Annex 4

Manual for Designing Countermeasure of Small/Medium Size Slope Disasters Risk Sites

The Project for Control and Mitigation of Slope Disasters
in the Central District in Republic of Honduras

Manual for Designing Countermeasure of Small/Medium Size Slope Disasters Risk Sites

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AMDC
JICA Expert Team

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Chapter 1.　Countermeasure for landslide

1.1　Planning of the countermeasure

1.1.1　Safety factor

Landslide countermeasures stabilize landslides by drainage groundwater that triggers landslides, improving slope balance by transforming the topography, or directly fixing the landslide soil mass with a structure.

In planning countermeasure works, it is necessary to quantitatively evaluate the effectiveness of the works and the amount of works. That quantitative evaluation is assessed by an index of the safety factor.

Here is an explanation of the concept of the safety factor.

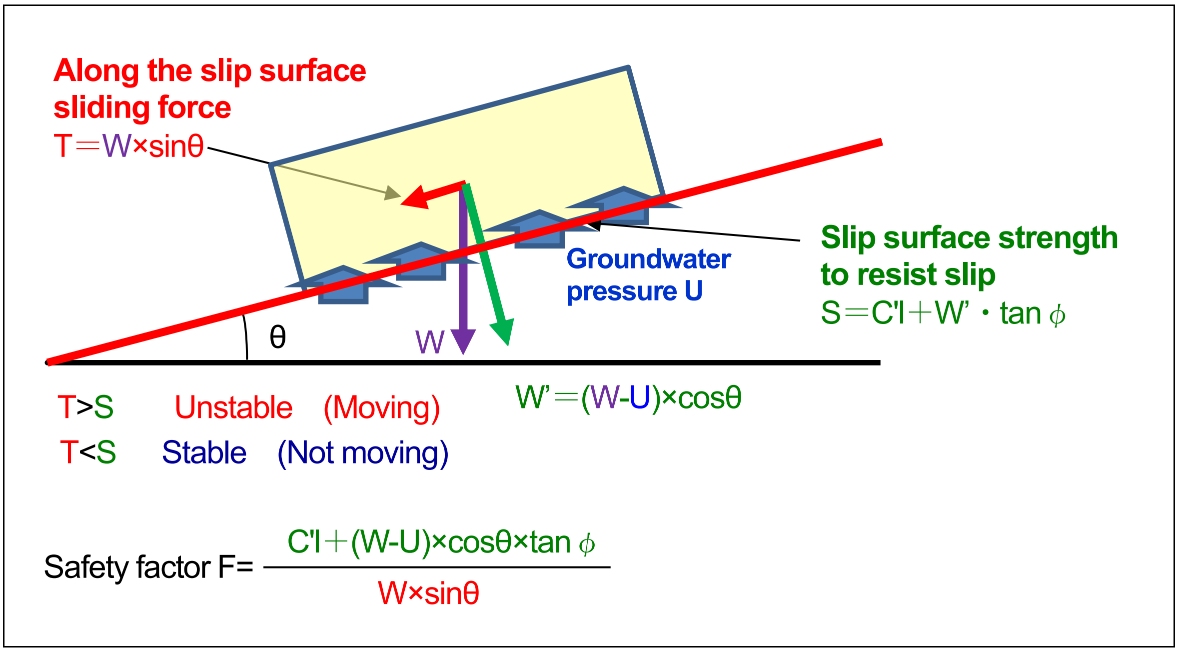


Figure 1　Conceptual drawing of the safety factor

The safety factor is a balance ratio between the force of slipping along the slip surface and the strength of the slip surface resisting the slip. (See above figure)

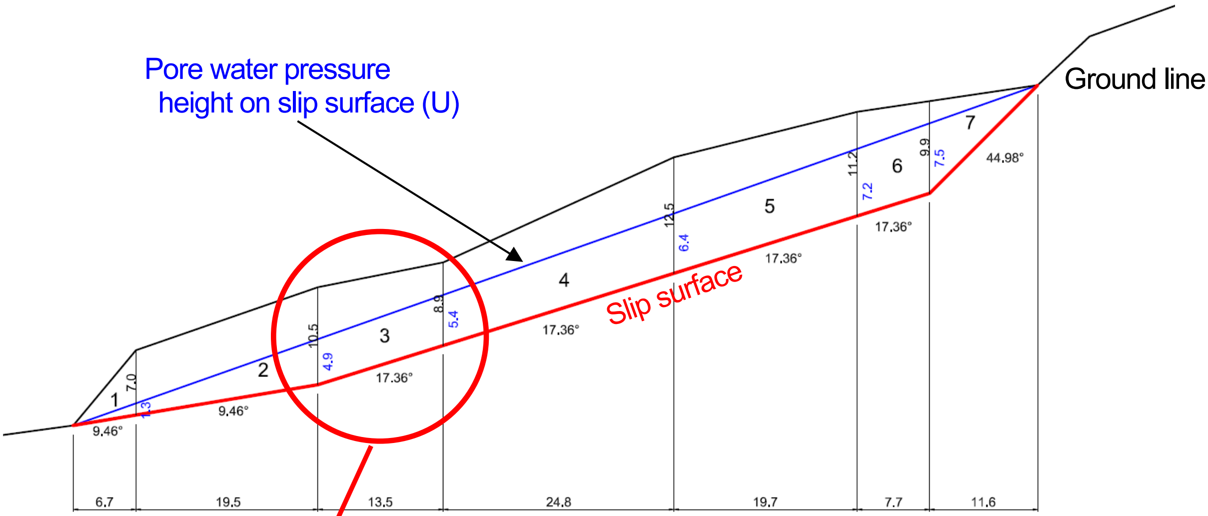
When the sliding force and the resistance are equal, the safety factor F = 1.00 is evaluated. Depend on underground water situation and slide situation safety factor always changes. Also, if landslide activity is recognized, it is evaluated as F < 1.00, if landslide is stopped, it is evaluated as F > 1.00.

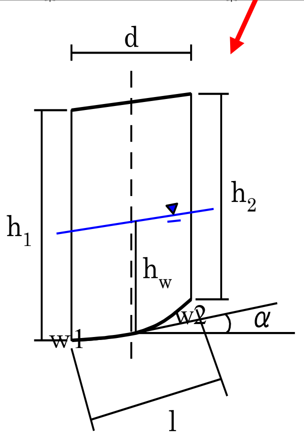
When the amount of groundwater increases due to rainfall, etc., the strength against slippage decreases, imbalance and cause sliding. In the above formula　“U” increases and the resistance decreases. Andthen, safety factor is reduce, it is evaluated that slope stability is reduce.

Next, we explain how to calculate the safety factor

To calculate the factor of safety of a slope, the landslide body is divided into a number of slices as shown in the figure, and the sliding force and resistance strength are calculated for each slice.

Then, the results are summed up to calculate the safety factor of the landslide.





h_1 : Thickness of the landslide soil mass downstream of the slice

h_2 : Thickness of the landslide soil mass upstream of the slice

d : Width of the slice

θ : Gradient of the slip surface

hw : pore water pressure height

(in this case, the average value between the upstream(w1) and downstream(w2) sides of the slice)

l : Length of the slip surface (in this case, slice width/cosθ)

Slip surface strength to resist slip

$S = C'l + (W-U)\times\cos\theta\times\tan\phi$

C' : Cohesion (kN/m2)

W : Weight of landslide body $(h1+h2)/2\times d\times\gamma t$

γt : Unit weight of landslide soil mass

U : Pore water pressure $hw\times d$

ϕ : Internal Friction Angle of slip surface

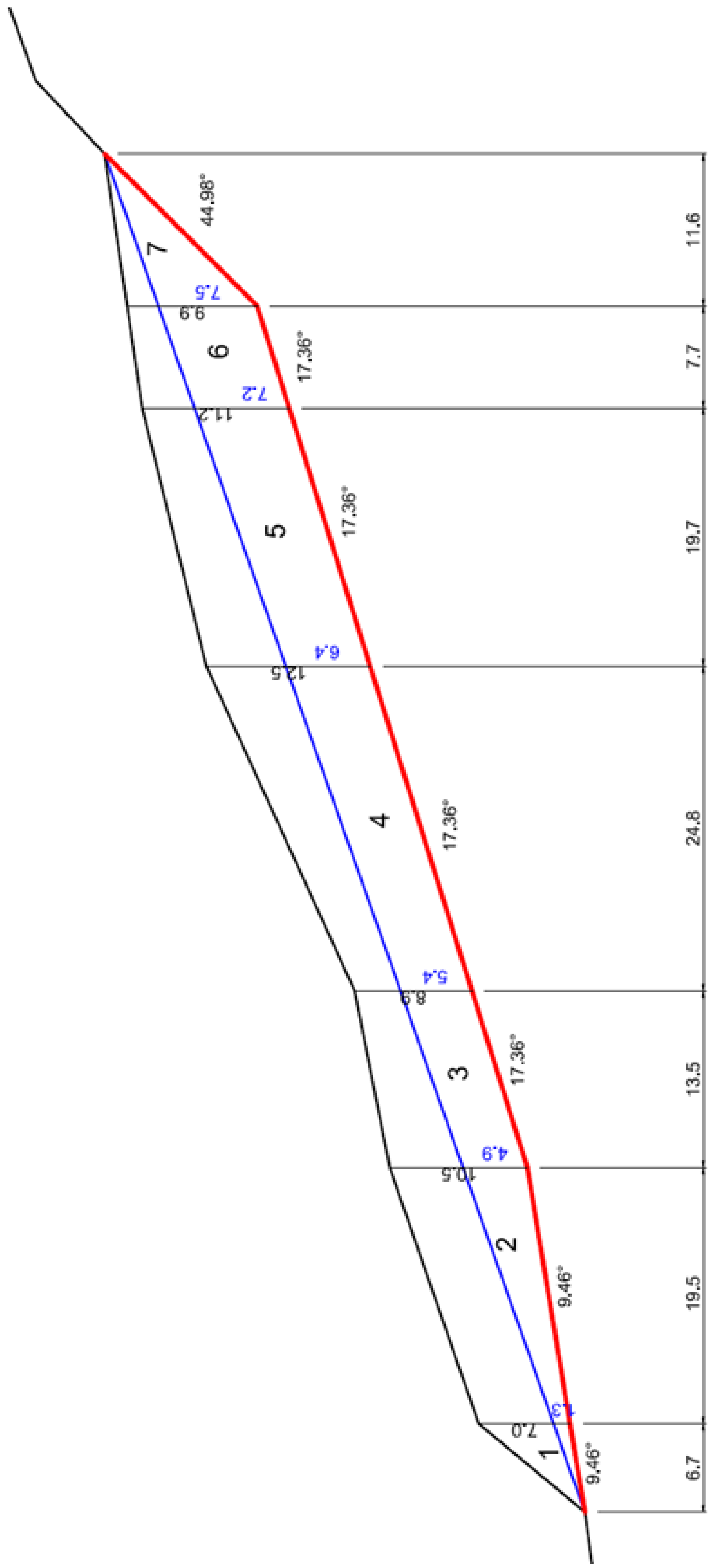
Along the slip surface sliding force

$T = W\times\sin\theta$

Safety factor of landslide

$F = \Sigma S / \Sigma T$

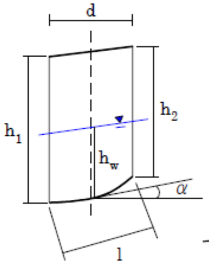
An example of calculation is shown on the next page.

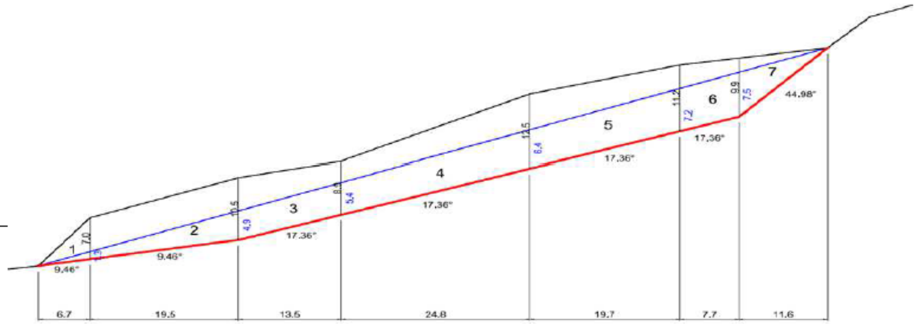

44,98°
7
7,5
9,9
6
17,36°
7,2
11,2
5
17,36°
6,4
12,5
4
17,36°
5,4
8,9
3
17,36°
4,9
10,5
2
9,46°
1,3
7,0
1
9,46°
11,6
7,7
19,7
24,8
13,5
19,5
6,7

$$Fs = \frac{S}{T} = \frac{\sum\{c \cdot l + (W - U \cdot d)\cos\alpha \cdot \tan\phi\}}{\sum W \cdot \sin\alpha} = \boxed{1.00}$$

Soil Constants (Soil Parameter)

No.	Unit Weight		Cohesion	Internal Friction Angle	
	γ_t (kN/m^3)	γ_{sat} (kN/m^3)	c (kN/m^2)	φ (°)	tanφ
1	18.00	20	12.95	17.5	0.3153
2					
3					
4					
5					





Slice No.	Height (L) h_1 (m)	Height (R) h_2 (m)	Wide d (m)	Area A (m^2)	Unit Weight γ_t (kN/m^3)	Weight W (kN/m)	Length l (m)	Angle α (°)	W.L. Height h1 (m)	W.L. Height h2 (m)	W.L. Height h_w (m)	Pore Water P U (kN/m^2)	Cohesion c (kN/m^2)	tanφ	S	T
1	0.00	7.00	6.70	23.45	18.00	422.10	6.79	9.5	0.00	1.30	0.65	6.37	12.95	0.315	205.892	69.376
2	7.00	10.50	19.50	170.63	18.00	3071.25	19.77	9.5	1.30	4.90	3.10	30.40	12.95	0.315	1026.744	504.788
3	10.50	8.90	13.50	130.95	18.00	2357.10	14.14	17.4	4.90	5.40	5.15	50.50	12.95	0.315	687.199	703.299
4	8.90	12.50	24.80	265.36	18.00	4776.48	25.98	17.4	5.40	6.40	5.90	57.86	12.95	0.315	1341.912	1425.180
5	12.50	11.20	19.70	233.45	18.00	4202.01	20.64	17.4	6.40	7.20	6.80	66.69	12.95	0.315	1136.383	1253.773
6	11.20	9.90	7.70	81.24	18.00	1462.23	8.07	17.4	7.20	7.50	7.35	72.08	12.95	0.315	377.483	436.292
7	9.90	0.00	11.60	57.42	18.00	1033.56	16.40	45.0	7.50	0.00	3.75	36.77	12.95	0.315	347.669	730.582
														Σ	5123.28	5123.29

1.1.2 Conservation target and planned safety factor

Landslides subject to landslide countermeasure work are generally large in scale and often consist of multiple moving blocks, so it often takes a considerable number of years to complete the work. On the other hand, since many houses and public facilities are located on the landslide slope, it is essential to implement non-structural measures such as accurate warning and evacuation when landslide activity intensifies.

Therefore, it is important that landslide prevention plan will be formulated with consideration given to the implementation of non-structural measures so that a warning and evacuation system can always be secured.

The landslide prevention plan is based on the results of landslide surveys and analyses, which are carried out in advance, and considers the phenomenon of each landslide (topography, geology, scale, sliding conditions, etc.), the importance of the conservation target, the urgency of the project, the effect of the project, etc. The scale and contents of the plan will be determined taking into consideration the above.

In this manual, it is discribed to focus on structural measures.

（1） Conservation target

It is identified the conservation target of the landslide prevention plan by considering the scale of the target landslide and its occurrence/movement mechanism.

The types of damage covered by the landslide prevention plan are listed below.

- Damage to human lives, houses, roads, fields, public facilities, etc. on landslide slopes
- Damage associated with movement of landslides to human lives, houses, roads, fields, public facilities, etc. located below the landslide slope
- Flood damage in the upstream area of the natural dam formed by depositing a landslide mass in stream
- Debris flow and flood damage downstream due to natural dam failure

（2） Planned safety factor

As a general landslide countermeasure work, assume the current safety factor to be 0.95 to 1.00 according to the current sliding situation, and comprehensively consider the landslide occurrence/movement mechanism, the importance of the conservation target, and the degree of expected damage. Therefore, the design safety factor (P.Fs) is set to 1.10 to 1.20.

In addition, even in the case of securing immediate safety through emergency measures, etc., the planned safety factor (P.Fs) shall be set at 1.05 or higher.

1.1.3 Selection and planning of countermeasure work method

（1） Classification of landslide countermeasure work

Landslide countermeasure work are divided into Control work and Restraint work.

Control work is a method to stop or mitigate the landslide movement by improving the balance of sliding force and resistance force of the landslide by changing the natural conditions such as the topography of the landslide site and the state of groundwater.

Restraint work is a method of stopping part or all of the landslide activity using the resistance force of the artificial structure.

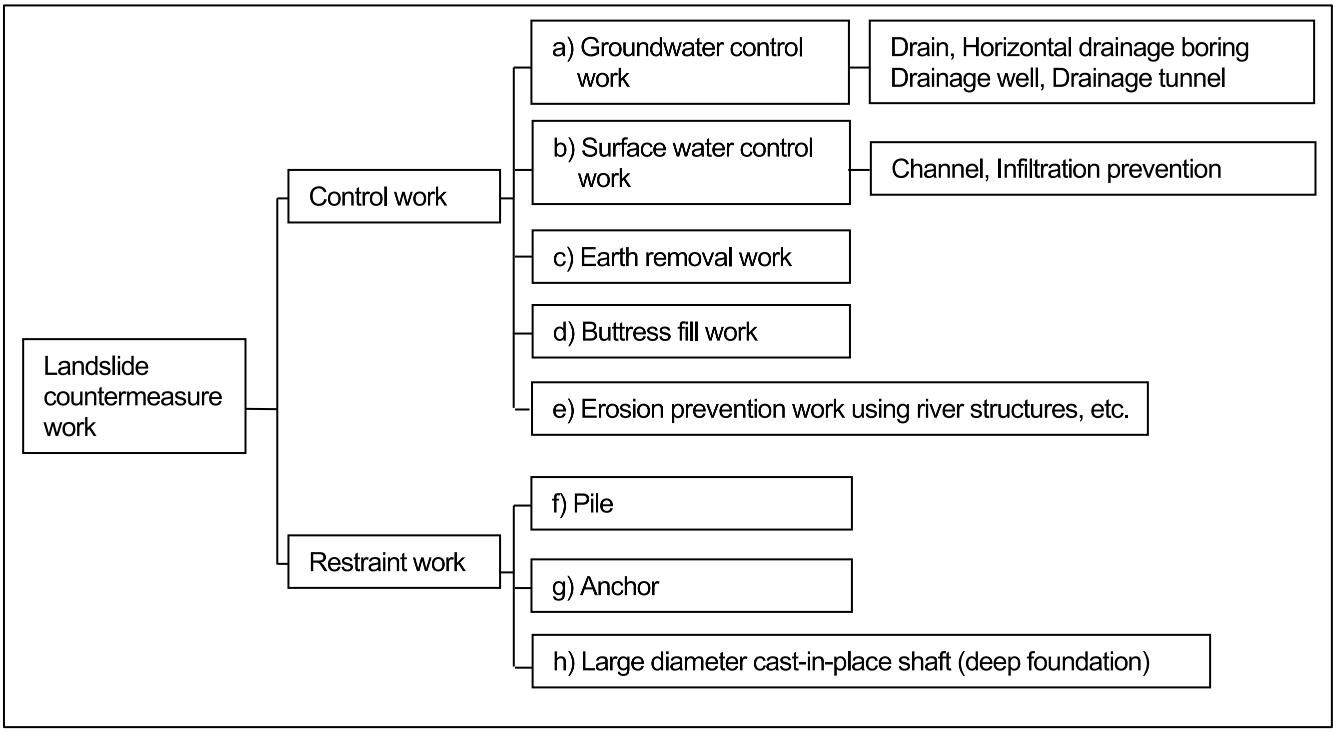


Figure 2　Classification of landslide countermeasure work

The landslide prevention work should be selected in consideration of predisposing factors and triggers, especially the relationship between rainfall and groundwater and landslide movement, topography/geology, landslide size, movement pattern, movement speed, conservation target, economic efficiency (total cost including maintenance and management as well as construction), and priority of the work to be adopted.

In principle, a detailed investigation should be conducted to clarify the characteristics of the target landslide before planning countermeasures.

Although it is difficult to discuss planning methods for countermeasure works in a uniform manner because the characteristics of landslides vary from site to site, the following are points to keep in mind when planning prevention works, focusing on landslide triggers, reduction of sliding forces and addition of resistance forces, landslide activity, landslide scale, and construction locations of countermeasure works.

1) Landslide triggers (removal of triggers)

Removing landslide triggers is generally the most effective preventive measure. It is no exaggeration to say that the cause of many naturally occurring landslides is the increased supply of groundwater due to heavy rains, long rains, and melting snow. Therefore, surface water drainage and groundwater drainage are important construction methods that should be considered first. On the other hand, when an artificial act is the trigger, an effective emergency measure is to restore the triggering event. For example, when cutting or embankment is the trigger, it is effective to restore it to remove its influence as much as possible.

2) Reduction of sliding force, addition of resistance force

A typical method of reducing the sliding force of a landslide (the denominator of the stability analysis formula) is soil removal at the head of a landslide. This type is fast-acting and effective. Care should be taken to ensure that there are no unstable slopes or other landslide blocks. On the other hand, typical construction types that add resistance (the numerator of the stability analysis formula) are buttress fill work and pile work. The former is one of the effective construction methods, which is carried out at the toe of the landslide. Anchor work is also a commonly used construction method.

3) Landslide activity

In the case of a landslide with a high moving speed, it is impossible to construct restraint work, and even if it is constructed, it may be destroyed. Therefore, first remove artificial factors such as cutting and embankment, and implement control works such as groundwater drainage such as surface water drainage and horizontal boring. After reducing the moving speed, deterrent work will be planned as necessary.

4) Scale of landslide

Taking groundwater drainage as an example, if the scale of the landslide is small, it is not so difficult to construct a horizontal boring through the slip surface from the ground surface. However, as the scale increases, the length of the bore also increases, so the efficiency of removing groundwater near the slip surface decreases. Therefore, drainage wells and sometimes drainage tunnels are efficient and economical construction methods. In the same way, if the scale of the landslide is large, it will be difficult to employ piling work even if the deterrence work is taken, and anchor and shaft will be selected.

5) Construction position of countermeasure work

Since the head of a landslide becomes a tensile zone with many cracks and gaps, it is effective to install groundwater control work and surface water control work. In addition, groundwater control work are often constructed to prevent the inflow of groundwater from outside the landslide site. In addition, soil removal work will be carried out at the top of the landslide. On the other hand, since the end of the landslide is a compression zone, it is suitable for buttress fill work and restraint works.

1.1.4 **Controls work**

Control work is a construction method that improves the balance between sliding force and resistance strengtge and stops or mitigates landslide movement by changing the topography of the landslide and groundwater conditions. When planning, consider the total cost including maintenance, and plan the appropriate layout by combining the following types rationally.

（1）Surface water contorol work

The surface water control works prevent the infiltration of rainfall and re-infiltration from springs, swamps, waterways, etc., and suppress the rise of groundwater. Surface water conrtol works include channel works and Infiltration prevention works, and a construction method that can be quickly constructed according to the landslide situation should be selected. The channel works should be planned according to the topography of the landslide, and large earthworks should be avoided. Also, when control surface water flowing into the landslide, it should be planned in the peripheral area of the stable landslide area away from the landslide cracks and scarps.

Although the effect of surface water drainage works cannot be expressed quantitatively at present, it is desirable to implement them as a countermeasure against landslides. This method is particularly effective when rain fall amount and landslide movement are closely related.

1) Channel work

Channel works are installed to quickly collect rainfall within the landslide area and drain it outside the area, and to eliminate inflow water from outside the area.

(A) Water catchment channel work

Water catchment channel works are usually placed across slopes to quickly collect rainfall and surface water on the slopes. The water catchment channel works will be relatively wide and shallow, and will be connected to the Water drainage channel works.

(B) Water drainage channel work

Water drainage channel works are used to drain collected water quickly outside the landslide site, so their cross-sections must be determined by water flow calculations. Water drainage channel works are to be installed in valley topography. In principle, Water drainage channel works should be provided with band works at intervals of 20 to 30m.

2) Infiltration prevention work

Infiltration prevention work is a method of filling cracks with clay or cement or covering with plastic sheet. As measures to prevent water leakage from swamps and waterways, we plan to cover with impermeable materials, excavate swamps, replace and improve channels, and etc.

（2）Ground water contorol work

Groundwater control works drain the groundwater that flows into or seeps into the landslide area and the groundwater that is distributed within the area, and decrease the pore water pressure (groundwater level) act at slip surface of the landslide. Groundwater control works are roughly divided into shallow groundwater drainage works for groundwater flowing in the stratum near the surface and deep groundwater drainage works for deep groundwater near the slip surface.

The planned decreasing the groundwater level differs depending on the type of countermeasure work, topography of the landslide, geology, soil quality, and the condition of the presence of groundwater, depend on the situation, it is studied and decided.

If it is difficult to obtain results from groundwater level analysis or similar locations, the following values may be used as a reference. However, the value shown here is an empirical value when the groundwater control works is appropriately placed in the landslide, and should be considered as the maximum expected drop in groundwater level. Therefore, continuous observation will be carried out after construction, and if the target reduction in groundwater level is not observed, the construction method will be reexamined and additional work will be considered.

Horizontal drainage boring	3.0m
Drainage wel	5.0m
Drainage tunnel	8.0m

1) Shallow groundwater control work

(A) Drain work

Drain works are installed to remove groundwater distributed in shallow layers or to quickly remove infiltrate water due to rain. In particular, when removing abundant groundwater in soil layers with low hydraulic conductivity, plan aggressively. The groundwater depth that can be removed is about 2m from the ground surface.

(B) Channel and drain combinated work

Channel and drain combinated works are installed to prevent the inflow and infiltrate of surface water and to remove groundwater that has infiltrated from the surface to a shallow depth. Since shallow groundwater is formed by permeation of surface water, the structure will be a combination of drains and channels drainage in recesses and valleys on the ground surface.

(C) Horizontal drainage boring

Horizontal drainage borings are designed to remove groundwater from shallow layer that cannot be removed by channel and drain combinated works, etc., and should be planned if construction is possible from the topographical point of view. It is desirable to plan the diameter, length, angle, etc. of horizontal drainage borings based on the results of groundwater analysis.

2) Deep Groundwater control work

(A) Horizontal drainage boring

Horizontal drainage borings, planned as deep groundwater drainage, are installed to drain deep groundwater distributed near slip surfaces and groundwater along faults and fracture zones. After confirming the existence of deep groundwater in the landslide block and the groundwater level, plan to install for the aquifer. The tip interval of horizontal drainage boring is generally 5 to 10 m, and it is often planned to drill 5 to 10 m through the slip surface.

(B)Drainage well

Drainage wells are installed to drain deep groundwater. In particular, it is planned when groundwater is to be collected intensively at a deep level or when the length of the horizontal boring is longer than about 50m.Drainage wells do not expect water collection from the walls of the drainage well, but expect a large amount of water collection from underground water veins by horizontal drainage boring in the wel.

In the case of active landslides, the depth of the catchment well is generally planned to be at least 2m shallower than the depth of the slip surface to ensure the stability of the well and the drainage boring. In the case of installing at nomoved landslide, the foundation of the drainage well may be installed on stable ground through the slip surface.

The location and size of the wells will be determined by taking into consideration the effectiveness of water cllection, safety during construction, maintenance and management, etc.

In particular, the arrangement and construction method will be examined so that the drainage from the drainage wells to the surface will be natural drainage. If it is not possible to directly drain water from the drainage well to the surface, a relay well should be planned. In any case, the drainage boring should not cross the slip surface in principle so as not to be cut by the landslide.

Drainage wells are used in landslide areas where groundwater is stratified or pulsed and intensive groundwater removal is required. If the groundwater distribution is multilayered, it is necessary to collect groundwater in two or more horizontal drainage boring in the direction of depth.

If the soil is soft and there is a large amount of spring water, excavation is difficult, so other methods are adopted. Also, in places where there is a lot of movement, an increase in lateral pressure causes distortion in the well, which may cause breakage. Therefore, it is desirable to avoid construction at such places as much as possible not only from the viewpoint of maintenance after construction but also from the viewpoint of disaster prevention during construction. Therefore, in determining the location of the drainage wells, it is a general rule to confirm the geology and bedrock by boring survey.

When installing two or more drainage wells, the location and quantity should be determined in consideration of the construction length of horizontal drainage borings in well, the area affected by the lowering of the groundwater level due to thedrainage wells, and the local groundwater conditions.

(C)Drainage tunnel

Drainage tunnels are planned when it is difficult to drain deep groundwater using drainage wells or horizontal drainage borings. Drainage tunnels are constructed for the purpose of drainage groundwater near the slip surface by drainage boring installed inside the tunnel.

In addition, it is roughly divided into a bottom tunnel that place under the slip surface and a peripheral tunnel that is installed around the landslide site. As a general rule, tunnel excavation within the landslide mass should not be carried out.

Drainage boring is carried out by upward or horizontal boring from the boring room in the tunnel.

（3）Earth removal work

Earth removal works are carried out to remove the body at the landslide head and reduce the sliding force of the landslide. When planning earth removal work, it is necessary to conduct a thorough investigation and study in advance so as not to induce potential landslides on the upper slope.

If landslides are distributed on the upper slope, this construction method should be avoided.

It is the volume of soil to be removed should be determined based on a stability calcuration based on an accurate understanding of the scale of the landslide and the position of the slip surface.

After earth removal works, efforts will be made to restore the natural environment by planting trees on the slope surface and the site where the soil was removed.

If the movement of the landslide is large and it is dangerous for workers to enter the landslide area and the slope below the landslide, or if it is dangerous to work on steep slopes, the introduction of unmanned construction technology should be considered.

Earth removal works requires investment in soil transport, soil treatment, maintenance and management of the cut slope surface and it may take time to acquire land. On the other hand, it is a construction method that has few problems of function deterioration such as slime adhesion to the drainage holes after construction such as horizontal drainage borings and drainage wells. Therefore, if it is judged to be advantageous after comparing the total cost including workability, soil treatment, site, functional deterioration risk, maintenance, etc., it should be adopted positively.

（4）Buttress fill work

Buttress fill work is installed to embank a well-drained soil mass at the toe of landslide and increase the resistance strength to landslide sliding force. It was confirmed that no new landslides were induced on the embankment and its surrounding slopes. Since the buttress fill work is often located on the river bed of a river or mountain stream, it may be necessary to replace the river water way or revetment work.

