Table17.6.6 Selection of Prevention Countermeasure Method

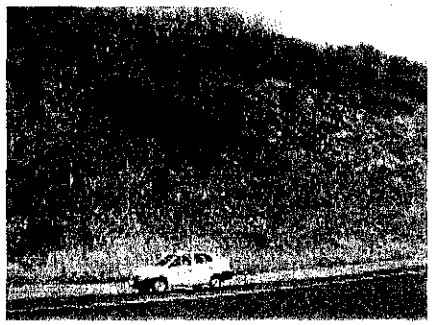
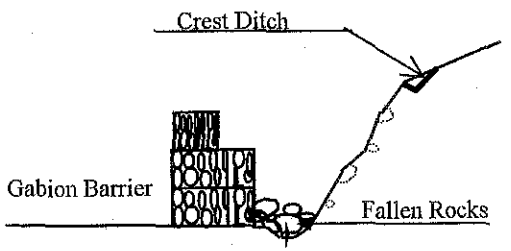
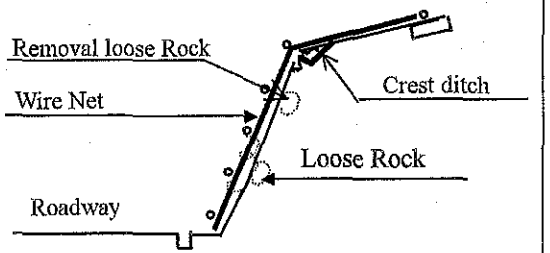
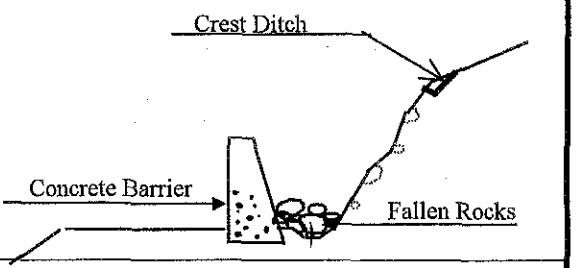
ID : N001A290	Topography	The Foot of The Ridge	Height and Incline	H =20 ～ 40 m , θ =45～52 deg.	The kind of The Rock	Alternation of Andesite and Tuff
Situation of Slope	Impact of Rain (Inflow water)	Leak out a little	*Stability Analysis*	*Unnecessary*	Purpose of Countermeasure	Rockfalls
	The Dry Season 				The Rainy Season 	
Comments	Because the crack interval of andesite is narrow, subdivided unstable stone is generated a lot. Therefore, many small stones fall. The talus remains thin on the slope, it becomes unstable in the rainy season. Inflow warter is confirmed at whole slope.					
Alternative of Countermeasure	**Removal + Barrier with gabion wall +Drainage** 		**Removal + Prevention net + Drainage** 		**Removal + Barrier with concrete wall + Drainage** 	
Workability Structural feature	-Wire of gabion cannot resist against energy of the assumed falling rock. △		-The construction results are not in Nicaragua. -This type is almost permanent structure. ○		- The concrete barrier will be too big size for resistance against energy of the assumed falling rock. △	
Environment Impact	-*Deterioration of environment* will be forecast by damage of gabion. △		-It is necessary to cut trees. △		-Installing the concrete barrier lacks harmony with the surrounding. △	
Influence on Road	-It is difficult to stop completely jumping over rock by barrier. Width for construction of barrier is enough. △		-There is no problem. ◎		-It is difficult to stop completely jumping over rock by barrier. Width for construction of barrier is enough. △	
Maintenance	-It is necessary to remove collected rock. -Durability depends on the life of the wire. △		-Durability depends on the life of the wire of net. △		-Because the structure is too large, the space for the removal of fallen rocks is necessary. △	
Economy	-This alternative is cheapest of all. Because maintenance cost is high, costs of three alternatives is almost even. ○		-Net materials are expensive, but maintenance cost isn't high. ○		-Maintenance cost is high. △	
Evaluation	-The gabion isn't steady by the collision of assumed falling rock. **3**		-This type prevents completely dispersion of rock collapse. **1**		-The concrete barrier isn't steady by the collision of assumed falling rock. **2**	

Table17.6.7 Selection of Prevention Countermeasure Method

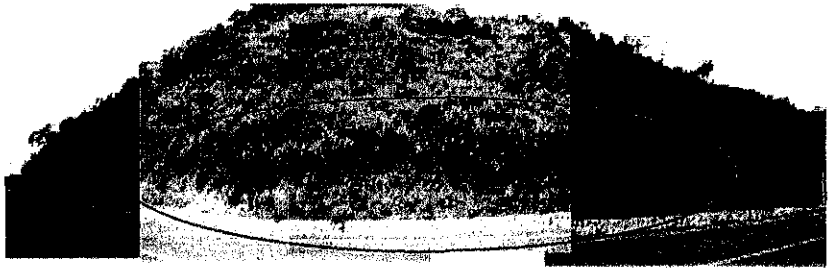
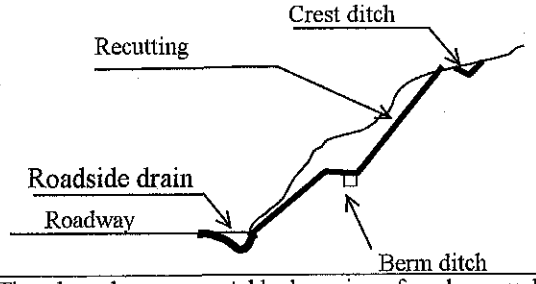
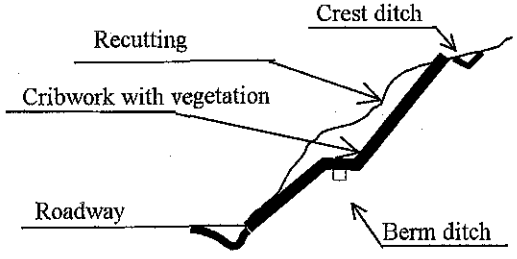
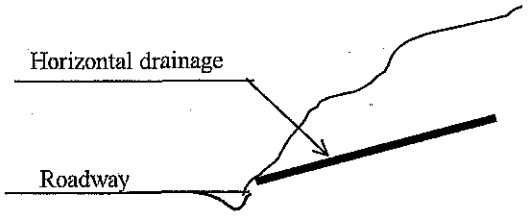
ID : N001A280	Topography	The Foot of The Ridge	Height and Incline	H =7 ～ 11 m , θ =45～75 deg.	The kind of The Rock	Tuff
Situation of Slope	Impact of Rain (Inflow water)	Inflow water	Stability Analysis	Necessary	Purpose of Countermeasure	Rockfalls
Situation of Slope	The Dry Season 				The Rainy Season 	
Comments	Red mark is clear slide scarp, blue mark is colluvium. The change was not especially seen through the dry season and rainy season. The stability of the slope is necessary, because the slide scarp approaches to the vicinity of the electric tower(yellow mark). The inflowater from the talus and the installed french drain were confirmed.					
Alternative of Countermeasure	**Recutting ＋ Drainage** 		**Recutting + Cribwork with vegetation +Drainage** 		**Horizontal drainage** 	
Workability Structural feature	-The slope become unstable by raise of underground water, but this alternative cannot suppress the rise of underground water level. △		-The slope become unstable by raise of underground water, but this alternative cannot suppress the rise of underground water level. △		-Underground water level is suppressed by horizontal drainage, therefore the slope become stable. ○	
Environment Impact	-Slope is expected of natural vegetation. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○		-The present condition of slope surface will be maintained because it will be not touched. ◎	
Influence on Road	-Traffic control is necessary during construction, but here is no influence after construction. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○		-One lane is restricted by the boring. △	
Maintenance	-The maintenance is necessary until the vegetation takes root. △		-The maintenance is necessary until the vegetation takes root. △		-The inspection is necessary water volume from the horizontal drainage. ○	
Economy	-It is the most economical in three alternatives . ○		-The cost of cribwork is expensive. △		-The horizontal drainage is expensive, but other costs are unnecessary . ○	
Evaluation	-This alternative is beneath in maintenance and environmental. 2		The purpose of cribwork is for the vegetation and it does not take part in stability. 3		-This alternative is economical and effective. 1	

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Table17.6.8 Selection of Prevention Countermeasure Method

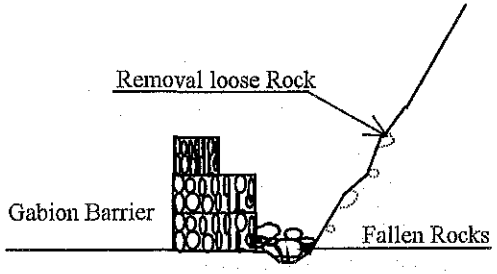
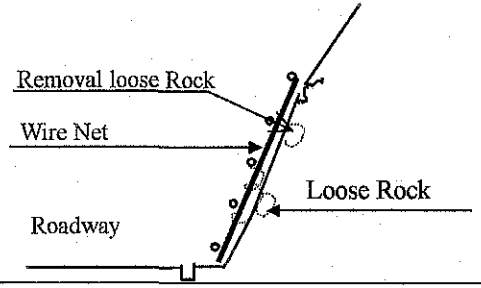
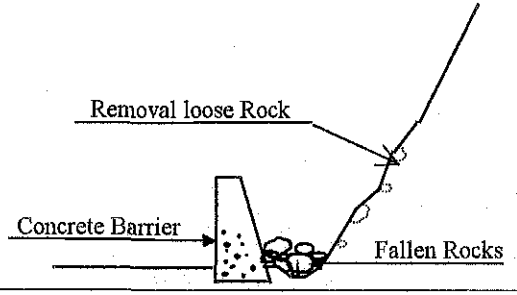
ID : N001A240	Topography	The Foot of The Ridge	Height and Incline	H =12 ～ 18 m , θ =45～57 deg.	The kind of The Rock	Almost Tuff and Andesite is a part.
Situation of Slope	Impact of Rain (Inflow water)	No exist	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rockfalls
Situation of Slope	The Dry Season 				The Rainy Season 	
Comments	Inflow warter was not seen in the rainy season. Loosening advanced and the small rock collapse was confirmed at ten places. There are falling rocks at part marked in red.					
Alternative of Countermeasure	**Removal + Barrier with gabion wall** 		**Removal + Prevention net** 		**Removal + Barrier with concrete wall** 	
Workability Structural feature	-Wire of gabion cannot resist against energy of the assumed falling rock. △		-The construction results are not in Nicaragua. -This type is almost permanent structure. ○		- The concrete barrier will be too big size for resistance against energy of the assumed falling rock. △	
Environment Impact	-Deterioration of environment will be forecast by damage of gabion. △		-It is necessary to cut trees. △		-Installing the concrete barrier lacks harmony with the surrounding. △	
Influence on Road	-It is difficult to stop completely jumping over rock by barrier. Width for barrier is not enough. △		-There is no problem. ◎		-It is difficult to stop completely jumping over rock by barrier. Width for barrier is not enough. △	
Maintenance	-It is necessary to remove collected rock. -Durability depends on the life of the wire. △		-The environment deterioration is eased by partially constructing the net. △		-It is necessary to remove fallen rocks. -The maintenance of the structure is unnecessary. ○	
Economy	-Because maintenance cost is high, costs of three alternatives are almost even. ○		-Net materials are expensive, but maintenance cost isn't high. ○		-The cost is middle of all. But the costs of three alternatives are almost even. ○	
Evaluation	-The gabion isn't steady by the collision of assumed falling rock. Width for barrier is not enough. 3		-This type prevents completely dispersion of rock collapse. **1**		-The gabion isn't steady by the collision of assumed falling rock. Width for barrier is not enough. 2	

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Table17.6.9 Selection of Prevention Countermeasure Method

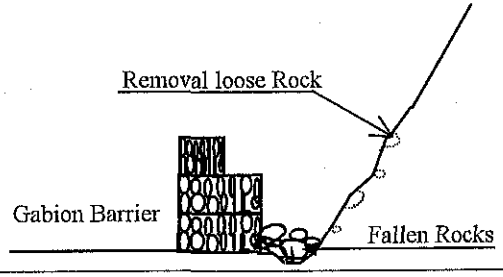
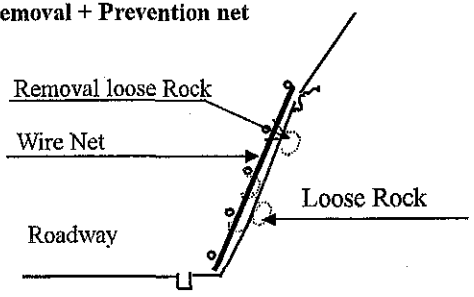
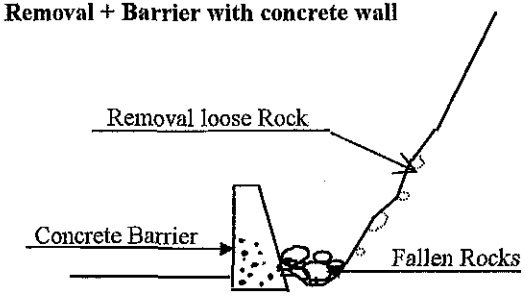
ID : N001B230	Topography	The Foot of The Ridge	Height and Incline	H ≈13 ～ 33 m , θ =40～65 deg.	The kind of The Rock	Almost Tuff and Andesite is a part.
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rock Collapse
Situation of Slope	The Dry Season 				The Rainy Season 	
Comments	Left side photograph; The part marked in red is andesite, it is distributed in the upper part of slope. Tuff that weathering is early is distributed in the lower part of slope. The andesite becomes on the overhang and falls. Right side photograph; Upper red mark is loose andesite and lower red mark is tuff. Seepage is oozing from the boundary of the andesite and the tuff					
Alternative of Countermeasure	**Removal + Barrier with gabion wall** 		**Removal + Prevention net** 		**Removal + Barrier with concrete wall** 	
Workability Structural feature	-Wire of gabion cannot resist against energy of the assumed falling rock. △		-The construction results are not in Nicaragua. -This type is almost permanent structure. ○		- The concrete barrier will be too big size for resistance against energy of the assumed falling rock. △	
Environment Impact	-Deterioration of environment will be forecast by damage of gabion. △		-It is necessary to cut trees. △		-Installing the concrete barrier lacks harmony with the surrounding. △	
Influence on Road	-It is difficult to stop completely jumping over rock by barrier. Width for barrier is not enough. △		-There is no problem. ◎		-It is difficult to stop completely jumping over rock by barrier. Width for barrier is not enough. △	
Maintenance	-It is necessary to remove collected rock. -Durability depends on the life of the wire. △		-The environment deterioration is eased by partially constructing the net. △		-It is necessary to remove fallen rocks. -The maintenance of the structure is unnecessary. ○	
Economy	-Because maintenance cost is high, costs of three alternatives are almost even. ○		-Net materials are expensive, but maintenance cost isn't high. ○		-The cost is middle of all. But the costs of three alternatives are almost even. ○	
Evaluation	-The gabion isn't steady by the collision of assumed falling rock. Width for barrier is not enough. 3		-This type prevents completely dispersion of rock collapse. 1		-The gabion isn't steady by the collision of assumed falling rock. Width for barrier is not enough. 2	

