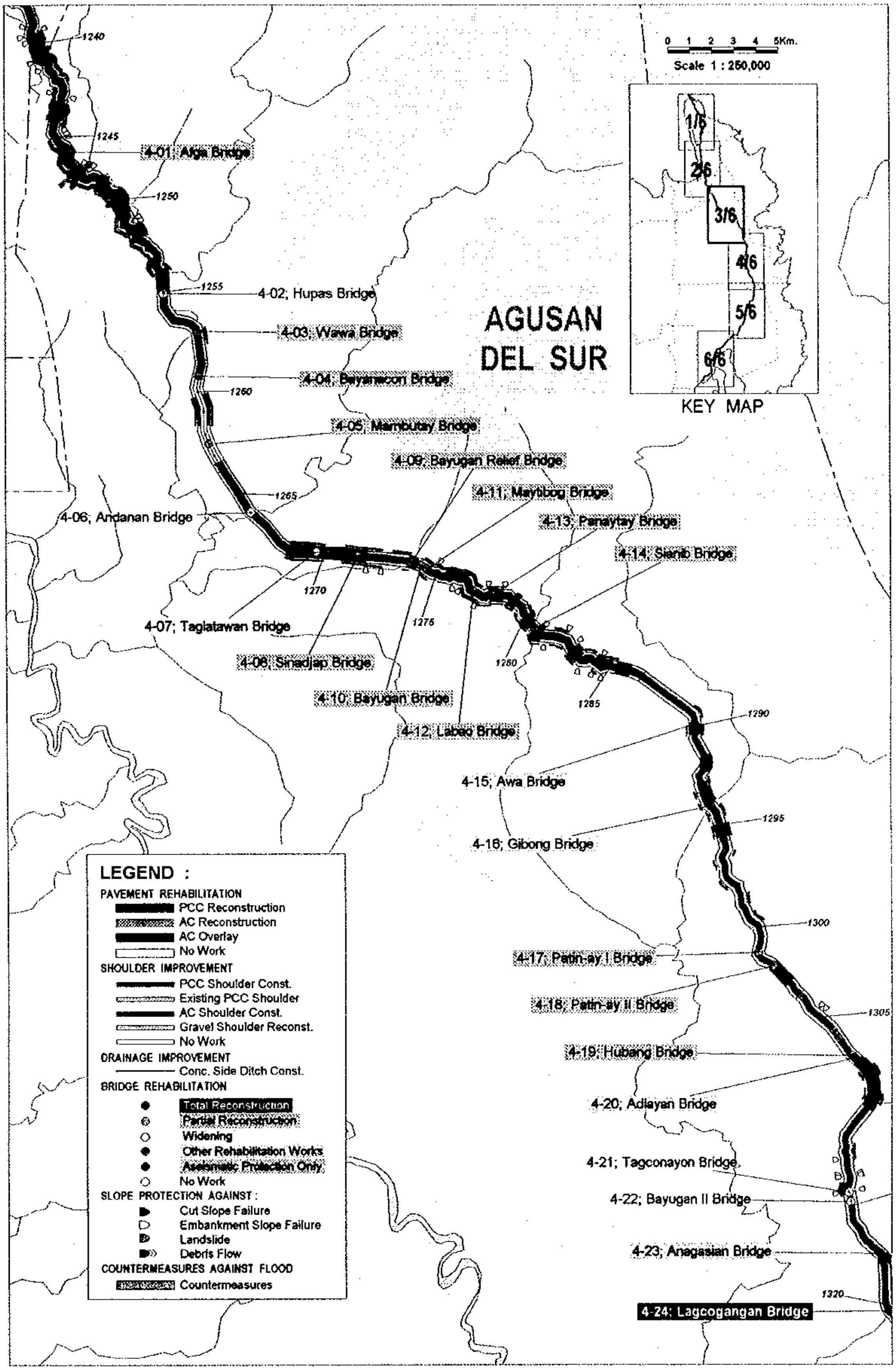


FIGURE 13.2 - 1 PROPOSED REHABILITATION WORKS (3/6)