Since buttress fill work is effective when used in combination with earth removal removal work at landslide top, it is often planned to combine them. In addition, considering the rise of the groundwater level behind the buttress fill work, it is desirable to use a groundwater control work together.

The buttress fill volume will be decieded using a stability calcuration. The buttress fill will be greened to restore the natural environment and scenery. In addition, as mentioned in the earth removal work, the construction method should ensure the safety of the workers.

（5）Erosion prevention work using river structures, etc.

Erosion prevention works using river structures, etc. are planed to protect the river bank and stabilize the edge of the landslide, in case that riverbed degradation or bank erosion due to running water impairs the stability of the landslide mass and triggers the occurrence of a landslide.

River structures for landslide prevention include check dams, groundsills, revetments, and water dikes. There are also plans to detour rivers.

If a check dams, groundsills are installed immediately downstream of the landslide area, the sedimentation will prevent collapse and erosion at the end of the landslide. When installing checkdams, groundsills, etc., in principle, they should be installed on stable position that are not affected by landslides, directly downstream of the landslide area.

1.1.5 Restraint work

Restraint work is a method to stop all or part of the landslide movement by adding resistance force of the structure. When planning, the total cost including maintenance and management should be taken into consideration, and the following types of structures should be planned to be placed appropriately, either individually or in reasonable combination.

The following types of restraint works are available.

/It is method that directly resist the sliding force of landslide body by shear resistance and bending resistance of steel pipes, reinforced concrete, etc. : "Pile" and " Large diameter cast-in-place shaft ".

/It is method that stabilize slopes by utilizing the tensile strength of tendons (steel materials, etc.): "Anchor".

（1）Pile work

Pile work is a method of directly resisting the sliding force of a landslide moving mass by adding shear resistance and bending resistance by inserting steel pipe piles, etc., through the slip surface into the immobile layer.

Pile work is a method in which multiple steel pipe piles are generally placed in a row perpendicular to the direction of landslide movement to resist the sliding force of the landslide as one unit.

Therefore, when the landslide activity is active and movement of 1mm/day or more is expected, unless the planned piles are installed at the same time, the piles will work individually and cannot be expected to be effective,

so construction should be done after confirming that the landslide activity has generally stopped due to emergency measures and control work.

Therefore, construction should be carried out after confirming that landslide activity has generally stopped due to emergency countermeasures and control works.

In principle, the planned location should be below the center of the landslide block, and the location should be selected where the foundation for the pile rooting area is strong and the ground reaction force can be expected.

（2）Large diameter cast-in-place shaft work

Large diameter cast-in-place shaft work (Hereinafter described as "shaft") is a method in which the shaft is filled with reinforced concrete to resist the sliding force of the landslide by the resistance force of the shaft.

Shaft is planned when the slip force of the landslide is large and it is difficult to secure the specified planned safety factor (P-Fs) with pile work, and when the foundation ground is favorable.

Shaft is a method in which a shaft with a diameter of 2.5 to 6.5 m is excavated up to the immovable layer, and the shaft is filled with reinforced concrete and converted into a pile. Shaft is used when ground conditions make it difficult to drill large-diameter holes by machine, or when steel piles cannot resist the sliding force of a landslide. It is necessary to pay attention to safety management of construction during shaft excavation. In addition, it is necessary to conduct sufficient investigations and studies on groundwater and spring water in advance to ensure that drainage treatment during excavation is sufficiently carried out.

（3）Anchor work

Anchor work is method inserting tendons (steel or other materials) from the slope surface into the immovable layer and stabilizing the slope using the tensile strength of the steel anchored in the immovable layer.

Anchor used as landslide countermeasures have two effects: one is to increase shear resistance by increasing vertical stress against the slip surface (clamping effect), and the other is to hold back the landslide soil mass by tensile force in the direction tangential to the slip surface when the landslide body slide(holding effect).

Anchor is a method of stabilizing landslides by anchoring high-strength steel to the immovable layer, transmitting the load acting on the head(ground surface) of the tension material to the anchorage layer(immovable layer), and integrating the reaction force structure (pressure recieving plate at ground surface) as a group with the landslide. This method is used when the landslide site is too steep and difficult to obtain sufficient ground reaction force with piles or shafts, or when the site is urgent and the effect of the method should be required as soon as possible.

1.2 Design of Countermeasure

1.2.1 Controls work

(1) Surface water control

1) Channel work

The channel construction consists of a water catchment channel that is placed in a dendritic pattern in the depression in the landslide slope, and a water drainage channel that drains the water. The drainage channels are arranged as shown in Figure 3. In addition, if necessary, surface water from outside the landslide block should not flow into the landslide block.

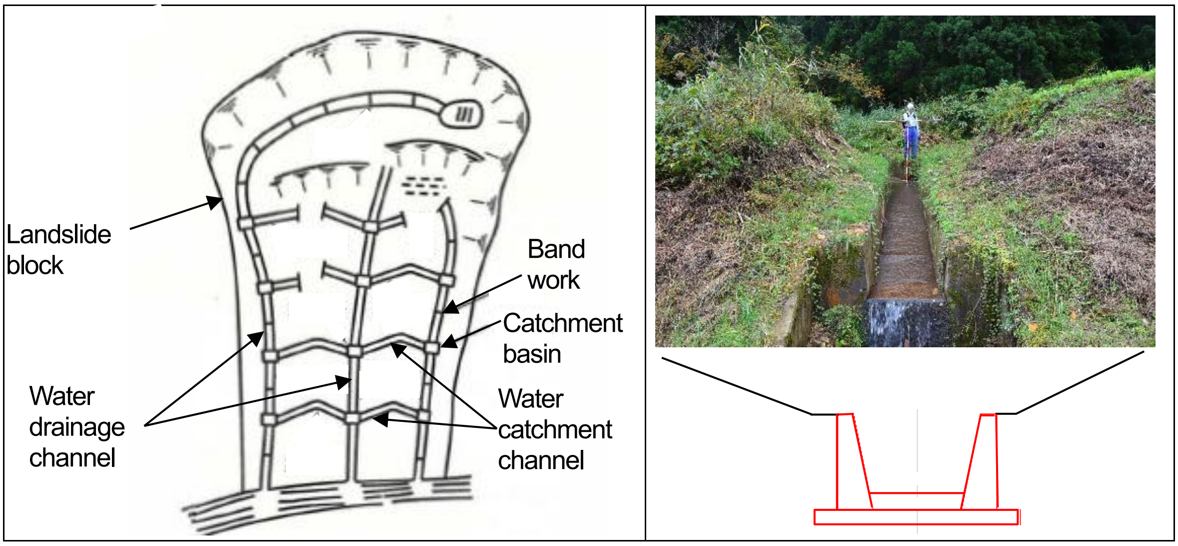


Figure 3 Example of channel layout and example of channel cross section

The following are points to be considered when designing the channel work.

/ The channel should be a moated channel to prevent collection of surface water from the landslide slope and re-infiltration of water collecting in the depression (Figure 4). The route of the channel should be selected to minimize excavation of the landslide slope.

/ The width of water catchment channel and small drainage channel should be as wide and shallow as possible, at least 30 cm, taking maintenance and management into consideration.

/ Channel should be bottom-lined to prevent re-infiltration of runoff, and catchment basins should be provided at junctions with branch lines, bends, and changes in gradient.

/ Main drainage channel is determined the cross-section of the channel by determining the planned maximum flood flow rate. In many cases, the planned rain amount is set to a magnitude of about 1/50 of the probability of exceedance (Japanese case). In addition, the cross-section of the channel should be designed with a margin of at least 20% to allow for reduction in cross-sectional area due to sediment deposition.

/ In case that shallow ground water is distributed, channels combinated with culvert should be installed.

/ Figure 5 shows a reference drawing of a catchment basin and a dropwork. Catchment basin or dropwork should be installed every 20 to 50 m.

/ Concrete U-shaped channels, semi-circular hume pipes, corrugated pipes, and plastic pipes are used as materials for channels. If deformation of the channel is expected due to landslides or ground surface movement, select a material that can easily follow the movement of the ground surface, such as a material with bending flexibility.

/ Periodic monitoring and maintain are necessary because joints of channel may open or be destroyed by uolift or subsidence of the ground caused by landslide movements, resulting in water leakage.

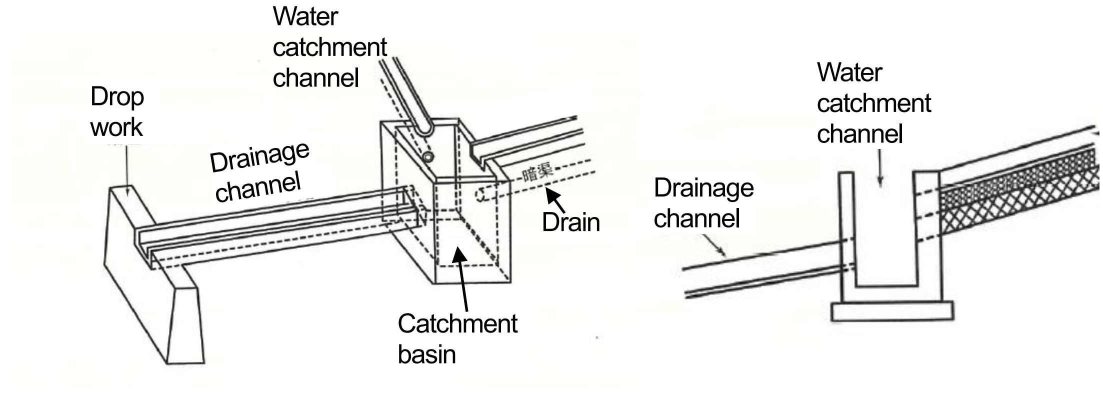


Figure 4　Reference drawing of catchment basin & drop work

Concrete channel

Soil bag channe

Corrugated steel material channel

Fabric formwork made channel
(It's possible to make free form)

Figure 5　Case study photos of channel (In Japan)

2) Infiltration prevention work

Major seepage control works include the following

1) Filling method: Filling cracks with clay or concrete, suitable for emergency measures.

2) Plastic sheet covering method: Covering cracks with plastic sheets, suitable for emergency measures.

3) Leakage prevention method: If there is leakage in a swamp, the bottom is covered with impermeable material such as asphalt.

Plastic sheet covering method

Leakage prevention method

Figure 6 Case study photos of channel (In Japan)

Next, it is described the " plastic sheet covering method," which is easy to construct and has been used in many cases.

The plastic sheet covering method is mainly used to cover open cracks with plastic sheet. Materials used include plastic sheets, anchor pins, sandbags, and ropes. The procedure is to spread the plastic sheet to cover the open crack. Anchor the head and sides of the blue sheet with anchor pins. The plastic sheets are laid one on top of the other so that there are no gaps between them. Next, place sandbags or suspend the sandbags to prevent the plastic sheets from being blown away by the wind.

To prevent water collected by the plastic sheet from reinfiltrate into the landslide area, a channel should be installed under the plastic sheet, to flow out surface water to the out of landslide area.

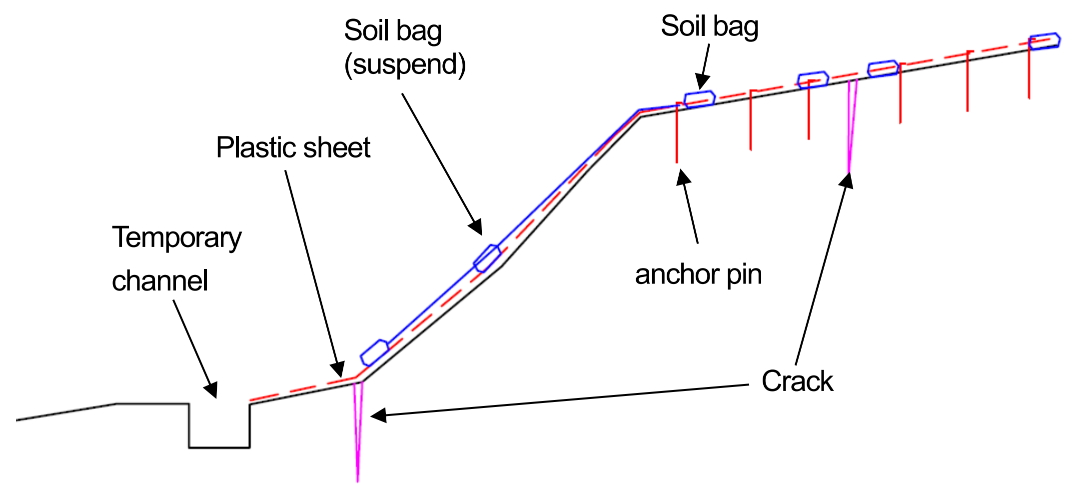


Figure 7 Reference drawing of plastic sheet covering method

(2) Ground water control

1) Drain work

In the design of drain works, the following points should be considered

/The layout of drain should be determined taking into account soil and groundwater conditions.

/ The length of each drain should be a straight line of about 20 m. Catchment basins should be provided to prevent clogging and re-infiltration of collected groundwater, and collected groundwater should be drained to surface drainage channels.

/ Drains should be up to a depth of about 2 m and the bottom should be lined with a tarpaulin to prevent leakage. Suction prevention material should be laid around the drain culvert to prevent soil and sand from being sucked out.

/ Filter material should be packed around culvert pipes to improve shallow groundwater collection.

/ If surface water is also to be collected, fill the drain to the ground surface with boulder or crushed stones.

/ Drain materials should be able to withstand a certain degree of ground movement and use perforated pipes. If the gradient is steep, fix the drain with piles, as shown in below figure.

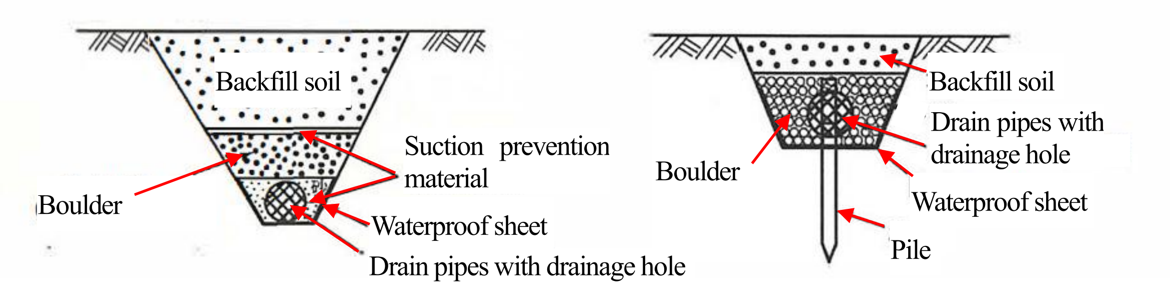


Figure 8　Reference drawing of drain work

In some cases, drain and channel construction are combined. An structural drawing example of this case is shown below.

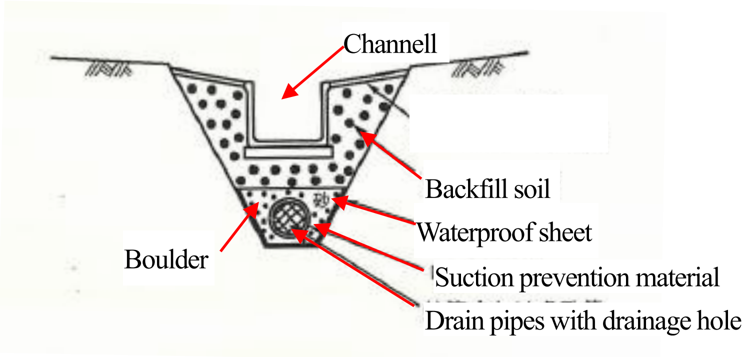


Figure 9　Reference drawing of drain and channel work

2) Horizontal drainage boring

Below drawing shows a conceptual diagram of a horizontal drainage boring. As shown in the figure, the location of the horiontal drainage boring should be determined the location of the groundwater layer should be taken into consideration. The following points should be considered in the design of horizontal drainage boring.

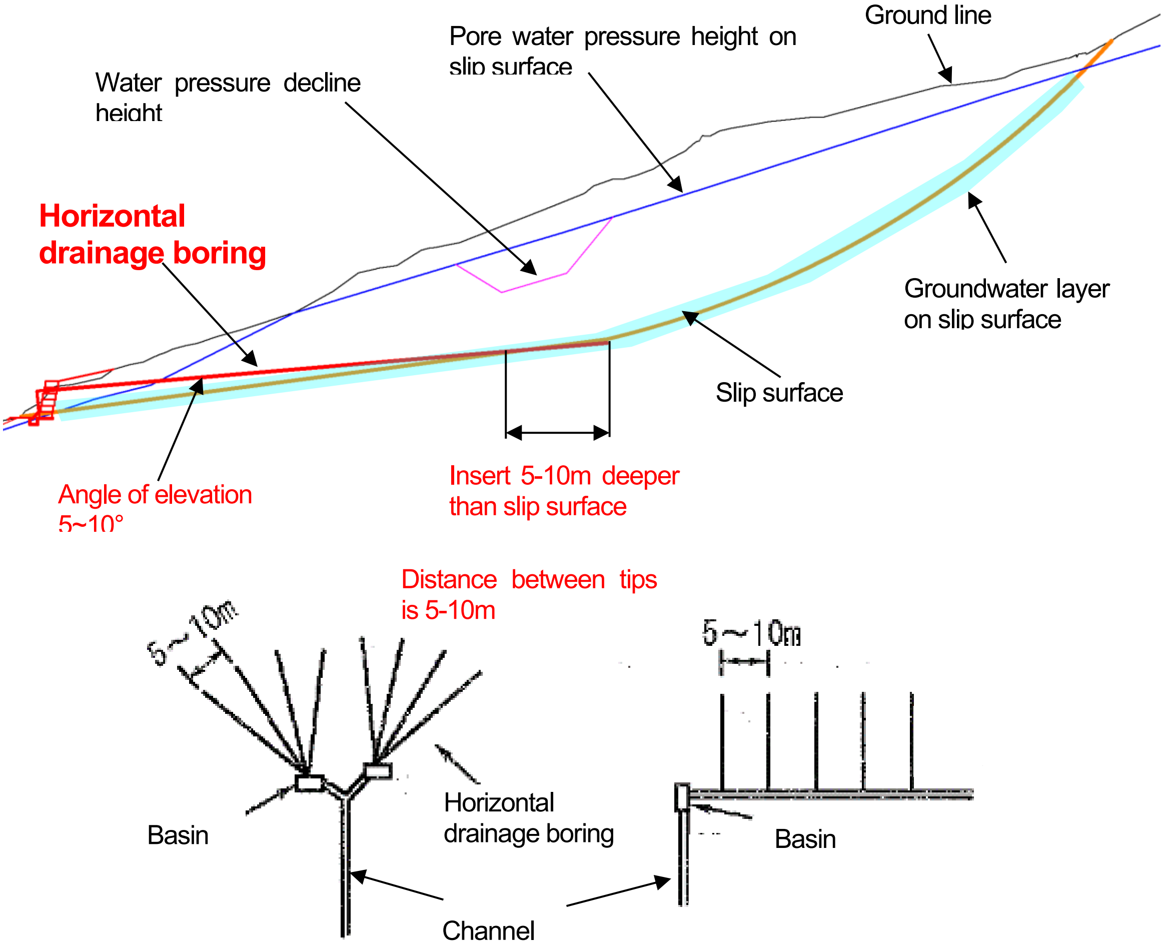


Figure 10 Conceptual diagram of a horizontal drainage boring

/ Horizontal drainage boring is generally installed in areas where shallow groundwater is concentrated, and is designed radially or parallel to each other with a spacing of 5 to 10 m at the top of the boring. The horizontal drainage boring should be designed to have 5~10m of extra drilling deeper than the slip surface.

/Collected groundwater should be drained out of the landslide area by directing it to a catchment basin or channel.

/The boring outlet should be located on stable ground, and a protection device should be installed to prevent collapse of the borehole mouth due to drainage.

/The boring drilling angle should be 5 to 10 ° in elevation angle to allow the collected groundwater to flow down naturally.

/ If the soil on the landslide slope is clayey and has a low hydraulic conductivity, the boring diameter may be increased.

/For the drainage pipe, a pipe with an inner diameter of 40 mm or more should be used, and a strainer should be processed. The strainer shall be circular or slit-shaped. An example of a circular strainer is shown in the figure below.

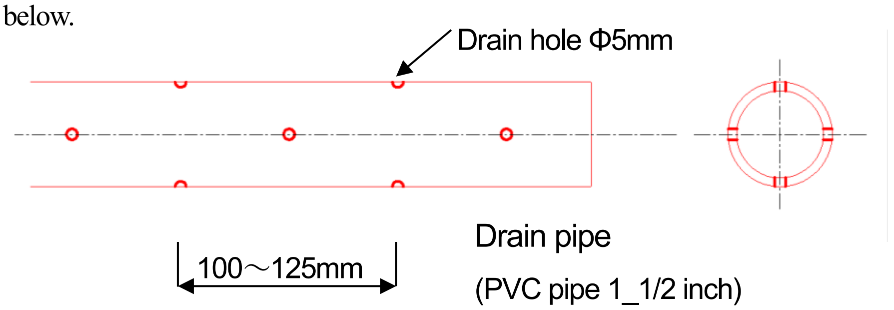


Figure 11　Reference drawing of drainage pipe

Estimation of the decline in groundwater level and calculation of safety factor of landslide is implemented as following

When estimating the effect of horizontal drainage boring, the reduction in pore water pressure is assumed, stability calculation is performed based on the result, and the safety factor is evaluated.

How to assume reduction in pore water pressure is shown as follow.

Case① Estimation by near site experience or geological characteristics.

Case② If it is difficult to estimate, empirically plan a reduction of about 3 m.

(Even if the calculated safety factor increases by 5% or more, the effect is limited to 5%)

Case③ Height and range of reduced pore water pressure is decided by Calculation.

In any case, it is necessary to carry out monitoring after the construction work to confirm the effect.

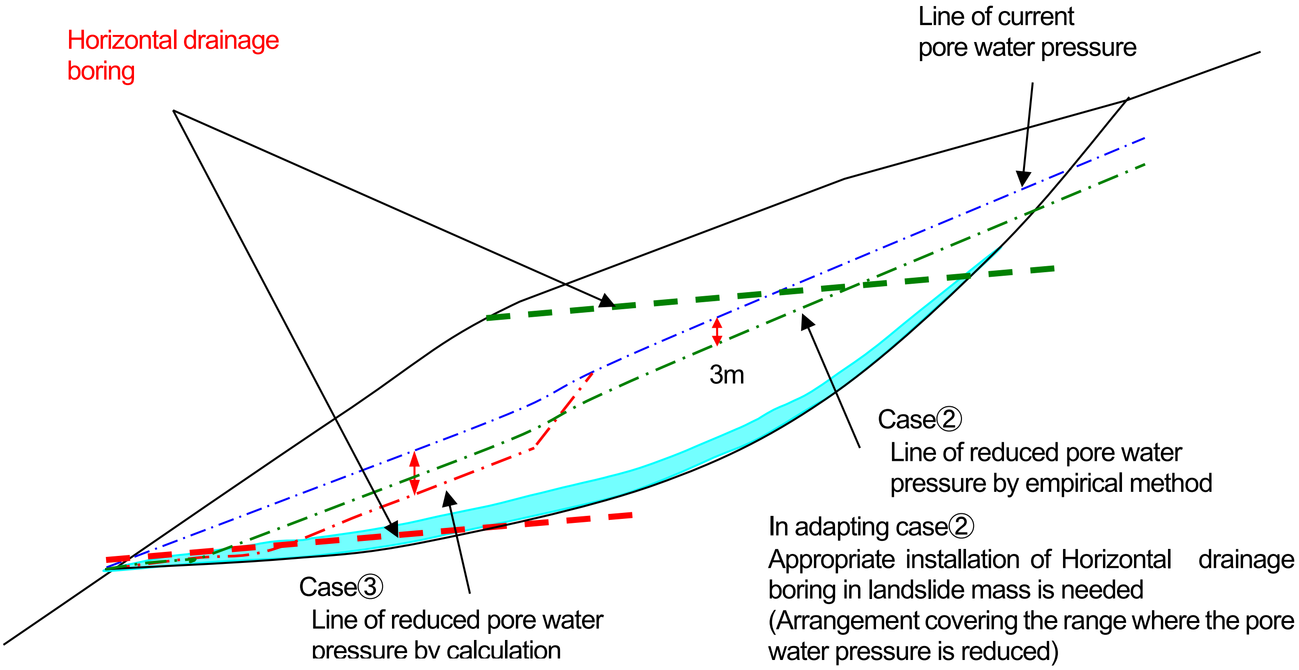


Figure 12　Method for estimation of the decline in groundwater level

Drilling situation

Instalation of drainage pipe

Drainage situation

Outlet (Gabionwall and Catchment basin)

Figure 13 Case study photos of Horizntal drainage boring (In Campo Cielo)

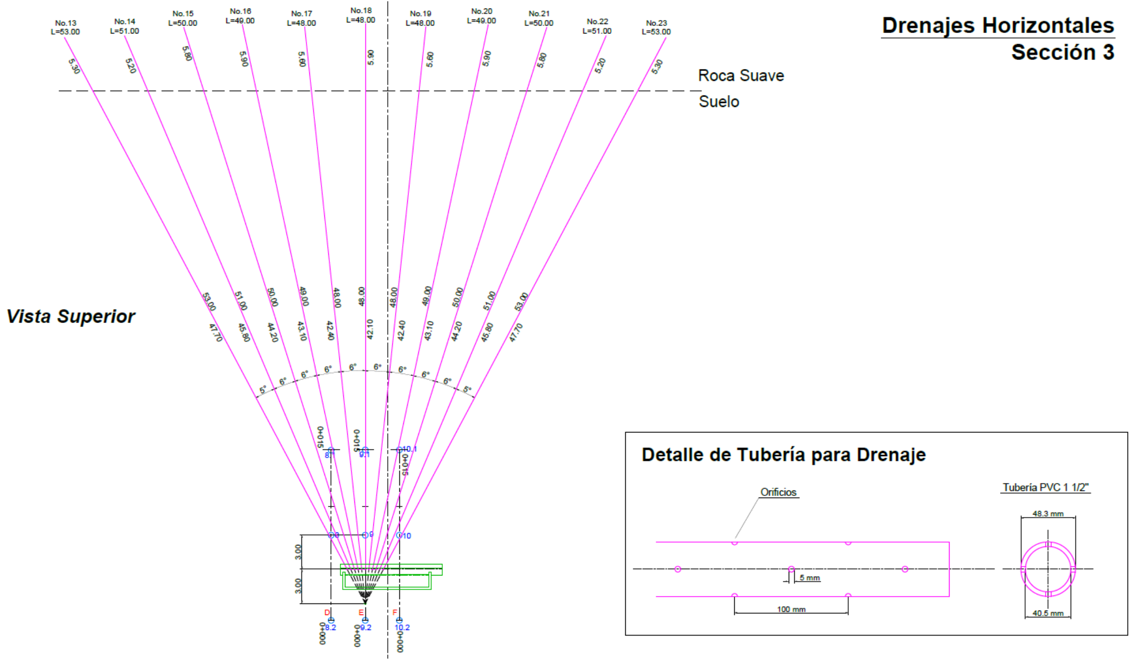
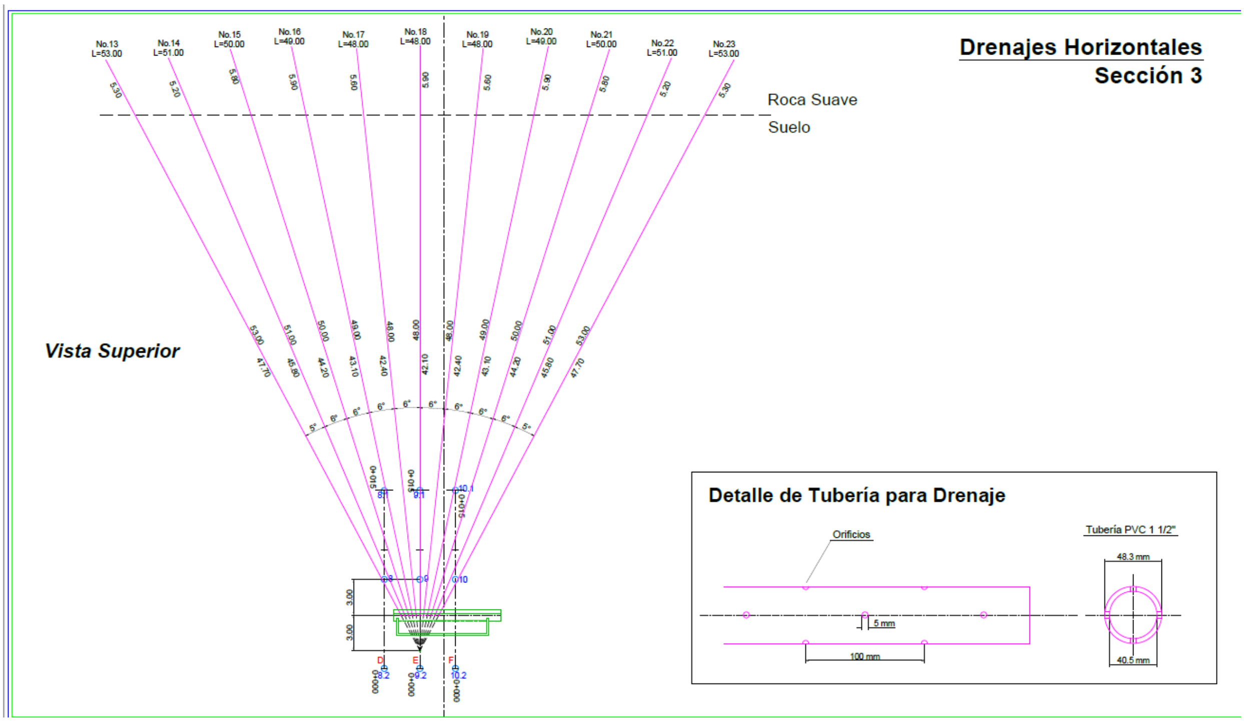


Figure 14 Drawing of horiznatal drainage boring (In Campo Cielo)

Drenajes Horizontales
Sección 3
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Roca Suave
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Vista Superior
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8.1
9.1
10.1
8
9
10
3.00
3.00
D
E
F
8.2
9.2
10.2
0+000
0+000
0+000
Detalle de Tubería para Drenaje
Orificios
Tubería PVC 1 1/2"
48.3 mm
5 mm
100 mm
40.5 mm

3) Drainage well

Drainage well is a method of excavating a well for water collection, and is used when intensively collecting groundwater at a deep slip surface position or when the extension of horizontal boring from the ground is too long.