Table17.6.10 Selection of Prevention Countermeasure Method

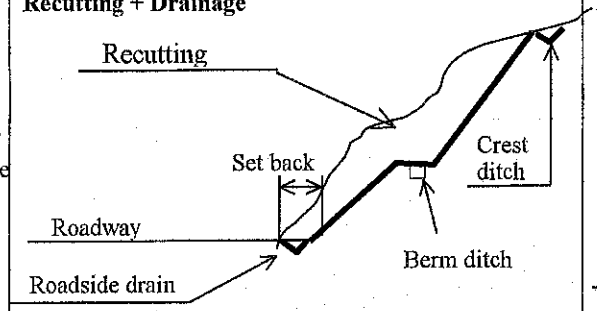
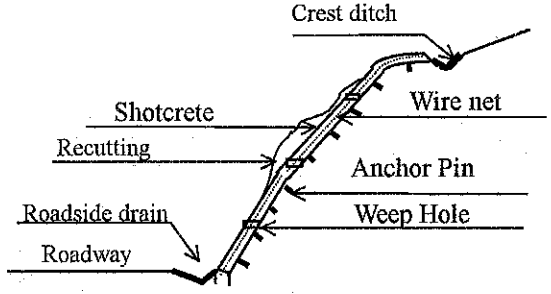
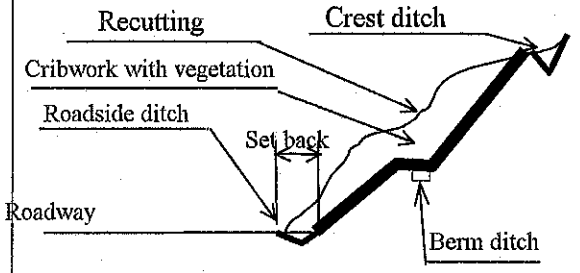
ID : N001B170	Topography	The Foot of The Ridge	Height and Incline	H =13 ～ 41 m , θ =42～70 deg.	The kind of The Rock	Almost Andesite but under part is Tufft.
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rock Collapse
Situation of Slope	The Dry Season 				The Rainy Season 	
Comments	Left side photograph; Red mark is andesite, its lower side is tuff that weathering is early. There are a lot of skin dropping because weathering is early, therefore andesite becomes unstable and collapses.				Right side photograph; Seepage is oozing from red mark portion in rainy season.	
Alternative of Countermeasure	**Recutting + Drainage** 		**Recutting + Shotcrete + Drainage** 		**Recutting + Cribwork with vegetation + Drainage** 	
Workability Structural feature	-Slope will be cut for the purposes of removal of weathering and to keep sight distance. ○		-The slope will be cut from the toe for removal of unstable materials in the upper part, and then shotcrete will be constructed. ○		-Slope will be cut for the purposes of removal of weathering and to keep sight distance. ○	
Environment Impact	-Slope is expected of natural vegetation. △		-It is difficult to harmonize with surroundings. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○	
Influence on Road	-Traffic control is necessary during construction, but here is no influence after construction. ○		-The is no problem. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. △		-It is necessary to confirm volume of oozing. ○		-The maintenance is necessary until the vegetation takes root. It is important to maintain anchor of cribwork. △	
Economy	-It is the most economical in three alternatives. ◎		-The cost is middle of all. ○		-The cost of cribwork is expensive. △	
Evaluation	-This alternative is economical and effective. **1**		-The environmental and the measures oozing are inferior. **2**		-The purpose of cribwork is for the vegetation, and it does not contribute almost in stability. **3**	

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Table17.6.11 Selection of Prevention Countermeasure Method

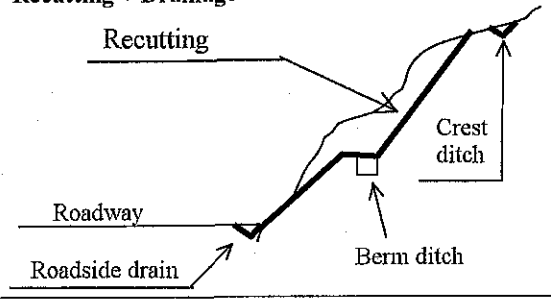
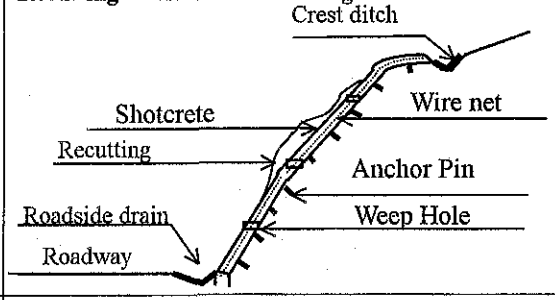
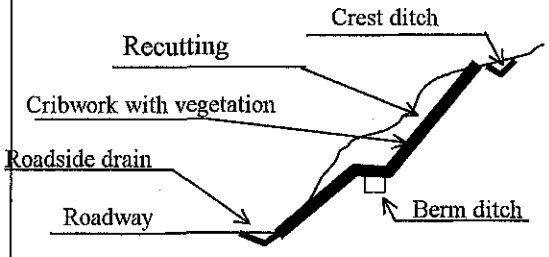
ID : N001B150	Topography	The Point of The Ridge	Height and Incline	H =7 ～ 13 m , θ =50～70 deg.	The kind of The Rock	Almost Tuff but Upper part are Andsite.
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rock Collapse
	The Dry Season 				The Rainy Season 	
Comments	There are vertical cooling joint. Cracks are open by weathering advance. There are comparatively large falling rocks. Prevention of weathering is necessary after cutting tuff. As a result, the andesite can be prevented from collapse.					
Alternative of Countermeasure	**Recutting + Drainage** 		**Recutting + Shotcrete + Drainage** 		**Recutting + Cribwork with vegetation + Drainage** 	
Workability Structural feature	- The weathering is measured by installation of drainage facilities. ○		-It is necessary special equipment. -It is excels for countermeasure of weathering. ◎		-The purpose of cribwork are for the vegetation and increase stability ○	
Environment Impact	-Slope is expected of natural vegetation. △		-It is difficult to harmonize with surroundings. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○	
Influence on Road	-Traffic control is necessary during construction, but here is no influence after construction. ○		-The is no problem. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. △		-It is necessary to confirm volume of oozing. ○		-The maintenance is necessary until the vegetation takes root. It is important to maintain anchor of cribwork. △	
Economy	-It is the most economical in three alternatives. ○		-The cost is middle of all. ○		-The cost of cribwork is expensive. △	
Evaluation	-This alternative is beneath in maintenance and environmental. 2		-It is the most effective in the weathering measures. Infiltration of water can be prevented by crest ditch. 1		-The purpose of cribwork is for the vegetation, and it does not contribute almost in stability. 3	

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Table17.6.12 Selection of Prevention Countermeasure Method

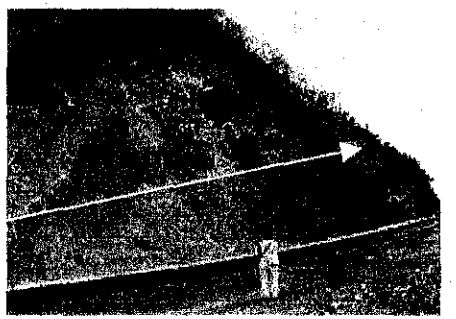
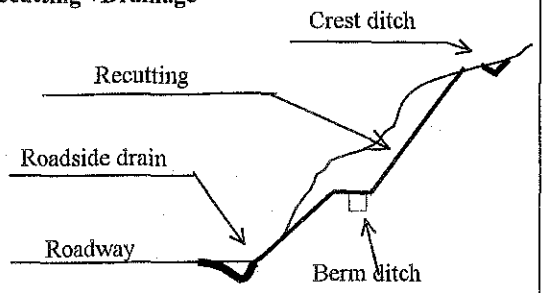
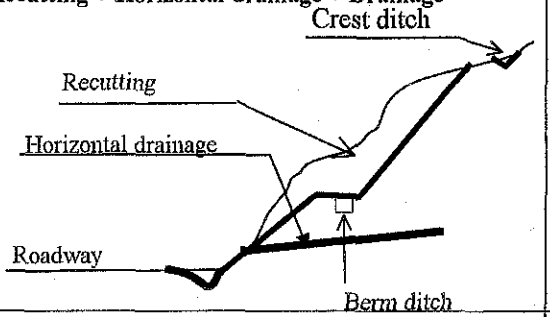
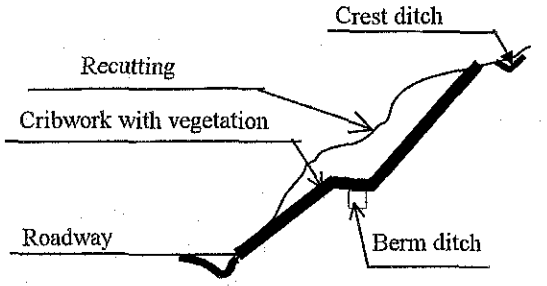
ID : N001B120	Topography		Height and Incline	H =17 ～ 50 m , θ =50～75 deg.	The kind of The Rock	Tuff and Andesite. Middle part of slope are Dyke.
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rock Collapse
	The Dry Season 				The Rainy Season 	
Comments	There is a collapse history. The part where the slope height is large is an intrusive rock and a hard rock. It is intrusive along the fault(white mark), therefore the rock is extremely weak at its both sides. The condition of a peripheral rock by influence of the fault is bad, and there is a possibility to be going to repeat a big collapse in the future. Drastic counter measurements are necessary					
Alternative of Countermeasure	**Recutting +Drainage** 		**Recutting + Horizontal drainage + Drainage** 		**Recutting + Cribwork with vegetation+ Drainage** 	
Workability Structural feature	-Large-scale collapse is prevented by cut of 55 ° . Stability will increase by drainage facilities. ○		-Horizontal drainage is added to left side alternative as the increase stability. △		-The purpose of cribwork are for the vegetation and increase stability ○	
Environment Impact	-Slope is expected of natural vegetation. △		-Slope is expected of natural vegetation. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○	
Influence on Road	-Traffic control is necessary during construction, but here is no influence after construction. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○	
Maintenance	-It is necessary to maintain slope surface. △		-The inspection is necessary water volume from the horizontal drainage. △		-The maintenance is necessary until the vegetation takes root. It is important to maintain anchor of cribwork. △	
Economy	-It is the most economical in three alternatives. ◎		-The cost is middle of all. ○		-The cost of cribwork is expensive. △	
Evaluation	-Drainage facilities are effective to prevent weathering. This alternative is the most effective economically. 1		-Inflow water after rain is much, but horizontal drainage is not necessary. 2		-The purpose of cribwork is for the vegetation, and it does not contribute almost in stability. 3	

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Table17.6.13 Selection of Prevention Countermeasure Method

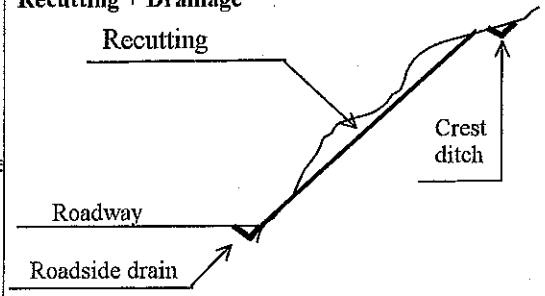
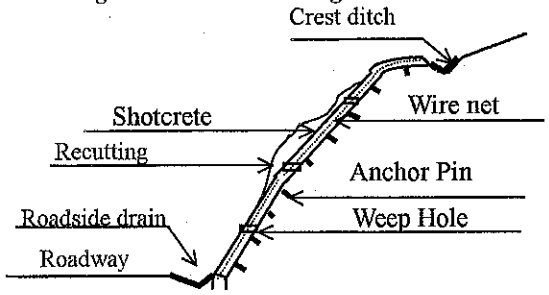
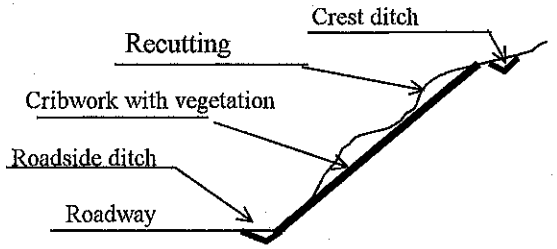
ID : N003B400	Topography	The Point of The Small Ridge	Height and Incline	H =8 ～ 18 m , θ =33～48 deg.	The kind of The Rock	Tuff and a part of Agglomerate
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rock Collapse and Toppling
	The Dry Season 				The Rainy Season 	
Comments	The surface water flow along the crack, and it ooze from the vicinity of the toe of the slope(red mark). The width of crack of tuff increases, the toppling phenomenon is caused.					
Alternative of Countermeasure	**Recutting + Drainage** 		**Recutting + Shotcrete + Drainage** 		**Recutting + Cribwork + Vegetation + Drainage** 	
Workability Structural feature	- The weathering is measured by installation of drainage facilities. ○		-Cutting is no need for stability. -It is excels for countermeasure of weathering. ◎		-The purpose of cribwork are for the vegetation and increase stability ○	
Environment Impact	-Slope is expected of natural vegetation. △		-It is difficult to harmonize with surroundings. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○	
Influence on Road	-Traffic control is necessary during construction, but here is no influence after construction. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. △		-It is necessary to confirm volume of oozing. △		-The maintenance is necessary until the vegetation takes root. It is effective for weathering ○	
Economy	-It is the most economical in three alternatives. ◎		-The cost is middle of all. ○		-The cost of cribwork is expensive. △	
Evaluation	-Drainage facilities are effective to prevent weathering. This alternative is the most effective economically. 1		-There is a problem in durability when there is a lot of inflow water after drain. 2		-The purpose of cribwork is for the vegetation, and it does not contribute almost in stability. 3	

Table17.6.14 Selection of Prevention Countermeasure Method

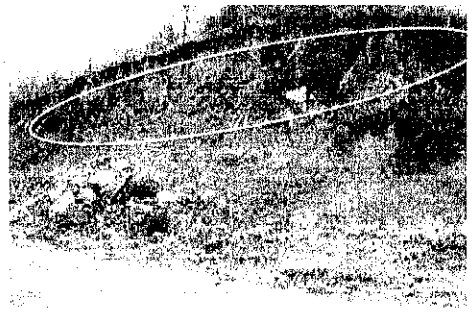
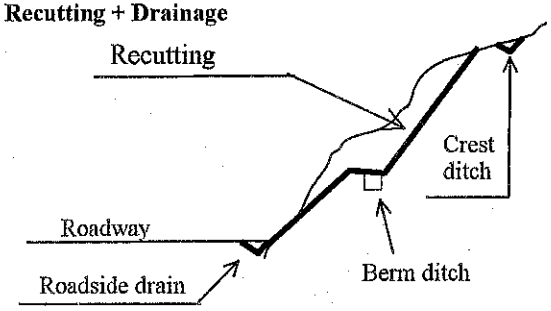
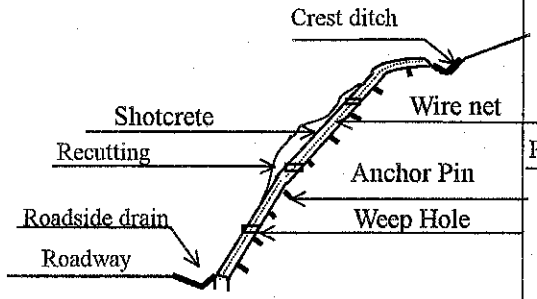
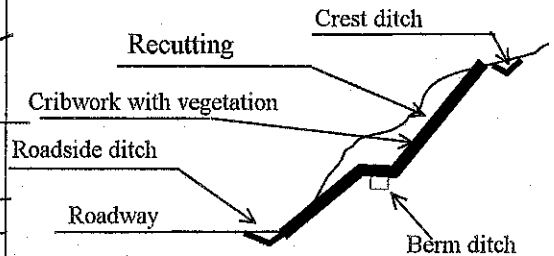
ID : N003B370	Topography	The Point of The Small Ridge	Height and Incline	H =8 ～ 18 m , θ =45～53 deg.	The kind of The Rock	Tuff
Situation of Slope	Impact of Rain (Inflow water)	No exist	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rock Collapse
Situation of Slope	The Dry Season 				The Rainy Season 	
Comments	There are two types tuff. Tuff marked in white has vertical cooling joint(hard rock; II B type) Lower side tuff that weathering is early(II A type) . Inflow water was not able to be confirmed in the rainy season.					
Alternative of Countermeasure	**Recutting + Drainage** 		**Recutting + Shotcrete + Drainage** 		**Recutting + Cribwork + Vegetation + Drainage** 	
Workability Structural feature	-There is not problem of construction. - The weathering is measured by installation of drainage facilities ○		-Special equipment is necessary. -It is excels for countermeasure of weathering. ◎		-The purpose of cribwork are for the vegetation and increase stability ○	
Environment Impact	-Slope is expected of natural vegetation. △		-It is difficult to harmonize with surroundings. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○	
Influence on Road	-Traffic control is necessary during construction, but here is no influence after construction. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. △		-It is necessary to confirm volume of oozing. △		-The maintenance is necessary until the vegetation takes root. It is effective for weathering ○	
Economy	-It is the most economical in three alternatives. ◎		-The cost is middle of all. ○		-The cost of cribwork is expensive. △	
Evaluation	-The purpose of prevention can be economically achieved. 1		-There is a problem in durability when there is a lot of inflow water. 2		-The purpose of cribwork is for the vegetation, and it does not contribute almost in stability. 3	