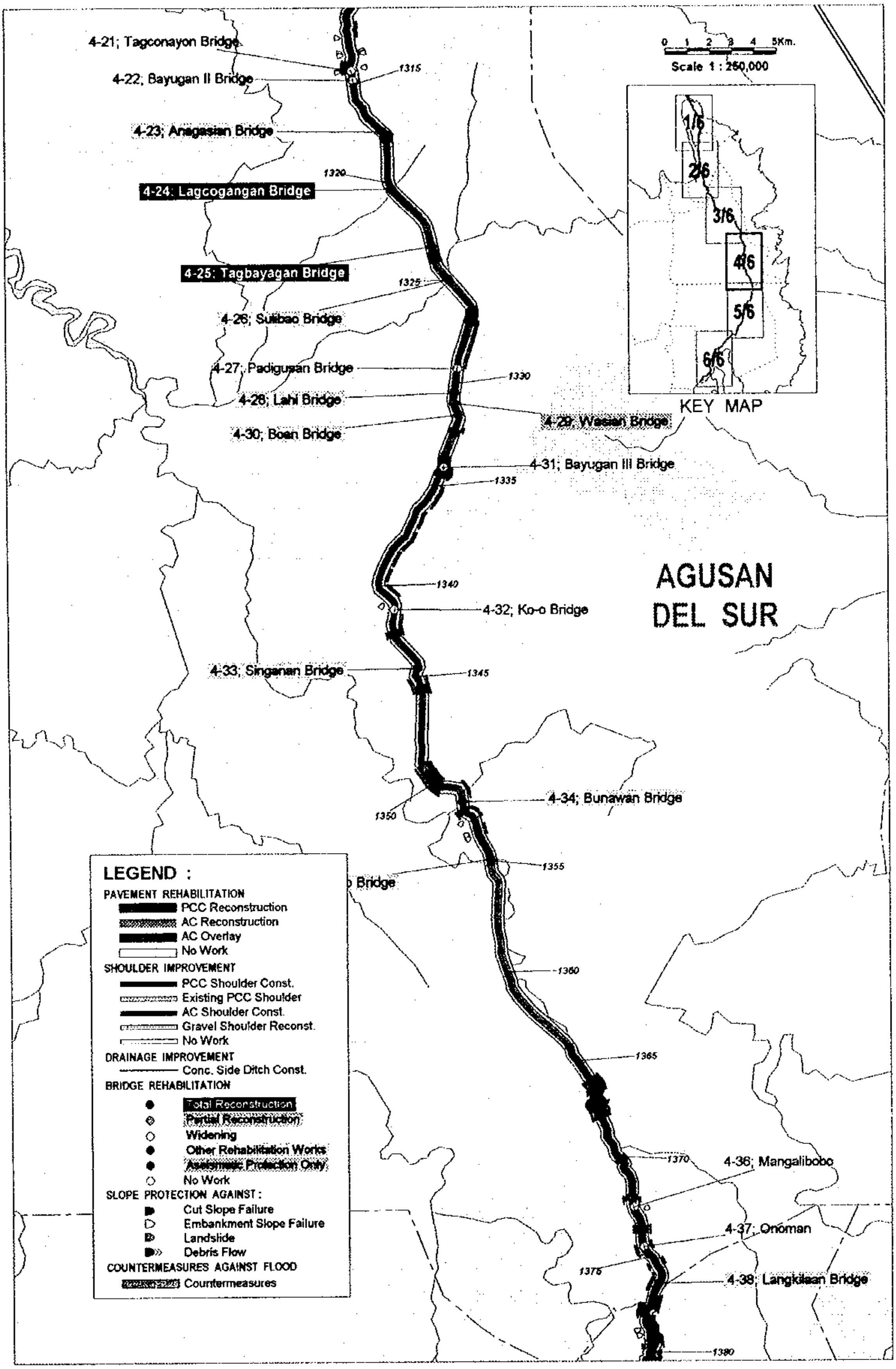


FIGURE 13.2 - 1 PROPOSED REHABILITATION WORKS (4/6)