Drainage well is installed in easy-to-construct and relatively stable ground, and the collection pipes are placed toward the groundwater layer. Therefore, the location of the drainage well should be determined by confirming the geological conditions through investigation borings.

When two or more drainage wells are to be installed due to the presence of groundwater over a wide area, they should be appropriately located considering the length of the horizontal drainage boring, the extent to which the water table will be lowered by the collection wells, the presence of groundwater, and other factors.

Drainage ground water in drainage well shall be through the drainage pipe (horizontal drainage boring in well), and drainage from the wall of the well is not expected.

During the construction of drainage well, it is an opportunity to directly observe the geology and soil conditions of the landslide slope, the location of the slip surface, and the condition of the slip surface. It should be noted that it is also possible to collect undisturbed samples, which should be used not only for construction work but also for research purposes.

Landslide soil masses are often extremely fragile due to weathering, and sufficient attention should be paid to safety management during excavation of drainage well and boring work in the drainage well.

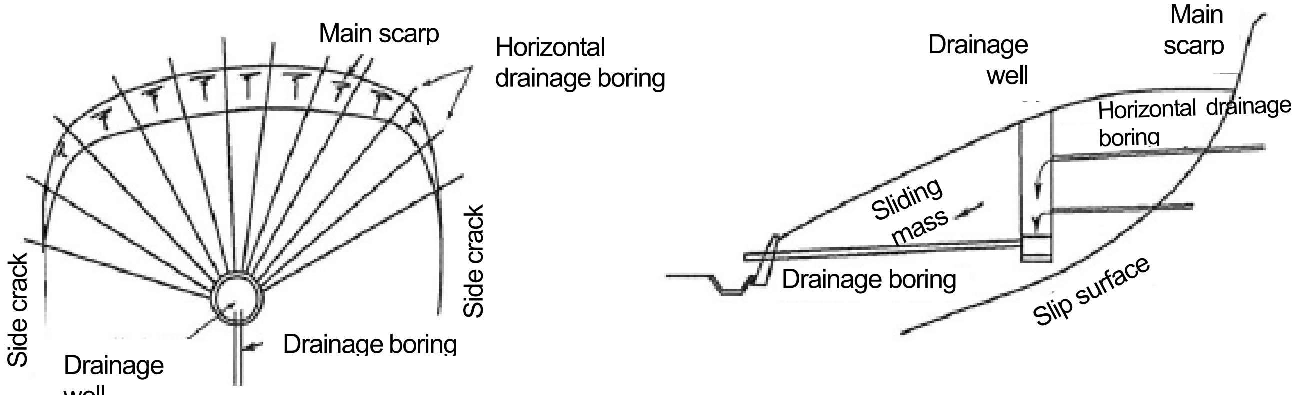


Figure 15　Conceptual diagram of drainage

(A) Depth of the drainage well

As a general rule, the depth of a drainage well should be place at least 2m upper the slip surface on a moving landslide slope, and should penetrate 2~3m under the slip surface (basement rock) on a stopped landslide slope or off a landslide slope.

This is because the drainage well will be destroyed near the slip surface as it moves if the bottom of the drainage well is allowed to penetrate below the slip surface on a moving landslide slope.

In addition, the depth of the slip surface is generally unknown on a stopped landslide slope, and it is difficult to identify the aquifer that will be adversely affected. Therefore, the bottom of the drainage well is made to penetrate into the base in order to increase the drainage well's water collection effect.

In addition, if the drainage well is constructed over a long period of time on a moving landslide slope, changes in soil properties and increases in soil pressure may cause the drainage well to be constructed. In addition, if the construction of a water collection well takes a long time on a moving landslide slope, it may be difficult to construct the well due to changes in soil properties and increased soil pressure. Therefore, it is necessary to shorten the construction period as much as possible.

(B)Structure of drainage well

The standard drainage well is cylindrical in shape with an inside diameter of 3.5~4.0m. However, if the soil type is gravel, boulder mixed sediment, hard rock, or crushed rock, and it is difficult to drill a horizonntal drainage boring, the inner diameter should be increased accordingly. In either case, sufficient consideration should be given to safety during construction.

In principle, the drainage well should be hollow for the maintenance of the water collection and drainage pipes. If the drainage well is threatened with destruction due to significant landslide movement after construction, the drainage well should be maintained by filling it with chestnut stones, cobble stones, etc. as an emergency measure.

The bottom of the drainage well should be covered with a 50 cm-thick layer of concrete to prevent groundwater supply to the landslide layer or base from contributing to the landslide activity.

Generally, steel (liner plate) and reinforced concrete are used for drainage well materials.

The materials should be determined in consideration of the ease of delivery of materials to the construction site and the total cost from construction to maintenance. Generally, construction sites are located in mountainous areas, where it is often difficult to transport materials using large machinery, and a large amount of materials are rarely used at the same location. In such cases, lightweight materials with good workability are used.

To prevent outsiders from entering the drainage well, the top of the well should be raised about 1 m above the ground surface, and a canopy and protective fence should be installed at the top of the drainage well. A ramp shall be installed inside the drainage well.

Liner plate drainage well

Reinforced concrete drainage well

Figure 16　Case study photos of drainage well (In Japan)

(C) Design of a steel-structured (liner plate) drainage well (Japanese case study)

Drainage wells must be structured so that they will not be destroyed by loads acting from the outer surface. In principle, the only load acting on the outer surface of the drainage well shall be earth pressure, and water pressure shall not be considered. In principle, earth pressure generated by landslide movement is not considered. If deformation of the drainage well is anticipated, lateral struts or vertical stiffeners are used to reinforce the drainage well. In addition, if uneven soil pressure is anticipated, the design should take this into account.

The cross-section (thickness) of a member for safety against buckling is determined by the following equation using the maximum earth pressure Pmax acting on the outer surface of the drainage well.

$$q_A = \frac{3 \cdot E \cdot I}{f \cdot R^3} \quad \rangle \quad P_{t\,\max}$$

q_A : Allowable external pressure on the outer surface of the drainage well　(kN/m^2)

E　: Young's modulus　(kN/m^2)

I　: Secondary moment of cross section per 1.0m depth of liner plate（m^4/m)

However, the effective cross-sectional secondary moment considering water collection holes, bolt holes, etc. is $0.8I_0$

(I_0: the cross-sectional secondary moment when there are no water collection holes, bolt holes, etc.)

F　: Safety factor (1.5 to 2.0)

R　: Radius of drainage well (m)

Ptmax : Maximum earth pressure acting on the outer surface of the drainage well　(kN/m^2)

Liner specifications are determined by selecting a safe liner thickness for maximum soil pressure or by adding reinforcement rings.

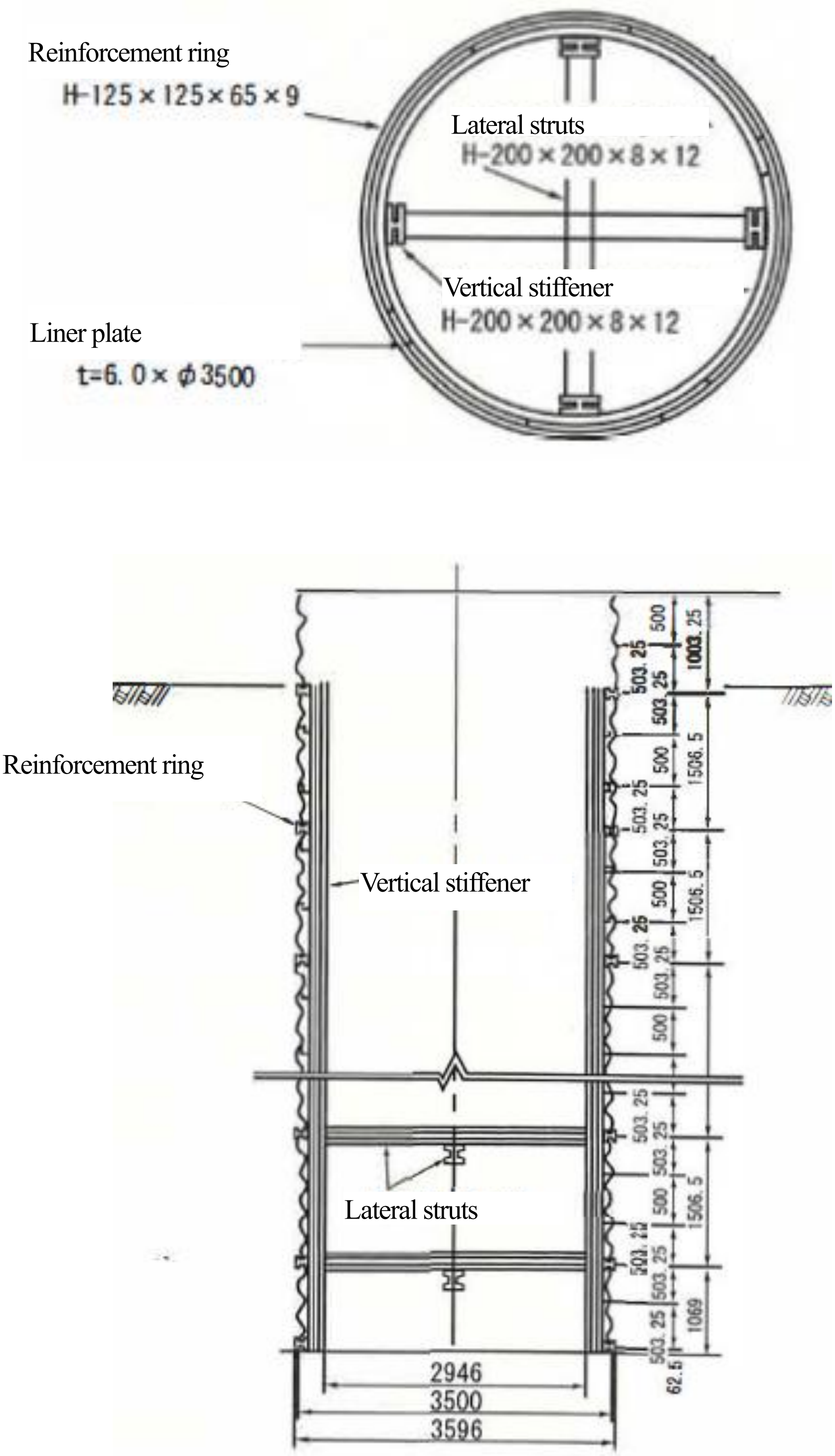


Figure 17 Example of drainage well with liner plate

The maximum soil pressure acting on the outer surface of a drainage well can be calculated using Terzaghi's formula which takes into account the arch action (circular action) of the surrounding soil or Rankine's formula. In general, the following equation, which assumes that the earth pressure does not increase above a depth of about 15 m and that the triangular distribution of static earth pressure is used in many cases.

$Ph = k \cdot \gamma \cdot h$ $\quad h<15m$

$Ph = 15 \cdot k \cdot \gamma$ $\quad h \geqq 15m$

Ph : Soil pressure (kN/m2)

K : Static earth pressure coefficient (0.5 regardless of sandy or clayey soil)

γ : Unit volume weight of soil layer (kN/m3)

h : Depth from ground surface (m)

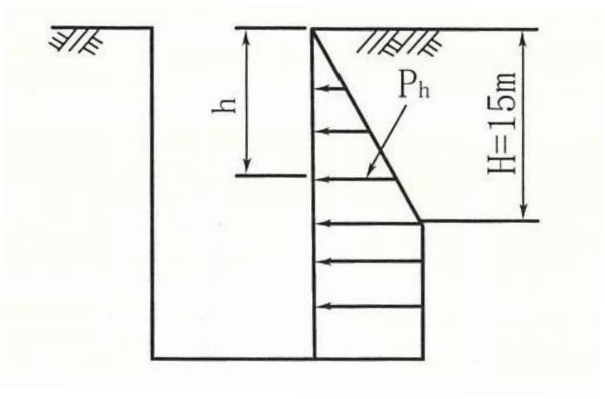


Figure 18 Earth pressure acting on the outer surface of the drainage well

(D) Design of a reinforced concrete drainage well (Japanese case study)

This drainage well is used, for example, in the following cases

/When the geology is generally relatively homogeneous, such as sandy soil, and the drainage well settles easily under its own weight.

/ When the ground is sandy soil, which is prone to boiling due to large amounts of groundwater.

/ When the ground is soft clay that is prone to heaving (the phenomenon of the covering layer being pushed up by the pressurized groundwater).

(E) Drainage boring

In principle, the permanent drainage from drainage wells should be natural drainage from drainage boring. In case of mechanical drainage, breaking down of machinally cause fail to eliminate groundwater and then landslide may re-active. And also requires a large budget for normal maintenance.

Drainage boring lengths are often up to 80 m. The standard drainage pipe is a steel pipe with an inner diameter of 80 to 100 mm. If a large amount of groundwater is expected to be drained, the boring diameter should be increased or multiple drainage borings should be constructed, as appropriate.

If the length of the drainage borehole is long or it is difficult to construct a drainage boring, a relay well should be installed at a distance of 70~80 m and connected to the drainage boring. The end of the drainage boring should be located inside the landslide prock and lead out of the landslide area by a channel. The drainage boring outlet should be protected by gabion, retaining wall, etc.

(F) Horizintal drainage boring

The standard length of a horizontal drainage boring is 50 m. However, if the boring is drilled into the slip surface just at the landslide top, the length may be 80 to 100 m.

The direction, spacing, number of borings, etc. are determined based on the results of geological and groundwater investigations, but the direction, spacing, number of borings, etc. may be changed depending on the water collection conditions during construction.

The horizontal drainage boring should be rigid PVC pipes with an inner diameter of 40 mm or more, and be equipped with strainers in the same manner as the pipes for horizontal drainage boring (on the ground).

4) Drainage tunnel

Drainage tunnels are used when the size of the landslide is large, the moving layer is thick, or the speed of movement is large. This is because the depth of drainage wells becomes large when the purpose is to remove deep groundwater, and it is also difficult to construct in the case of a landslide with a large movement speed.

In principle, drainage tunnels are not installed in the landslide body, but in the stable base rock, and the groundwater acting on the slip surface is drainage by drainage boring in the tunnel or connecting the tunnel drainage well.

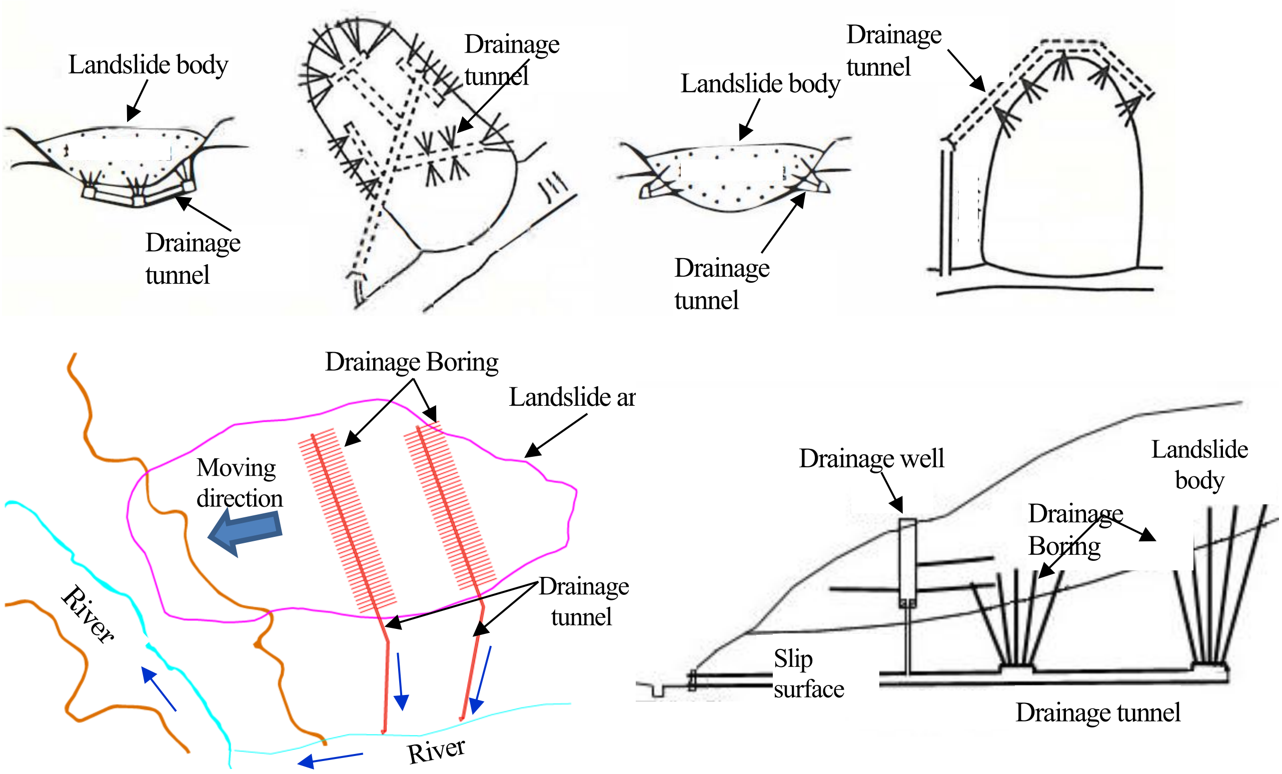


Figure 19 Drainage tunnel layout image

(A)Drainage tunnel placement

The distance from the top of the drainage tunnel in the base rock to the slip surface should be at least twice the tunnel diameter, taking into account the extent of ground loosening. The drainage tunnels should be placed in consideration of the distribution of groundwater layer that affect the landslide, and in particular, drainage from the landslide head and both sides of the landslide where groundwater tends to collect. In addition, drainage tunnel outlet should be located where the ground is as firm as possible.

(B)Longitudinal slope of Drainage Tunnels

The longitudinal slope of the drainage tunnel should be angled toward the tunnel mouth to allow natural drainage of collected groundwater. In general, the slope should be less than 15/1000.

(C)Cross-section and structure of drainage tunnels

The cross-sectional shape of drainage tunnels can be horseshoe, circular, semi-circular, trapezoidal, or rectangular, depending on the materials used. In principle, tunnels should be hollow for maintenance and management, including water collection facilities, and should be lined for durability.

The cross section of the tunnel should be determined in consideration of the total cost from construction to maintenance, taking workability during maintenance, including construction, into account.

Materials used for lining include concrete, liner plate, corrugate, etc.

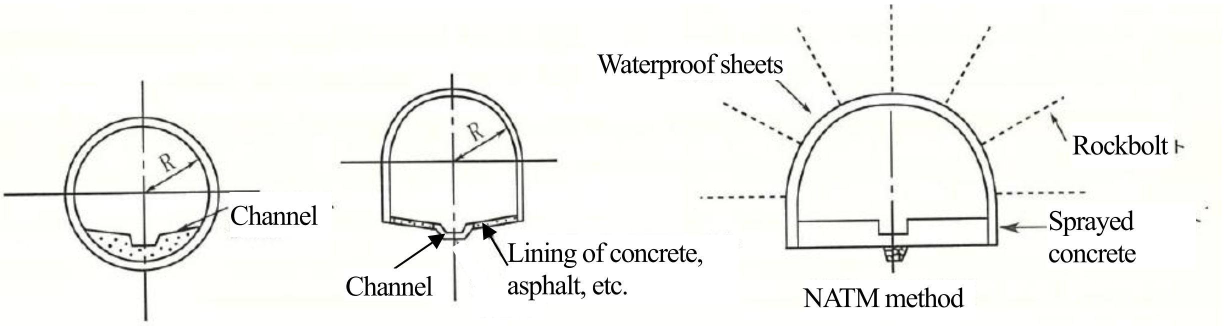


Figure 20 Example of cross-sectional shape of drainage tunnel

(D) Emergency escape access route

When the length of drainage tunnels exceeds 1,000 m, it is necessary to provide a ramp or shaft for escape in case of emergency for safety management.

(E) Collect of groundwater

In principle, groundwater drainage by drainage tunnels shall be by drainage boring. Boring should be planned to radiate horizontally or upward from the inside of the tunnel toward the groundwater layer. The angle of the boring should be determined by considering the distance to the groundwater layer, the total length of the boring, and the length of the section that crosses the groundwater layer.

When boring at a steep angle, a boring space with a larger cross section of the tunnel should be provided if necessary. For more information on the length of drainage boring and drainage pipe, please refer to the Horizontal drainage boring section.

(F) Drainage of collected groundwater

In principle, the bottom of the drainage tunnel should be constructed in the same structure as the channel construction to prevent groundwater collected by the drainage boring from seeping back into the ground.

When liner plates or corrugated plates are used for lining the drainage tunnel, the bottom of the tunnel should be made of concrete to maintain its function as a drainage channel, since there is a large possibility of water leakage due to damage to joints or loosening of bolts at the bottom of the tunnel.

(G) Earth pressure acting on drainage tunnels

The amount of earth pressure acting on the drainage tunnel shall be determined by taking into consideration the geology, size of the tunnel cross section, construction method, type of lining, construction period, and the nature of the ground.

(H) Materials for Tunnel Support

Tunnel supports can be made of wood or steel. In general, wood is used for solid bedrock or in case that tunnel is backfilled after short-term, while steel is used for areas subjected to earth pressure or for long periods of time before the next construction. Recently, the NATM method using shotcrete and rock bolts has been used.

(3) Earth removal work

The amount of soil to be removed, the location of the soil to be removed, the slope of the cut gradient and the height of the slope should be determined by slope stability analysis.

The stability of the upper slope and the existence of potential landslides should be thoroughly investigated before designing the earth removal works, and sufficient consideration should be given to whether or not this method can be adopted to prevent the earth removal from reducing the stability of the slope behind and triggering landslides. The slope protection after the soil is removed will also be considered.

1) Effects of earth removal on landslide stability

It can be divided into at least 3 parts on this landslide.

The angle of the slip surface differs depending on the part, and the slope stability properties differ.

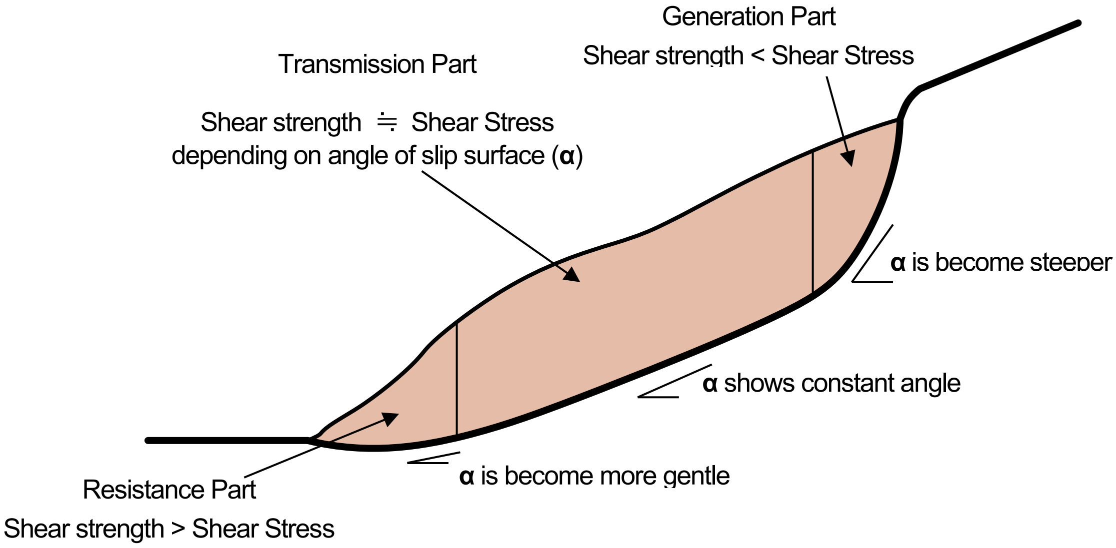


Figure 21 Stability balance for each landslide area

Earth removal work help the landslide mass to remove the sliding moment

Earth removal work→ sliding moment：T（=W･sinα）decrease

resistant moment：S（=W･cosα×tanφ'）decrease

The effectiveness differs on each location

Top : good : Safety factor increases, T＞S on each slice
Middle : not good : Safety factor is almost same, T≒S on each slice
End : bad : Safety factor decreases, T＜S on each slice

The effect of earth removal work depends on the location.

As shown in the next figure, it is effective for landslide top where the slip surface slope is steep.

On the contrary, it is not preferable at the end of landslide where the slope of the slip surface becomes gentle, as it reduces stability.

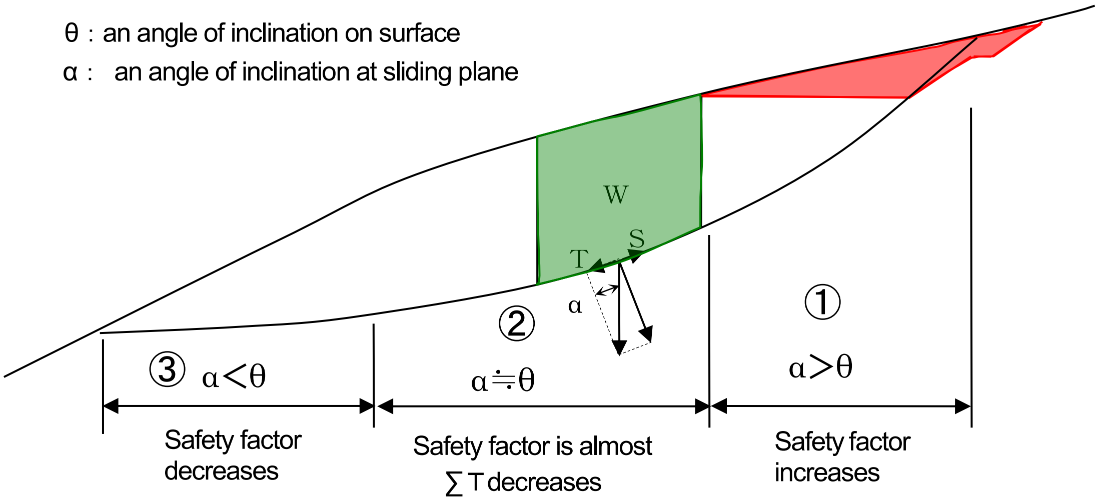


Figure 22 Differences in earth removal effects for different landslide area

2) Cut slope

The following figure shows a conceptual diagram of a cut slope and a cut slope. The slope and vertical height of the cut slope should be determined based on a preliminary investigation of the stability of the slope due to geological conditions and other factors. This is because the cut slope may gradually become unstable over time, leading to surface failure.

In the case of soft rock, the slope of the cut slope should be about 1:0.5 to 1:1.2, and the width of a small step should be about l.0 to 2.0 m every 7 m. In the case of sandy soil, the slope of the cut slope should be about 1:0.5 to 1:1.2.

In the case of sandy soil, the slope of the cut slope at 5 to 10 m of straight height is about 1:1.0 to 1:1.5, and the width of the small step is about 1.0 to 2.0 m for every 5 to 10 m of straight height in most cases.

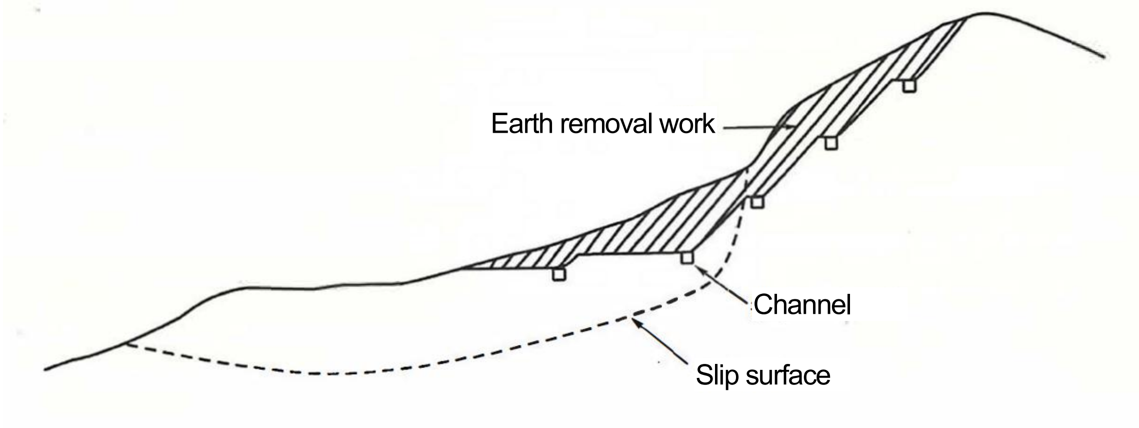


Figure 23 Earth removal work and cut slope work

3) Investigation of Backslope Stability

Before any earth removal, the stability of the upper slope and the presence or absence of potential landslides should be thoroughly investigated. This is because earth removal may degrade the stability of the back slope and induce further landslides. If there is a potential landslide on the upper slope, it will be necessary to implement countermeasure for the upper slope landslide, so a thorough study is required, including the feasibility of this method.

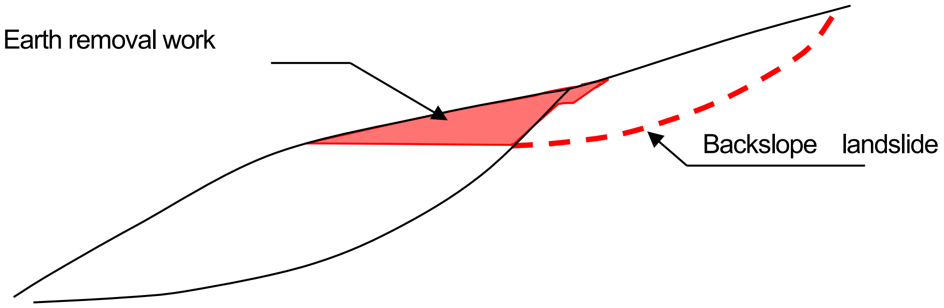


Figure 24 Earth removal and backslope landslide

4) Slope protection work

After earth removal, the slope is generally susceptible to softening and slope failure due to rainfall and other factors. Therefore, we will provide surface drainage channels and small steps according to the topography of the area, and install drainage channels to improve drainage.

The slope should be covered with vegetation or structures to prevent erosion and weathering. If the surface is not suitable for vegetation or cannot be stabilized by vegetation alone, it should be protected with stone pitching, concrete block pitching, or crib work.

(4) Buttress fill work

The buttress fill work should be designed to add resistance to landslide sliding forces by placing embankment at the end of the landslide slope, and the amount and location of the embankment should be determined by slope stability analysis.

In designing the embankment, the stability of the embankment base should be examined based on the results of the investigation of the foundation soil, and sufficient attention should be paid to the treatment of the groundwater behind the embankment.