Table17.6.15 Selection of Prevention Countermeasure Method

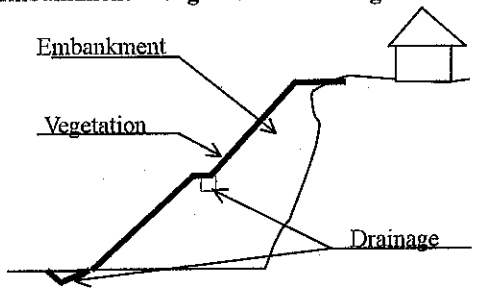
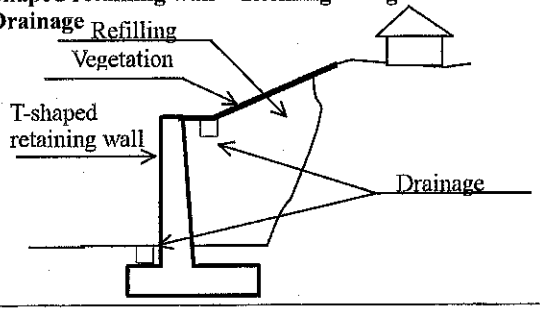
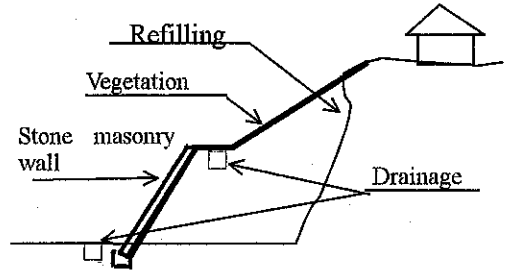
ID : N003B320	Topography	The Point of The Small Ridge	Height and Incline	H =7 ～ 9 m , θ =48～75 deg.	The kind of The Rock	Tuff
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rock Collapse
	The Dry Season 				The Rainy Season 	
Comments	The weathering of tuff is advancing, the distributed layer of scoria at leg of slope is weak to rain, and collapse is early. The inflow water was confirmed from the part marked in red in rainy season.					
Alternative of Countermeasure	**Embankment + Vegetation + Drainage** 		**T-shaped retaining wall + Refilling + Vegetation + Drainage** 		**Stone masonry + Refilling + Vegetation + Drainage** 	
Workability Structural feature	-Behavior of existing slope and constructed embankment is problem. △		-There is no problem of loosening of the backfill by the retaining wall. Construction is no problem. ◎		-There is no problem of loosening of the backfill by the retaining wall. Construction is no problem. ○	
Environment Impact	-Embankment harmonizes with surroundings by the vegetation. ◎		-Retaining wall has feeling of stability and somewhat overpowering. It harmonize with surrounding by vegetation ○		-Retaining wall has feeling of stability and somewhat overpowering. It harmonize with surrounding by vegetation ○	
Influence on Road	-The width of the road is insufficient. △		-There is no problem of the width of the road. ◎		-Stone masonry height is up to 5m, therefore the width of the road is insufficient. △	
Maintenance	-It is necessary to maintain behavior of existing slope and constructed embankment. △		-Maintenance is not necessary. ◎		-Maintenance is not necessary. ◎	
Economy	-It is the most economical in three alternatives. But it has problem of width of the road. ◎		-Retaining wall is expensive. △		-Stone masonry is expensive. ○	
Evaluation	-It is difficult to select for lack of width of the road. **3**		-This alternative excels in the structure and maintenance. **1**		-It is difficult to select for lack of width of the road. **2**	

Table17.6.16 Selection of Prevention Countermeasure Method

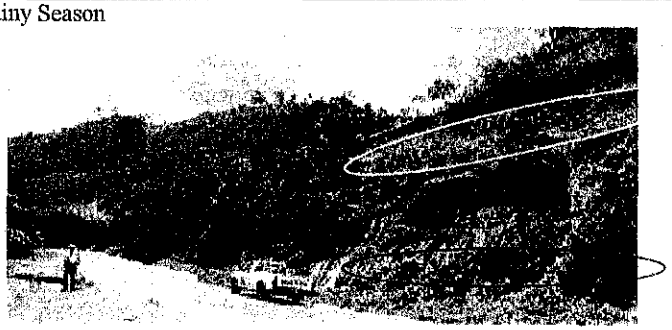
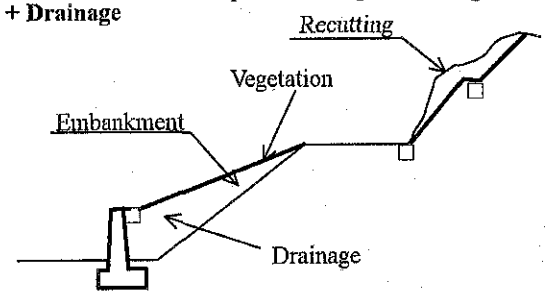
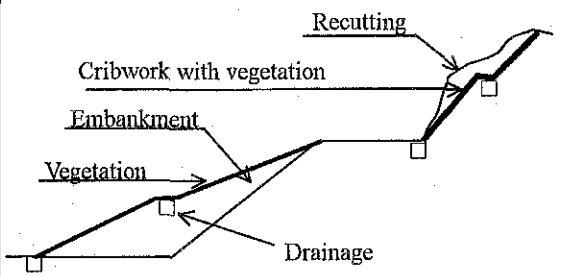
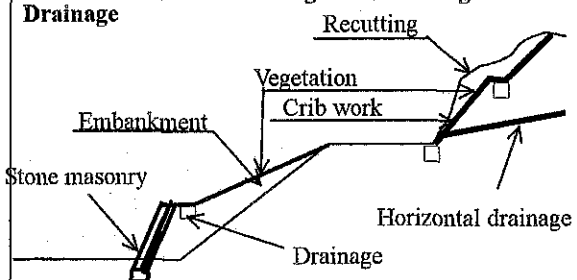
ID : N003C230	Topography	The Point of The Small Ridge	Height and Incline	H =8 ～ 16 m , θ =48～60 deg.	The kind of The Rock	Tuff
Situation of Slope	Impact of Rain (Inflow water)	Leak out a little	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rock Collapse, Slope Sliding
Situation of Slope	The Dry Season 				The Rainy Season 	
Comments	The weathering of tuff is advancing, its geological features collapse easily and are weak to rain. The transformation was not seen at fill. Water collected in leg of slide scarp(white mark). The seepage and small collapsing was confirmed.					
Alternative of Countermeasure	**Recutting + Drainage** **Embankment + T-shaped retaining wall + Vegetation + Drainage** 	**Recutting + Crib work + Vegetation + Drainage** **Embankment + Vegetation + Drainage** 	**Recutting + Crib work + Vegetation +Horizontal drainage + Drainage** **Embankment + Retaining wall + Vegetation + Drainage** 		
Workability Structural feature	-Cut slope is stability by cutting of 45 °. -Embankment increase stability by installation of retaining wall ○		-Cutting slope is stability by cutting of 45 °. -Embankment increase stability by bench cutting of existing slope ○		-Cutting slope is stability by cutting of 45 °. -Embankment increase stability by installation of stone masonry. ○	
Environment Impact	-Cut slope is expected of natural vegetation. ○		-Vegetation is needed for nature park, therefore cribwork will be installed for vegetation. ◎		-Vegetation is needed for nature park, therefore cribwork will be installed for vegetation. ◎	
Influence on Road	-One lane is operated while constructing ○		-One lane is operated while constructing ○		-One lane is operated while constructing ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. ○		-The maintenance is necessary until the vegetation takes root. ○		-The maintenance is necessary until the vegetation takes root. ○	
Economy	-Retaining wall is expensive. ○		-Cribwork is expensive. ○		-Cribwork, stone masonry, and horizontal drain is expensive △	
Evaluation	-Retaining wall is unnecessary for stability. 3		-Cut slope excels in stability and the environmental. -Vegetation is needed for nature park. 1		-Stone masonry and horizontal drainage are unnecessary for stability. 2	

Table17.6.17 Selection of Prevention Countermeasure Method

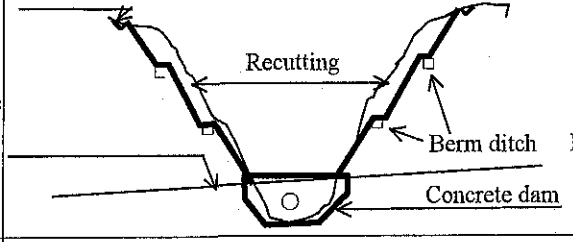
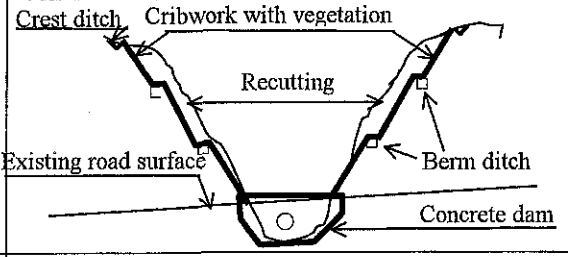
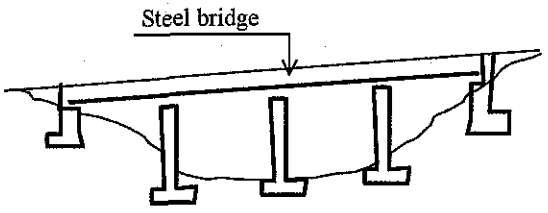
ID : N003E170	Topography	The Mountainside	Height and Incline	H =10 ～ 22 m , θ =45～62 deg.	The kind of The Rock	Alternation of Tuff and Andesite (Alteration zone)
Situation of Slope	Impact of Rain (Inflow water)	Debris Flow Inflow water	Stability Analysis	Unnecessary	Purpose of Countermeasure	Debris Flow and Rockfalls
	The Dry Season 				The Rainy Season 	
Comments	The quality of rock is changed. The difference of hard and soft is violent because of the place. The weathering belt in the hillside has surface collapse due to shallow seepage. The main disaster is flash flood than debris flow. The main disaster is flash flood than debris flow.					
Alternative of Countermeasure	**Recutting + Drainage** **Concrete dam + Box culvert** 		**Recutting + Cribwork with vegetable+ Drainage** **Concrete dam + Box culvert** 		**Recutting + Cribwork with vegetable+ Drainag** **Steel bridge** 	
Workability Structural feature	-Construction is not so difficult. ○		-Construction is not so difficult. The purpose of cribwork are for the vegetation and increase stability ○		-The bridge of the length of about 100m is necessary. -Countermeasure of the approach road slope is necessary △	
Environment Impact	-Slope is expected of natural vegetation. -It is difficult to harmonize with surroundings until taking root. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○		-The environment is prevented from deteriorating by vegetation among the cribwork. ○	
Influence on Road	- Detour of traffic is necessary during construction. △		- Detour of traffic is necessary during construction. △		- Detour of traffic is necessary during construction. △	
Maintenance	-Maintenance is not for stability. ○		-The maintenance is necessary until the vegetation takes root. ○		-The maintenance is necessary until the vegetation takes root. Maintenance of bridge is unnecessary. ○	
Economy	-This alternative is cheapest of all. Maintenance cost is higher than other alternatives ◎		-The cost is middle of all. ○		-Cost of new bridge construction is very expensive. △	
Evaluation	-Weathering can be considerably prevented by installation of drainage facilities. 1		-Cut slope excels in stability and maintenance. -The necessity of cribwork is vague. 2		-The purpose of shift of road alignment is avoidance of debris flow. The bridge is unnecessary for stability. 3	

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Table17.6.18 Selection of Prevention Countermeasure Method

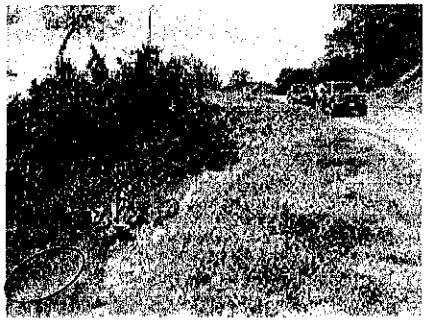
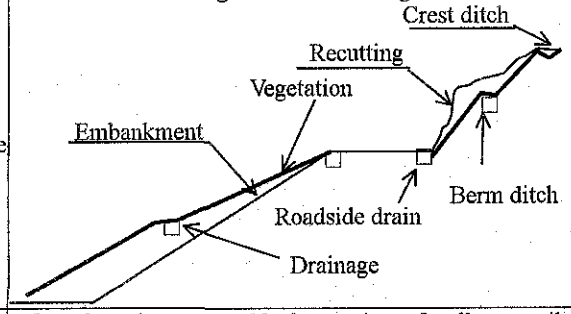
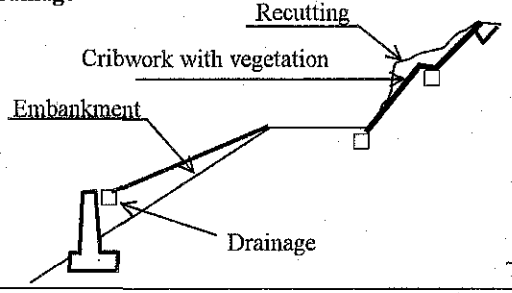
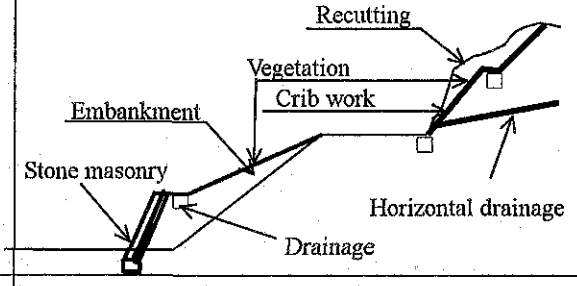
ID : N003C150	Topography	The Mountainside	Height and Incline	H =13 ～ 29 m , θ =48～50 deg.	The kind of The Rock	Tuff
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Necessary	Purpose of Countermeasure	Slope Sliding, Rock Collapse
	The Dry Season 				The Rainy Season 	
Comments	Weathering of tuff is advancing. The inflow water from part marked in red was confirmed. A part marked in white is collapse topography. There is a slide scarp at inner part. The vicinity of the toe of slope is a steady tuff.					
Alternative of Countermeasure	**Recutting + Drainage** **Embankment + Vegetation + Drainage** 		**Recutting + Cribwork with vegetation + Drainage** **Embankment + T-shaped retaining wall + Vegetation + Drainage** 		**Recutting + Crib work with vegetation + Drainage** **Embankment + Retaining wall + Vegetation + Drainage** 	
Workability Structural feature	-Cut slope become stable by cutting of collapse soil. -Embankment increase stability by bench cutting of existing slope. ○		-The purpose of cribwork is for the vegetation and increase stability. ○		-The purpose of cribwork is for the vegetation and increase stability. ○	
Environment Impact	-It harmonizes with surrounding by vegetation on embankment. Slope is expected of natural vegetation○		-It harmonizes with surrounding by vegetation ◎		-It harmonizes with surrounding by vegetation. ◎	
Influence on Road	-One lane is operated while constructing ○		-One lane is operated while constructing. ○		-One lane is operated while constructing. ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. Embankment side is private land. ○		-The maintenance is necessary until the vegetation takes root. The width of land use is minimum. ○		-The maintenance is necessary until the vegetation takes root. The width of land use is middle. ○	
Economy	-This alternative is cheapest of all. ◎		-Cribwork and retaining wall are expensive. △		-Cribwork, stone masonry and horizontal drainage are expensive. △	
Evaluation	-The purpose of prevention can be economically achieved. 1		-Cribwork and retaining wall are unnecessary for stability. 3		-Stone masonry and horizontal drainage are unnecessary for stability. 2	

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Table17.6.19 Selection of Prevention Countermeasure Method