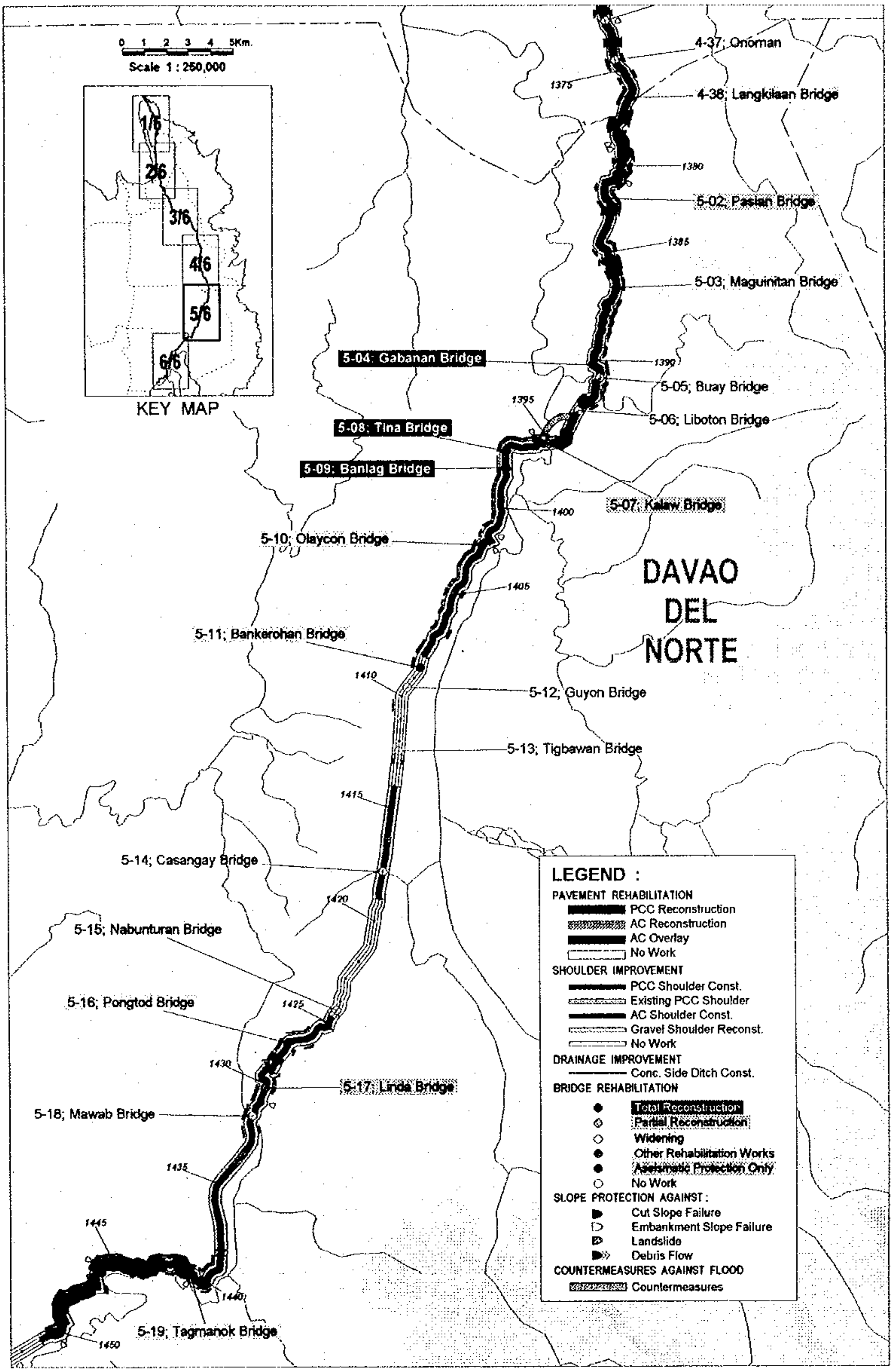


FIGURE 13.2 - 1 PROPOSED REHABILITATION WORKS (5/6)