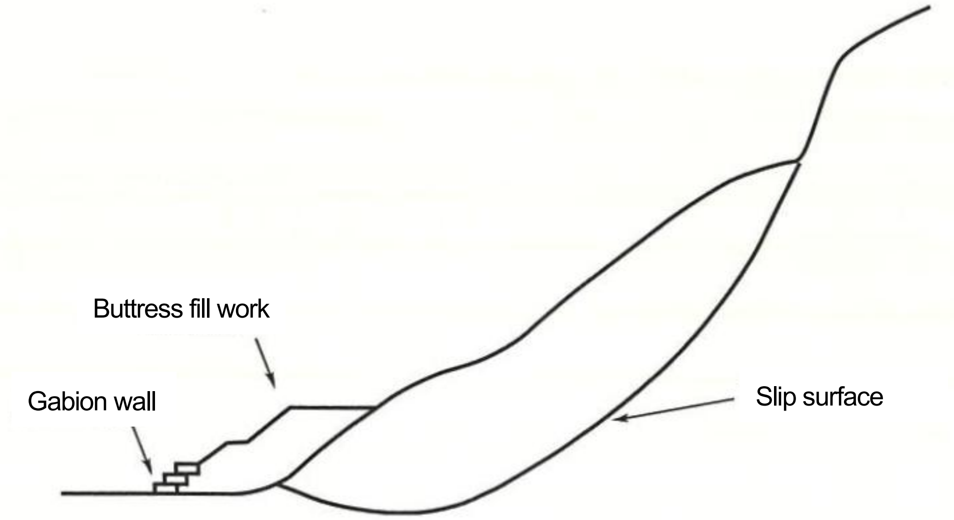


Figure 25 Image diagram of buttress fill work

1) Embankment

The height of fill and slope of the embankment should be determined based on the fill material and the soil characteristics of the embankment base soil.

In general, the average slope of the embankment slope should be 1:1.5~1:2.0, and steps of about 1.0~2.0m are often provided at every 5m of the embankment. A channel should be provided at each step.

2) Coutermeasure for groundwater

Since springs are generally found at the end of landslide slopes and facilities such as horizontal drainage boring may be installed, it is necessary to ensure that the fill does not obstruct the drainage of such water.

If there is a shallow groundwater aquifer at the fill location, the groundwater outlet may be blocked by the fill and its load, and the slope may become unstable due to a rise in the groundwater table behind the slope.

Therefore, careful attention should be paid to the groundwater treatment of the area behind the embankment.

Drain works at the bottom of the embankment and drain works (drainage sheets) within the embankment are recommended.

3) Slope protection work

Since the embankment surface is easily subject to collapse and erosion due to rainfall, it is necessary to protect the surface by means of slope protection. It is preferable to use vegetation and erosion control mat to protect the slope surface, and to avoid using rigid structures such as concrete lining as much as possible.

As a general rule, a retaining wall should be installed at the edge of the embankment.

Retaining wall structures should be able to follow deformation and have excellent water permeability.

4) Consideration for lower slopes of embankment

When Filling, it is important to care of the slope stability under the landslide.

For Buttress filling, the safety factor is improved by filling a large amount of soil at the end of landslide, therefore the risk of landslide of lower slope at embankment may be increase.

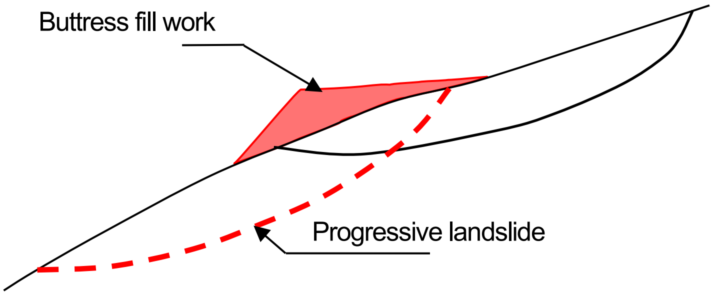


Figure 26 Buttress fill work and lowerslope landslide

(5) Erosion prevention work using river structures

Erosion control works by river structures are designed to prevent streambank failure caused by erosion of the landslide slope terminus by flowing water, and to prevent the activation of landslide movement.

When the end of a landslide slope is eroded by running water, this can cause stream bank failure and increase landslide movement. For this reason, erosion prevention methods such as river structures are used to prevent erosion at the end of landslide slopes.

When check dam, ground sill, revetment, etc. is constructed immediately downstream of a landslide slope, the sand deposited by the structure can be expected to prevent collapse and erosion at the end of the landslide slope, and also to provide fill.

/ Excavation during construction should be kept to a minimum so as not to impair the stability of the landslide.

/Install groundwater control work as necessary so that the groundwater level within the landslide slope does not rise due to the installation of facilities.

/When constructing river structures, in the landslide area during movement, they should be flexible to deformation and safe against the effects of running water.

/In the case of a landslide that is actively moving, use a structure that does not require excavation, or install check dam at a safe position downstream, and it is expected that deposited soil effects as buttless fill work for landslide.

1.2.2 Restraint work

(1) Pile work

Pile work shall be designed to obtain the prescribed deterrent force considering the topography and geology of the target landslide site.

In designing pile work, the stability of the piles against internal stresses when the designated deterrent force is acted on the piles should be considered, and passive failure in the mobile layer moving layer downward the piles, failure of the rooting ground, and penetration of the soil mass between the piles should be prevented.

1) Functions and Classification of Pile work

Landslide control piles can be classified into the following categories based on their functions.

<Bending piles>

Bending piles are designed under the condition that shear force and bending stress are generated in the pile due to deformation of the landslide soil mass during the sliding of the landslide. There are two types of bending piles: "wedge piles" and "cantilever piles".

/Wedge piles

A wedge pile is a pile that is designed to be subjected to the shear force and bending stress generated when the pile moves together with the moving soil mass and bends above and below the slip surface, assuming that the sliding force of the landslide acts as a concentrated load at the slip surface.

/Cantilever pile

When the ground reaction force on the downward of the pile cannot be expected, the pile is regarded as a cantilever beam and designed as if the sliding force of the landslide acts on the pile in the moving layer as a distributed load or a concentrated load. Cantilever piles are used when piles are installed at the end or near the head of a landslide.

< Shear pile>

Shear piles are designed assuming that the sliding force of the landslide acts as a concentrated load on the slip surface and that only shear force is considered, assuming the condition that the landslide mass is not deformed (no bending stress is generated in the pile) during the sliding of the landslide.

2) Applicable Conditions for Pile Work

The application conditions for pile construction should be fully considered. In the previous case, the thickness of the moving layer was often less than 20m. And the following conditions should be considered: the piles should not be used in soft ground, the moving layer should not be broken up into small landslide blocks by many cracks, and the piles should be installed during a period when landslide activity is dormant.

In addition, it should be noted that the design of the piles is based on the assumption that the piles are elastic and that the ground reaction force around the piles can be expected at all times except for the cantilever piles.

In adopting shear piles, it is necessary to carefully consider that there is no risk of bending failure of the piles. Shear piles have been known to tip over in case of shallow landslides.

3) Deterrent force of pile work

To obtain a given planned safety factor, the deterrent force Pr (kN/m) borne by the pile per unit width is determined by the following formula.

$$P.Fs = \frac{\Sigma(W \cdot \cos\theta - U) \cdot \tan\phi' + c' \cdot \Sigma l + P_r}{\Sigma W \cdot \sin\theta}$$

$$P_r = P.Fs \cdot \Sigma W \cdot \sin\theta - \Sigma(W \cdot \cos\theta - U) \cdot \tan\phi' - c' \cdot \Sigma l$$

Pr : Deterrent force of pile per unit width (kN/m)
P. Fs : Planned safety factor
W : Weight of split pieces (kN/m)
U : Pore water pressure acting on the split piece (kN/m)
l : Length of slip surface of split piece (m)
θ : Inclination angle of the sliding surface at the split piece (°)
Φ' : Internal friction angle of the sliding surface (°)
C, : Adhesive force of sliding surface (kN/m)

When using the control works (ground water control work, earth removal work, buttless fill work) together, U, W, and l on the right side of the above formula are varied according to the amount of effectiveness of each control works method to obtain the required deterrent force for the pile works.

4) Pile Installation Location

As a general rule, the location of pile installation should be in a compacted area of the landslide soil mass with a relatively gentle slope of the slip surface below the center of the landslide movement block, and the thickness of the movement block should be relatively thick so that passive failure will not occur.

If the area of prevention work is limited to the upper end of the landslide movement block, the location of the piles may be in the tensile zone where the slope of the slip surface is relatively steep. In this case, it is necessary to design under the condition that the soil mass on the slope below the piles will slide down and ground reaction force cannot be expected (Cantilever pile).

The location of the pile to be installed in the compression section should be determined by comparing the sliding force Ti and resisting force Ri for each segment from the end of the landslide movement block to find the boundary between ΣRi > ΣTi (compression section) and ΣRi < ΣTi (tension section), and selecting a location below this boundary where the earth pressure behind the pile is sufficient.

$$T_i = W_i \cdot \sin\theta_i$$
$$R_i = \left(W_i \cdot \cos\theta_i - U_i\right) \cdot \tan\phi' + c' \cdot l_i$$

Ti : Sliding force for each split piece (kN/m)
Ri : Resisting force for each split piece (kN/m)
Wi : Weight of each split piece (kN/m)
Ui : Pore water pressure acting on the split piece (kN/m)
li : Slip surface length of the split (m)
Θi : Inclination angle of the slip surface at the split piece (°)
Φ' : Internal friction angle of the slip surface (°)
C' : Adhesive force of slip surface (kN/m)

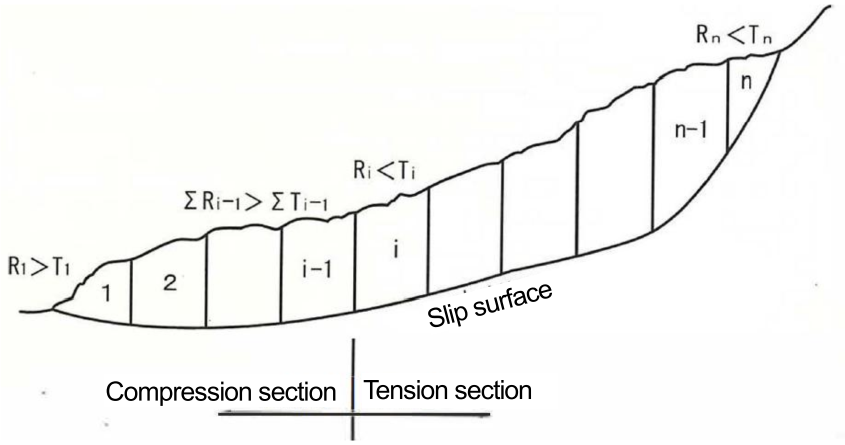


Figure 27 Compression and tension sections in a landslide cross-section

When piles are installed at the end of a landslide, it is necessary to ensure that new slide due to passive failure does not occur at the upward of the pile.

For this purpose, it is necessary to satisfy P.Fs' (formula 2) ≧ P.Fs (formula 1).

$$P.Fs = \frac{\Sigma\left\{\left(W_{ab} \cdot \cos\theta - U_{ab}\right) \cdot \tan\phi' + c' \cdot l_{ab}\right\} + P_r}{\Sigma W_{ab} \cdot \sin\theta} \quad \text{.........} \; (1)$$

P. F s : Safety factor of the subject landslide after pile installation

Pr : Deterrent force of pile per unit width (kN/m)

Wab : Weight of split piece at slip surface a b (kN/m)

lab : Length of the slip surface of the split piece at the slip surface ab (m)

Uab : Pore water pressure acting on the split piece at slip surface ab (kN/m)

θ : Inclination angle of the slip surface at the split piece in the slip surface ab (°)

Φ' : Internal friction angle of slip surface ab (°)

c' : Adhesive force of slip surface ab (kN/m2)

$$P.Fs' = \frac{\Sigma\left\{\left(W_{ax} \cdot \cos\theta_{ax} - U_{ax}\right) \cdot \tan\phi_{ax}' + c_{ax}' \cdot l_{ax}\right\} + \Sigma\left\{\left(W_{xy} \cdot \cos\theta_{xy} - U_{xy}\right) \cdot \tan\phi_{xy}' + c_{xy}' \cdot l_{xy}\right\}}{\Sigma W_{ax} \cdot \sin\theta_{ax} + \Sigma W_{xy} \cdot \sin\theta_{xy}}$$

.... (2)

P. Fs' : Safety factor of the assumed slip surface axy after pile installation

Wax : Weight of split piece at slip surface ax (kN/m)

Wxy : Weight of split piece at slip surface xy (kN/m)

lax : Length of slip surface of each split piece at slip surface ax (m)

lxy : Length of slip surface of each split piece at slip surface xy (m)

Uax : Pore water pressure acting on the split piece at slip surface ax (kN/m)

Uxy : Pore water pressure acting on the split piece at slip surface xy (kN/m)

θax : Inclination angle of the slip surface at the split piece in the slip surface ax (°)

θxy : Inclination angle of the slip surface at the split piece in the slip surface xy (°)

Cax' : Adhesive force of slip surface ax (kN/m2)

C xy' : Adhesive force of slip surface xy (kN/m2)

Φ'ax : Internal friction angle of slip surface ax (°)

Φ'xy : Internal friction angle of slip surface xy (°)

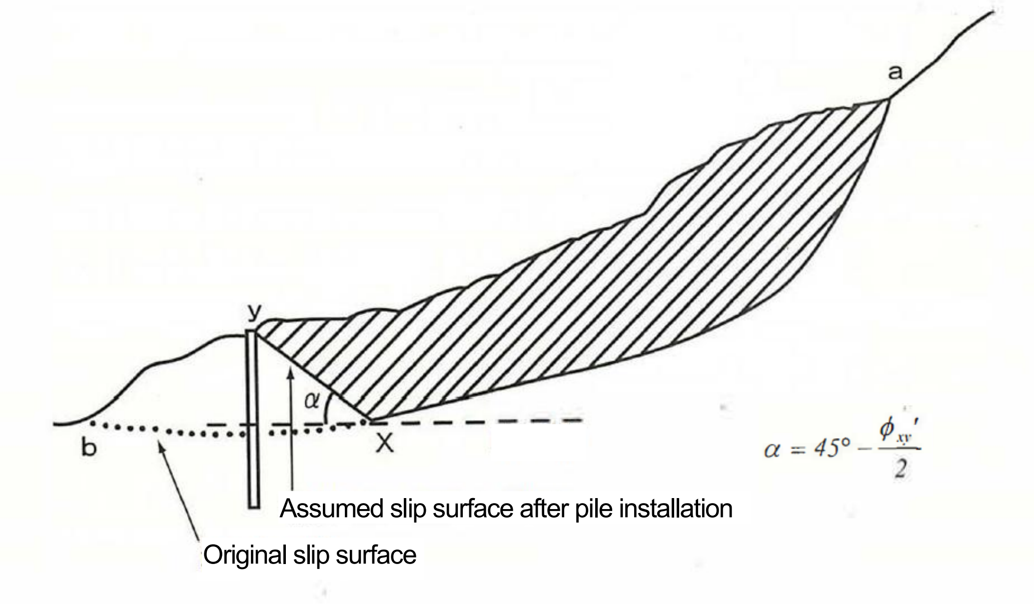


Figure 28　Passive failure at the upper part of the pile

5)　Design External Forces on Piles

In designing piles, in principle, consideration shall be given to bending stress and shear stress.

If the structure or land to be preserved for landslide prevention work is limited only to the tension part of the landslide movement block, the piles may be installed at a point close to the target to be preserved, even if it is in the tension part of the landslide block.

In this case, the pile is not secured to have any ground reaction force of the downward of the pile, and the pile will be subjected to all the landslide sliding forces from the slope above the pile, so cantilever pile to be able to accommodate this force must be designed.

6)　Type and strength of pile material

The strength of steel materials used for piles shall satisfy the design strength. Long-term allowable stress and short-term allowable stress should be used for the strength of the pile material depending on the load acting on the pile. In case of using control work, the short-term allowable stress shall be used as a general rule.

The values in the table should be used as reference for design strength. (Example in Japan)

	Short-term allowable stress (N/mm2)		Long-term allowable stress (N/mm2)	
	Shear stress	Bending stress	Shear stress	Bending stress
Tensile strength 400N/mm2	118	206	78	137
Tensile strength 490N/mm2	162	279	108	186

7) Pile Placement

Piles should be placed so that they are generally right-angled to the direction of landslide movement and equally spaced.

The spacing of the piles should be considered in the design conditions of the adopted piles. However, depending on the character of the soil masses, loosening of the ground due to drilling or separation of soil between piles masses may occur. Therefore, the spacing in the following table should be used as a standard, and should be within 8 times the diameter of the pile.

In order to avoid damage to the foundation due to pile installation, the distance between borehole walls should be at least 1m. If the distance between borehole walls is less than 1 m, the pile arrangement shall be staggered.

Thickness of the moving layer at the pile installation position	Pile interval
0～10m	～2.0m
10～20m	～3.0m
20m～	～4.0m

8) Rooting into the foundation

The length of the rooting-in of the pile into the foundation shall be determined so as not to cause failure of the foundation due to loading stresses on the pile. The rooting-in length shall be considered in consideration of the design conditions of the adopted pile. The space between the borehole wall and the piles should be filled to integrate the piles with the foundation soil. Therefore, a grout pipe shall be inserted between the borehole wall and the pile, and mortar grouting shall be performed to fill the cracks in the foundation and to provide spacing between the borehole wall and the pile.

Drilling

Inserting pile

Grouting

Figure 29 Pile construction situation

(2) Large diameter cast-in-place shaft

Large diameter cast-in-place shaft (hereafter referred to as "shaft”) be designed to obtain the prescribed deterrent force, taking into consideration the topography and geology of the landslide site.

In designing the large diameter cast-in-place shafts, the stability of the shafts against internal stresses when the prescribed deterrent force is applied to the shafts should be checked, and the passive failure of the moving layer upper slope the shafts, the failure of the foundation ground, and separetion of moving layer between the shafts should be prevented.

Shaft work is used under the following conditions

/ When the landslide is large and requires significant deterrent force.

/ When topographical constraints don’t allow piling materials or construction equipment to be carried in.

/ When groundwater is drained out as a drainage well and then the shaft work is completed as a drainage well.

Since the cost of shaft work is huge, it is only planned when there is an important conservation target, other economical control and restraint works cannot be planned, and when the target is subject to considerably large landslide force.

1) Applicable location

The selection of the optimum location for shaft construction is basically the same as for pile work. Landslide moving masses can be divided into compressive and tensile zones according to their movement characteristics.

The slope of the ground surface on the pile downward side, cracks around the installation location, and small collapses also affect the function of the pile. In deciding the installation location, the condition of the mobile layer on the pile downward side, the condition of the mobile layer on the pile upward side, the target of preservation, workability, etc. should be fully considered.

The details of the examination are the same as those for pile construction.

2) Functions and Classification of shaft

The design method of shaft construction can be roughly classified into the design as rigid piles and the design as bent piles, and is generally determined by the following equation.

β 1 ≦ 2 ・・・・・・・ rigid pile

β 1> 2 ・・・・・・・ bent pile

$$\beta = \sqrt[4]{\frac{K \cdot d}{4 \cdot E \cdot I}}$$

K : Coefficient of horizontal subgrade reaction of the moving layer (kN/m3)

d : Outer diameter of shaft (m)

EI : Flexural rigidity of shaft (kN-m2)

（The modulus of elasticity, E, can be calculated using the modulus of elasticity of concrete or by dividing the steel and concrete by the ratio of their cross-sectional areas. I : Moment of inertia of area of the shaft (m4))

l : Depth of slip surface at construction location (m)

3) Shaft construction standards

Deformed reinforcing bars are generally used as the steel material for shaft. When H-shaped steel or steel pipes are used for steel members, treatment should be taken to ensure integrity with concrete, or the allowable bond stress should be reduced.

For the allowable stress of concrete, the design standard strength shall be determined in consideration of the workability of casting in place.

4) Structure, arrangement and spacing of shaft

/ Structure

The shaft shall be a cylindrical reinforced concrete structure. If the shaft is to function as a drainage well, it may be a hollow reinforced concrete cylinder.

The steel bars shall be arranged in a circular arrangement with a single row, but a maximum of three rows of bars shall be arranged according to the required amount of steel bars.

/ Arrangement

The shaft should be single row so that all the piles can bear the landslide thrust equally. Staggered arrangement should not be adopted because the upstream shaft is prone to rupture. The arrangement should be roughly right-angled to the direction of landslide movement and equally spaced.

/ Spacing

The spacing of shafts should be determined considering the stability against separation of soil between piles masses, stability of the foundation, and workability. As a rule of thumb, the center spacing should be 2.5 to 8 times the diameter, and the spacing should be determined considering the geology of the moving layer and the depth of the slip surface.

The number of shafts to be installed should be one line for each landslide block. If it is unavoidable to install multiple line shafts, the displacement of the landslide moving layer at the shaft installation location should be fully considered.

(3) Anchor work

Anchor work is a construction method that attempts to counter the landslide sliding force by utilizing the tensile strength of the steel material that has setted by grouting in the basement rock layer.

It is a construction method in which the reaction force structure and the ground are integrated and stabilized by transmitting the load acting on the anchor head to the anchor body (anchorage ground) via the tension part.

1) Outline of anchor work

Anchor work are made up of three basic components

/Anchor head (including the pressure plate)

/Tensile section

/Anchorage section (anchor body and anchorage ground)

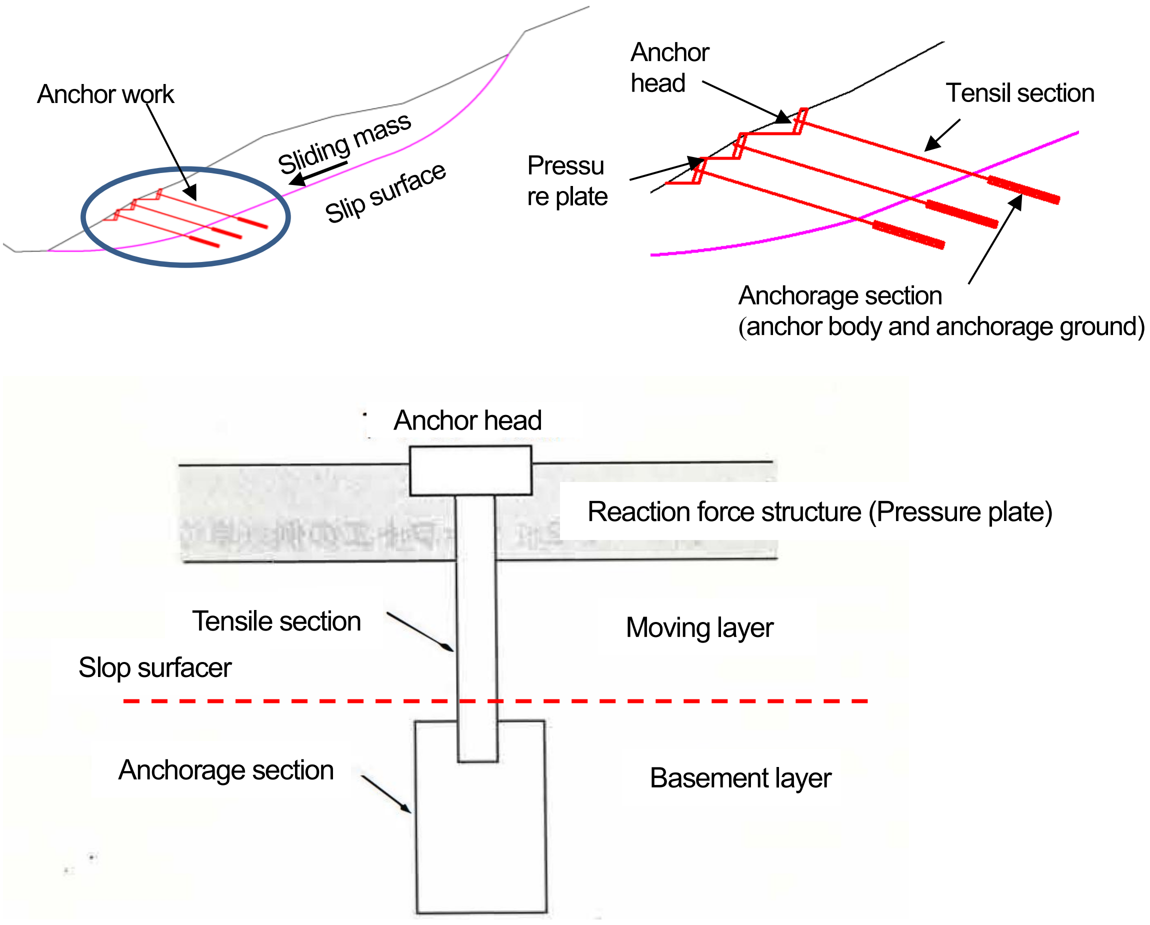


Figure 30 Structural image of anchor work

Anchor used for landslide countermeasures are designed to stabilize landslide by transmitting the load acting on the anchor head to the anchorage section through the tensile section, and by integrating the landslide moving layer and basement layer.

The anchorae shall be designed to obtain the prescribed deterrent force considering the topography and geology of the target landslide site, to ensure the stability of the anchor tensile section, Anchorage section (anchor body and anchor ground) and structures (pressure receiving plate, etc.) against the tensile force.

The location of anchor, location of anchorage ground, anchor arrangement, tilt angle of anchors (angle between anchoring direction and horizontal plane), and scale and structure of facilities shall be carefully determined in consideration of topography, geology, and movement conditions of the landslide site.

Anchor have the following effects in resisting landslide force.

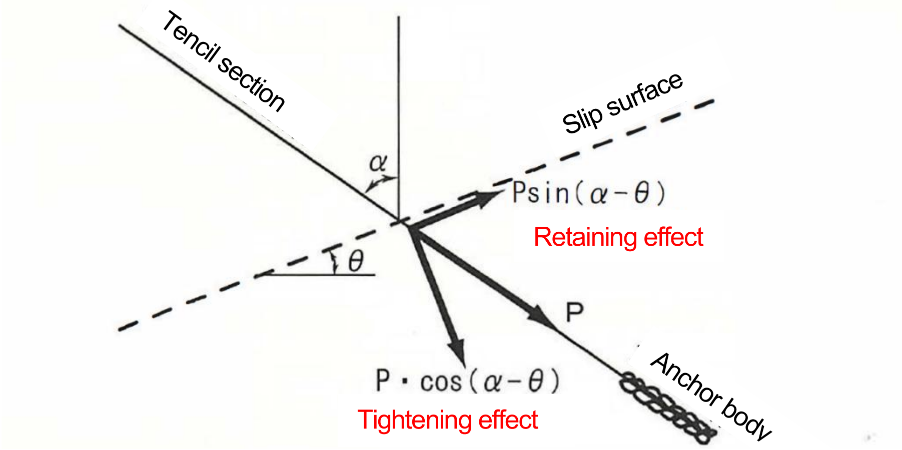


Figure 31 Function of anchor

/ Tightening effect

This is an effect to increase the shear resistance by increasing the vertical stress against the slip surface. In order to expect a clamping effect, the moving layer must not deform significantly in compression or consolidation when a tension force is applied.

Therefore, it is difficult to expect a tightening effect when the moving layer is composed of clay, collapsed soil, or weathered rock rich in fractures. It is also difficult to expect the effect when the slip surface depth is deep.

/ Retaining effect

When a landslide mass tries to move along the slip surface, the anchor's force tangential to the slip surface is used to hold the landslide soil mass back.

By making the steel material resist tensile force, anchor is used for landslides with large sliding forces or landslides where it is difficult to prevent by pile.

Anchor for the purpose of preventing landslides are often installed at the landslide end with the expected "trapping function". In designing, the most appropriate of these functions should be selected, taking into consideration the tilt angle of the anchor, the gradient and depth of the slip surface, etc. In some cases, both of these effects are considered in the design.

2) Calculation of Required Anchor force

There are two types of anchor works used for landslide countermeasures: /those that use a tightening effect and / those that use a retraction effect.

Calculation of the required anchor force in the design of anchor works is determined by the following equation for each function.

/Calculation of the required anchor force using the tightening effect

$$P.Fs = \frac{\{\Sigma(W \cdot \cos\theta - U) + P \cdot \cos(\alpha - \theta)\}\tan\phi' + c' \cdot \Sigma l}{\Sigma W \cdot \sin\theta}$$

/C alculation of of the required anchor force using the anchoring effect

$$P.Fs = \frac{\Sigma(W \cdot \cos\theta - U) \cdot \tan\phi' + c' \cdot \Sigma l + P \cdot \sin(\alpha - \theta)}{\Sigma W \cdot \sin\theta}$$

P. Fs : planned safety factor

W : Weight of split piece (kN/m)

U : Pore water pressure acting on the split piece (kN/m)

P :Required anchor force (kN/m)

Φ' : Internal friction angle of slip surface (°)

c' : Adhesion force of surip surface (kN/m)

1 : Length of slip surface of split piece (m)

θ : Inclination angle of the slip surface (°) (See Figure 32)

α : Anchor placement angle (°) (See Figure 32)

3) Anchor placement

Anchor should be placed considering the stability of the pressure plate location and surround ground, and the anchor ground, as well as the effect on adjacent structures. The location of anchorage section and the direction and spacing of anchors must be assumed in advance at the beginning stage of the design phase.

/Planned location of anchor

When the angle of intersection between the anchor and the slip surface is close to a right angle, such as at the head of a landslide where the slope of the slip surface is steep, the anchor deterrent effect becomes small and the anchor may be sheared off.

Careful consideration should be given to the planned location of anchors, and in principle, the head of the landslide should be avoided.

/ Impacts on adjacent structures

If there are underground structures, tunnels, piles, etc., in the vicinity of the anchor placement location, it is necessary to consider the impact of the anchor on these structures.

/ Inclination angle of anchors

The inclination angle of anchors should not be determined solely by mechanical advantage, but should be determined by considering topography, geology, construction conditions, etc. However, as a general rule, anchor angles between -5° and +5° from the horizontal plane should be avoided due to anchor construction problems (residual slime and grout material breathing).

/ Anchor spacing

Anchor spacing shall be determined in consideration of anchor parameters such as anchor force, anchor diameter and anchor length.

4) Stability Consideration of structure

/ For anchor work, the tensile material, pressure plate, and anchor body are determined specificaition that can be stable against the design anchor force (tensile load).

/ For the tensile material of the anchor construction, use a material that can reliably transmit the anchor force to the anchor body. The allowable tensile stress of the tensile material shall have a safety factor sufficient for the tensile strength and yield strength of the tensile material.

/ The conditions for the pressure receiving plate shall be as follows

The ground supporting the pressure plate shall be stable against settlement due to tension.