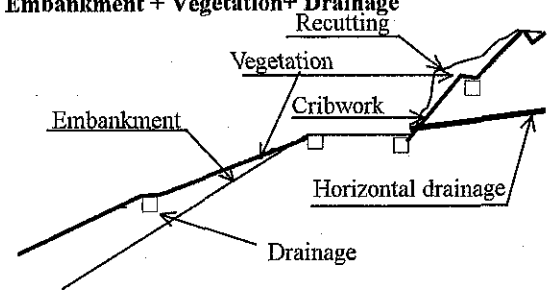
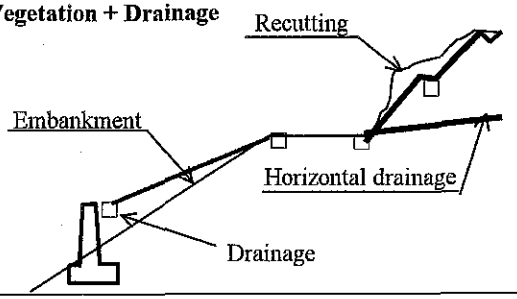
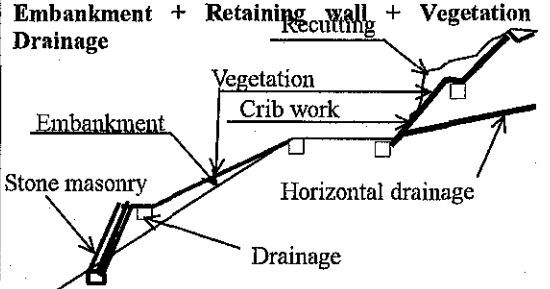
ID : N003C140	Topography	The Mountainside	Height and Incline	H =6 ～ 9 m , θ =45～60 deg.	The kind of The Rock	Tuff
Situation of Slope	Impact of Rain (Inflow water)	Inflow water	Stability Analysis	Necessary	Purpose of Countermeasure	Slope Sliding, Rock Collapse
	The Dry Season 				The Rainy Season 	
Comments	Weathering of tuff is advancing. There is a watercourse in the rock and it was confirmed by the oozing from embankment. It is necessary to examine the installation of the horizontal drainage to control the water level. The cut gradient will be determined according to the boring result and the position of the church. T-shaped retaining wall will be necessary because it minimizes width of land use of coffee plantation.					
Alternative of Countermeasure	**Recutting + Cribwork with vegetation + Horizontal drain + Drainage Embankment + Vegetation+ Drainage** 	**Recutting + Horizontal Drain + Drainage Embankment + T-shaped retaining wall + Vegetation + Drainage** 	**Recutting + Cribwork with vegetation + Drainage + Horizontal drainage Embankment + Retaining wall + Vegetation + Drainage** 			
Workability Structural feature	-The purpose of cribwork is for the vegetation and increase stability. But it does not contribute almost in stability ○	-Some technologies are necessary. -Embankment increase stability by installation of retaining wall. ◎	-Construction is not difficult. -Some technologies are necessary. ◎			
Environment Impact	-It harmonizes with surrounding by vegetation. The vegetation on the cut side is done with cribwork. ○	-Cut slope is expected of natural vegetation. △	-It harmonizes with surrounding by vegetation. The vegetation on the cut side is done with cribwork. ○			
Influence on Road	-One lane is operated while constructing ○	-One lane is operated while constructing ○	-One lane is operated while constructing ○			
Maintenance	-The maintenance is necessary until the vegetation takes root. The width of land use is maximum. △	-The maintenance is necessary until the vegetation takes root. The width of land use is minimum. ◎	-The maintenance is necessary until the vegetation takes root. The width of land use is middle. ○			
Economy	-Cribwork is expensive. ○	-Retaining wall is expensive. ○	-Cribwork and stone masonry are expensive. △			
Evaluation	-The width of land use is maximum, therefore It has an impacts on coffee plantation. 3	-The width of land use is minimum, therefore It decrease an impacts on coffee plantation 1	-The width of land use is necessary more wide than T-shaped retaining wall. 2			

Table17.6.20 Selection of Prevention Countermeasure Method

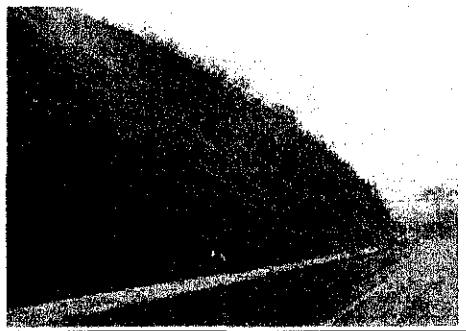
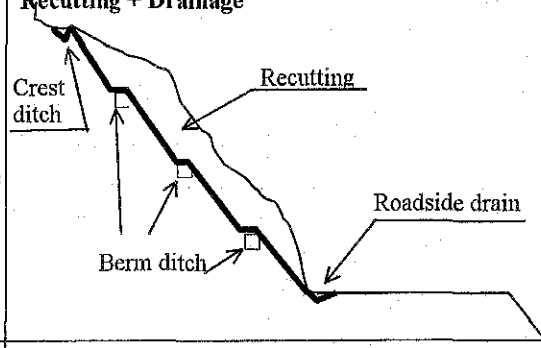
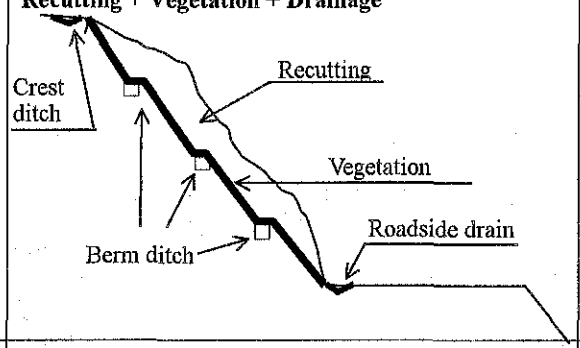
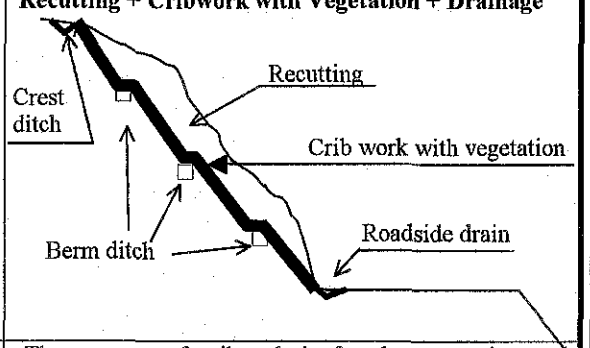
ID : N005A010	Topography	The Mountainside	Height and Incline	H =23 ～ 38 m , θ =41～48 deg.	The kind of The Rock	Talus and Tuff
Situation of Slope	Impact of Rain (Inflow water)	Inflow water Surface Water	Stability Analysis	Necessary	Purpose of Countermeasure	Rockfalls
	The Dry Season 				The Rainy Season 	
Comments	The slope consists mainly of talus of diluvial age over tuff. The existing road became unstable by the leg of talus was cut. The crest ditches were installed after collapse, but the infiltrating water is oozing. Falling rock continues because the gradient of cut is too steep.					
Alternative of Countermeasure	**Recutting + Drainage** 			**Recutting + Vegetation + Drainage** 		**Recutting + Cribwork with Vegetation + Drainage** 
Workability Structural feature	-Large-scale collapse is prevented by cut of 35 ° . Stability will increase by drainage facilities. ○			-Vegetation is added to left side alternative as the increase stability. ○		-The purpose of cribwork is for the vegetation and increase stability. But it does not contribute almost in stability. ○
Environment Impact	-Slope is expected of natural vegetation. △			-Slope is expected of natural vegetation. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○
Influence on Road	-One lane is operated while constructing ○			-One lane is operated while constructing ○		-One lane is operated while constructing ○
Maintenance	*-It is necessary to maintain slope surface.* △			-The maintenance is necessary until the vegetation takes root △		-The maintenance is necessary until the vegetation takes root △
Economy	-It is the most economical in three alternatives. ◎			-It costs the maintenance expense of the vegetation. ○		-Cribwork is expensive. △
Evaluation	-The purpose of prevention can be economically achieved. 1			The effect of the vegetation cannot be expected. 3		-The effect that corresponds to expense of cribwork cannot be expected. 2

Table17.6.21 Selection of Prevention Countermeasure Method

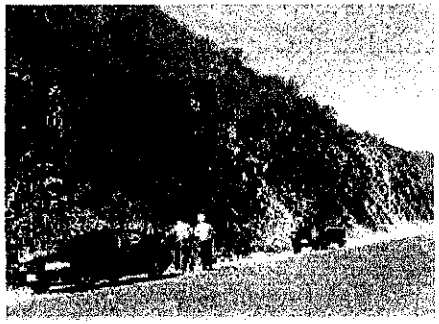
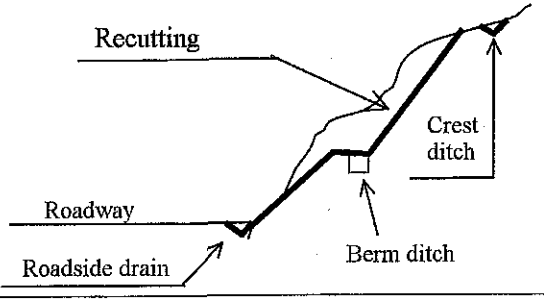
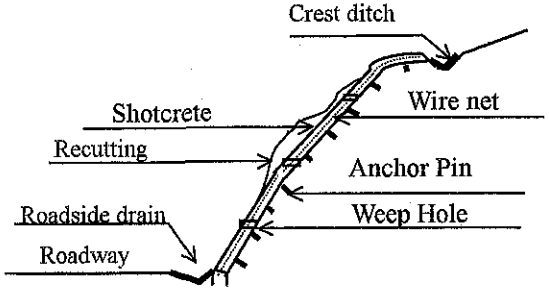
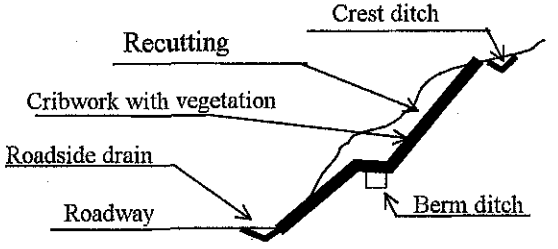
ID : N0026A060	Topography	The Mountainside	Height and Incline	H =9 ～ 14 m , θ =53～63 deg.	The kind of The Rock	Tuff
Situation of Slope	Impact of Rain (Inflow water)	After water	Stability Analysis	Unnecessary	Purpose of Countermeasure	Rockfalls
	The Dry Season 				The Rainy Season 	
Comments	The surface dropping and falling rock stand out in rainy season. The layer of weathering tuff collapses, therefore andesite near shoulder become overhanging and collapses. Tuff becomes collapse along the cracks because it is subdivided by repeating dry and wet.					
Alternative of Countermeasure	**Recutting + Vegetation + Drainage** 		**Recutting + Shotcrete + Drainage** 		**Recutting + Crib work with vegetation + Drainage** 	
Workability Structural feature	-Construction is not difficult. Cutting is inferior in respect of the weathering measures △		-It is necessary special equipment. -It is excels for countermeasure of weathering. ◎		-Construction is not difficult. -Some technologies are necessary. ◎	
Environment Impact	-Slope is expected of natural vegetation. △		-It is difficult to harmonize with surroundings. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○	
Influence on Road	-Traffic control is necessary during construction, but here is no influence after construction. ○		-Traffic control is necessary during construction, but here is no influence after construction. ○		Traffic control is necessary during construction, but here is no influence after construction. ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. △		-It is necessary to confirm volume of oozing. ○		-The maintenance is necessary until the vegetation takes root. It is effective to the weathering measures. ○	
Economy	-It is the most economical in three alternatives. ◎		-The cost is middle of all. ○		-Cribwork is expensive. It is the most expensive of all. △	
Evaluation	-Maintenance, environmental, and weathering are inferior. 2		-It is the most effective in the weathering measures. Infiltration of water can be prevented by crest ditch. 1		Stability and the environmental are excels after measures. But it is expensive. 3	

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Table17.6.22 Selection of Prevention Countermeasure Method

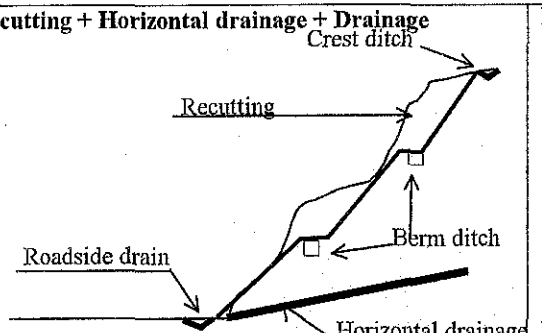
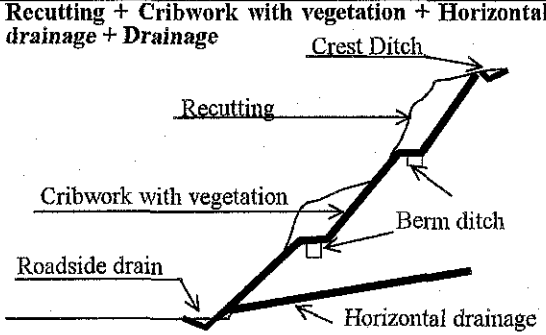
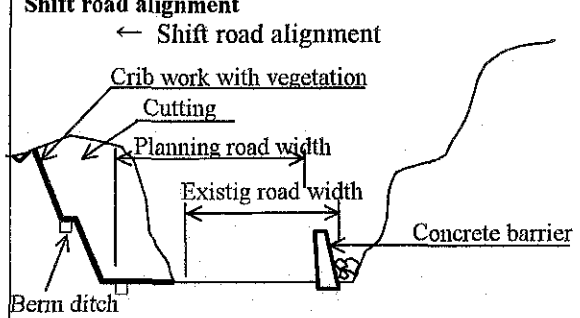
ID:N0026B140	Topography	The Mountainside	Height and Incline	H =11 ～ 33 m , θ =50～60 deg.	The kind of The Rock	Tuff and Andesite , The Portion is Fracture Zone.
Situation of Slope	Impact of Rain (Inflow water)	Inflow water	Stability Analysis	Necessary	Purpose of Countermeasure	Rock Collapse
	The Dry Season 				The Rainy Season 	
Comments	The width of crashed zone of tuff is about 50m. The angle of slide scarp is 60° ,and it is instability. Falling rock was confirmed in dry season, it enters the rainy season and has increased further. 40° is recommended as the angle of cutting. The slope has the small collapsing in the vicinity of the crashed zone. The inflow water was confirmed from the cracks.					
Alternative of Countermeasure	**Recutting + Horizontal drainage + Drainage** 		**Recutting + Cribwork with vegetation + Horizontal drainage + Drainage** 		**Shift road alignment** 	
Workability Structural feature	-Large-scale collapse is prevented by cut of 40 ° at fracture zone, 55 ° at the other zone. Stability will increase by horizontal drainage facilities. ○		-Cribwork is added to left side alternative as the increase stability and vegetation. ○		-The road alignment is shifted, and then concrete barrier is installed. Cribwork is installed after slope is cut at the opposite side △	
Environment Impact	-Slope is expected of natural vegetation. △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○		-Vegetation is done among the cribwork , but opposite side remain slope of existing condition △	
Influence on Road	-One lane is operated while constructing ○		-One lane is operated while constructing ○		-One lane is operated while constructing ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. Inspection of slope surface is necessary. △		-The maintenance is necessary until the vegetation takes root. ○		-Maintenance of cribwork side is unnecessary, but maintenance of existing slope side is necessary. ○	
Economy	-It is the most economical in three alternatives. ◎		-Cribwork is expensive. △		-Cutting and concrete barrier are expensive. △	
Evaluation	-Slope increases stability; because slope is cut to gentle gradient, and horizontal drainage is installed. 1		-The purpose of cribwork is for the vegetation, and it does not contribute almost in stability. 2		-The barrier is too big size. An economical effect cannot be demonstrated by shifting. 3	