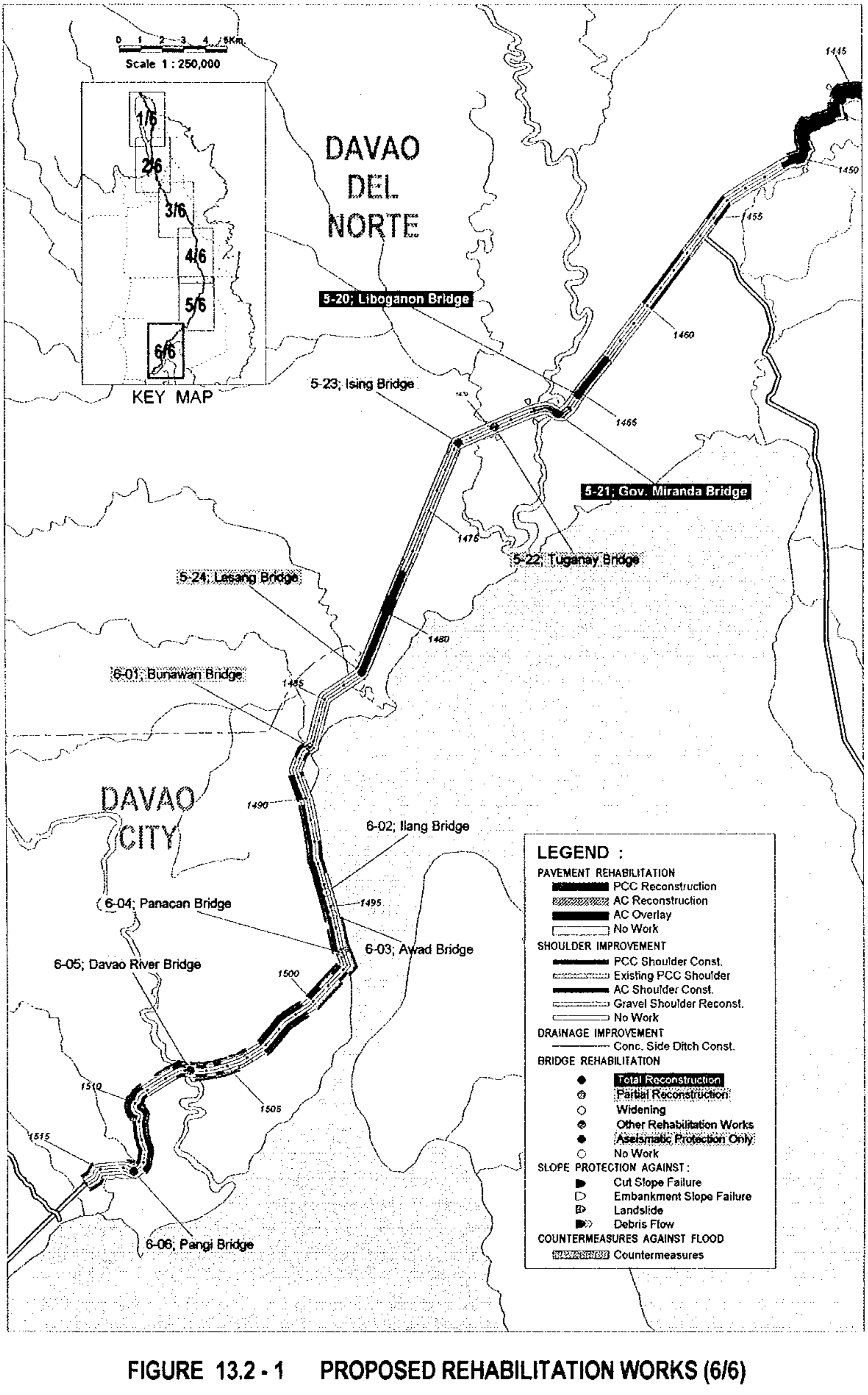


FIGURE 13.2 - 1 PROPOSED REHABILITATION WORKS (6/6)

CHAPTER 14

CONSTRUCTION PLAN

14.1 CONTRACT PACKAGING

Division of the project into contract packages was determined in consideration of the following factors:

- Construction period
- Construction cost
- Road length
- Type of work

Basic considerations given in the contract packaging were as follows:

a) Considering the disturbance to traffic and inconvenience to local people during construction, construction period should not be too long, preferably not exceeding three years. Usually construction period depends much on construction cost of the package.

b) Construction cost of a package should be within the appropriate range. If too low, reliable contractors may lessen their interest and if too high, construction period is very long. According to the past performance, contractor's average monthly accomplishment is ₱5 to 20 million (₱5 to 10 million in rainy season and ₱10 to 20 million in dry season) and construction period is usually set to be 1 to 3 years, appropriate range of construction cost of a package is ₱100 to 400 million.

c) There are two ways of packaging:

Area basis packaging:	Start and end points are determined and all works comprised between the two points are covered in a package, and
Work basis packaging:	Only similar nature of works are selected and form a package.

The work basis packaging is more advantageous if the works require special technique and equipment. If not, the area basis packaging is more advantageous because of better efficiency, manageability and economy. Since all works comprised in this project can be done only by commonly used equipment and require no special technique, the area basis packaging is applied to this project.

Based on the above considerations, the project was divided into 19 contract packages as shown in Table 14.1-1, and Figure 14.1-1.

TABLE 14.1-1 CONTRACT PACKAGES

Package No.	Section Length (km)	Major Works				Construction Cost (Million Pesos)	Construction Period (Months)
		Pavement Rehabilitation (km)	Bridge Rehabilitation (No.)	Slope Protection (No.)	Countermeasures for Flood (km)		
1	54.29	6.66	11	7	3.90	206.6	20
2	22.36	9.44	8	10	3.39	268.0	24
3	20.86	2.21	7	-	6.74	209.1	21
4	30.10	6.13	11	5	1.87	137.6	18
5	13.27	12.98	1	12	-	234.1	22
6	15.05	10.50	5	-	-	183.2	20
7	24.43	24.17	9	16	-	335.6	28
8	13.86	13.44	3	2	-	150.0	19
9	16.83	16.66	5	5	-	199.9	20
10	25.59	25.36	5	1	-	294.1	25
11	14.78	5.59	2	4	9.00	235.1	22
12	12.64	12.49	1	1	-	159.0	19
13	18.45	18.40	4	3	-	286.2	24
14	(2.40)	-	-	-	2.50	104.0	17
15	29.50	16.58	5	4	0.85	226.4	22
16	31.39	26.17	3	4	-	345.4	29
17	12.00	2.30	1	-	1.55	372.7	31
18	29.71	4.80	6	2	-	169.2	19
19	18.25	-	2	-	-	195.0	20
TOTAL	403.36	213.88	89	76	29.80	4,311.2	