The pressure plate is stable against bending failure and push-through shear failure.

/ The anchor body shall have a sufficient safety factor against design anchor force (tensile load).

/The anchor body shall be designed to allow pressure-injection grouting. The quality of the grout shall be sufficient to withstand the design loads.

5) Ensuring durability

In order to maintain stability over the long term, anchor structure shall be designed to provide sufficient corrosion protection for the tensioner and head, and shall be capable of being re-tensioned.

Chapter 2. Countermeasure for slope failure

2.1 Planning of the countermeasure

2.1.1 Classification of Countermeasure work

(1) Classification of Countermeasure work

Slope failure is caused by erosion of the ground surface, soil layer strength loss and weight gain due to water content, increased pore water pressure, piping, and weathering. Slope failures can be classified into two major categories: control works, which mitigate these factors and avoid the risk of slope failure, and restraint works, which directly anchor the slope with a structure.

Retardation works aim to stabilize slopes by changing natural conditions such as topography, geology, surface water, and groundwater conditions. Restraint works aim to restrain slope collapse or sliding by installing structures.

In particular control works are defined as those that are constructed to reduce the effects of rainwater, and restraint works are those that change the balance of the slope so that collapse does not occur even if rainwater acts on the slope.

The main types of countermeasures of slope failure are shown in the figure below.

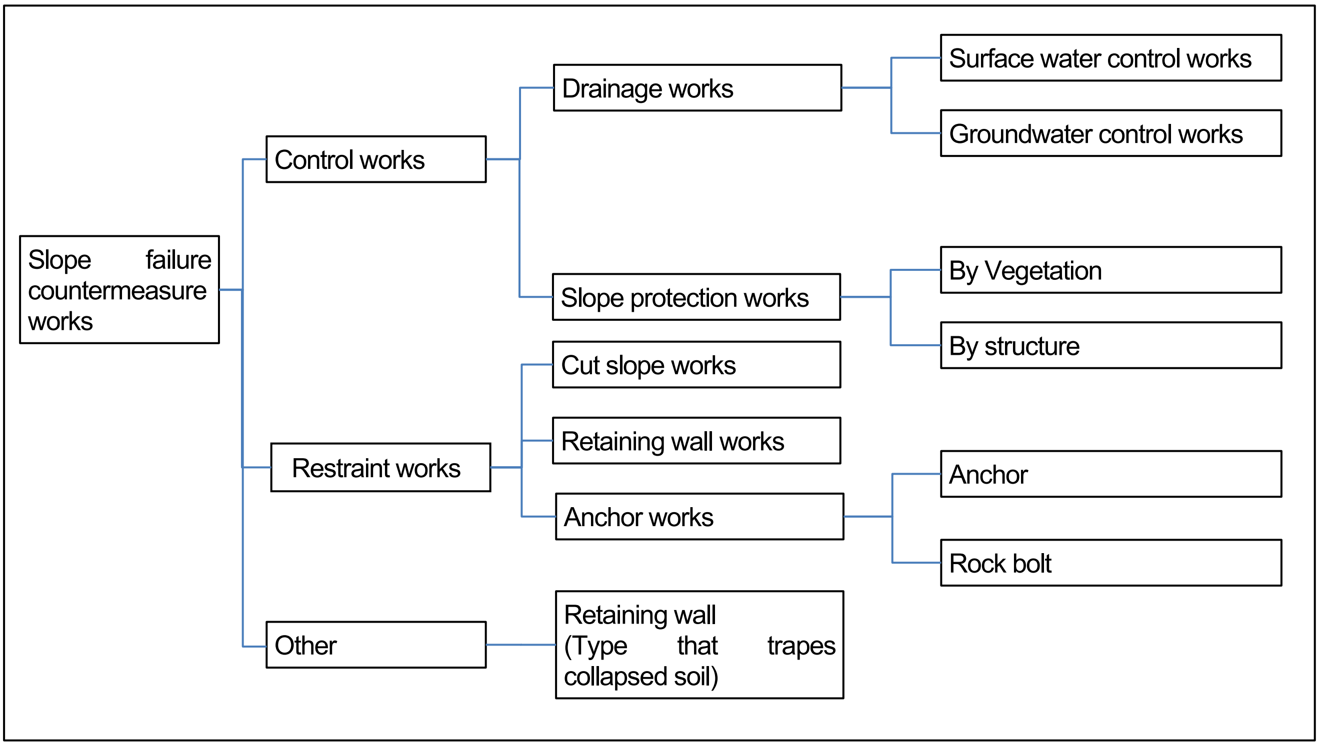


Figure 32 Classification of slope failure countermeasure work

(2) Outline of countermeasure（Control work）

1) Drainage work (See chapter 1.1.4)

(A) Surface water control works

This is the most basic method of slope stabilization. It is a method to stabilize slopes by eliminating surface water and groundwater that trigger slope failure. It is introduced in most construction projects and is inexpensive.

Collecting surface water and draining it quickly off the slope or preventing surface water from flowing into the slope.

Channel at the shoulder of slopes, channel at the step, Channels at the bottom of slopes, longitudinal channel at slope, seepage prevention works.

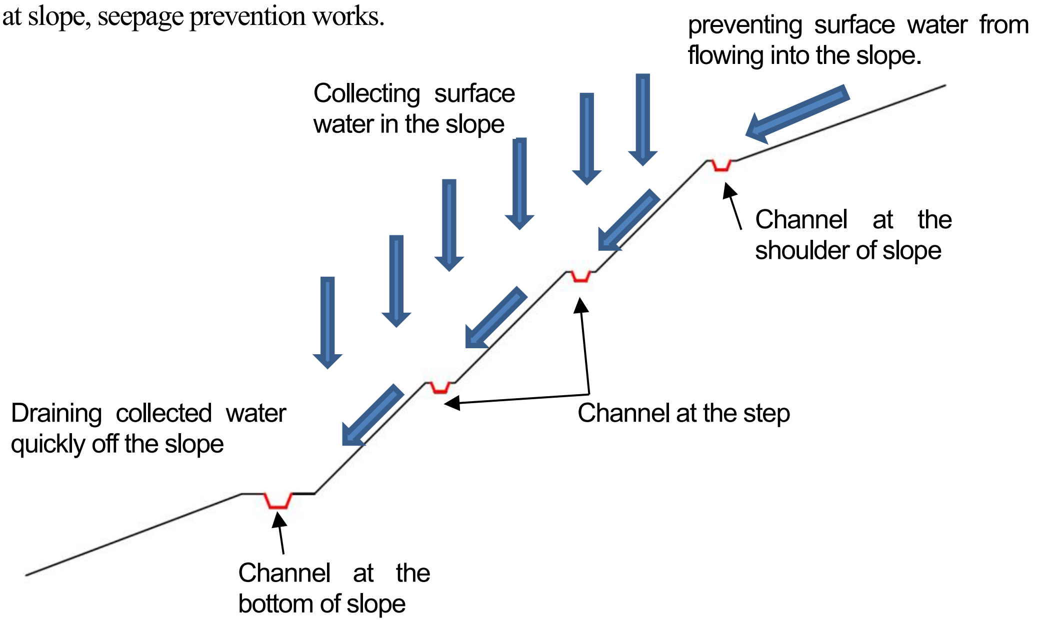


Figure 33　Image diagram of surface water control work

(B) Groundwater control works

Groundwater control works

Drainage groundwater from the slope, reduce pore water pressure, and stabilize the slope

Drain, Horizontal drainage boring, drainage well is adopted.

Details of this method are shown in P.9 “Chapter 1. Countermeasure for landslide 1.1.4（2）Ground water contorol work”.

2) Slope protection work

This method is used to cover slopes and control erosion.

There are two main types of slope protection methods: vegetated slope protection and structural slope protection.

(A) Vegetation slope protection work

This is a method of controlling erosion by covering slopes with vegetation.

This method is used on cut slopes with no spring water, and is generally applied to slopes cut to a stable gradient.

In Japan, seed dispersal, spraying of soil, spraying seed with vegetation base material and soil, vegetation sandbag, and turfing are being implemented.

Vegetation mat work

Vegetation base material spraying work

Figure 34 Case study photos of vegetation slope protection work

(B) Structual slope protection works

a) Shotcrete work

Shotcrete work is a method of spraying concrete(mortar) on natural slopes (cliffs) and slopes that are prone to weathering and erosion, and is constructed to protect slopes from weathering and erosion and to prevent small collapse and rock fall.

Shotcrete work is a method of spraying concrete(mortar) with a thickness of 3-10 cm onto a cliff or slope, and generally has no deterrent, and It is a premise that the slope is self-sustaining and stable.

Figure 35　Case study photos of shotcrete work

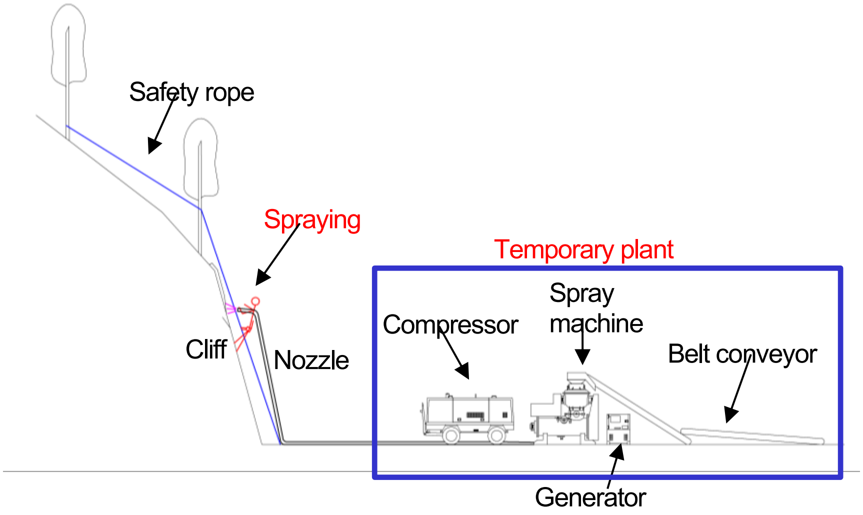


Figure 36　Image diagram of shotcrete work

b) Pitching work

The pitching work is used to prevent weathering and erosion of slopes

It is used when the slope is less than 1:1.0 and the slope is less than 5m high and 7m long. This method is used for uncohesive soil, mudstone, soft rock, and cohesive soil.

Methods include masonry pitching, concrete block pitching, and concrete pitching.

Stone pitching is a method of preventing weathering and erosion of slopes with stones. The standard thickness is 30 to 40 cm, and the gaps between the stones are basically filled with concrete.

Concrete block pitching is a method to prevent weathering and erosion of slopes by using flat concrete blocks. Concrete blocks are often reinforced by filling the back of the blocks with concrete.

Concrete pitching is a method of placing concrete directly on slopes to prevent weathering and erosion.

This method is used when shotocrete is difficult, such as in rock layer with many joints and cracks or debris. The thickness of concrete lining is 20 to 80 cm, often 50 cm.

In general, unreinforced concrete is used for slopes as gentle as 1:1.0, while reinforced concrete is used for slopes as steep as 1:0.5.

Concrete pitching

Concrete block pitching

Figure 37　Case study photos of pitching work

c)　Crib work

Slopes are covered with cast-in-place concrete cribwork or precast concrete cribwork, and to cover inner frame by vegetation, concrete, or other materials prevent weathering and erosion of the slope.

Some cast-in-place concrete frame construction methods have the role of restraint works, and are often used as restraint works.

It is generally that beam size is generally 15 cm to 60 cm, and grid size is generally 1.2 m to 3.0 m.

In case of using for as restraint works, the size is set according to the target collapse scale and the design strength of the anchors and rockbolts.

Figure 38　Case study photos of crib work

(3) Outline of countermeasure（Restraint work）

1) Cut Slope work

This is a method of changing the gradient and height of a slope by cutting slope to be able to ensure stability of slope even when subjected to rainwater affect.

This method is removing unstable parts and to improve the slope gradient according to the properties of the soil or rock that make up the slope.

It is the most basic method of collapse control construction and one of the most effective if implemented safely. It is often used in combination with drainage work and slope protection work.

Often used in combination with other restraint works (retaining walls, rock bolting, anchoring, etc.) when the extent of the cut is restricted due to land use.

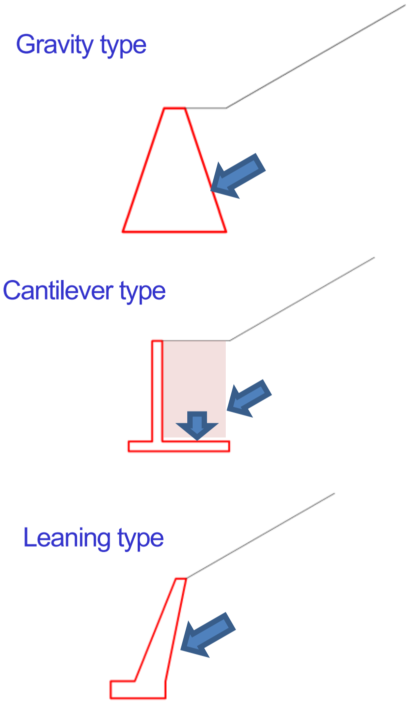
2) Retaining wall

The retaining wall is an earth retaining structure that is continuously provided in the shape of a wall for the purpose of stabilizing the slope.

Retaining walls are classified according to the main material, shape, mechanical stability mechanism, etc.

As a measure against collapse, the size of the slope that can be supported by the retaining wall is limited, and it is often used to fix the slope toe.

Classifications of retaining walls are as follows

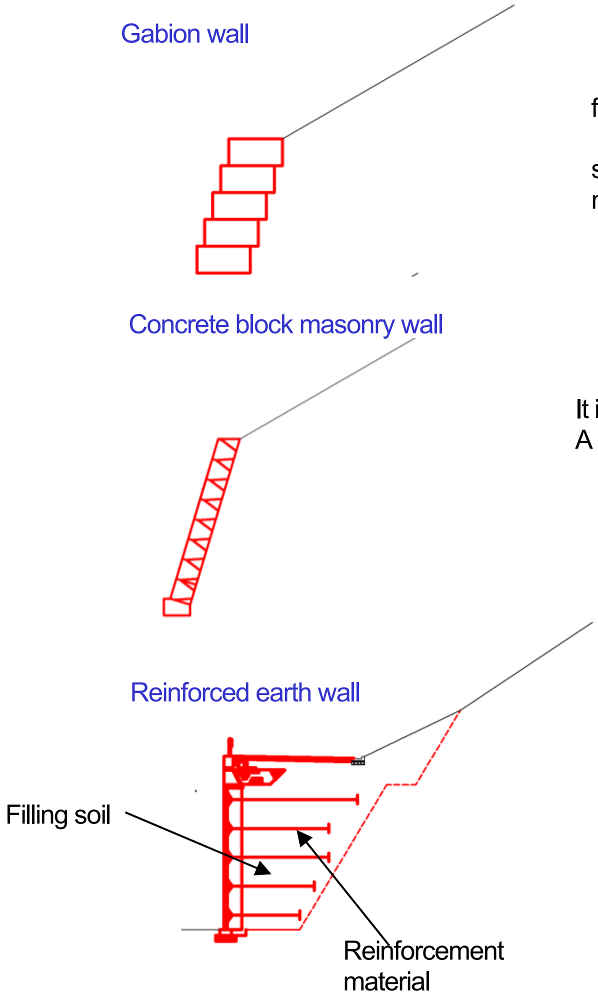


A type that resists earth pressure due to the gravity of the retaining wall
Concrete structure is common

A type that resists earth pressure due to the gravity of the soil upper the retaining wall and the member strength of the cantilever.
Reinforced concrete structure is common

The type that resists earth pressure due to its own weight by leaning the retaining wall against a slope

Figure 39　Classification by stability mechanism



Retaining wall made of a basket braided by wire and filled with stones.

It's made in various parts of the world because of its simple structure, easy to construct and easy to obtain material.

It is a retaining wall type made by stacking concrete blocks. A leaning type retaining wall is common.

Soil retaining structure that constructs a vertical or near-vertical wall surface by laying reinforcements in the embankment.

Figure 40 Classification by material

If it is not possible to directly control the collapse of the slope, there are cases that retaining wall (type that trapes collapsed soil) planned.

This type generally has a space on the back of the retaining wall to receive the collapsed soil.

Also, the rockfall protection wall that catches rock falls has the same shape.

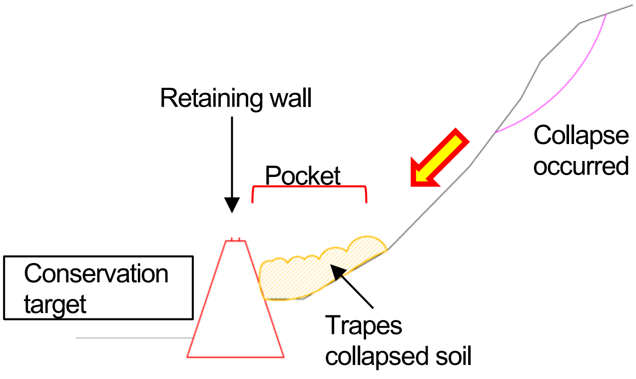


Figure 41 Image diagram of retaining wall type that trapes collapsed soil

3) Anchor, Rockbolt work

This method is used in combination with crib work, retaining walls, and concrete pitching work to increase the stability of slopes in order to prevent the collapse of weathered rock, cracked rock, and surface soil. In addition, the method prevents collapse by tensioning and connecting unstable rock (bedding, cracked, jointed rock) with stable bedrock at deep layer by anchor material.

Characteristics of anchor and rock bolt construction are shown below.

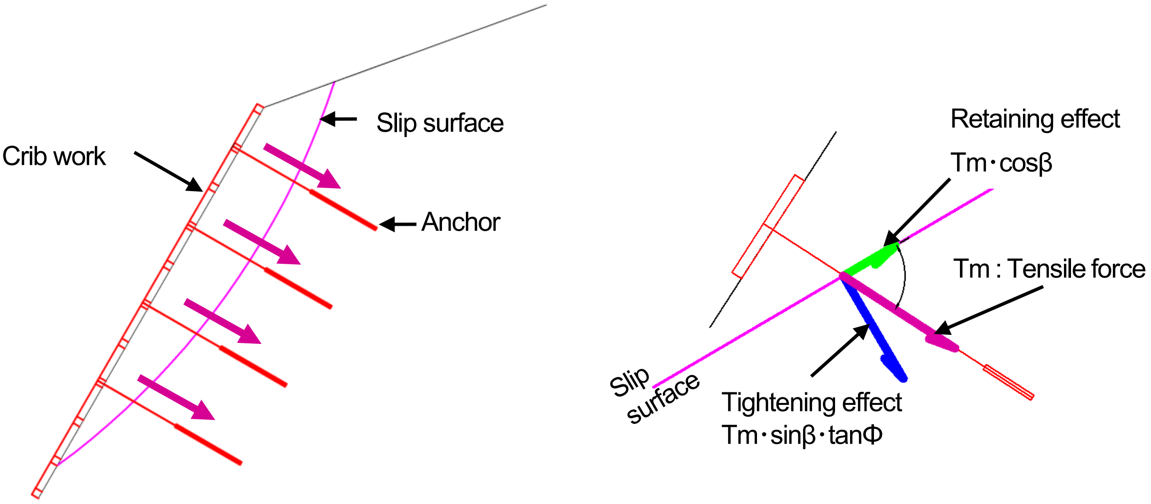


Figure 42 Image diagram of anchor work

Anchor work is method to stabilize by changing the landslide balance by applying tensile force to the anchor material.

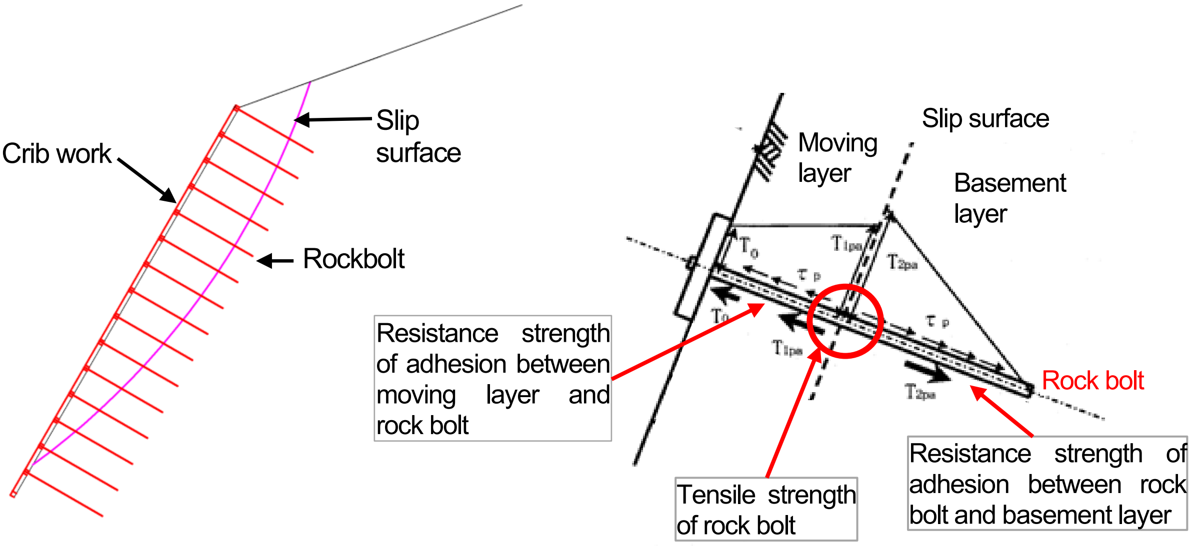


Figure 43 Image diagram of rock bolt work

Rock bolt work do not apply tensile force unlike anchors.

It is a construction method to reinforce the slope by the three resistance forces applied to the bolt.

2.1.2 Selection of construction method

The basis of designing slope failure prevention works is to understand what factors and in what form the slope will fail.

After the collapse form and factors are determined by the investigation, the applicability of the method for the entire slope should be determined by considering the environment/landscape, slope height, scale, construction conditions, etc., the actual construction status in the past, and the estimated construction cost, etc.

After the collapse factors and forms of collapse are assumed, the slope should be planned to be stabilized by preventing collapse (mainly by restrainting), and next preventing surface erosion and partial collapse by weathering (mainly by controlling). If more than one type of collapse is anticipated, the same procedure should be followed for each of them.

(1) Concept of countermeasure work method selection

The typical flow of the study is as follows

- Minimal removal of unstable soil masses: This method is used for high-risk masses such as overhangs, when there is no way but to remove them or when it is clearly more economical to do so.

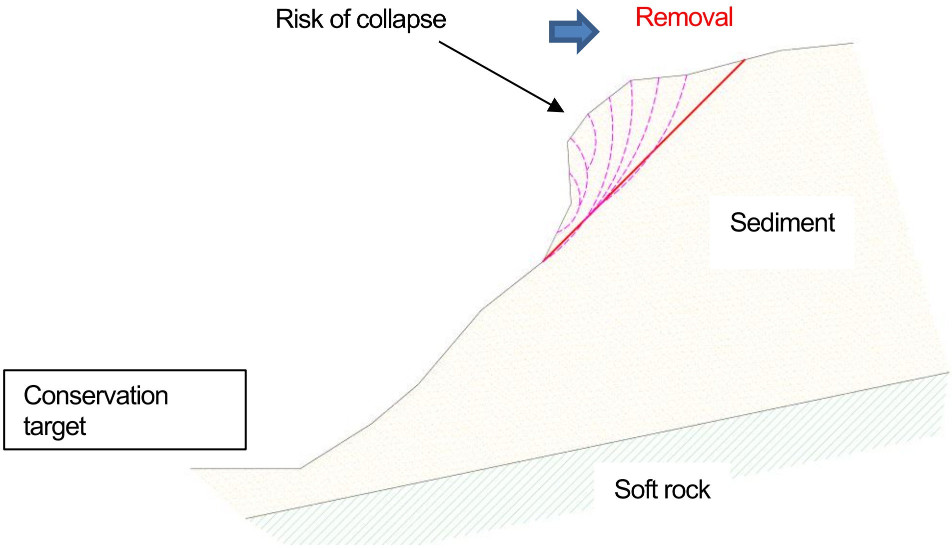
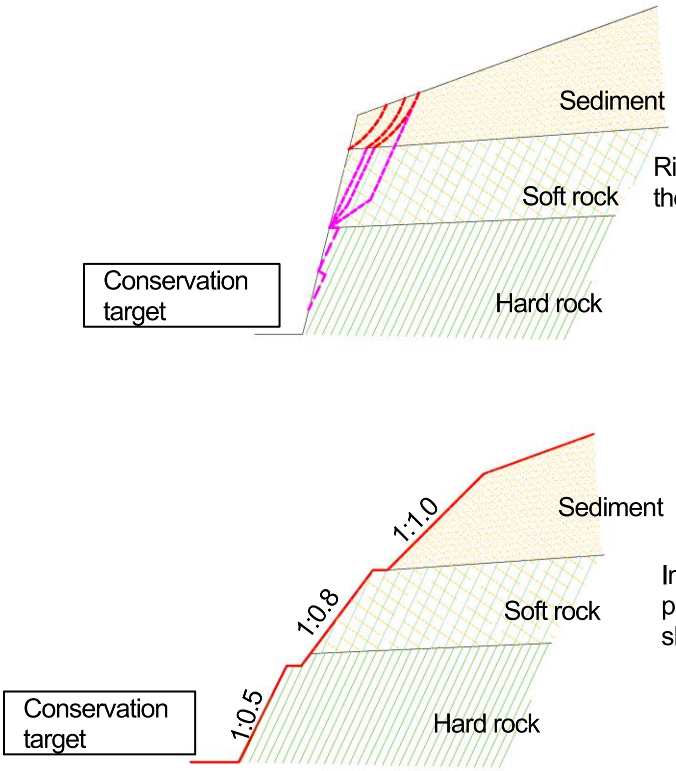


Figure 44 Image diagram of removal of unstable soil masses

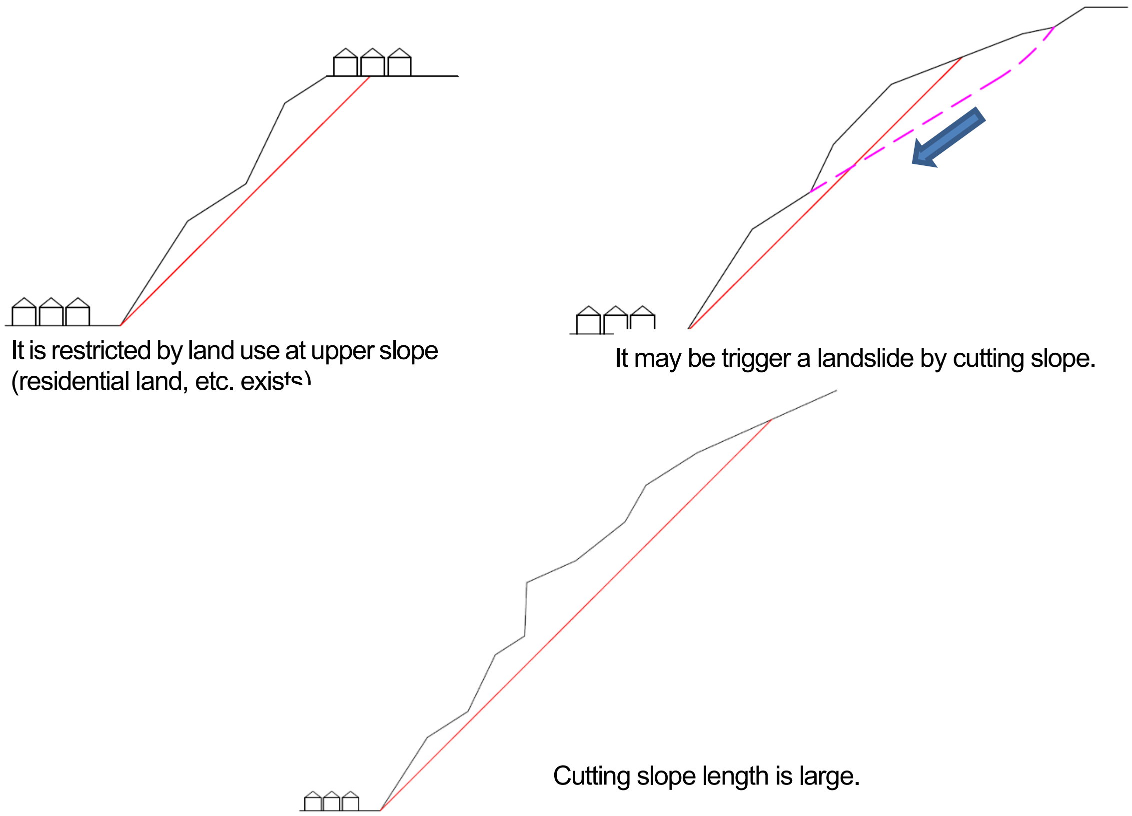
- Improvement of the slope shape: The slope should be cut as gently as possible considering the stability gradient suited to the soil and geological conditions of the target slope. However, in many cases, there are restrictions when the slope length is large or the land is insufficient.



Risk of collapse caused by the properties of the soil or rock that make up the slope

Improve the slope gradient according to the properties of the soil or rock that make up the slope

Figure 45 Image diagram of Improvement of the slope shape



It is restricted by land use at upper slope (residential land, etc. exists)

It may be trigger a landslide by cutting slope.

Cutting slope length is large.

Figure 46 Image diagram of cases that the choice of construction method is restricted

- Install restaint work: In case that Improvement of the slope shape and removal unstable area are not able to stable the slope, restraint work is adopted.

At this time, the strength of the foundation ground of structure placement position and the necessary deterrent force should be calculated.

Consider the stability of the entire slope and consider appropriate deterrent facilities.