Table17.6.23 Selection of Prevention Countermeasure Method

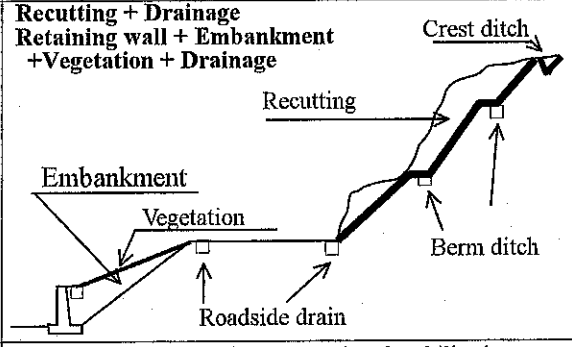
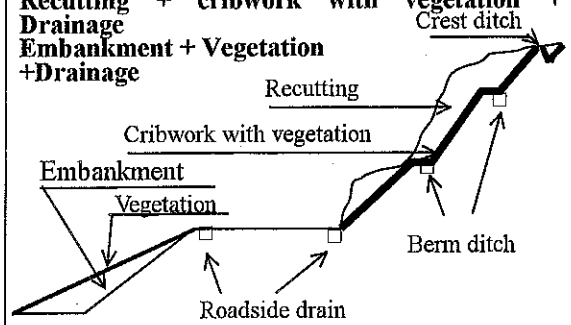
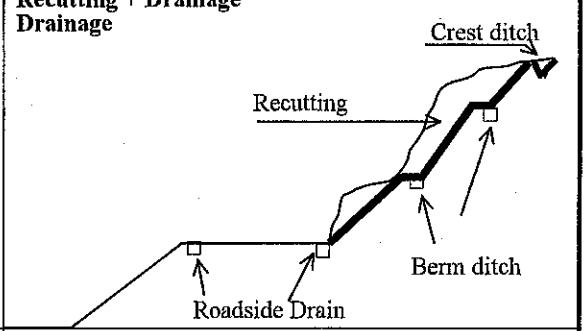
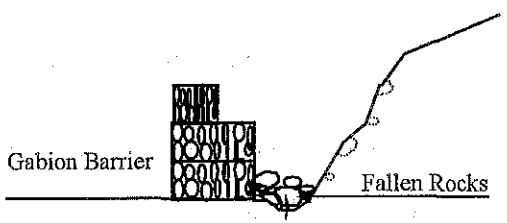
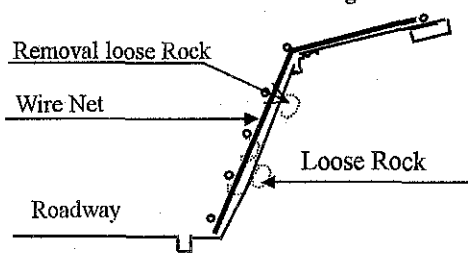
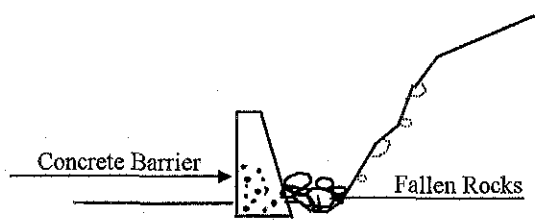
ID : N0026A150	Topography	The Mountainside	Height and Incline	H =18 ～ 56 m , θ =48～56 deg.	The kind of The Rock	Agglomerate, Tuff and Andesite , (Alteration zone)
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Necessary	Purpose of Countermeasure	Rockfalls
Situation of Slope	The Dry Season 				The Rainy Season 	
Comments	The whole of slope is a changing in quality action and a fragile rock. Marked in red is slide scarp, it is a supply source of the falling rock and the collapse, and it piles up in the place which slope was marked in white. The slope on the road side collapses easily, too and minute gravel diffuse to the road. The inflow water was confirmed at four positions in rainy season.					
Alternative of Countermeasure	**Recutting + Drainage Retaining wall + Embankment +Vegetation + Drainage** 		**Recutting + cribwork with vegetation + Drainage Embankment + Vegetation +Drainage** 		**Recutting + Drainage Drainage** 	
Workability Structural feature	-Large-scale collapse is prevented and stability increase by cut of 55 ° . Retaining wall is installed at embankment side. ○		-Cribwork and vegetation are added to left side alternative as the increase stability. Embankment increase stability by bench cutting of existing slope. ○		-Large-scale collapse is prevented and stability increase by cut of 55 ° .Roadside ditch is installed at shoulder of slope at embankment side. ○	
Environment Impact	-Slope is expected of natural vegetation at cut slope side △		-The environment is prevented from deteriorating by vegetation among the cribwork. ○		-Slope is expected of natural vegetation at cut slope side. △	
Influence on Road	-One lane is operated while constructing ○		-One lane is operated while constructing ○		-One lane is operated while constructing ○	
Maintenance	-The maintenance is necessary until the vegetation takes root. Inspection of slope surface is necessary. △		-The maintenance is necessary until the vegetation takes root. ○		-Inspection of slope surface is necessary. ◎	
Economy	-Retaining wall of embankment side is expensive. ○		-Cribwork is expensive ○		-It is the most economical in three alternatives. ○	
Evaluation	-Slope increases stability; because slope is cut to gentle gradient, and economical drainage system is installed. Retaining wall is unnecessary for stability. 3		-The purpose of cribwork is for the vegetation, and it does not contribute almost in stability. Embankment is unnecessary for stability. 2		-Slope increases stability; because slope is cut to gentle gradient, and economical drainage system is installed **1**	

Table17.6.24 Selection of Prevention Countermeasure Method

ID : N0026B160	Topography	The Mountainside	Height and Incline	H =11 ～ 22 m , θ =53～70 deg.	The kind of The Rock	Tuff and Andesite ,
Situation of Slope	Impact of Rain (Inflow water)	After rain	Stability Analysis	Necessary	Purpose of Countermeasure	Rock Collapse
	The Dry Season 				The Rainy Season 	
Comments	Cracks of andesite are open. The toppling phenomenon has been caused. The removals of unstable rocks are necessary.					
Alternative of Countermeasure	**Removal + Barrier with gabion wall +Drainage** 		**Removal + Prevention net + Drainage** 		**Removal + Barrier with concrete wall + Drainage** 	
Workability Structural feature	-Wire of gabion cannot resist against energy of the assumed falling rock. △		-The construction results are not in Nicaragua. -This type is almost permanent structure. ○		- The concrete barrier will be too big size for resistance against energy of the assumed falling rock. △	
Environment Impact	-Deterioration of environment will be forecast by damage of gabion. △		-It is necessary to cut trees. △		-Installing the concrete barrier lacks harmony with the surrounding. △	
Influence on Road	-It is difficult to stop completely jumping over rock by barrier. Width for barrier is not enough. △		-There is no problem. ◎		-It is difficult to stop completely jumping over rock by barrier. Width for barrier is not enough. △	
Maintenance	-It is necessary to remove collected rock. -Durability depends on the life of the wire. △		-The environment deterioration is eased by partially constructing the net. △		-It is necessary to remove fallen rocks. -The maintenance of the structure is unnecessary. ○	
Economy	-Because maintenance cost is high, costs of three alternatives are almost even. ○		-Net materials are expensive, but maintenance cost isn't high. ○		-The cost is middle of all. But the costs of three alternatives are almost even. ○	
Evaluation	-The gabion isn't steady by the collision of assumed falling rock. Width for barrier is not enough. 3		-This type prevents completely dispersion of rock collapse. 1		-The gabion isn't steady by the collision of assumed falling rock. Width for barrier is not enough. 2	

17.6.2 Selection of Countermeasures for Bridge Foundation Scouring

1) Junquillal

According to the hydrological analysis, the sectional area for the river is inadequate at the bridge. It is therefore necessary to take the following countermeasures:

- Replace existing bridge with new bridge with adequate sectional area.
- Ensure and keep the required sectional area for the new bridge.

This river is a natural river and has no embankments. Therefore, the difference between the level of the riverbed and surrounding countryside is small. Therefore, it is impossible that the NIC.1 around the main bridge would be submerged even if a flood or rainfall that only statistically happens once a year occurred. However, because scouring of the foundation around bridge piers has been detected (i.e., 4-5 m in size extending from the pier, Photo 17.6.1), scouring countermeasures for the existing bridge foundation shall be taken. Finally, it is desirable to construct a new bridge with the necessary sectional area once the recommended improvements are made.

Photo 17.6.1
Trace of Bridge Foundation Scouring

As described in Chapter 17.2.2, the materials used for protecting a riverbed are as follows:

(i) Gabion
(ii) Concrete foot protection
(iii) Precast-concrete block

However, due to the reasons listed below, gabions shall be selected for the riverbed protection work (Figure 17.6.2).

- The bearing capacity of the riverbed is weak because it consists of cohesive soil, meaning that differential settlement can easily occur. For that reason, utilization of concrete and concrete blocks could lead to structural deformation and damage.
- In contrast to concrete materials, gabion can respond to differential settlement and deformation flexibly. It is also easy to repair.
- Since land around the bridge consists of paddy fields, it is advisable to apply a countermeasure that will not degrade water quality.
- Because river flow velocity is slow, it is unnecessary to use heavyweight materials such as concrete blocks.

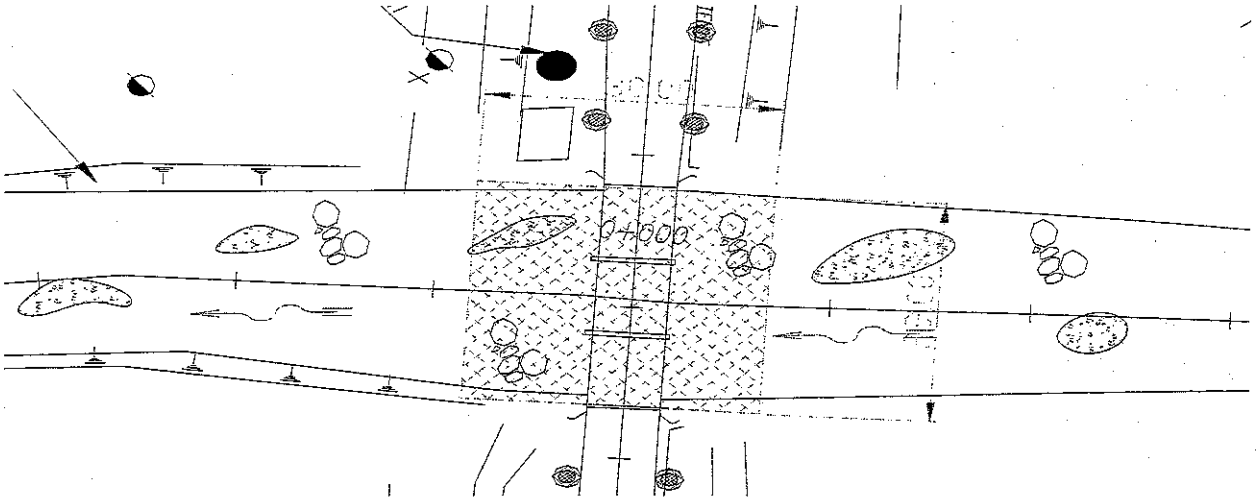


Figure 17.6.2 Area of Protection Work

2) San Nicolas

Because scouring prevention countermeasures have not been taken, there is hole at the foundation of the abutment on the Managua side due to the outflow of soil at the back of said abutment. The major factors that are the cause of this scouring are as follows:

- The gradient of the river channel is steep (2.42%).
- The river flows close to a damaged abutment.
- Others.

Because the collapse at the back of the abutment is highly advanced, the following countermeasures to protect the front-end of the abutment are proposed.

- Embank the front-end of the abutment and create a concrete slope at a ratio of 1:1 (see Figure 17.6.3)
- Protect abutment directly with stone masonry revetment **(Figure 17.6.4)**

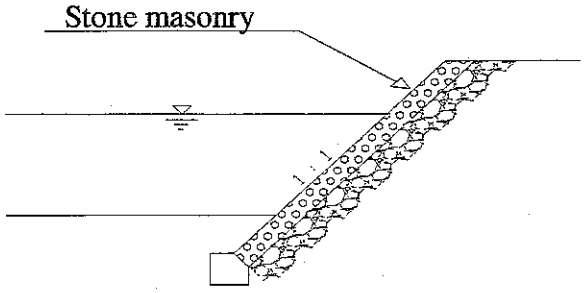


Figure17.6.3 Concrete Revetment (1:1)

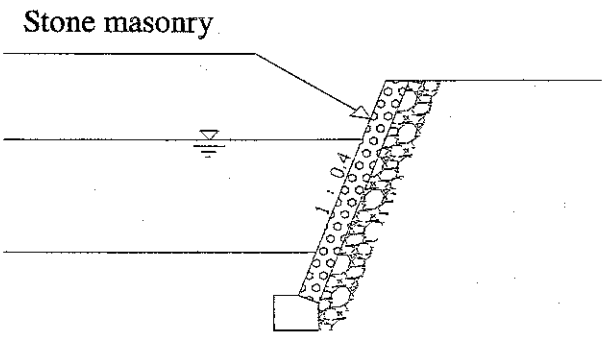


Figure 17.6.4 Stone Masonry Revetment (1:0.4)

Stone Masonry revetment shall be applied because of the following reasons (Figure 17.6.5). The height of the Stone Masonry revetment shall be 5 m in consideration with the water level in case of flood. In addition to that, because the river channel flows close to the abutment side that took an effect of scouring, protection measure shall be implemented base on the following spec.

- In order to minimize obstruction to the sectional area of river channel by protection measure, the gradient shall be 1:0.4.
- Length of transition area shall be 20m from the edge of the bridge to the upstream side in order to minimize the impact on the.

Further more, protection measure for the riverbed shall be implemented in the front of revetment by the gabion with 3 meter width.

Although the improvement work of river is necessary in order to make the gradient gentler by means of raising of level of riverbed, water controlling work, and so on, the protection measure for riverbed in front of the abutment and around the bridge is suggested, judging from the following cite situation.

- The riverbed consists of bedrock.
- The flow volume is not large, and the velocity of water flow is slow.

No large wreck of scouring of bridge foundation can be identified except for the part of the abutment.

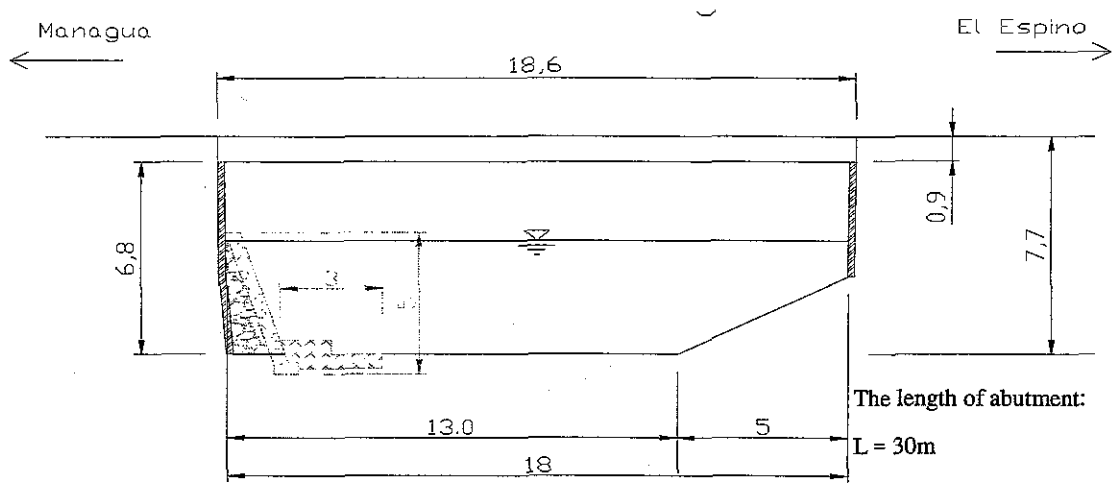


Figure 17.6.5 San Nicolas counter measure

3) Las Chanillas

The characteristic of this river is the high velocity of the water flow. The reasons of high velocity seem to be as follows:

- The gradient of riverbed is steep (1.7%).
- The surface of riverbed is relatively uniform and the coefficient of roughness is

small.

- The alignment of river channel in the both sides of river is straight and the change is few.

The highly advanced scouring can be identified near the bridge pier, and no major damage can be seen at the abutment part. Therefore, counter measure for the scouring around the bridge piers shall be examined.

As for the materials used for the counter measure, referring to the Table 17.5.5, precast-concrete block shall be used for the revetment around bridge piers. The reasons of selection of counter measure are as follows. In addition, the construction range shall be 4 meter around bridge pier based on the Table 17.5.3 (Figure. 17.6.6). The weight of block needs to be around 5 t due to the fast velocity of water flow (Table 17.5.5).

i) The velocity of water flow is high (5 m/sec), and the grain diameter of rubble would be quite large (d50 = about 70cm would be necessary).
ii) It is possible to implement construction work even in the season when more or less flow exists on the river channel.
iii) The initial cost of investment is higher than the gabion, but the maintenance would be unnecessary.
iv) If the cast in place concrete were applied, the construction work would be implemented in the dry season. So there is a restriction of the term of construction work.
v) Although the temporary yard for the production is necessary, the restriction of the yard for temporally facilities is small because precast-concrete members are used.
vi) The facilities for block production are available in Inali and Tapascali.

4) San Ramon

The concrete wreck that seems to be originated from old bridge remains in the El Esoino side of the river channel(**Photo 17.6.2**), and there is major scouring of riverbed between this concrete wreck and abutment.