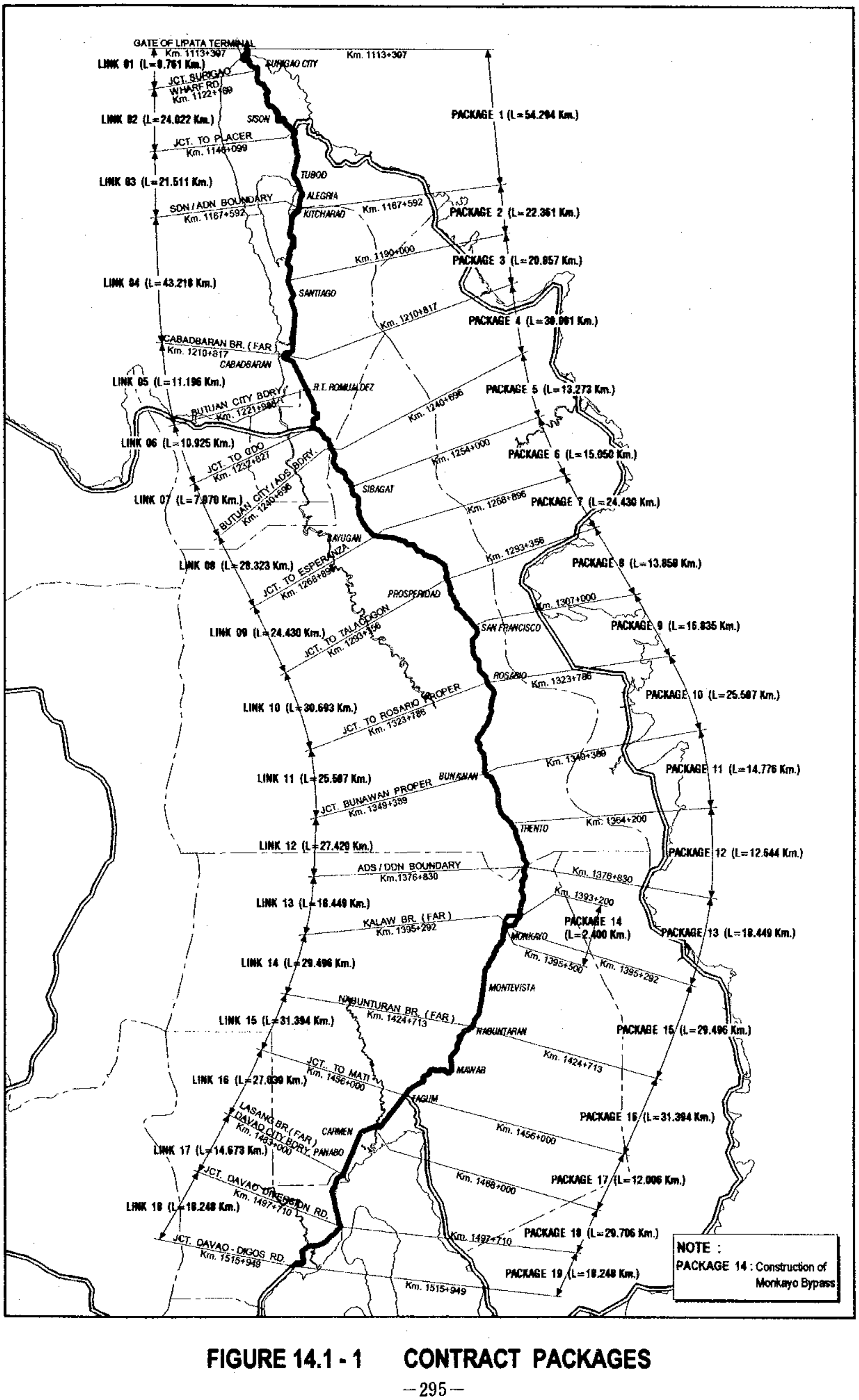


FIGURE 14.1 - 1 CONTRACT PACKAGES

14.2 CONSTRUCTION METHOD AND TRAFFIC MANAGEMENT DURING CONSTRUCTION

14.2.1 Basic Principles

Major requirements in construction are as follows:

1) In principle, construction works shall be done in accordance with the "DPWH Standard Specifications for Public Works and Highways, 1988".

2) Since the Study Road is the only trunk road connecting Surigao and Davao and there is no alternative road, road traffic shall be maintained during construction within the existing road width in principle, except in case of constructing a short detour road as needed in some bridge rehabilitation works.

14.2.2 Construction Method

There are two kinds of construction methods, namely labor-based and equipment-based construction method. In the selection of construction method, following factors should be assessed:

- Project type and quality required
- Construction period
- Economic aspect

This project is the rehabilitation of existing major road, therefore, following are required:

- High quality of work is required to ensure the structural stability and durability under the continuously increasing traffic loads.

- Construction period should be as shorter as possible to avoid disturbance to existing traffic.

In view of above, labor-based construction method is not appropriate for this project and adoption of equipment-based construction method is recommended.

Major work items included in this project are shown in Table 15.1-4 in Chapter 15. All works can be done by usual equipment-based construction method used in the Philippines and described in detail in the DPWH Standard Specifications for Public Works and Highways.

14.2.3 Traffic Management during Construction

Traffic management plan during construction is summarized as follows:

1) Roadway Rehabilitation

In principle, roadway rehabilitation works are executed side by side. During the construction of one side, the other side is open to traffic in one-way operation controlled by signal (by traffic signal or manually). Construction length is determined depending on traffic volume. The longer construction length causes the more reduction of capacity because of loss time necessary to clear the way. Standard construction length is as follows:

AADT	Construction length
below 4,000	300^m
4,000 - 7,000	200^m
over 7,000	100^m

2) Bridge Rehabilitation

There are three ways as follows:

Method A : Detour road construction
Prior to the rehabilitation/reconstruction work, a detour road is constructed including a temporary bridge, usually adjacent to the existing bridge.