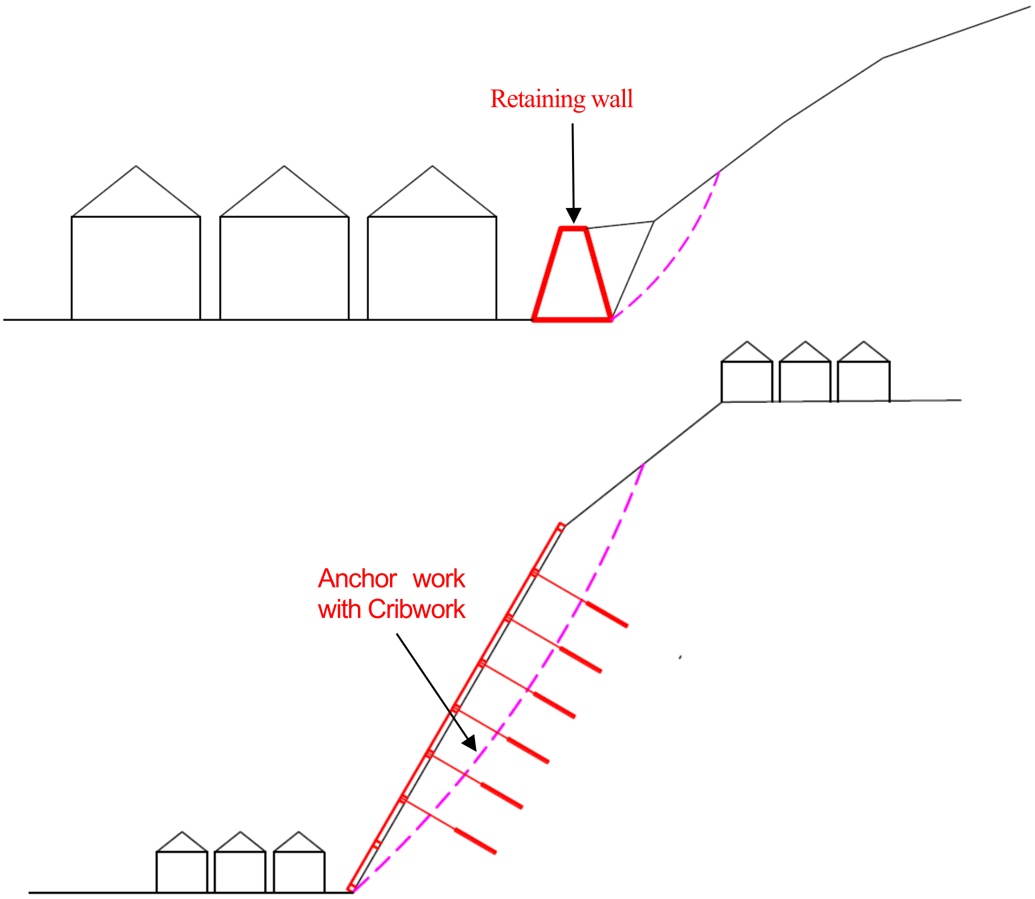
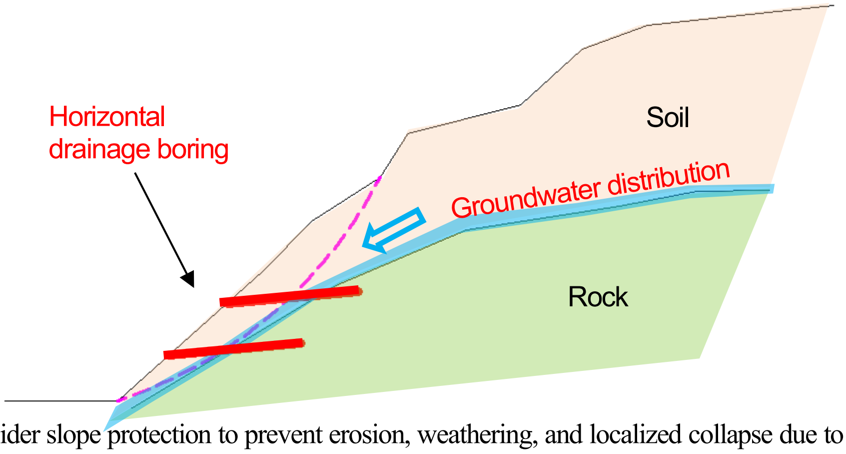


Figure 47　Image diagram of cases that restaint work is installed

- If it is known from the investigation results that the slope stability is affected by groundwater, plan facilities such as horizontal drainage boring.



・Consider slope protection to prevent erosion, weathering, and localized collapse due to surface water. If there is water flowing in from the land behind the site, drainage works should be considered.

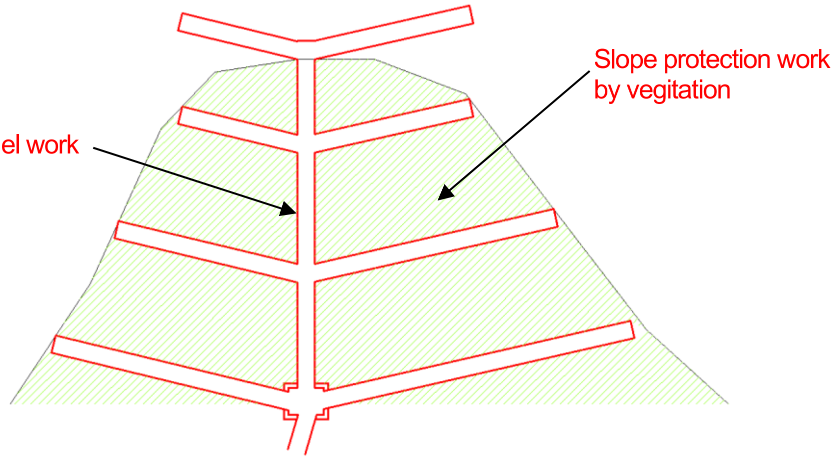


Figure 49 Image diagram of cases that surface control work is installed

(2) Case study of countermeasure work method selection

1) Case that improve slope shape

The target slope is a steep slope behind a human habitation where weathered sandstone is distributed.

The surface layer is in a weakened condition due to severe weathering, and localized collapses occur during rainfall.

The geological conditions of the subject slope are as follows

/Layer 1: Significantly weathered sandstone, N value of around 10

/Layer 2: Weathered sandstone, N value 20-30

/Layer 3: Sandstone, N value 50~

Layer 1 is weakened, and there are some areas of loosen. Localized collapses have occurred during heavy rainfall. Layer 2 is exposed on a steep cliff behind a house. It is expected to be weathered and weakended by rainwater erosion in the future. Layer 3 is in a stable condition with little weathering.

Under the present conditions, the weathered sandstone layer at the surface(layer1) is at risk of collapse, and the underlying Layer 2 is feared to be weakened by weathering progress and in transition to collapse.

Therefore, the policy for countermeasures is as follows

/Remove unstable soil/significantly weatherd rock

/Reduce the impact of rainwater and weathering and weakening by drainage and slope protection works.

/To Install restraint works (retaining wall) to prevent collapse even if rainwater impacts and weathering progresses.

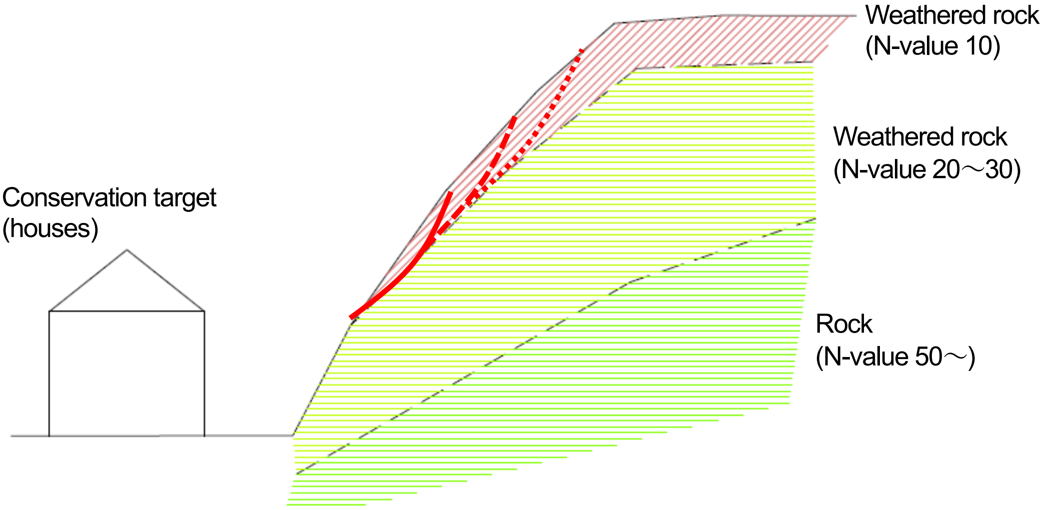


Figure 50 Longitudinal section of slope before countermeasures

Attention point of selecting a construction method is following.

/Remove unstable soil/significantly weatherd rock

Cutting slope work is implemented to remove the layer1 that is unstable state.

Angle of the cutting slope should be that slope can be stable.

The slope of the cut slope should have a small step to reduce the velocity of surface water, and a channel should be placed in the small step to drain surface water.

/ Drainage and slope protection works

Vegetation base material spraying work is installed on the slope to encourage the introduction of vegetation.

The covering by vegetation is intended to reduce erosion by surface water.

Channel is installed to drain surface water at the step.

/Install retaining wall

At bottom of the cutting slope, retaining wall is installed.

Retaining wall is leaning type made by concrete.

Rockfall protection fences will be installed in case that rock fall occurre doe to eroded by unexpected amount rainfall at the upper slopes.

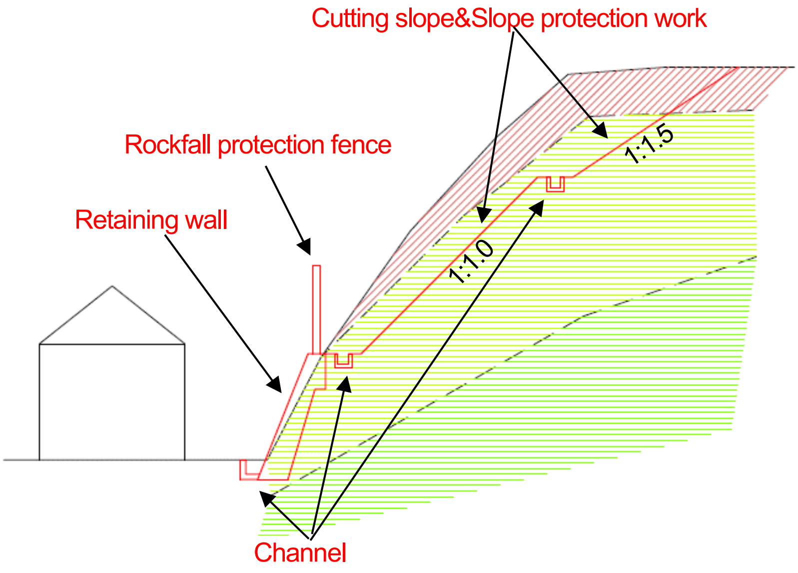


Figure 51　Longitudinal section of countermeasure work plan

2) Case that countermeasures are installed with restraint works

The target slope is a steep slope behind a house, and there are houses on the upper part of the steep slope.

The geological structure is weathered mudstone with dip slope structure, and it has risk to occure collapose regulated by this rock structure.

The geological conditions of the subject slope are as follows

/Layer 1: Weathered mudstone, N value 20-30

/Layer 2: Mudstone, N value 50~

Weathered mudstone in the layer1 is weakened by weathering and easily separates along the bedding plane.

The risk of collapse of the weathered rock regulated by the bedding plane in the future is very high.

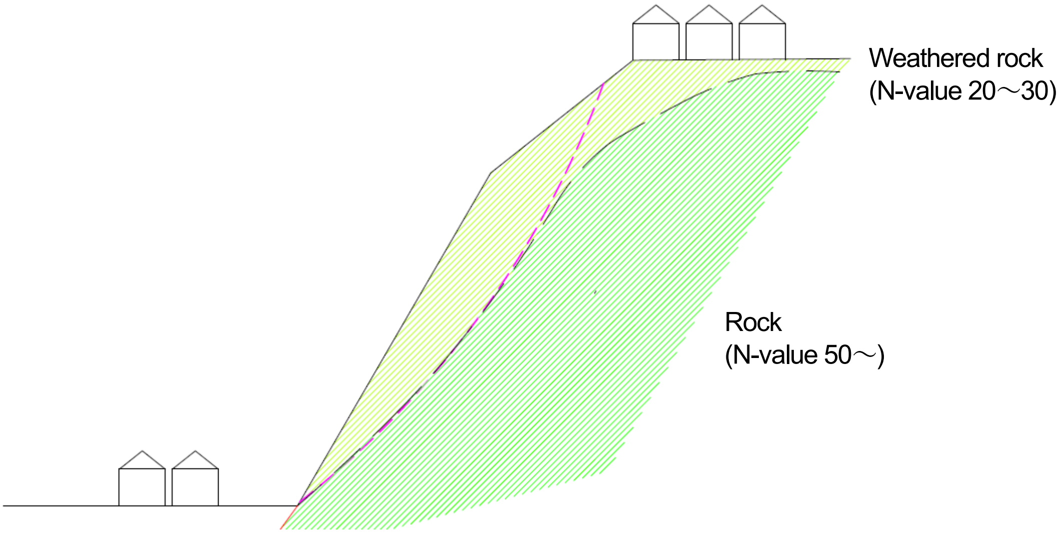


Figure 52　Longitudinal section of slope before countermeasures

In order to stabilize the slope at risk of collapse, the choice is to remove or fix the unstable rock mass.

However, removal of the unstable rock mass would be difficult because it would require a very large slope cut, and the cut would require the relocation of houses on the upper part of the slope.

Therefore, it is decided to use restraint works to fix the unstable rock mass.

Therefore, the policy for countermeasures is as follows

/The collapse shown in the figure is the largest collapse that can occur on the slope.

/However, it is highly likely that smaller-scale collapses will also occur at various locations on the slope, so it is necessary to construct countermeasures so that the entire slope can be stabilized.

/It is adopted anchor work that prevent collapse by tensing and connecting unstable rock to deep, stable bedrock with anchoring materials.

/The pressure receiving structure on the ground surface is the Cribwork, which also has the function of protecting the slope.

/Anchors are distributed on the slope to stabilize the entire slope.

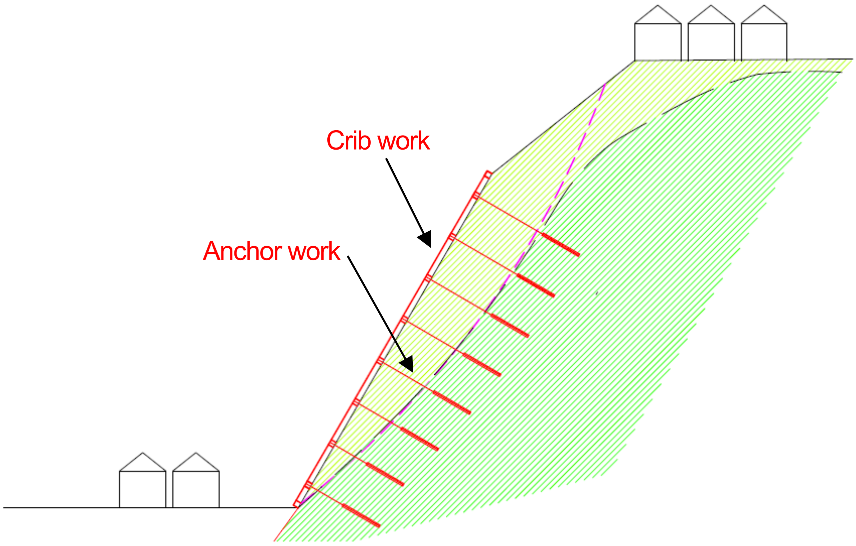


Figure 53 Longitudinal section of countermeasure work plan

2.2 Design of Countermeasure

2.2.1 Control work

(1) Drainage work

It used to collect surface water, drain it off-slope, and prevent it from flowing into the slope are generally called surface water control work, and include slope shoulder drainage channels, drainage channels at step, vertical drainage channels, and seepage prevention works.

It used mainly for collecting groundwater, draining it off the slope, and preventing it from flowing into the slope is generally called a groundwater control work, drain works and horizontal drainage boring are mainly used on slope failure countermeasure.

In planning and designing drainage works, the weather, topography, ground surface coverage, geology, soil type, groundwater, spring water, cross-section and condition of existing drainage facilities on and around the slope, and drainage system should be investigated, and the drainage system should be rationally planned and designed to balance the drainage system as a whole.

Details of this method are shown in P.15 “Chapter 1. Countermeasure for landslide 1.2.1 control work”.

(2) Slope protection work

1) Vegitation work

Vegetation work is a method of protecting slopes by allowing vegetation to flourish on the slope surface. By covering the slope with plants, erosion of the slope by rainwater can be prevented and weathering can be controlled.

On the other hand, vegetation work does not have the same mechanical capacity as a structure, so it should be conbinate with slope protection structure if there is a risk of slope collapse.

Slope protection work by vegetation consists of vegetation work that introduces plants to the slope and vegetation foundation work that creates an environment for plants to grow by means of structures. When the slope gradient is too steep to construct the vegetation work alone, the vegetation work and the vegetation foundation work are combined.

The following conditions, methods, and plants to be introduced must be met when applying vegetation work.

/The foundation of plant growth should be stable for a period of time until the plants are fully grown.

/The plants to be introduced should be compatible with the environmental conditions of the construction site.

/The selection of the plants should be in accordance with the objectives of the vegitation work.

/The construction should be carried out at a time suitable for the germination and growth of the plants.

The following methods are used for vegetation work.

(A) Vegetation base material spraying work

This method involves spraying organic base material (containing seeds and fertilizers) 3 to 10 cm thick onto a wire mesh installed slope, using a shotcrete machine, depending on the vegetation target and application conditions.

(B) Vegetation sheet

This is a method of attaching a sheet of product with seeds, fertilizers, etc. to the entire slope surface and fixed with anchor pin.

(C) Vegetation matting

A net (synthetic fiber, coconut fiber, etc.) to which seeds, fertilizers, fertilizer bag are directly attached is attached is spread over the entire slope surface and fixed with anchor pins, pegs, etc.

2) Shotcrete work

Shotcrete work is a method of covering cliffs and slopes with mortar or concrete. It is one of the most widely used methods to cover deteriorated cliff surfaces due to weathering, etc., because it is very effective in blocking air, temperature changes, and seepage water, and it is easy to construct.

Since this method prevents weathering and erosion, it is not effective in deterring collapse by itself, and it is important to determine the stability of the slope at the planning stage.

If there is a risk of collapse, restraint works should be used in combination.

3) Pitching work

The pitching work is used to prevent weathering and erosion of slopes, methods include masonry pitching, concrete block pitching, and concrete pitching.

Here we introduce concrete pitching work, which is widely used in Japan.

Concrete pitching work is a slope protection work method in which concrete is placed on rock slopes to prevent weathering and reinforcement of the rock slope. The thickness is generally 20 to 80 cm. The thickness is determined by considering the condition of the ground, slope height, slope gradient, and presence or absence of freezing. If the slope condition is not good, the use of a lean-to retaining wall that takes earth pressure into consideration or the use of rock bolts and anchors should be considered.

A general diagram of concrete pitching work is shown below.

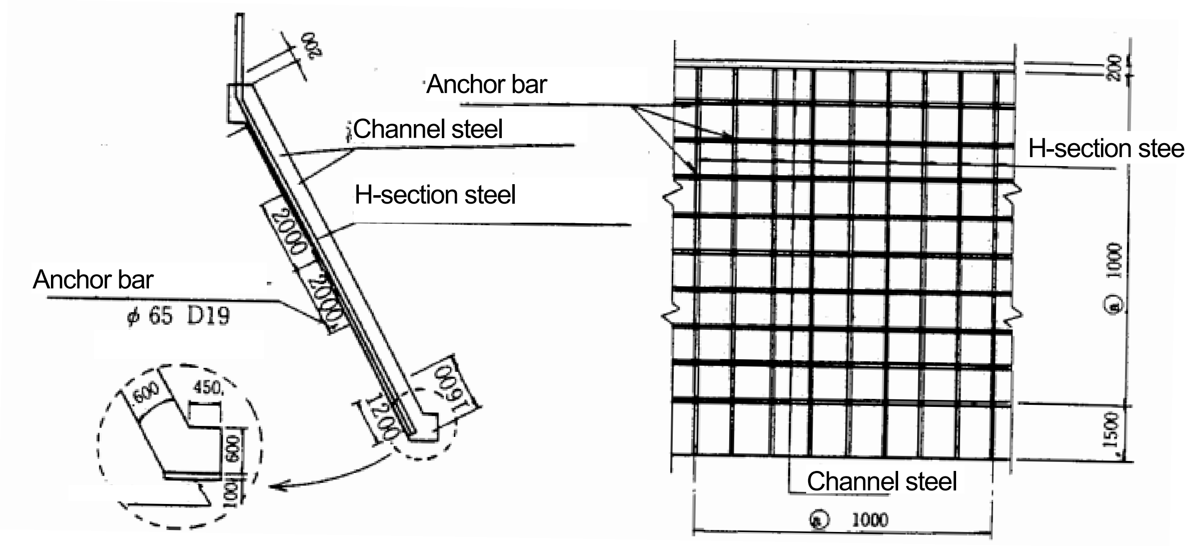


Figure 54 General diagram of concrete pitching work

4) Crib work

Crib work is a method of stabilizing slopes by creating a grid of mortar and concrete on the slope. It is used to prevent surface collapse and as a reaction force structure for anchors and rock bolts.

The size of the beam cross section, beam pitch, and amount of beam reinforcement bar are considered according to the scale of the targeted collapse and the specifications for use with rock bolts or anchors.

Crib work is classified into sprayed, precast concrete, and cast-in-place concrete, and is selected according to construction conditions and objectives based on the following characteristics

/Sprayed cribwork is a method of installing a formwork on the slope surface and spraying mortar, which can be used for construction on high or uneven surfaces.

/Precast concrete crib work is a method of assembling factory-made framing members on the slope, which provides stable quality and excellent aesthetics.

/Cast-in-place concrete crib work is a method in which formwork is placed on the slope and concrete is placed, and is suitable for flat, low slopes with large cross-sections.

Cribwork by spraying is currently the most commonly installed method in Japan.

Here we introduce Cribwork by spraying.

A wire mesh formwork is installed on the slope, and reinforcing bars are placed inside the formwork. There, mortar is sprayed with a spraying machine to create a beam. The inside of the frame is treated with vegetation and mortar spraying.

Beams are generally 150 x 150 mm to 600 x 600 mm in cross-section and 1.15 m to 3.0 m in pitch.

In some cases, rock bolts or anchors are installed at the beam cross points.

A general diagram of crib work is shown below.

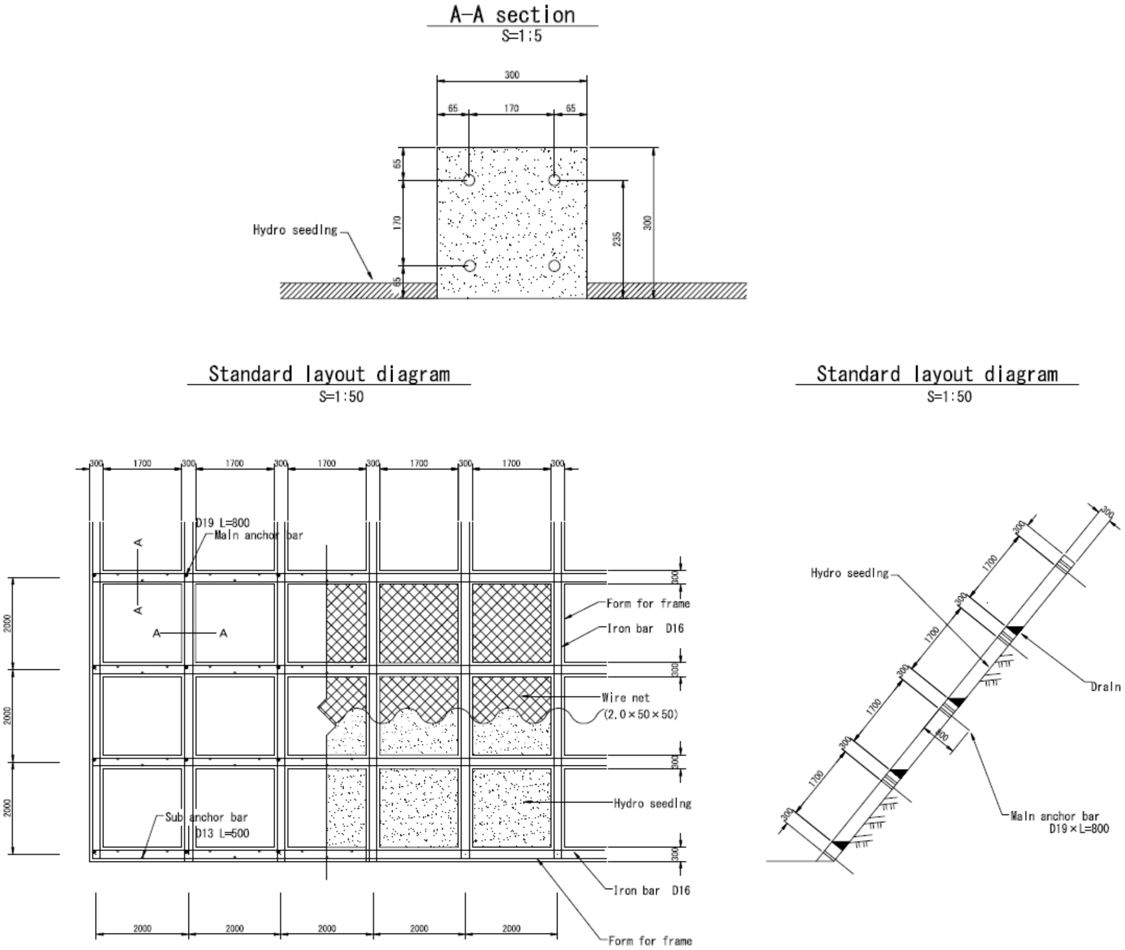


Figure 55 General diagram of crib work

2.2.2 Restraint work

(1) Cut slope work

Cutting slope is the most basic and important method of countermeasure for slope failure. Cutting the unstable soil and rock masses that make up the slope, or cutting the slope to a stable gradient, is the most reliable method of preventing slope failure.

The surface of the cut slope should be protected from erosion and weathering by means of slope protection works that take into account the site conditions so that erosion, rockfall, and collapse do not occur again.

In some cases, the cutting slope scope is restricted due to site constraints or environmental and landscape considerations, which may require a steeper cutting than the stable gradient. In these cases, a combined (composite) method of cutting slope and other restraints work (ground anchors, rock bolts, etc.) is used to ensure stability.

1) Cutting slope gradient

The following table shows the standard values for cutting slope gradient according to geological and soil conditions and slope height (Case in Japan). However, for slopes with the properties listed below, special care should be taken to examine the stability and determine the slope gradient.

Standard Gradients of Cut Slope (Japan standard)

Soil classification		Cut Slope Height	Gradient Vertical : Horizontal
Hard rock			1:0.3 to 1:0.8
Soft rock			1:0.5 to 1:1.2
Sand	Not dense, and poorly graded		1:1.5 to
Sandy soil	Dense	Less than 5m	1:0.8 to 1:1.0
		5 to 10m	1:1.0 to 1:1.2
	Not dense	Less than 5m	1:1.0 to 1:1.2
		5 to 10m	1:1.2 to 1:1.5
Sandy soil mixed with gravel or rock masses	Dense, or well graded	Less than 10m	1:0.8 to 1:1.0
		10 to 15m	1:1.0 to 1:1.2
	Not dense, or poorly grade	Less than 10m	1:1.0 to 1:1.2
		10 to 15m	1:1.2 to 1:1.5
Clayey soil		0 to 15m	1:0.8 to 1:1.2
Clayey soil mixed with rock masses or cobble- stone		Less than 5m	1:1.0 to 1:1.2
		5 to 10m	1:1.2 to 1:1.5

Slopes characteristics requiring attention in determining the cutting gradient are as follows

(A) Slopes prone to collapse such as colluvial soils, strong weathered rock slope, old landslides, and former collapsed sites.

(B) Slopes composed of expansive rocks, Tertiary mudstones, serpentinites, and rocks with low resistance to weathering.

(C) Slopes composed of fracture zones and rocks with many cracks

(D) Slopes with dip slope structure

(E) Slopes with high groundwater content

2) Considering point planning cutting slope

The following are points to be considered when planning the cutting slope according to the above-mentioned geological and soil characteristics.

(A) Slopes prone to collapse such as colluvial soils, strong weathered rock slope, old landslides, and former collapsed sites.

Talus slope, weathered rock slopes, volcanic mudflows sediment slope, and former collapsed slope are sometimes covered low-consolidated collapsed soils. Cutting slope at such like slope has risk to occure collapse.

When planning cutting slope at the slope, it is nessesary to attend following contents.

The factors that affect the stability of the slope are as follows.

/ Whether or not the cut is deeper than the groundwater level before the cut.

/ Cohesion of matrix of soil, grain size

/Whether or not the bedrock distribution is dip slope structure against cuting slope direction.

/ Whether there is a history of collapse.

Before planning cutting slope, it should be implemented a survey and evaluated the stability of the slope due to the cutting slope.

(B) Slopes composed of expansive rocks, Tertiary mudstones, serpentinites, and rocks with low resistance to weathering.

Mudstone, shale, low-solids tuff, and serpentine of the Tertiary age are become weaken from the surface layer of the slope, because of stress release by excavation and followed by repeated dry/wet and freeze-thaw cycles, and then collapse often occure as shown in following figure.

On such slopes, even if the slope is hard and stable at the time of excavation, it tends to become weaken as time passes after excavation. Therefore, the following points should be considered from the design stage.

/ To take measures to prevent flowing surface water into the slope.

/ Protection works should be carried out to prevent weathering as much as possible.

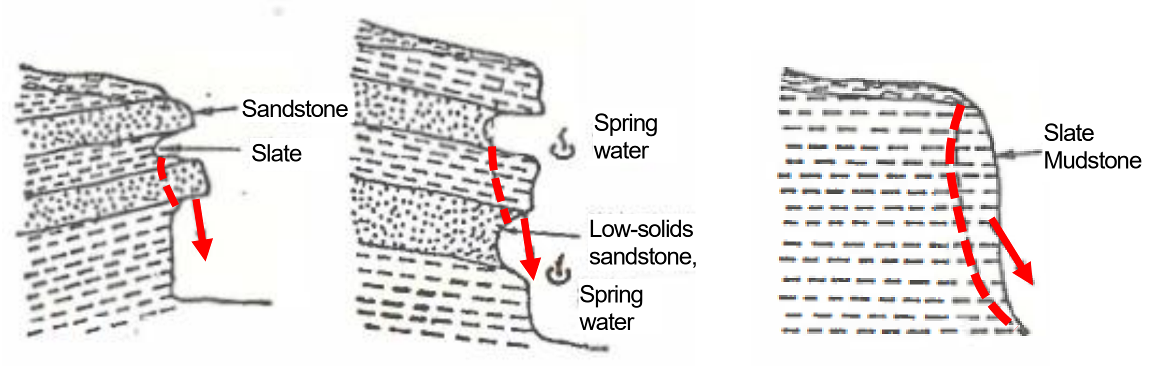


Figure 56 Image diagram of collapse

(C) Slopes composed of fracture zones and rocks with many cracks

In fault fracture zones and weathered bedrock areas, many fractures and weak lines develop in the ground. This is especially true in bedrock areas that have undergone long-term crustal deformation, such as Mesozoic and Paleozoic sedimentary rocks and old igneous rocks.