As a result of survey of river and bridge, no cause of scouring could be identified except for this concrete wreck. Therefore, the wreck of old bridge abutment shall be removed, and the protection measure for riverbed shall be taken. The following materials are given as protection measure for riverbed:

i) Gabion
ii) Stone Riprap with mortar
iii) Concrete block

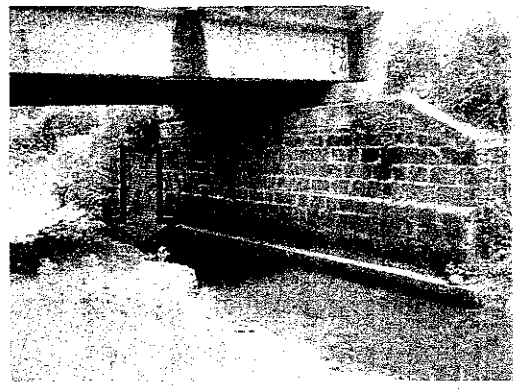


Photo 17.6.2 Track of old bridge and water flow

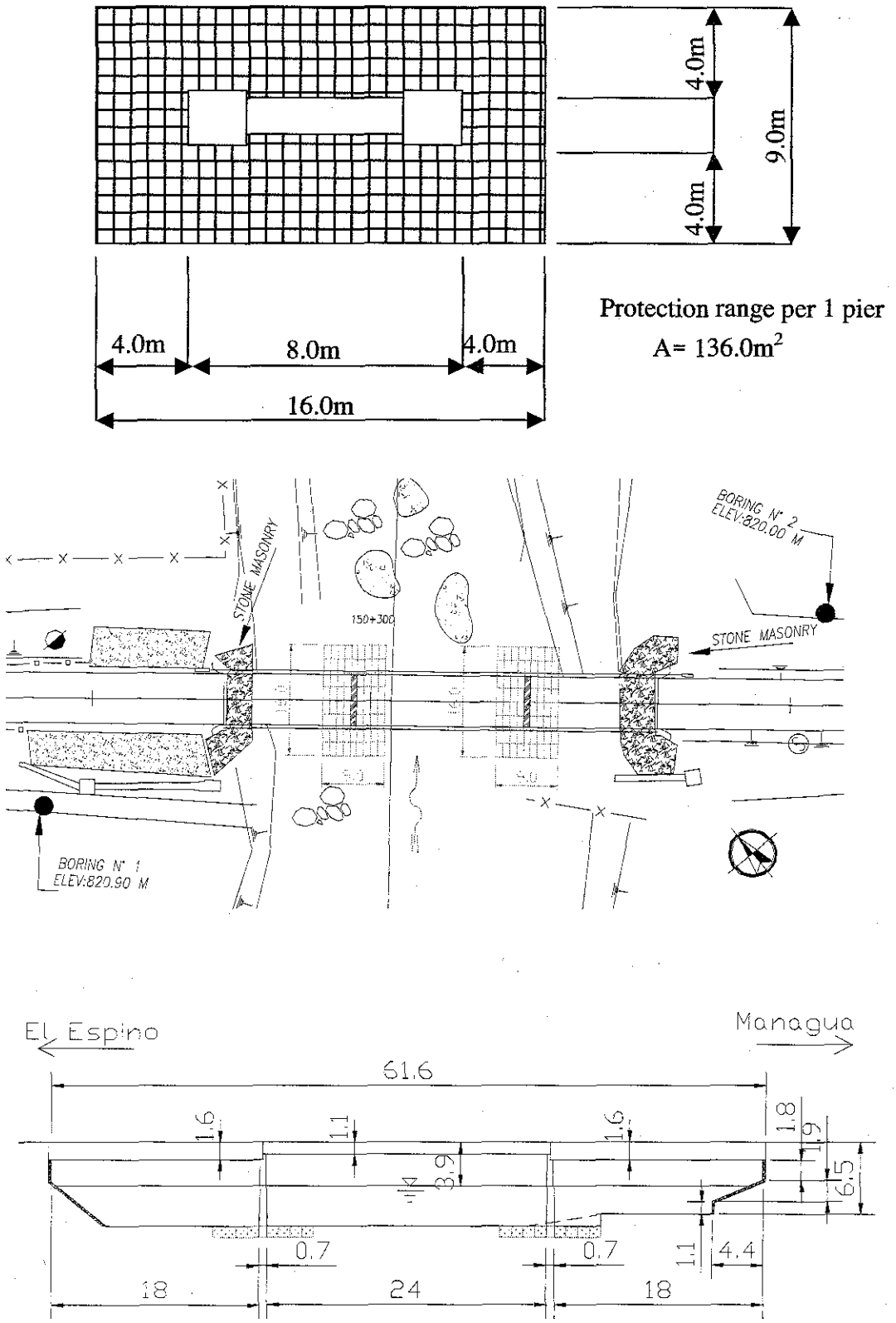


Figure 17.6.6 Protection Range around Piers

In consideration of the following condition, protection measure by gabion shall be suggested.

- The river is small stream with small volume of water flow.
- This bridge is concrete bridge whose age is over 50 years old, and it is highly possible of this bridge to be replaced in the near future.

In consideration of the range of wing revetment of the existing bridge, the range of protection measure shall be up to 3 meter from the both upstream and downstream side of the bridge.

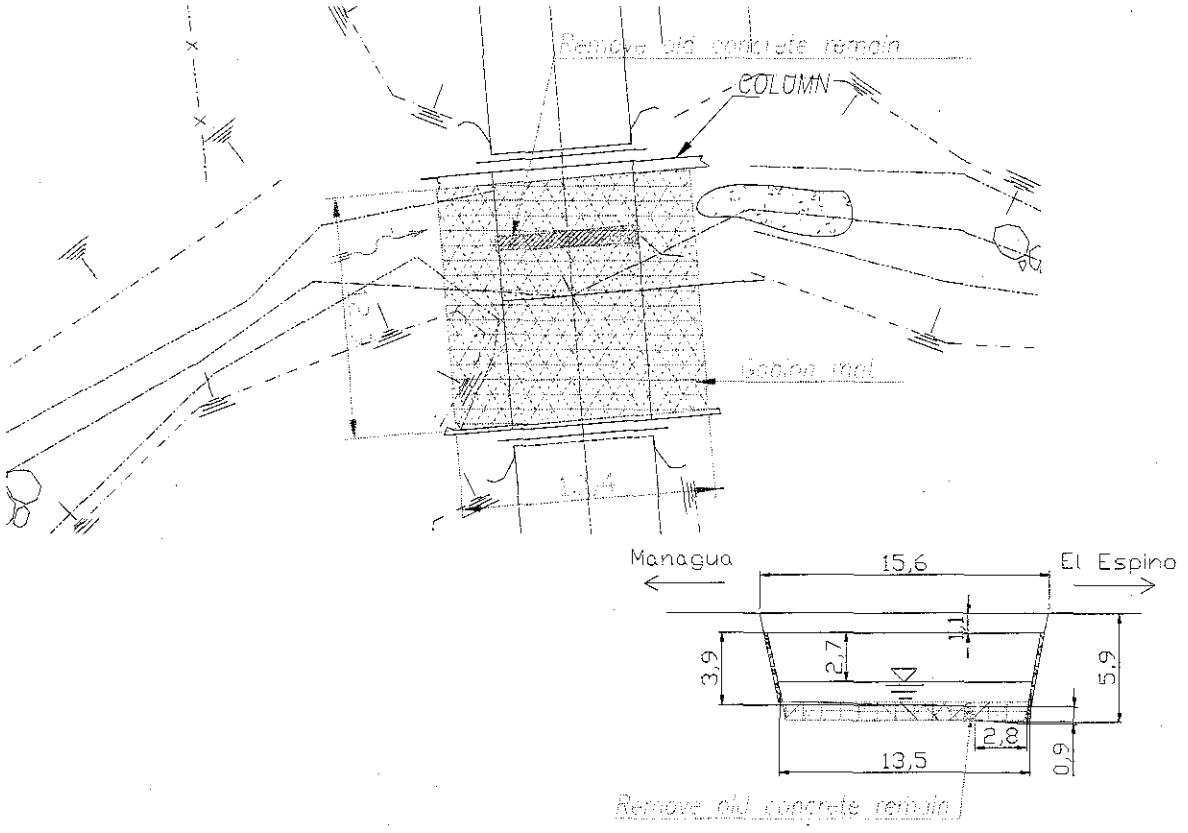


Figure 17.6.7 Abstract of Counter Measure

5) Inali

No major truck of scouring was seen through the actual site survey of this bridge. But, detailed survey identified that there are factors of scouring resulting from the river characteristics and the structural characteristics of bridge.

i) Factors resulting from the river characteristics

The possible reasons for the very high velocity (4.92 m/sec) of the river same as Las Chanilas are follows.

- The gradient is relatively steep (1%).
- The alignment of the river is linear.
- The riverbed condition is uniform with small changes in the shapes and grain diameter of riverbed.

ii) Factors resulted from the structural characteristics of bridge

- The bridge length (64m) is shorter than the river width of both the upstream side (85m) and downstream side (95m).
- The revetment of the front of abutment projects into the river channel, resulting in narrower river channel.
- The distance between piers and revetment of the front of abutment is short.

Therefore, counter measure shall be examined for these factors. The countermeasure is shown in the Table 17.6.25 and the Figure 17.6.8.

Table 17.6.25 Countermeasures for Inali Bridge

Aims to Achieve	Countermeasures	Reasons for Selection
i) To improve the revetment of the front of abutment in order to extend the sectional area of river channel ii) To improve the revetment of the front of abutment in order to ensure and keep the distance between the pier and abutment	Protection of abutment by Stone Masonry revetment (gradient of the front = 1:0.4)	To ensure and keep the sectional area of river channel
iii) To protect foundation around piers against scouring although no abnormality including scouring can be identified.	Precast concrete blocks shall be used same as Las Chanilas. The weight of concrete block shall be 5 t/piece, and the range of protection measure shall be 4 meter around the pier based on Table 17.5.3.	To follow the case in Las Chanillas
iv) To protect the riverbed in front of the abutment	The protection measure for the riverbed in front of the abutment against scouring shall be taken by the concrete blocks. The protection measure work shall be implemented by the range of 3 meters width from the front of abutment. The used concrete blocks shall be same as those used for piers.	Because the abutment projects into the river channel.
v) To protect the slope of approach which projects into the river channel.	The protection measure shall be taken for the both upstream side and downstream side of the slope by concrete. The protection measure work against scouring shall be taken for the riverbed at the bottom of the slope in the downstream side by using gabion.	
vi) To protect the river bank and promote the sedimentation by installing the groyne at the part wider than the bridge.	To install the groyne for the left bank by using gabion, right-angled to the bank. Width:4m,length:25m,interval:50m	By installing the groyne, to promote the sedimentation of soils on the widened river, to protect the bank, and to protect the approach

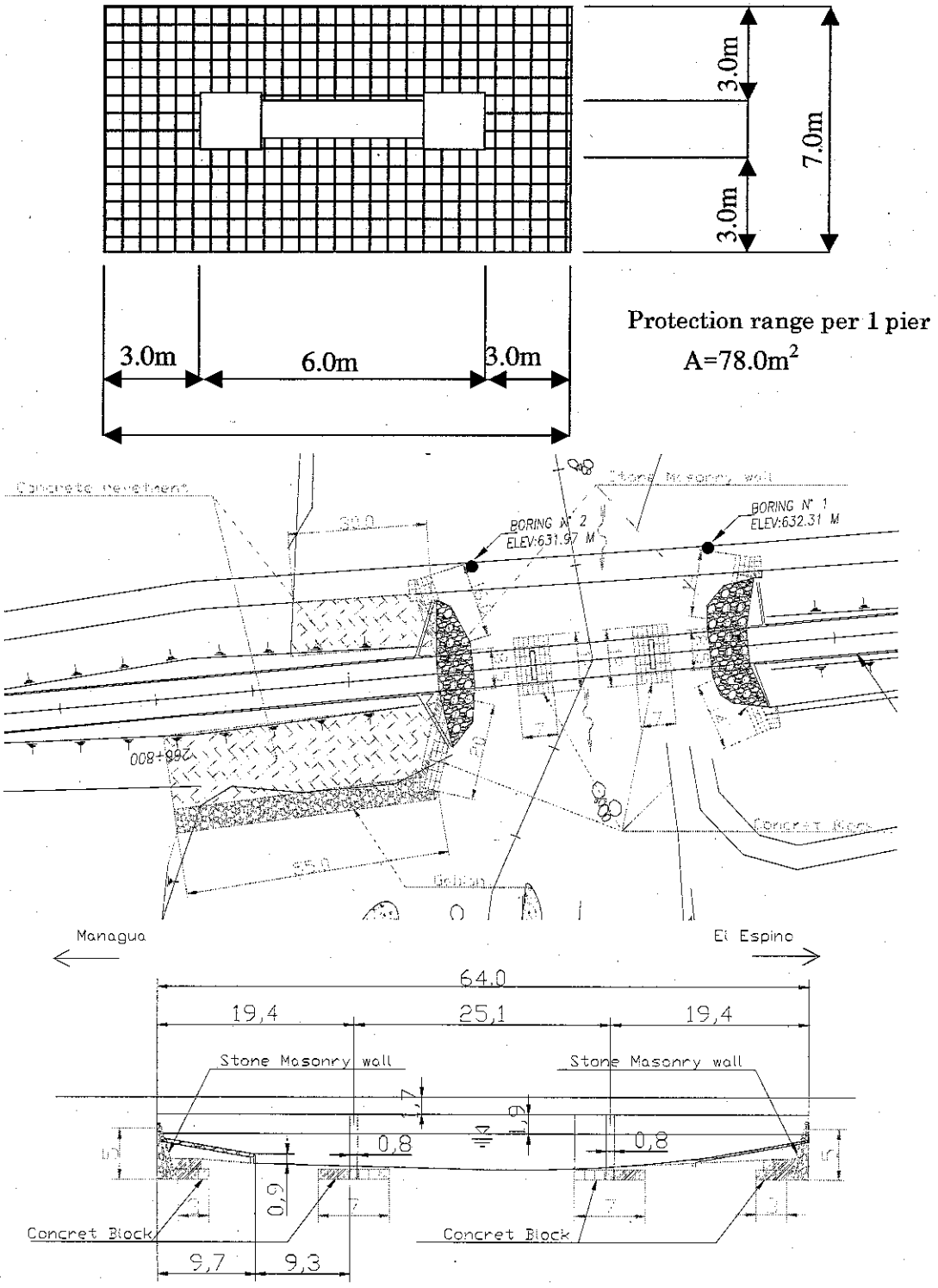


Figure 17.6.8 Protection Range around Abutment and Piers

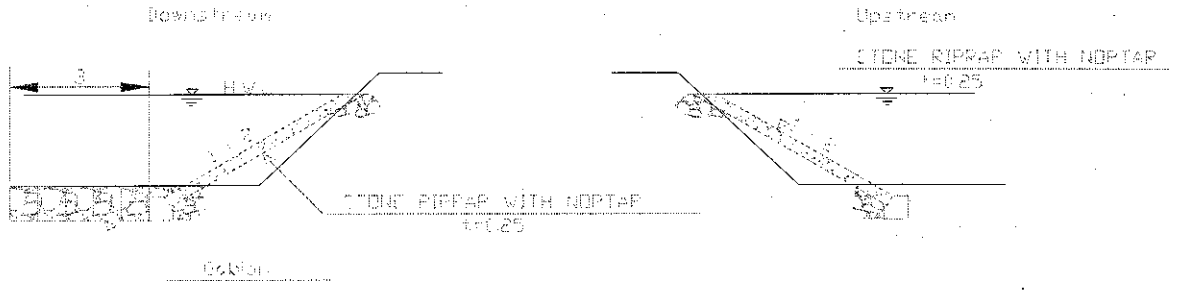


Figure 17.6.9 Reinforcement for approach

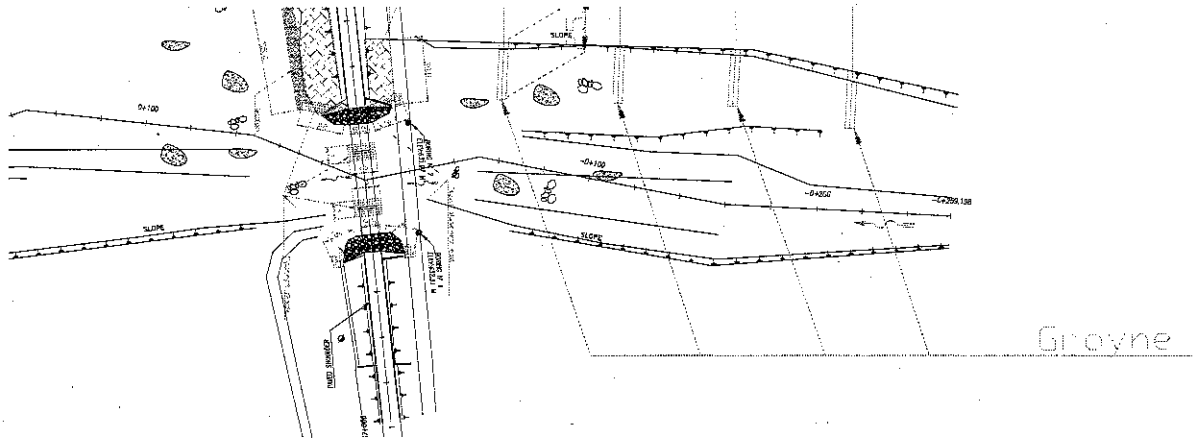


Figure 17.6.10 Groyne

6) Tapacari

This bridge is the largest among the target bridges of the survey, with the maximum water flow of 1260m^3/sec. But, the slope is gentle, so the water velocity is not so high. However, because this bridge is located at the extensively curving part of the river, the river section covered by this bridge is separated into a part with highly progres :d scouring (Managua side) and a part where the sand can accumulate easily (El espino side), both of which are taken effects on by the complicated river flow. The tracks of major scouring are identified around the Managua side abutment and around the 2 piers(P1, P2) in the Managua side. In addition, because the revetment of front of the abutment projects into the river channel same as Inali, the distance between the abutment and the pier (side span length) is short. This seems to be one of the factors that promote the scouring. Therefore, the counter measure shall be planned for the purpose of improvement of revetment of abutment and protection for scouring around piers. The counter measure is shown in the Table 17.6.26, the Figure 17.6.11, and the Figure 17.6.12.