Method B : Usage of existing road in full width
If rehabilitation/reconstruction work does not affect the traffic at all, existing road is used for traffic as is.

Method C : Usage of existing road in partial width
When work is executed side by side or for a limited portion, a portion not under construction is open to traffic, usually in one-way operation.

Application of the methods is as follows:

- Total Reconstruction

Either of the first two methods is applied; Method A when a bridge is reconstructed at the same location as the original bridge, or Method B when a bridge is reconstructed adjacent to the original bridge and the road is re-aligned later. Each method requires the following additional cost; detour road construction cost in case of Method A, and approach road construction cost in case of Method B. Costwise, Method A is more advantageous when a temporary bridge is short, roughly less than 30m, while otherwise Method B is superior. Possibility of re-alignment from the viewpoints of road alignment, river condition and roadside environment is another factor to be assured when Method B is applied.

- Partial Reconstruction (Entire Slab, All Girders, Substructure)

In principle, Method A is applied. Method C is also applicable if side-by-side construction is executed, but not recommendable because of the problems which may arise such as heavy traffic disturbance, remarkable reduction of work efficiency and creation of weak points at joint.

- Widening

  Method C is applied, securing one-lane traffic in the middle of bridge. In case of construction of additional bridge instead of widening of existing bridge, Method B is applied.

- Extension

  Method A is applied.

- Major Repair

  Method B or C depending on the work area.

- Minor Repair

  Method B or C depending on the work area. In case of provision/reconstruction of slab overlay, side-by-side construction is executed.

- Protection from Scour

  Method B is applied.

- Approach Road Protection

  Method C is applied. In case of approach road embankment slope protection, middle portion of road is open to traffic and in case of provision of approach slab, one side of road is open to traffic by side-by-side construction operation.

- River Control

  Method B is applied.

- Aseismatic Protection

  Method B is applied, except for provision of mechanical connection device between girder and abutment in which Method C is applied with side-by-side construction operation.

3) Slope Protection

Traffic management during execution of slope protection works is as follows:

- Cut Slope Failure

  Since work area is limited to shoulder in most cases, two-way traffic operation can be maintained with care. In case that work area extends to a part of carriageway, one-lane operation controlled by signal is required.

- Embankment Slope Failure

  In most cases, work area extends to a part of carriageway but in no case, both lanes are affected. Therefore, one-way traffic operation is executed.

- Debris Flow

  Two types of measures are proposed; with and without raising of road. Raising of road is performed side by side and accordingly one-way traffic is maintained during construction. Other works than raising of road is in the same situation as cut slope protection work.

- Fall

  Same as in cut slope failure.

- Landslide

  Countermeasures are taken at both mountain side slope and valley side slope. Those works do not affect any portion of roadway.

14.3 EQUIPMENT AND MATERIAL REQUIREMENTS

1) Equipment

Major equipment required for this project is listed in Table 15.1-3 in Chapter 15. All necessary equipment is the one commonly used in the Philippines and easily procurable.

2) Material

Major materials required for this project are listed in Table 15.1-1 in Chapter 15. Materials are classified into two; goods on the market and materials to be obtained from sources/quarries near the project sites. Goods on the market include portland cement, bituminous materials, reinforcing steel, prestressing steel, fuel, lumber, steel mesh of gabion, etc. All goods necessary for this project are easily procurable, and no such goods as do not appear on the market are required. Materials from sources/quarries include soil, aggregates, boulders, etc. Location, quality and quantity of material sources affect the construction cost. Figure 14.3-1 shows the locations and roughly estimated quantities of the material sources located near the Study Road. The quality and quantity of materials are subject to further investigation in the stage of detailed engineering design.