When such ground is cut, the slope often collapses along the cracks and weak lines.

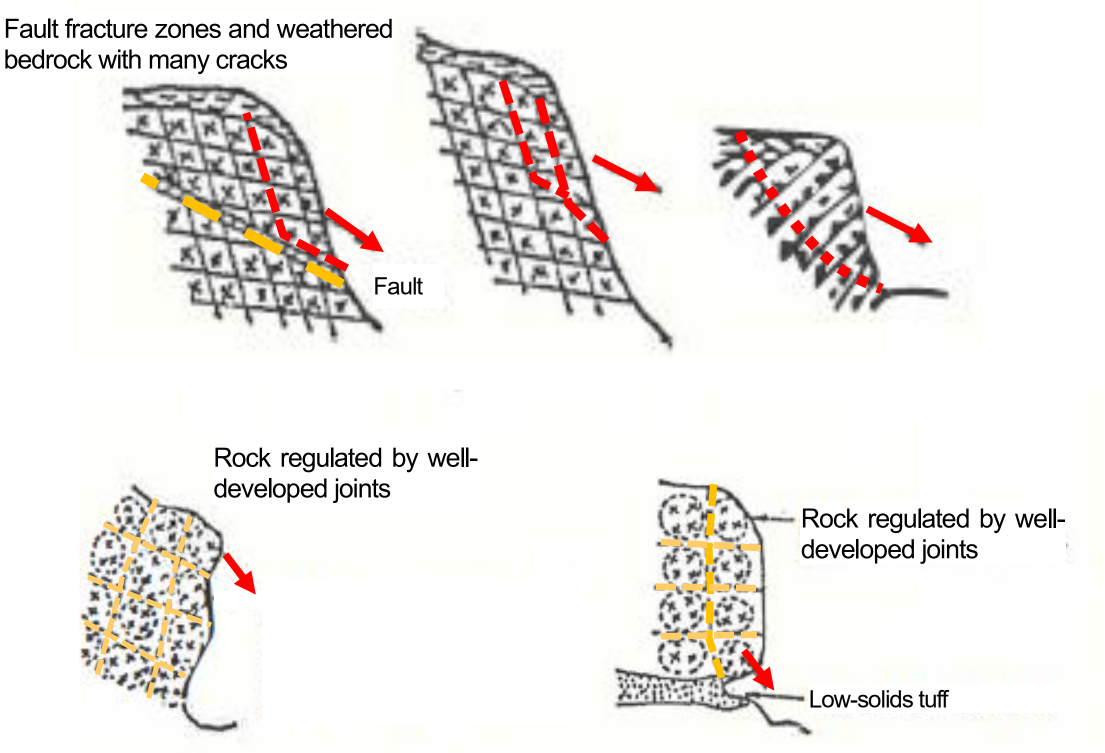


Figure 57 Image diagram of collapse

For such slopes, it is important to investigate the distribution and structure of loosening areas and faults in the bedrock by borehole investigations, seismic surveys, etc., and to assume the scale of destabilization and collapse that may occur as a result of cutting slope, to prepare a cutting slope plan taking into the installing of restraint works.

(D) Slopes with dip slope structure

In case that fractures develop regularly in a certain direction, such as schistosity of schist, bedding plane of sedimentary rock and columnar and sheet joints in igneous rocks, and the direction of inclination of these fractures is the same as cutting slope direction, this relationsip slope and fracture is dip slope structure. When cutting slope is implemented on such a slope, collapse may occur as shown in the figure below.

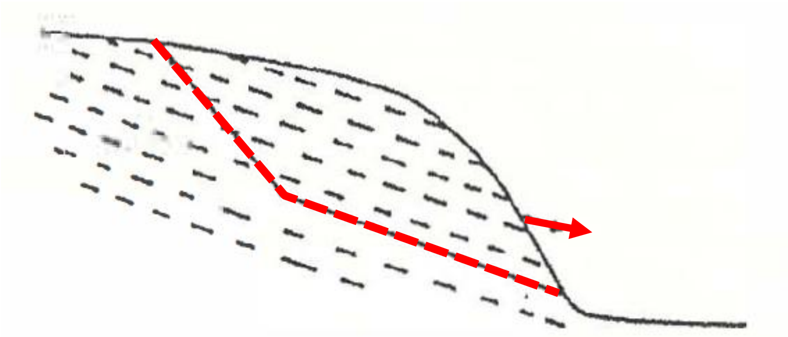
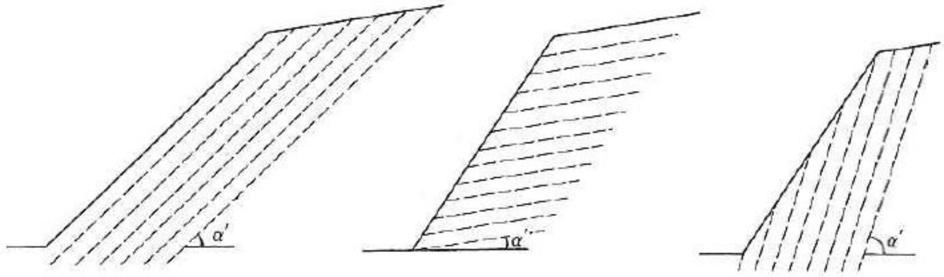


Figure 58 Image diagram of collapse

The stability of cutting slopes on dip slope strucuture is influenced by the relationship between the gradient of the dip slope and the gradient of the cutting slope, as shown in the figure below.

The slope of the cut slope should be equal to or slower than the slope of the dip slope structure.



General dip slope structure $(30^\circ<\alpha'<60^\circ)$ Gentle dip slope structure $(\alpha'<30^\circ)$ Steep dip slope structure $(60^\circ<\alpha')$

Figure 59 relationship between the gradient of the dip slope and the gradient of the cutting slope

It is important to understand the conditions of the bedrock during the planning process. Depending on the conditions of the fractures, the presence of weathered layers, and the distribution of groundwater, there is a risk of rock landslides.

(E) Slopes with high groundwater content

Groundwater is directly or indirectly responsible for most of the failures of slopes. Therefore, regardless of the geological conditions, when cutting in areas with many spring water or high groundwater table, the slope of the slope should be made as low as possible because of the unstable nature of the slope.

In addition, when cutting in such an area with a high groundwater table, it is necessary to first consider the drainage works before considering the gradient of the cutting slope.

(2) Retaining wall work

Retaining wall construction is planned for the following purposes

/To stabilize the lower part of the slope (footing).

/ To deter small-scale collapse in the middle of the slope.

/ As a foundation for slope protection works such as glue frame works.

/ To prevent damage by catching a collapse from the upper part of the slope at the lower part of the slope.

/ When reinforcing embankment construction.

Excavation of the foundation for a retaining wall has a great influence on the stability of the slope during and after construction, and should be minimized as much as possible. For the same reason, the excavation of the lower part of the slope should also be kept to a minimum. If the foundation ground does not have sufficient bearing capacity, the use of other methods, such as pile foundations, should be considered.

When installing a retaining wall on a slope where there is a lot of spring water, sufficient attention should be paid to drainage so that water pressure does not build up behind the retaining wall.

The retaining wall must be stable against earth pressure acting on the structure.

Stability calculation methods for evaluating the stability of retaining wall structures are briefly described below (methods used in Japan)

1) Calculation of earth pressure acting on retaining wall

The calculation of earth pressure is based on the Coulomb theory, and the retaining wall is designed as if it is acted by active earth pressure.

If the slope behind the retaining wall is uniform and the gradient is less than Φ (internal friction angle), the Coulomb formula can be used.

If the slope behind the retaining wall is not uniform, the Trial wedge method is used to calculate the earth pressure.

Following shows Coulomb formula

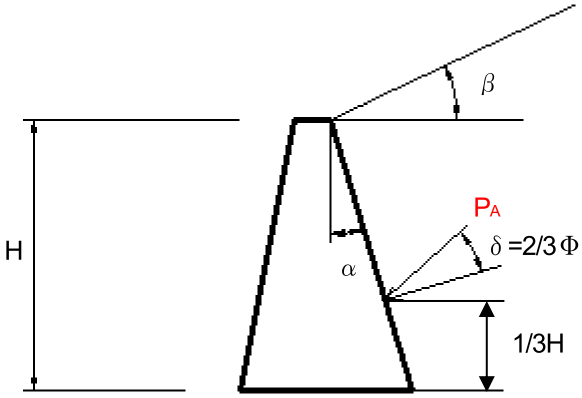


Figure 60　Calculation model of retaining wall

$$P_A = \frac{1}{2} \cdot K_A \cdot \gamma \cdot H^2$$

$$K_A = \frac{\cos^2(\phi - \alpha)}{\cos^2\alpha \cdot \cos(\alpha + \delta) \cdot \left\{ 1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \beta)}{\cos(\alpha + \delta) \cdot \cos(\alpha - \beta)}} \right\}^2}$$

$$P_v = P_A \cdot \sin(\delta + \alpha)$$

$$P_H = P_A \cdot \cos(\delta + \alpha)$$

Coulomb formula

P_A : Earth pressure

K_A : Coefficient of earth pressure

γ : Unit volume weight of back soil (kN/m3)

H: Height of soil retaining work (m)

ϕ : Internal friction angle of back soil (degree)

α : Gradient angle of backside of soil retaining work (degree)

(Minus when the back side is reverse gradient)

β : Surface inclination angle (degree)

δ : Wall surface friction angle of backside and back soil (degree)　2/3 ϕ

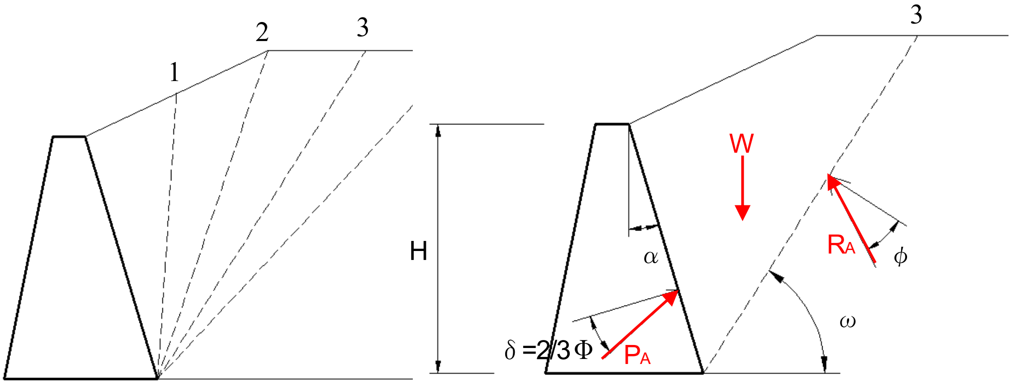
h: Height from the bottom of retaining work at the point of application of earth pressure (m)

h=1/3H

P_V: Vertical component force of earth pressure

P_H: Horizontal component force of earth pressure

Following shows Trial wedge method.



The calculation is performed many times while changing the value of the slip angle ω to obtain the value when the acting earth pressure is at its maximum

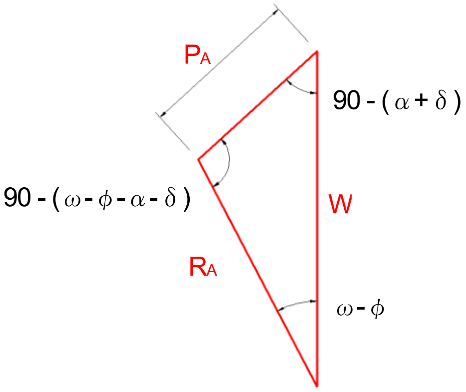


Figure 61 Calculation model of retaining wall (Trial wedge method)

$$P_A = \frac{W \cdot \sin(\omega - \phi)}{\cos(\omega - \phi - \alpha - \delta)}$$

$$P_v = P_A \cdot \sin(\delta + \alpha)$$

$$P_H = P_A \cdot \cos(\delta + \alpha)$$

Trial wedge method formula

W : Weight of the erth wedge(kN/m)

PA : Earth pressure(kN/m)

RA : Reaction force acting on the slip surface (kN/m)

ϕ : Internal friction angle of back soil (degree)

α : Gradient angle of backside of soil retaining work (degree)

(Minus when the back side is reverse gradient)

δ : Wall surface friction angle of backside and back soil (degree) 2/3 ϕ

Pv: Vertical component force of earth pressure

PH: Horizontal component force of earth pressure

2) Stability calcuration for Retaining Wall

With respect to the stability of retainingwall, items (A), (B) and (C) should be examined but, depending upon the site conditions and the scale of retaining wall, items (D) -should be also examined.

(A) Stability against sliding

(B) Stability against overturning

(C) Stability for bearing capacity of foundation ground

(D) Entire Stability including backfill and foundation ground

(A) Stability against sliding

The force, which tends to slide the retaining wall along the plane below the base, is the horizontal component of the earth pressure and is resisted by the shear resisting force created between the foundation ground and base. The factor of safety against sliding should satisfy the following formula:

$$F_S = \frac{\text{Resisting force against sliding}}{\text{Sliding force}} = \frac{(\Sigma V \cdot \mu + C_B \cdot B)}{\Sigma H}$$

ΣV : Total vertical load on the bottom of the base

ΣH : Total horizontal load on the bottom of the base

μ : Cofficientof friction between base and foundation ground

C_B : Adhesion between base and foundation ground

B : Width of base of retaining wall (m)

The safety factor shall be more than 1.50.

The width of base should be increased for stabilization, if the safety factor Fs of formula is not able to satisfy. However, if this is not possible because of restrictions such as topographic conditions, the depth of embedment should be increased in order to consider the passive earth pressure at the front, or projection at the bottom of base should be applied to increase horizontal resistance.

(B) Stability against Overturning

Load due to the self weight of retaining wall, surcharge and earth pressure will act to the bottom of base of retaining wall. The ground reaction below the bottom will vary depending upon the location of point to which the resultant of these loads works. In next formula, the distance d (m) from the toe to this point can be expressed by

$$d = \frac{\sum Mr - \sum Mo}{\sum V} = \frac{W \times a + Pv \times b - P_H \times h}{W + Pv}$$

ΣM r : Moment of resistance at toe of base of retaining wall (kN・m/m)

, ΣMo : Overturning moment at toe of base of retaining wall (kN・m/m)

, ΣV : Total vercal load at the bottom of base (kN/m)

W : Weight of retaining wall

Pv: Vertical component force of earth pressure

PH: Horizontal component force of earth pressu

a : Horizontal distance from toe of retaining wall to center of gravity of retaining wall

b : Horizontal distance from toe of retaining wall to position where earth pressure is acting

h : Height from the bottom of retaining work at the point of acted of earth pressure

The eccentricity distance "e" from the center of the retaining wall base to the point of action of the resultant force "R" is expressed by the next formula.

$$e = \frac{B}{2} - d$$

As the condition of stability against overturning, the acting position of the resultant must be within B/3 of the center of the retaining wall base width.

$$|e| \leq B/6$$

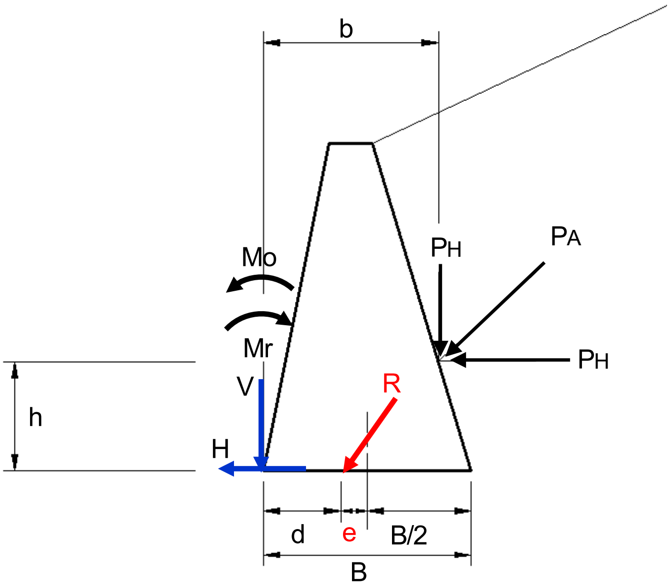


Figure 62 Method of finding the point of acting of the resultant force "R"

(C) Stability for Bearing Capacity of Foundation Ground

Ground reaction can be derived from following formula.

Following formula is case that the position of the resultant force R is within B/3 of the center of the retaining wall base width.

$$q_1 = \frac{V_o}{B} \cdot \left(1 + \frac{6e}{B}\right) \cdot$$

$$q_2 = \frac{V_o}{B} \cdot \left(1 - \frac{6e}{B}\right) \cdot$$

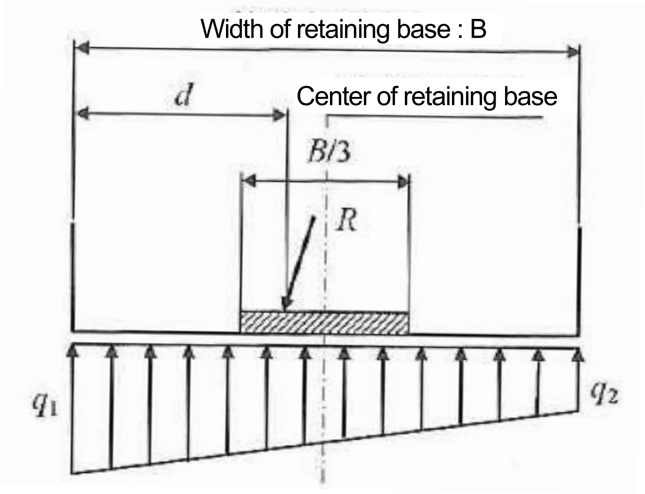


Figure 63 Point of resulting force “R” and ground reaction

The calculated ground reaction must be less than the allowable bearing capacity of the foundation ground.

(D) Entire Stability, Including Back slope (Embankment) and Foundation Ground

In the case of a retaining wall construction on ground incorporating a soft layer, the load of the embankment at the back of the wall may cause failure inside the ground, consolidation settlement by the embankment and/or lateral flow of the ground. The stability against such failure should be confirmed by analysing the possibility of circular sliding and other relevant matters.

When a retaining wall is constructed on a slope, it is necessery to analyse the stability of the entire slope, including the embankment at the back. Multiple retaining walls are occasionally constructed on a slope.

In this case, it is essential to confirm the entire stability of the slope in addition to analysis of the stability of individual retaining walls.

(3) Anchor work

1) Anchor work

Anchor work is used to stabilize slopes by imparting deterrence when there are joints or cracks in the bedrock that may lead to collapse or collapse, or when there is a risk of collapse on soil slopes. Anchor work is used in combination with other methods such as crib work, concrete lining, and retaining walls.

Details of this method are shown in P. 44 "Chapter 1. Countermeasure for landslide 1.2.2 restraint work (3) Anchor".

2) Rockbolt work

Rockbolt work is used to increase the stability of a slope or the entire slope by means of reinforcement inserted into the ground.

It is used for relatively small-scale collapse prevention, reinforcement of steep slopes, and reinforcement of temporary slopes for excavation of structures, etc.

As shown in following figure, rockbolt is used under various conditions, such as minimizing natural modification caused by soil cuttings, and applying the method to cut steep slopes or to temporarily construct a structure.

The soil nailing method used in Honduras is considered to be similar to this method.

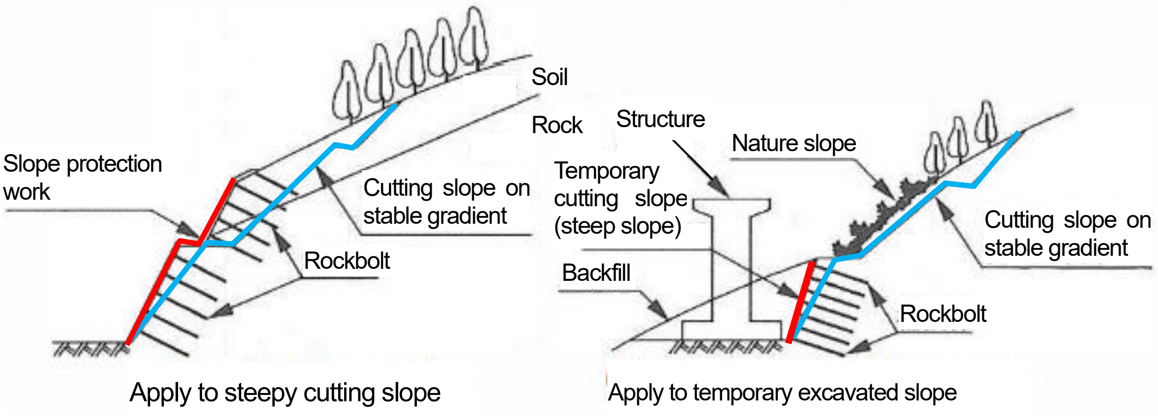


Figure 64 Case study of rockbolt work

In this section, it is explained briefly the design concept of Rockbolt as it is carried out in Japan.

The design can be divided into the empirical design method, which is applied when the collapse is minor, and other design methods based on stability calculations.

The empirical design method should be applied only when a shallow collapse of 2m depth or a collapse of loose rock is expected when the cutting is made at a standard slope as a countermeasure against collapse.

The empirical design parameters that omit stability calculations are shown in the table below.

The empirical design parameters

Factor	Parameter
Drilling diameter	ϕ65mm～
Bolt diameter	19 ～ 25mm
Bolt length	2 ～ 3m ※
Install pitch	1pc per 2m^2
Install angle	10 degrees downward from horizontal ～Right angle to slope

※2.0 m if the expected collapse depth is 1 m, 3.0 m if the expected collapse depth is 2.0 m

The following methods are used when designing using stability calculations.

$$F_{sp} \leqq \frac{\sum c\cdot l + \sum (W - u\cdot b)\ \cos\alpha\cdot\tan\phi + P_r}{\sum W\cdot\sin\alpha}$$

Fsp : Planned safety factor (Parmanent construction = 1.2, temporary construction = 1.05~1.10)

Pr : Deterrent force of reinforcement (= Tm・cosβ + Tm・sinβ ・tanϕ)

Tm : Design tensile force of reinforcement (= λ ・Tpa)

β : Angle between reinforcement and slip surface

ϕ : Internal friction angle of the slip surface

λ : Reduction factor of tensile force of reinforcement (= 0.7)

Tpa : Allowable tensile strength of reinforcement (=min[Tlpa, T2pa, Tsa])

The allowable tensile strength Tpa of the reinforcement is adopted most minimum value compare that the allowable pullout resistance of the reinforcement from the moving layer (T1pa), the allowable pullout resistance of the reinforcement from the unmoving layer (T2pa), and the allowable tensile strength of the reinforcement (Tsa).

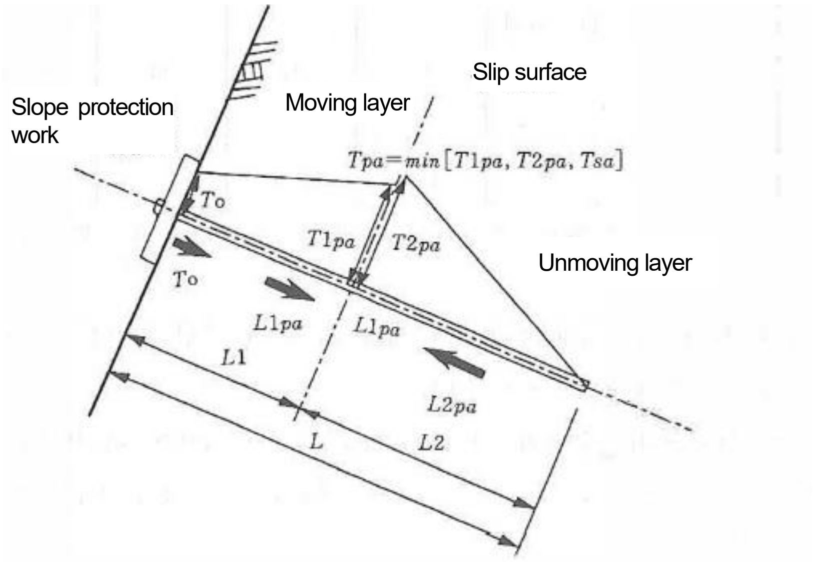


Figure 65 Tensile strength of reinforcement

When scribwork is used for slope protection, T1pa may be ignored. T2pa is calculated by the following formula.

$$T2_{pa} = \Sigma L2 \cdot t_a$$

L2 : Fixed length in unmoving layer (m)

ta : Allowable adhesion strength (=min [tpa, tsa]) (kN/m)

tpa : Allowable adhesion strength between the ground and the grouting material

(= [τ p・π ・D] / Fsa) (kN/m)

tca : Adhesion strength between reinforcement and grouting material (= τ c・π ・d) (kN/m)

τ p : Skin friction resistance between the ground and the grouting material (kN/ m2)

D : Diameter of drilling hole (m)

Fsa : Safety factor of skin friction resistance (Parmanent construction = 2.0, Temporary construction = 1.5)

τ c : Allowable adhision strength of reinforcement and grouting material (kN/m2)

d : Diameter of reinforcement (m)

Chapter 3. Countermeasure for rock fall

3.1 Planning of the countermeasure

3.1.1 Classification of Countermeasure work

(1) Classification of Countermeasure work

There are many types of rockfall countermeasures, and the principles of countermeasures are followings.

/Prevent weathering and erosion that cause rockfall.

/ To stop the generation of rockfall.

/ Absorb the energy of rockfall

/ Change the direction of rockfall and guide them to harmless areas

/ Resist with impact of rockfall and stop the movement of rockfall

Therefore, the functions, durability, workability, economy, and maintenance problems of each type of countermeasure must be carefully considered to select the most appropriate type and combination of countermeasures for the conservation target and slope conditions.

The rockfall countermeasures include prevention works to remove, fix, and restrain works at the source, and protection works to prevent damage caused by falling rocks.

Rockfall prevention work : This work represents countermeasures taken against the source of rockfall to remove or fix rocks that may fall. These countermeasures are reliable, but if there are many sources of rockfall, it is difficult to take such countermeasures completely.

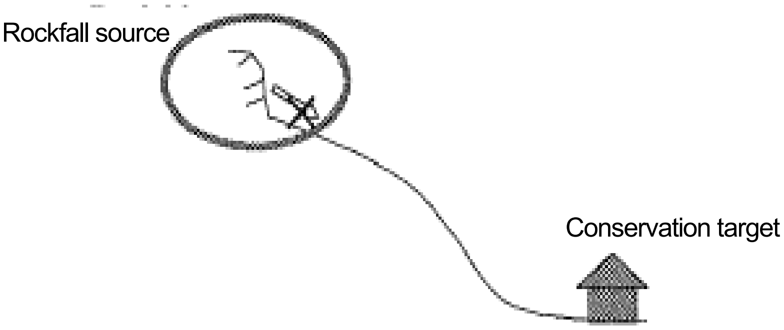


Figure 66 Image diagram of rockfall prevention work

Rockfall protection work : This work is performed to capture falling stones and reduce their energy on the side or lower part of the mountain between the source of rockfall and the object to be protected.

If the work is installed near the conservation target to be protected, the size of the countermeasure will be larger since energy of a falling stone becomes larger

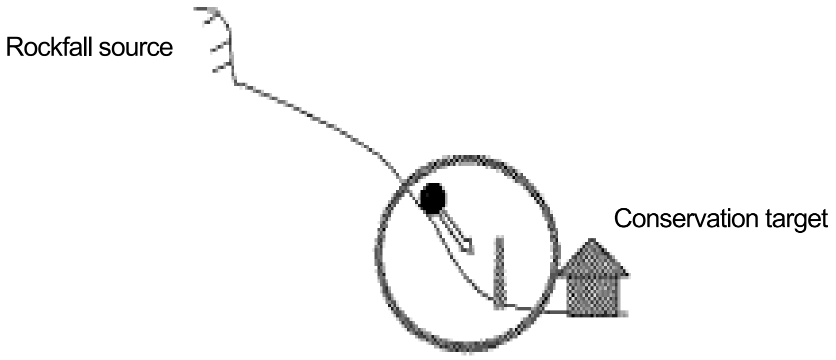


Figure 67　Image diagram of rockfall protection work

(2) Outline of countermeasure（Rockfall prevention work）

Rockfall prevention work is a source countermeasure for rockfall source (floating rocks and boulders) on slopes where rockfall is expected to occur, with the expectation of the following effects.

(1) Prevent the progression of erosion and weathering caused by surface water, freezing and thawing, temperature change, repetitive dry and wet weather, wind force, etc.

(3) Fixing of rockfall source

(4) Removal of rockfall source

(5) Prevention of rock fall associated with slope failure.

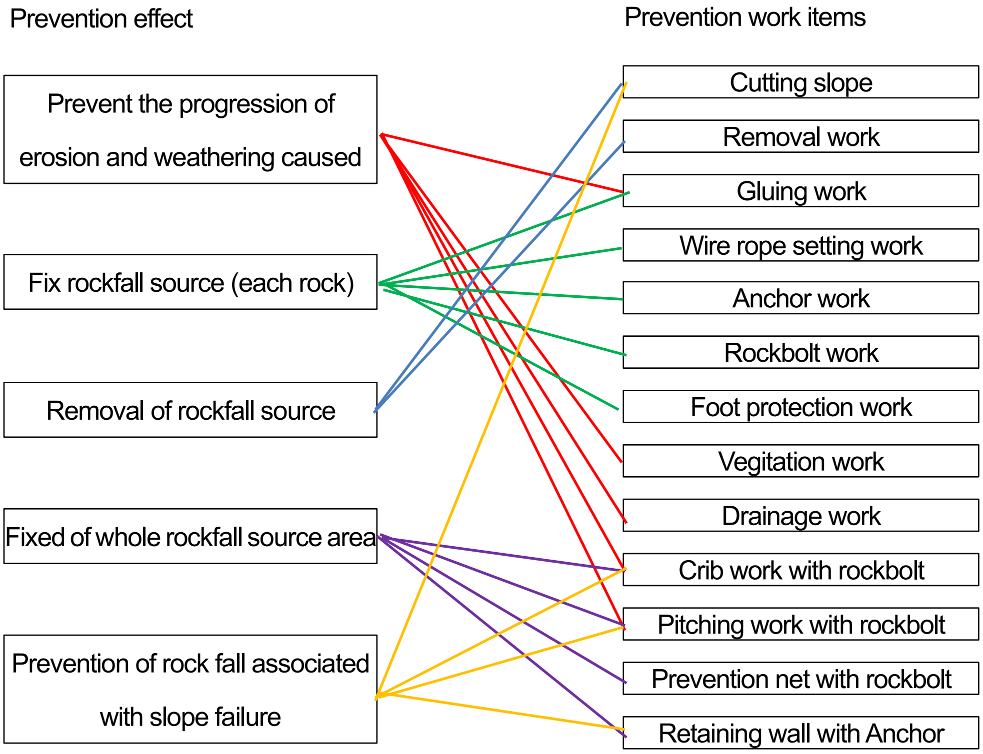


Figure 68　Types and effects of rockfall prevention works

Above figure shows various types of preventive works that have these effects alone or in combination. In selecting the method, the characteristics of each method should be considered, as well as the social conditions of the site, topography, geology, location of the conservation target, workability, economic efficiency, and other factors. In addition, trees growing on the slope have the effect of deterring falling rocks, and it should be noted that these trees may be cut down or may be cut down.