Table 17.6.26 Countermeasures for Tapacali Bridge

Aims to achieve	Countermeasures	Reasons for selection
i) To improve the revetment of front of the abutment in order to extend the sectional area of river channel. ii) To improve the revetment of front of the abutment in order to ensure and keep the distance from the pier	To protect the front of abutment by using concrete revetment (1:2)	Because the height of protection measure is more than 5 meter.
iii) To protect the scouring around the piers	The precast-concrete blocks shall be used. The weight of concrete block shall be 1 t/piece. The protection range shall be 3 meter around the pier, based on Table 17.2.8.	To follow the case in Las Chanillas
iv) To protect the riverbed in front of the abutment	The protection measure for the riverbed in front of the abutment against scouring shall be taken by the concrete blocks. The protection measure work shall be implemented by the range of 3 meters width from the front of abutment. The concrete blocks same as those for piers shall be used.	The abutment projects into river channel.

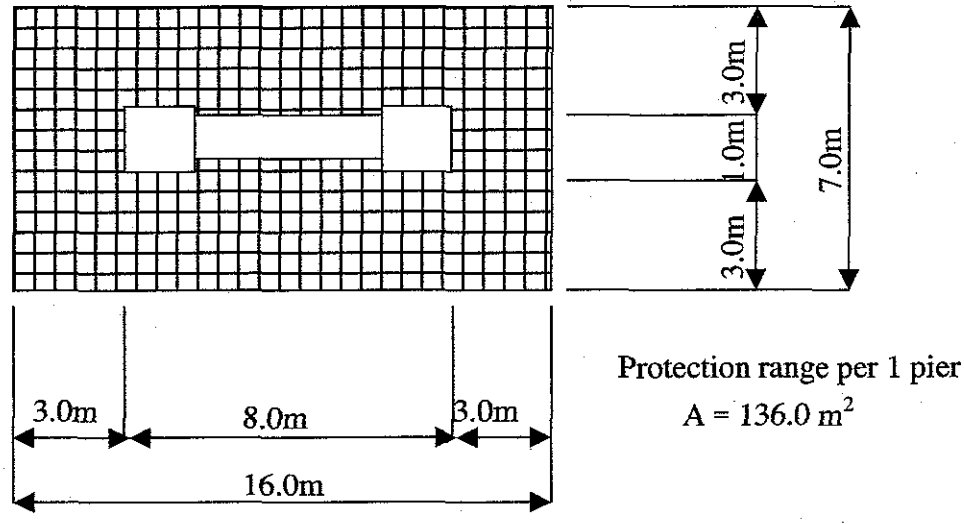


Figure 17.6.11 Protection Range around the Pier

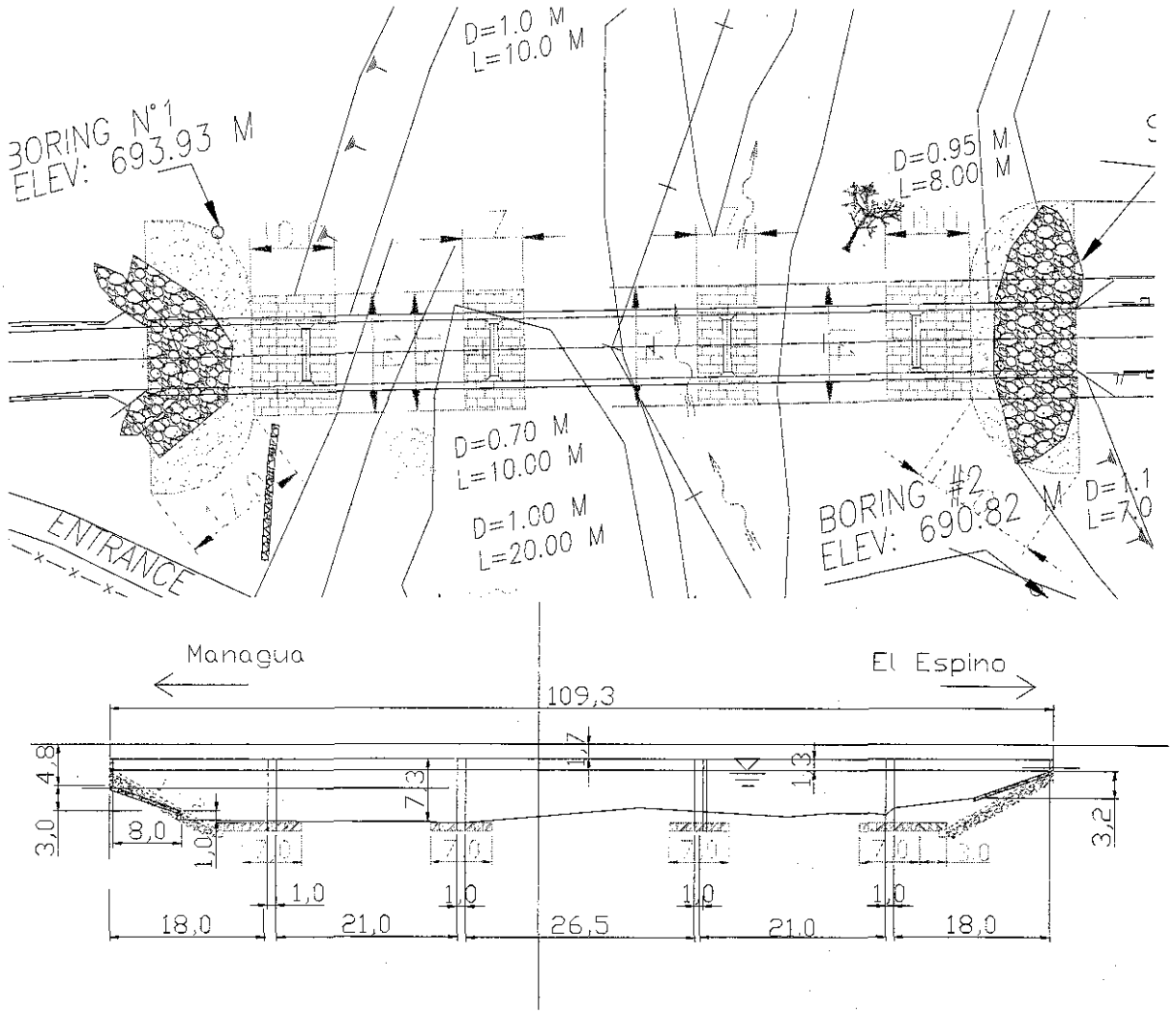


Figure 17.6.12 Abstractive Layout of Countermeasure

7) Guayacan

This bridge is oldest and most damaged among the target bridges of the survey. The differential settlement occurs around the Matagarupa side abutment, and the wind was damaged. From the survey result, the cause of differential settlement can be decided. However there are many factors of scouring in this bridge, as shown in the following, and the depth of scouring is deepest around the abutment around which the differential settlement occurs. Considering these conditions, the differential settlement seems to be resulted from the scouring. Although, generally speaking, the scouring occurs in the upstream side of bridge, the scouring occurs in the downstream side of this bridge. Considering these conditions, the major scouring seemed to be caused in the downstream side by turbulence of river flow disturbed by the bridge. The problems and issues to improve related to this bridge are shown in the Table 17.6.3.

Table 17.6.27 Problems at Guayacan Bridge

Factors of scouring	Problems	Causes	Improvement measures
River	The alignment of river is complicated, and the river water flows complicatedly at the bridge.	The river diverges in the upstream, and joins just before the bridge again.	To reinforce the joining part To improve the joining way
		The river is curving extensively at the downstream of bridge.	To reinforce the outside revetment
		The river channel was dug deeply by the scouring at the upstream side of the bridge.	To take a counter measure against scouring of bridge foundation
		The level of river channel becomes high due to the sedimentation in the downstream side of the bridge.	To remove the accumulated soils
	As a result of hydrological analyses, the level of water would be more than 1 meter higher than the level of road surface with the president bridge length.	The sectional area of river channel is insufficient.	To ensure and keep the sectional area of river channel
Type of bridge	The obstruction ratio is very high (27%).	The bridge type is arched shape, so the sectional area of river channel is very small.	To ensure and keep the sectional area of river channel by constructing new bridge or culvert close to the existing bridge.
	The position of bridge doesn't correspond to that of river.	The alignment of river changed through the flood in MICH.	To construct new bridge
	The bridge length (L=17m) is short compared with the river width (upstream side, downstream side)		To construct new bridge

As counter measures for above mentioned problems, plans to utilize the existing bridge (Plan 1 and Plan 2) and a plan to remove the existing bridge (Plan 3) shall be examined.

Plan 1 : To construct a box culvert in the side of Matagarupa in order to ensure and keep a sectional area.

Plan 2 : To construct a new bridge in the side of Matagarupa

Plan 3 : To replace the existing bridge with a new bridge

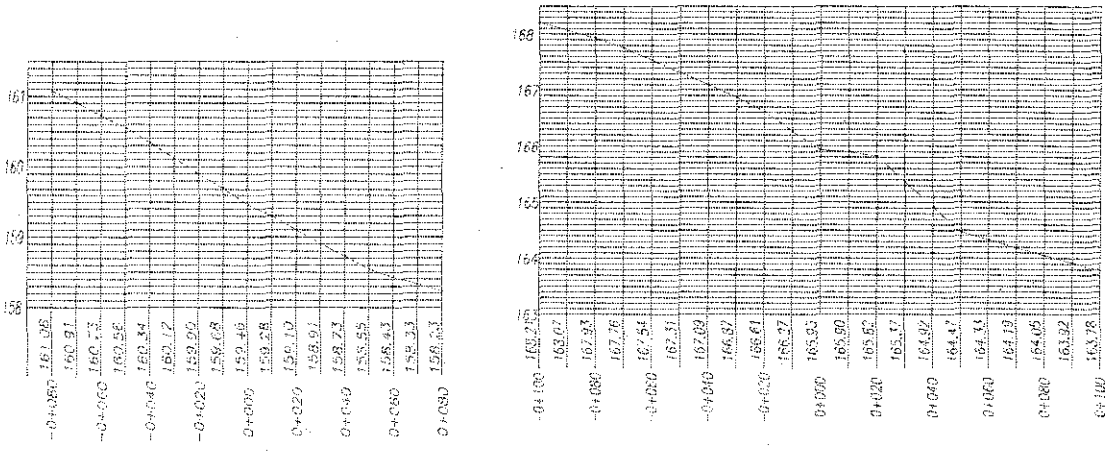
The comparison of each plan is shown in the Table 17.6.27. As a result of the comparison shown below, the Plan 3 (to replace the existing bridge with a new bridge) is suggested.

- Only plan 3 can solve the problem of scouring.
- There is no residence around this bridge, so raising the vertical alignment of road by 2 meters will not have large impacts.
- Because the existing bridge is almost 60 years old after being constructed and damaged to great extent, it will be necessary with strong possibility to replace or reinforce the existing bridge in a few years later.
- In case of utilizing the existing bridge, 2 new bridges of 20m-length will be constructed in the future. As a result, the cost will be relatively more expensive.

8) Solis and Papalon

The year of construction of both Solis bridge and Papalon bridge is relatively young (built in 1963). Nonetheless, due to the highly advanced scouring, the level of riverbed has been lowered below the subgrade of abutment by more than 60cm at Solis bridge, and up to almost same as subgrade of abutment at Papalon bridge, making the site condition very dangerous. It is estimated that the weathering of surface stratum of riverbed is highly advanced, and that the scouring of foundation was gradually promoted through the outflow of powdered fine granular by the water flow. According to the geological survey result, although the subgrade of abutment is weathered tuff, due to the small volume of river flow in this area, the weathering of riverbed surface is seemingly being speeded by the repetition of dry condition and wet condition. In addition, as shown in Figure 17.6.13, because the vertical alignment of whole river channel is uniform with gradient about 2%, not only the level of riverbed around the bridge but also the level of whole river channel descends uniformly.

Further more, the vertical alignment falls into disorder to some extent at the Papalon bridge, showing the influence of the bridge on the scouring. The sectional area at the Papalon bridge, which is smaller than that of the upstream and downstream of the river channel, is considered as the cause of this disorder

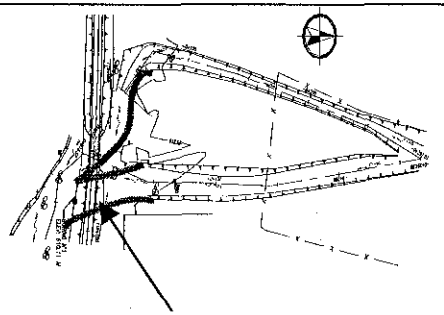
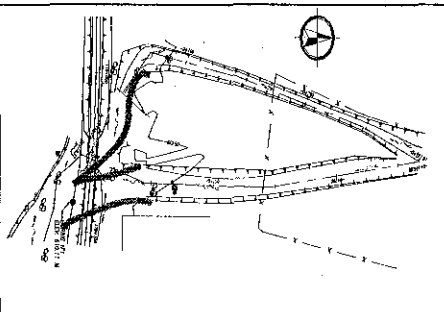
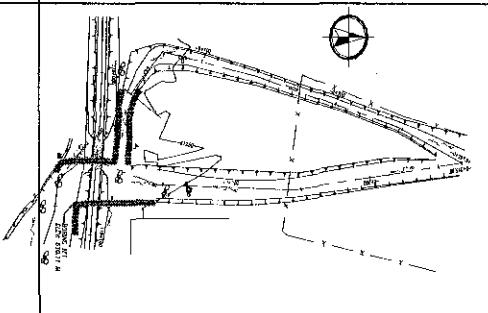


Solis **Papalon**

Figure 17.6.13 The Vertical Alignment of Riverbed at Solis Bridge and Papalon Bridge

Based on the above mentioned matters, the main cause of scouring at this bridge is not the impacts of bridge but the characteristics of river itself. The evidence for it is that there is no major problem related to the bridge including the sectional area at the bridge. In order to protect bridge foundation against scouring, it is necessary to protect the front of abutment by raising the level of riverbed at the existing bridge, and to change the vertical alignment of river channel in the upstream side of the bridge. Taking advantage of the condition that the volume of water flow is small, and that sufficient sectional area can be maintained even after raising the level of riverbed at both Solis bridge and Papalon bridge, the level of riverbed around the abutment shall be raised, and the vertical alignment of river in the upstream side of the bridge shall be gentle. The head shall be constructed in the downstream side of the bridge, and the vertical alignment shall be joined the existing river channel through transition section.
In order to raise or protect the level of riverbed at the bridge, concrete, gabion, and gravel can be thought as the materials. But because the river scouring is highly advanced, the stone riprap with mortar shall be used for the protection of the riverbed.
In addition, gabions and dumped rocks shall be used for the upstream part, and a head construction by gabions and stone Masonry shall be installed for the downstream part (**Figure 17.6.14**).