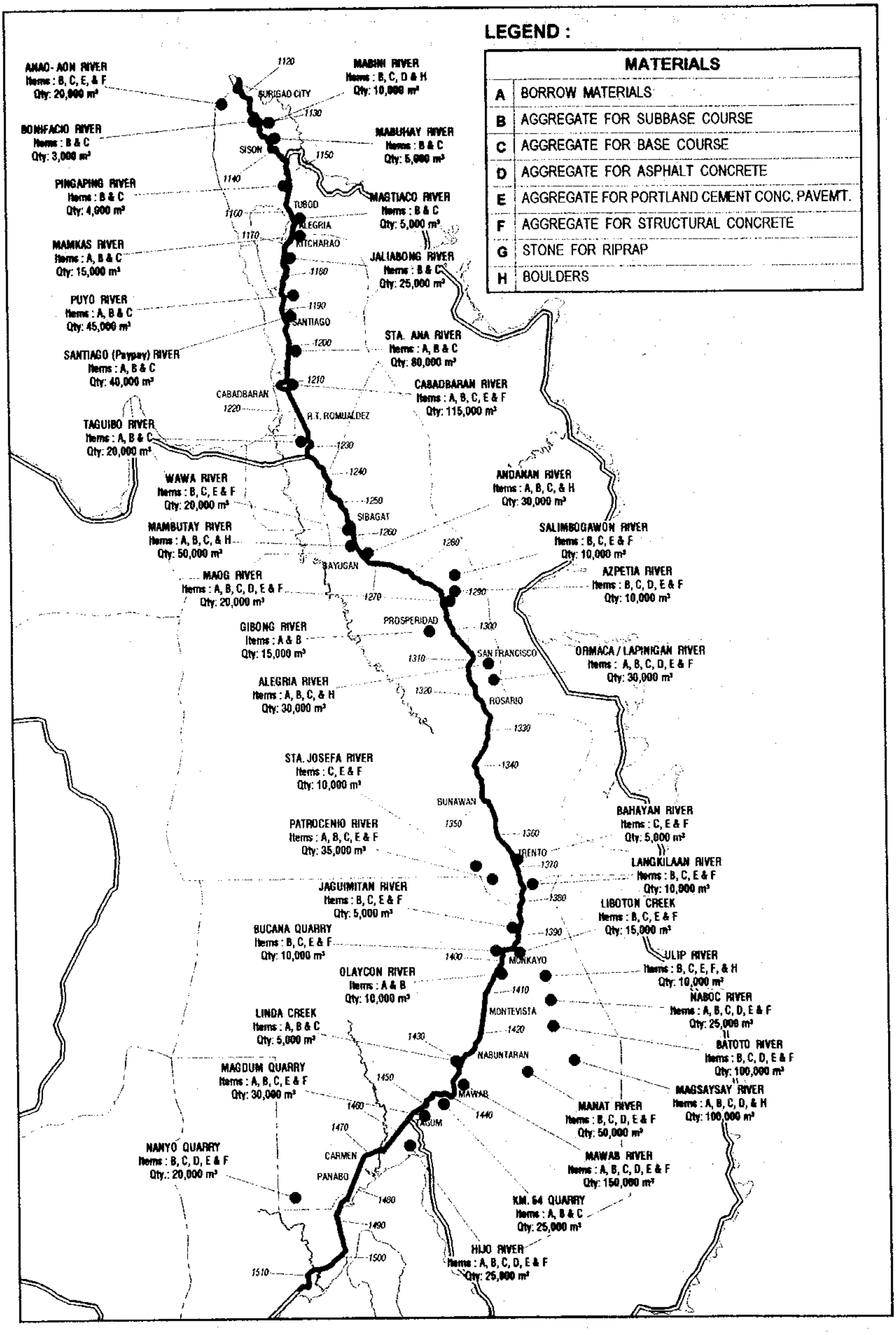


FIGURE 14.3 - 1 MATERIAL SOURCES

14.4 CONSTRUCTION PERIOD

Construction period depends on nature and volume of work, contractor's capability, weather, etc. Main factor is volume of work which is closely related to the construction cost. Roughly estimated construction period of each contract package is shown in Table 14.1-1.