Table 17.6.28 Examination of Type of Guayacan Bridge

Plans		Plan 1	Plan 2	Plan 3
Abstractive layout				
Abstract of structure		To construct box culvert in the side of Matagarupa. Then let the small stream flow through the existing bridge, and let the larger river flows through the new culvert.	To construct a new bridge in the side of Matagarupa. Then to let the small stream flow through the existing bridge, and let the larger river flow through the new bridge (L=20m).	To replace the existing bridge with a new bridge(L=30m)
Advantages and disadvantages	River	The river joins at the downstream of bridge, and the impacts on the scouring will be small.	The river joins in the downstream side of bridge, so the impact on the scouring will be small.	The river joins in the upstream side of the bridge, so the protection measure for the scouring of bridge foundation will be necessary.
	Road	It is possible to maintain the existing alignment. It is necessary to make diversion of the traffic on the construction	It is necessary to raise the vertical alignment of road by 2 meter higher than the existing alignment. It is necessary detour the traffic on the construction	It is necessary to raise the vertical alignment of road by 2 meter higher than the existing alignment.
	Structure	When the driftwoods stick at the bridge, they block the sectional area and become a cause of scouring. Therefore there remain problems including obstruction ratio, span length, and so on.	The obstruction ratio and span length will be improved. The arrangement of the existing bridge and a new bridge is complicated.	All problems will be solved.
	Economy	The initial cost is cheapest. But because the existing bridge is old, it will be necessary to replace the existing one in n the near future. As a result, this plan will be relatively expensive.	The initial cost is cheapest next to the Plan 1. But because the existing bridge is old, it will be necessary to replace the existing one in n the near future. As a result, this plan will be relatively expensive.	The initial cost is expensive, but the maintenance work in the future is unnecessary.
Evaluation		△	○	◎

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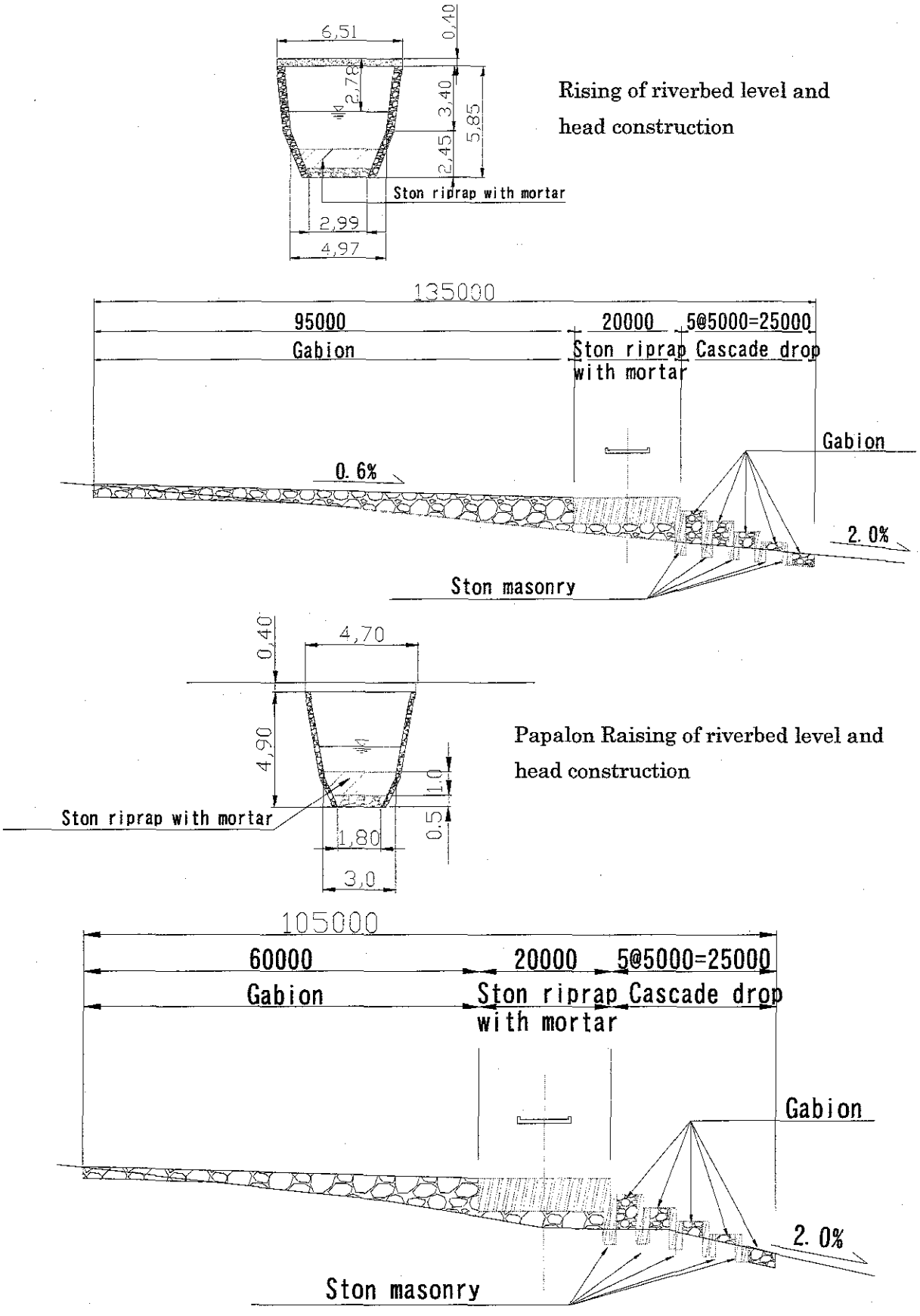


Figure 17.6.14 Abstract of Countermeasure at Solis and Papalon

9) San Juan de Dios

According to the result of hydrological analyses of this bridge, the level of flood that might occur once a hundreds years is almost same as the level of the road surface. From the viewpoint of hydrological analyses, the sectional area is insufficient at crossing point of the bridge, so it is advisable to substitute a new bridge with sufficient sectional area that satisfies the condition of the hydrological calculation. However, this river is a natural river without a bank, and the level of riverbed is not so different from that of ground around the river. For that reason, it is possible to judge that, even in case of a storm that might occur once a hundreds years, the flooded river water would seldom flow into the adjacent low land, and the road around this bridge will seldom be submerged. However, because, in case of the flood, the overflowed water would flow into the narrow river channel at bridge from all directions (Figure 17.6.15 Bold arrow mark), it would be easy of the riverbed at the upstream side of bridge to be scoured. This kind of phenomenon can be identified by the condition of actual site. Therefore, the protection measure for the scouring of abutment of piers shall be examined here. For the following reasons, protection by using gabion shall be selected as the protection measure for this bridge among those shown in the Table 17.5.5.

- The velocity of river flow is very slow (1 m/sec) at the crossing point of this bridge.
- The construction work and maintenance in the future is easy.
- The protection by using gabion is most economic.
- Because the size of this bridge is small and the clearance under the girder is short, it is difficult to implement the construction work by using concrete blocks.

The protection range against the scouring around the piers is 3 meters from the piers based on the calculation result about scouring range shown in the Table 17.5.3. But, in consideration to the counter measure against the scouring around the abutment, the protection range shall be as shown the Figure 17.6.15.

Further more, when the bridge is replaced with the improvement of NIC.26 road, or when the river and its banks are improved, it is advisable to substitute a new bridge that has a necessary sectional area. Judging from the survey result, the size of a new bridge shall be advisably one with the length of one span 25-30m.

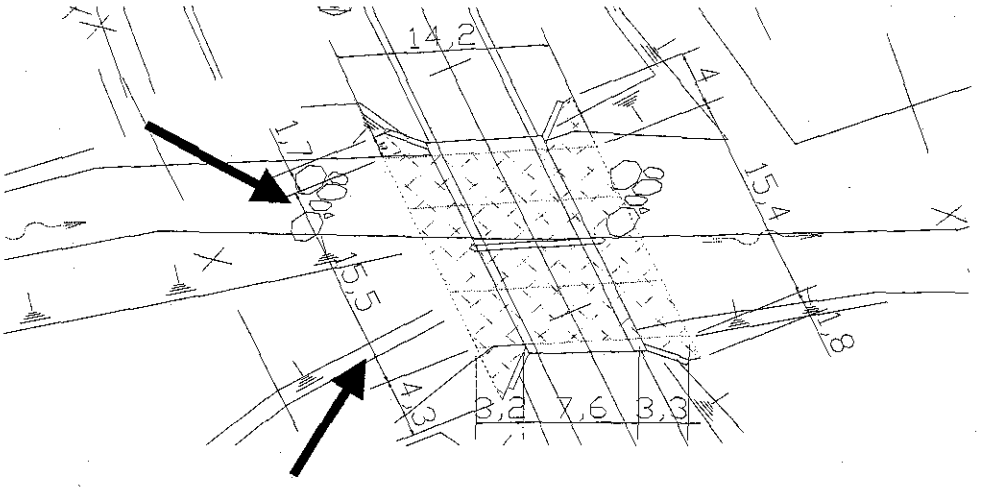


Figure 17.6.15 Abstractive Layout of Countermeasure of San Juan de Dios

10) La Banderita

The factors of the scouring at this bridge are as follow:

i) The piers have 2-column, rigid-frame structure.

ii) Although the level of subgrade of abutment is at level higher than the riverbed by about 3 meters, no protection measure has been taken.

iii) Compared with the central span length (15.4m), the side span length is short (6.6m). So the distance between the foundation of the abutment and the pier is very narrow (Figure 17.6.16).

iv) The gradient of the river channel is a little steep (1.79%).

However, because, compared with the size of the bridge, the volume of river flow is very small (72.6m^3), no track of scouring was identified except for the foundation of abutment. Therefore, the counter measure shall be examined for the purpose of protection of bridge foundation. Further more, although no track of scouring was seen around the piers, the protection measure against the scouring around piers shall be also taken in consideration to the rigid-frame structure of piers.

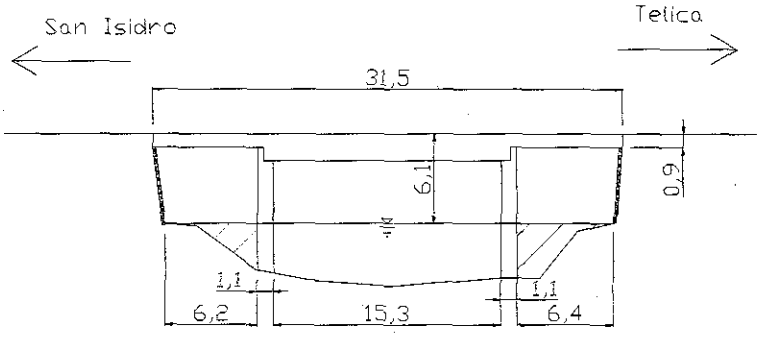


Figure 17.6.16 The Existing Bridge at La Banderita

There are 2 protection measures for the foundation of abutment including the concrete revetment (the gradient of the front = 1:1), and Stone masonry revetment (the gradient of the front =1:0.4). However, in order to ensure and keep the sectional area or river channel, the Stone masonry revetment (the gradient of the front =1:0.4) shall be applied for the protection of the front of the abutment. The range of construction shall be 10 meters from the edge of the bridge both in the upstream and downstream.

In order to protect the foundation of piers against the scouring, the protection measure by using gabion shall be selected among the counter measures shown in Table 17.5.5, taking into consideration conditions that the velocity of water flow is slow and that the volume of water flow is small. The protection range shall be 2 meters from the piers, based on the calculation result about the scouring range shown in Table 17.5.3. In addition to that, gabions shall be laid on the range of 3 meters width as the foot protection of the protection measure for the front of abutment (Figure 7.6.17).

Furthermore, because the piers of this bridge have the rigid-frame structure, partition wall shall be put between piers (Figure 7.6.18).

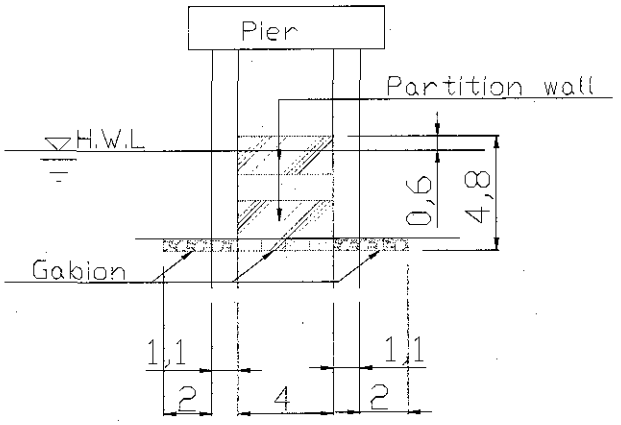
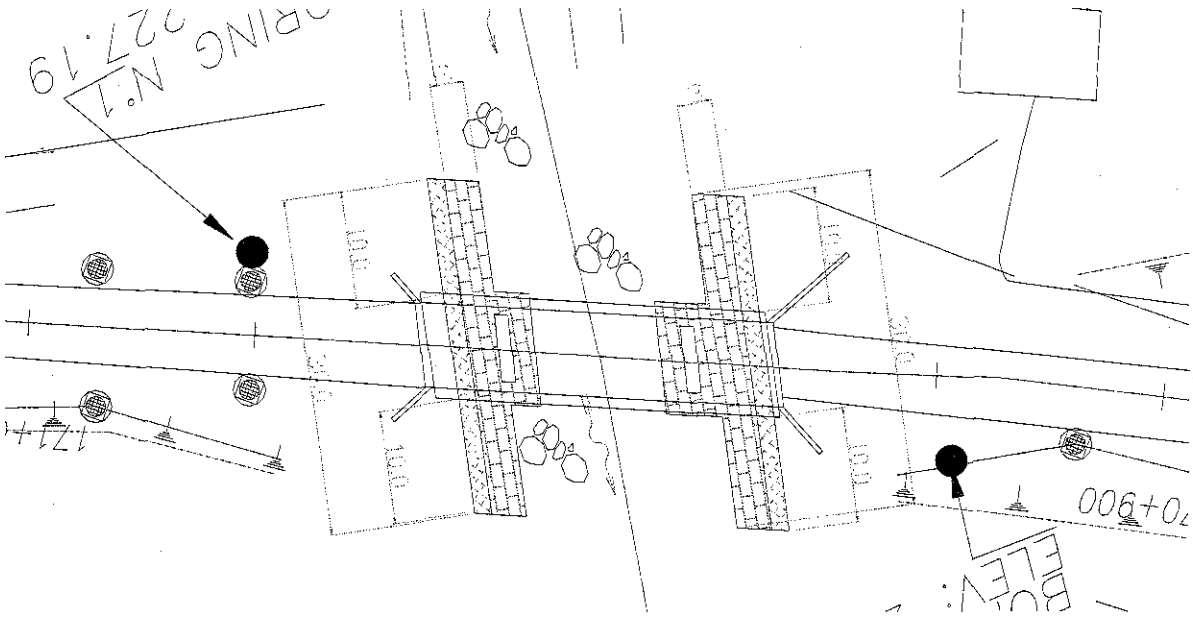


Figure 17.6.17 The Installation of Partition Wall



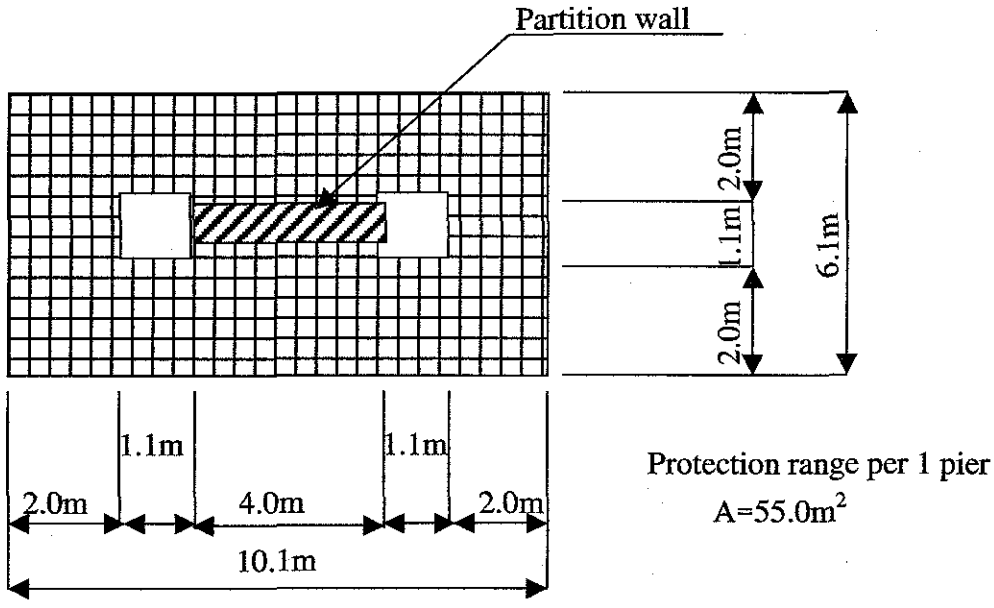


Figure 17.6.18 Protection Range against the Scouring