(3) Outline of countermeasure（Rockfall protection work）

A rockfall protection works is a catching measure to protect rockfall from slopes by installing a facility in the middle of the slope, at the edge of the conservation target to be protected, or on the conservation target (road).

The types of rockfall protection works can be classified according to the location installed as follows.

/Those installed in the middle zone between the source and the conservation target (in the slope)
    rockfall protection net, rockfall protection fence, rockfall protection retaining wall, etc.
/Those installed near the conservation target (lower part of the slope)
    rockfall protection nets, rockfall protection fences, rockfall protection shelves,
    rockfall protection retaining walls, rock sheds, rockfall protection earth embankments, etc.

3.1.2 Selection of Countermeasure work

Planning of rockfall prevention measures should be based on the results of the survey and hazard assessment of rockfall slopes, it is also important to take into account the characteristics nature of rockfall slopes.

It is necessary to select and plan the placement of various types of rockfall prevention and protection methods, recognizing that each method has its own structural limitations in preventing damage.

In planning the countermeasures against falling rocks using facilities such as rockfall prevention and protection, the stability of floating rocks, the size of falling rocks, the path of falling rocks, and the form of movement of falling rocks should be estimated based on the results of the investigation, and the most effective construction method should be selected at the necessary location.

Attention points of selection countermeasure are following

/ The results of the investigation of rockfall slopes should be utilized.

It is important to determine whether the falling rocks are caused by slope failure or by falling floating stone or boulders.

/ Although the source countermeasure is the most effective, the workability should be taken into consideration.

Is it possible to remove and fix stable location at the site, or is it possible to fix at current positon?

/ Consideration should be given to the fact that each type has its own functional limitation.

/ In many cases, a combination of each species is more effective than using each species alone.

The function, durability, workability, economy, and maintenance method of each type of countermeasure should be carefully considered when deciding the type of countermeasure to be used

The characteristics of countermeasure methods used in Japan are shown in the following table.

	Characteristics		Effects of Countermeasure					Durability	Maintenance Requirement	Difficulty of work	Reliability	Cost
Category	Type of work	Legend	Prevention of weathering / erosion	Prevention of occurrence	Change of Direction	Absorption of Energy	Resistance to Impact					
		◎	Excellent					Excellent	Low	Easy	Excellent	Inexpensive
		○	Good					Good	Medium	Fair	Good	Varies
		△	Good in some cases					Damage by rockfall	High	Difficult	Good in some cases	Expensive
Rockfall prevention work	Cutting			◎				◎	○	△	◎	○
	Removal work			◎				○	○	△	○	○
	Foot protection work			◎				◎	○	○	◎	○
	Gluing work		○	○				△	○	◎	△	△
	Anchor work			◎				○	◎	○	◎	○
	Wire rope setiing work			◎				○	○	△	○	◎
	Drainage work		◎					○	○	○	○	◎
	Net hurdling work		○	○	△			○	○	◎	△	◎
	Vegetation work		○	○				○	◎	◎	△	◎
	Shotcrete work		◎	○				○	○	◎	○	◎
	Pitching work		◎	◎				◎	◎	○	○	◎
	Cribwork		◎	◎				◎	◎	◎	◎	○
	Retaining wall		◎	◎	△			◎	◎	○	◎	○
	Rope Net + Rock bolt			◎				○	○	◎	○	◎
	Shotcrete + Rock bolt		◎	◎				○	○	○	◎	◎
	Pitching + Rock bolt		◎	◎				◎	◎	○	◎	○
	Cribwork + Rock bolt		◎	◎				◎	◎	○	◎	◎
	Cribwork + Anchor		◎	◎				◎	◎	○	◎	○
	Retaining wall + Anchor		◎	◎				◎	◎	○	◎	△
Rockfall protection work	Cover type Rock fall Protection Net			○	○	◎		○	○	◎	○	◎
	Pocket type Rockfall Protection Net				○	○	○	○	○	◎	○	◎
	Rockfall Protection Fence				◎	○	△	○	○	◎	○	◎
	Multiple step Rockfall Protection fence			△	◎	◎		○	○	◎	○	◎
	Rockfall Protection shelf				◎	◎	◎	◎	◎	○	○	○
	Rockfall Protection Retaining wall				◎	○	△	◎	○	◎	○	◎
	Rock shed				◎	◎	◎	◎	◎	○	◎	○

	Rockfall protection earth dyke/ditch			◎	○	△	◎	○	◎	○	○

Reference table for application of countermeasures for rockfall

The following is a flowchart of the countermeasure method selection in use in Japan.

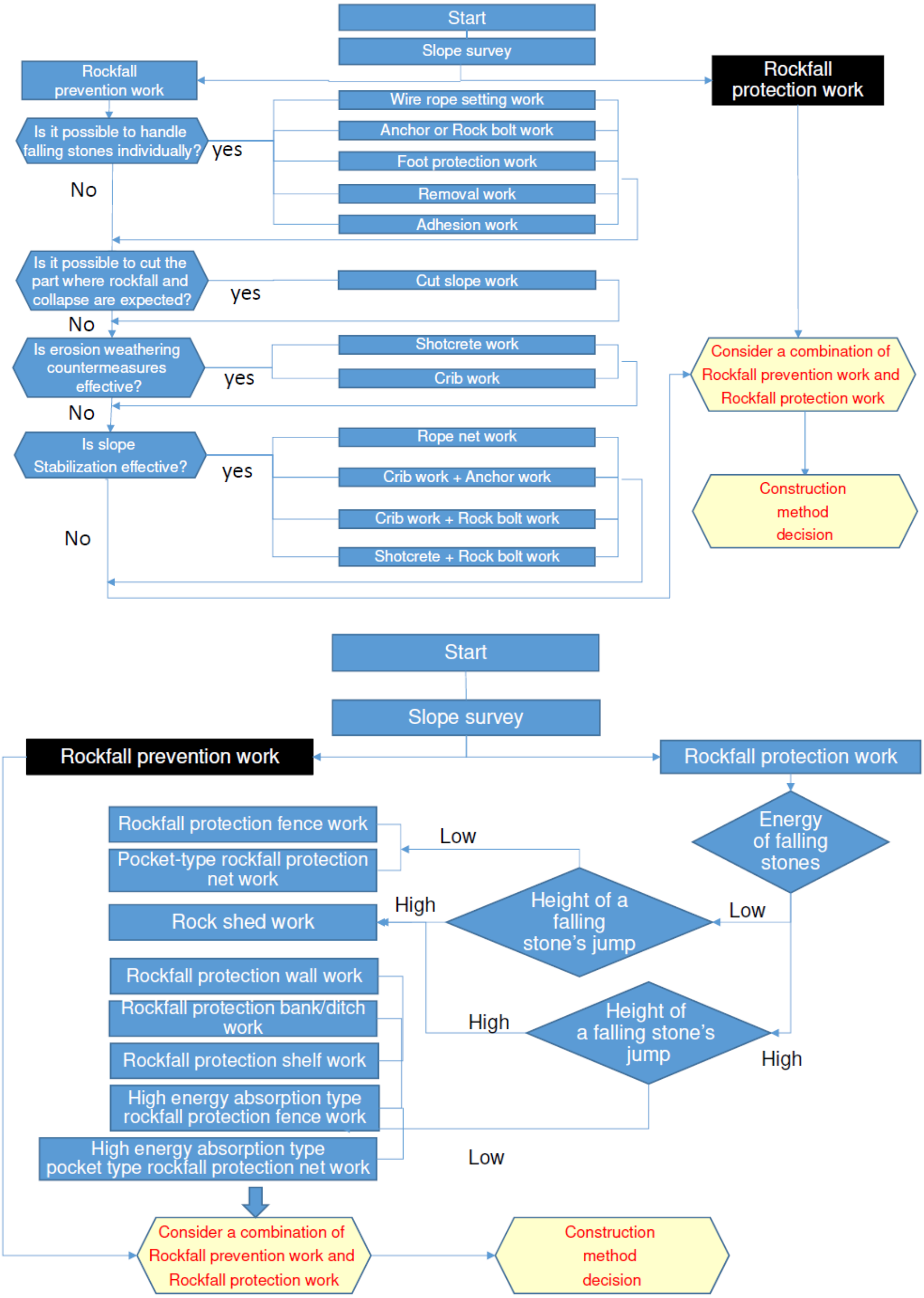


Figure 69 Flowchart of the countermeasure method selection

It is important to measure the type, scale, properties, and stability of the entire slope (whether it is rockfall caused by rock mass collapse or sediment collapse).

It is desirable to plan countermeasures in combination with rockfall protection works and rockfall prevention work effectively.

Rockfall protection work is a method of capturing falling rocks by absorbing or catching their energy. Different methods can handle different amounts of energy.

The figure below shows the corresponding energies of rockfall protection work commonly used in Japan.

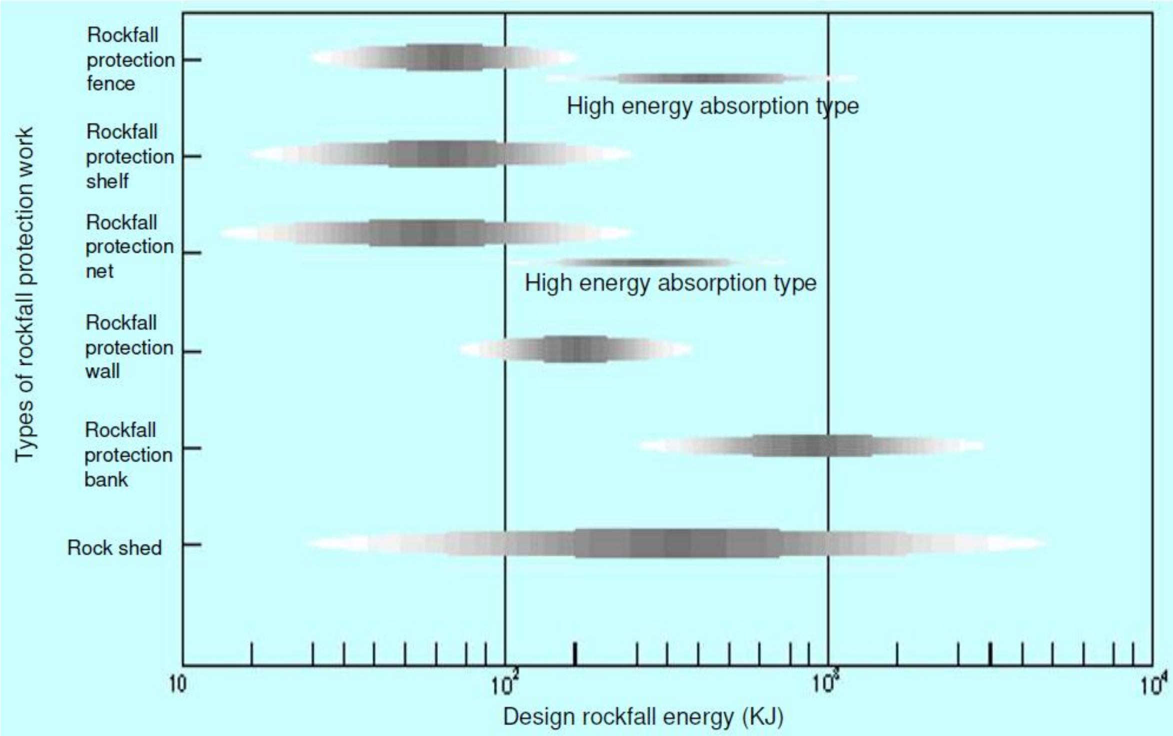


Figure 70 Available rockfall energy for each type of rockfall protection work (approximate)

3.2 Design of the countermeasure

3.2.1 Rockfall prevention work

Rockfall prevention works mainly remove, fix, and restrain the source of falling rocks, and are effective in reducing the frequency of falling rocks.

However, if the slope is long and steep, it may be difficult to completely stop rockfalls by only one method of rockfall prevention work. Therefore, several rockfall prevention work should be used in combination, or rockfall protection works should be taken to combineted.

This section introduces each method of rockfall prevention work and describes design considerations.

In addition, work types that overlap with landslide countermeasures and slope failure countermeasures are omitted.

(1) Cutting work and removal of unstable boulders

Cutting slope and removal of unstable boulders are method to remove unstable boulders that may fall from slopes by breaking them into small pieces, or to stabilize by cutting unstable rock slopes that are at risk of rockfall to prevent rockfall.

On slopes where there is a risk of rockfall due to collapse, cutting the slope to a stable gradient can stabilize the slope and prevent rockfall.

This case is that Huge unstable rock masses are distributed over the slope and it is difficult to fix them in-situ and to prevent rock fall by rock fall protective works. It is adopted method that is removed unstable rock mass by cutting slope. It is desirable to prevent weathering erosion by slope protection works on slopes after cutting

Figure 71 Case study of cutting slope work for unstable rock slope in Japan

(2) Adhesion work

This is a method of stabilizing unstable rock masses by adhering them to stable rock masses using adhesives. It is sometimes used to preserve scenic spots such as tourist attractions.

It is able to be got the effects by filling, closing, or adhering cracks using adhesive agents. Since injecting an adhesive into the voids such as cracks, it is possible to suppress instability by preventing infiltration of rainwater and reducing vibration due to earthquakes and winds.

Two types of adhesives have been developed: cement-based adhesives and resin-based adhesives. Each of these adhesives has its own characteristics in terms of solidification time, etc., and should be used according to the condition of the cracks. It is also important to clean the surface of the rock to improve adhesio

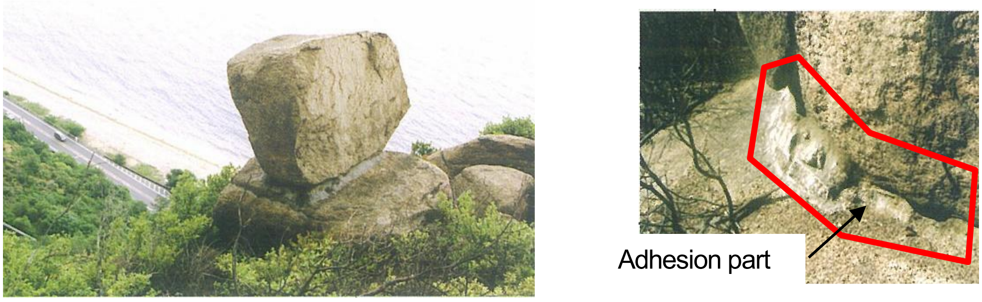


Figure 72 Case study of adhesion work in Japan

(3) Wire rope setiing work

Wire rope settingwork is considered a type of foot protection work. It is a method of securing unstable boulder on a slope by using a latticed wire ropes or several ropes to directly secure or hang the base of the boulders to prevent them from sliding or falling down.

This method is often used when unstable boulders are large or when they must be fixed on a slope as an emergency measure due to land constraints. The method itself is simpler than other methods, it is often used as a temporary structure before permanent measures are taken.

When covering or hanging unstable boulders with ropes, etc., sufficient stability must be ensured to prevent them from slipping out of the ropes, etc. And, the support part of the rope must be attached to a solid base rock using anchor bolts, etc., so that it can sufficiently withstand the weight of the unstable boulders, etc.

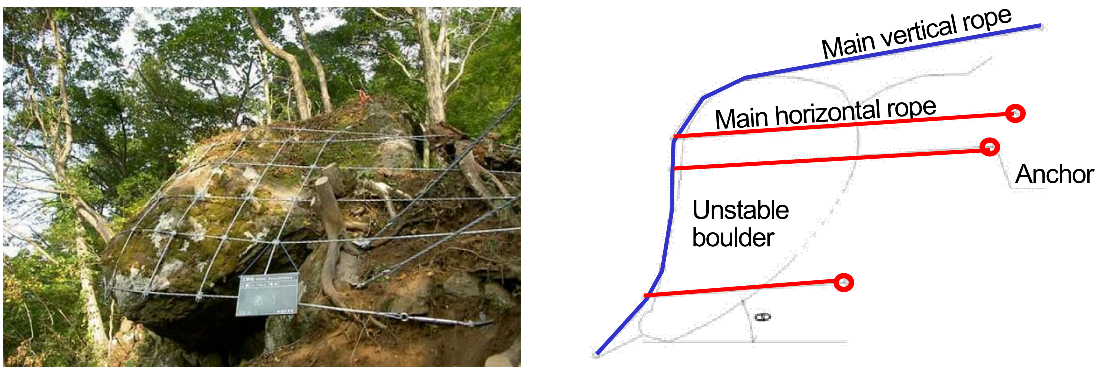


Figure 73 Case study of Wire rope setiing work in Japan

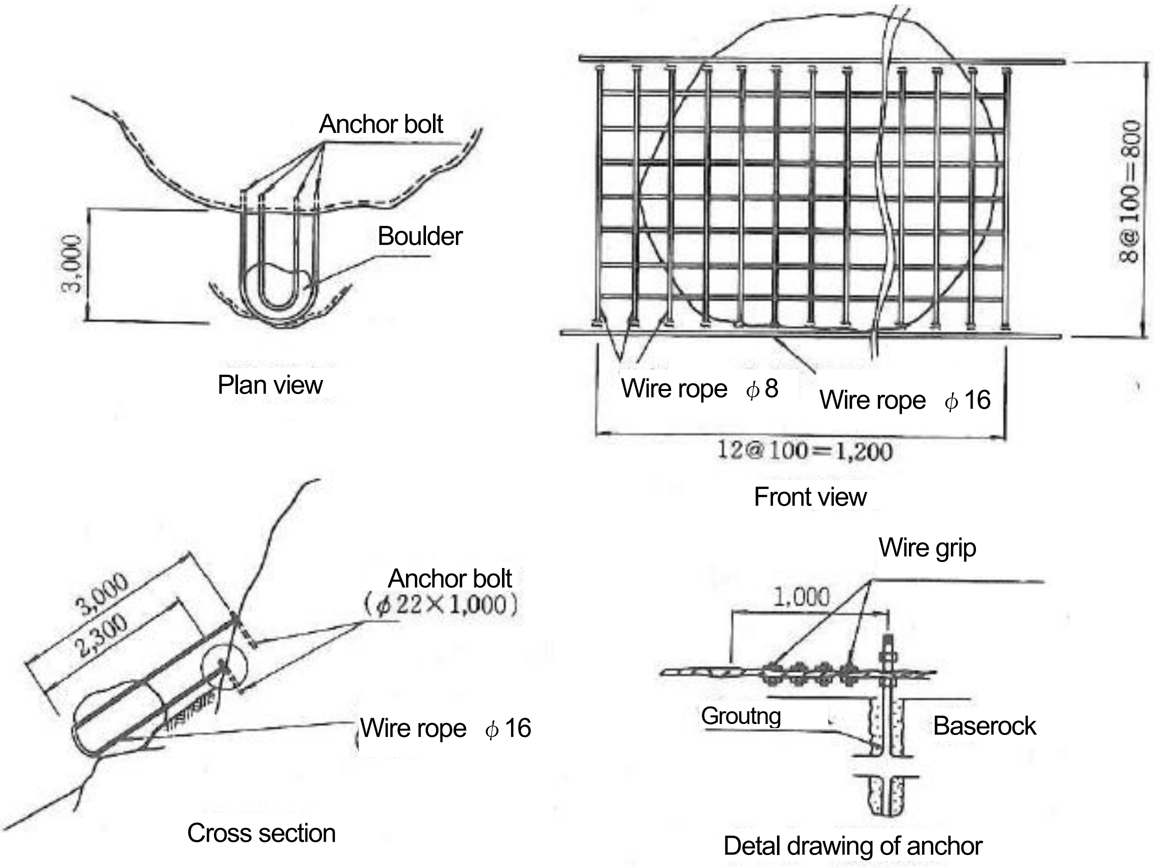


Figure 74 Reference drawing of wire rope setiing work

(4) Foot protection work

When unstable boulders are too big to be easily removed, this method is adopted.

This method ranges from relatively small-scale methods that use concrete or masonry to solidify the base of the unstable boulder, to large-scale methods that use reinforced concrete or H-steel pillars to hold it in place.

Foot protection work is a method of fixing large unstable boulders on a slope by consolidating the base and surrounding area with concrete or masonry to prevent them from moving.

When the weight of the unstable boulders is loaded to the foundation base, it is nessesary that foot protection work is placed on the stable foundation base to prevent falling out foot protection work with the unstable boulders. Then it is necessary to shape the foundation base or to excavate into a solid ground and set foundation here. In this case, unstable boulder may destabilize during excavation its foot, so ropes or other means (temporary net setting work) should be used to keep the excavation stable. It is necessary to ensure that the concrete is thick enough to prevent falling out unstable boulders from the foot protection work, and that it is installed so that it covers not only the base of the unstable boulders but also the surrounding area.

The effectiveness of the root-centering work will be significantly reduced if the foundation is eroded scoured by surface water flowing down the slope, etc. Therefore, it is necessary to pay attention to the topography around the foot protection work and to the shaping of the slope surface and to prevent foundation erosion.

Foot protection by masonry using is collecting small boulders afrom the surrounding slope and piled up and consolidate at base of unstable boulders. This method is also effective to fix small umstable boulders distributed on the slope.

Since this method is less durable than concrete foot protection wopr, care must be taken to avoid erosion, especially by surface water flowing.

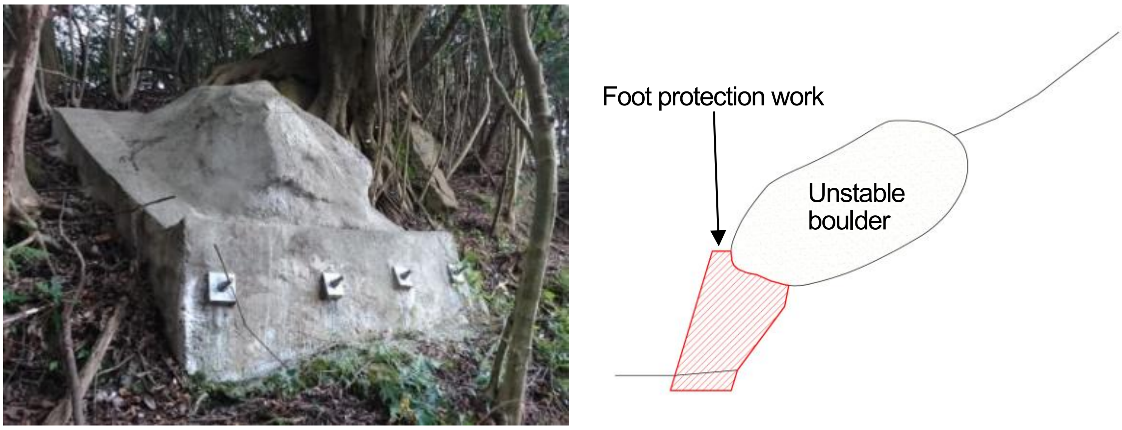


Figure 75　Case study of foot protection work in Japan

(5) Rope Net work

It is method that prevent the initial startup of unstable rocks and boulders scattered on the slope and hold them in place, by covering a grid of wire ropes at slope.

Vertical and horizontal rope is set intersection at 2.0m pitch and fixed by anchor at cross points. In addition, reinforcement ropes or high-tension nets are placed between the 2.0 m ropes.

This method suppresses the initial startup of unstable rock masses and prevents falling rocks by the tension strength of the ropes, reinforcement ropes and high-tension nets and the pull-out resistance of the anchors.

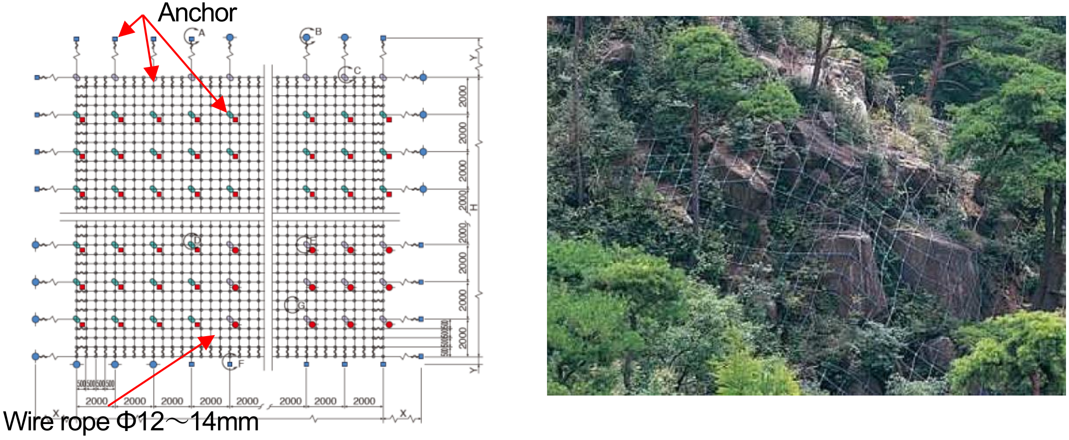


Figure 76　Case study of rope net work in Japan

3.2.2 Rockfall protection work

(1) Rockfall protection net work

Rockfall protection nets use lightweight materials such as wire mesh and wire rope to cover the entire surface of slopes where falling rocks may occur, and are classified into the following two types according to application.

/ Cover type Rock fall Protection Net

/ Pocket type Rockfall Protection Net

1) Cover type rockfall protection net

The wire mesh directly covers the slope where rockfall is expected, and the purpose is to drop the falling rocks along the slope without causing them to jump. It also has the function of preventing small rockfalls.

In general, since it is necessary to cover the area from the source to the edge of the conservation target, slopes with relatively small differences in elevation are targeted.

The design method is to study the specifications of ropes, wire mesh, and anchors that can handle the expected energy of falling rocks and the weight of the net itself.

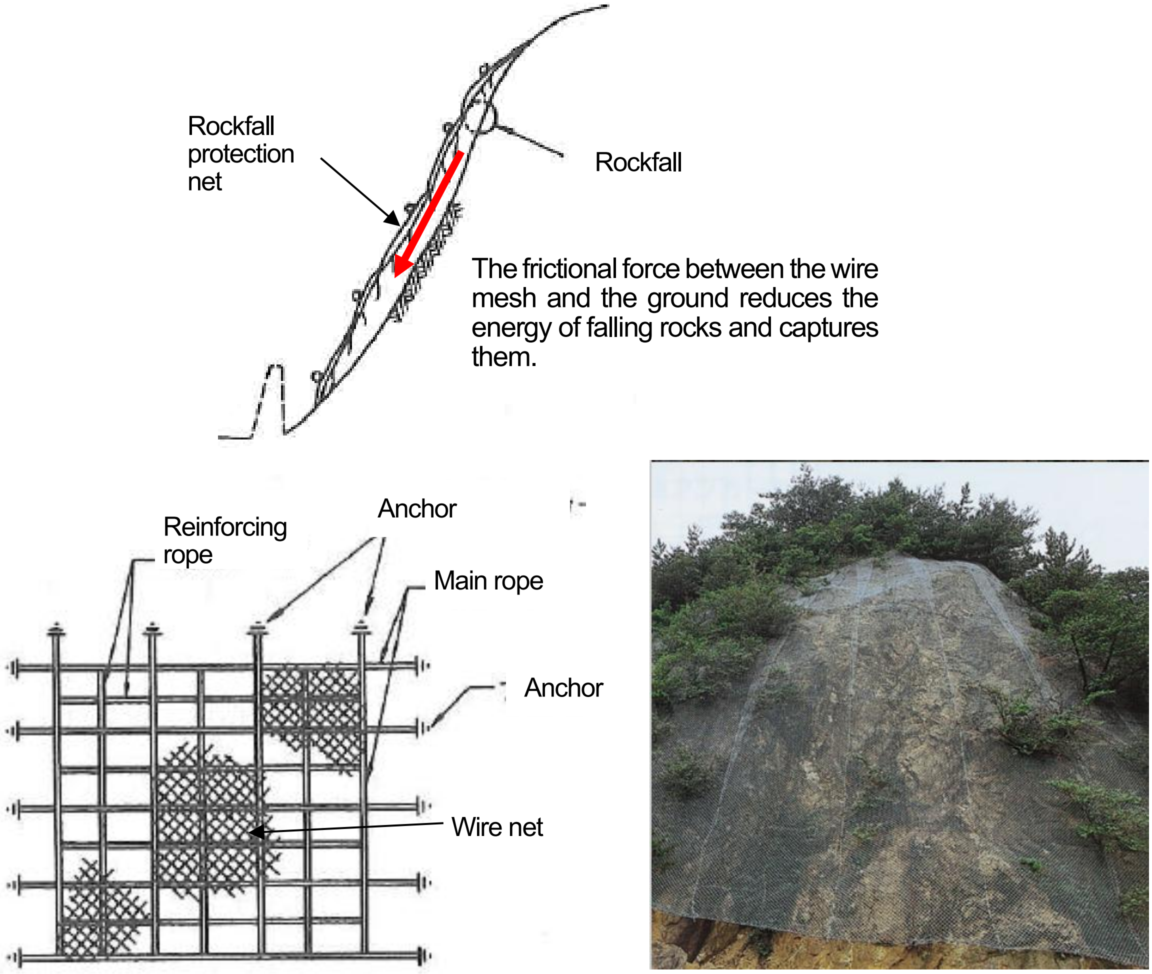


Figure 77 Case study of cover type rockfall protecction net in Japan

2) Pocket type rockfall protection net work

The structure has an opening at the top to allow rockfall from the top to enter the back of the mesh.

The energy of the falling rock is absorbed by the wire mesh by the impact of falling rocks on the wire mesh, and the rockfall is captured by being dropped along the slope.

It can be accommodated long slopes by installing at the bottom of a slope.

Rockfall energy is absorbed by the elongation of the wire rope, deformation of the wire mesh, and the integrated motion of the rockfall and the net when it impacts pocket type rockfall protection net.

It is designed the components so that the possible energy absorbed by the pocket type rockfall protection nets is not less than rockfall energy.

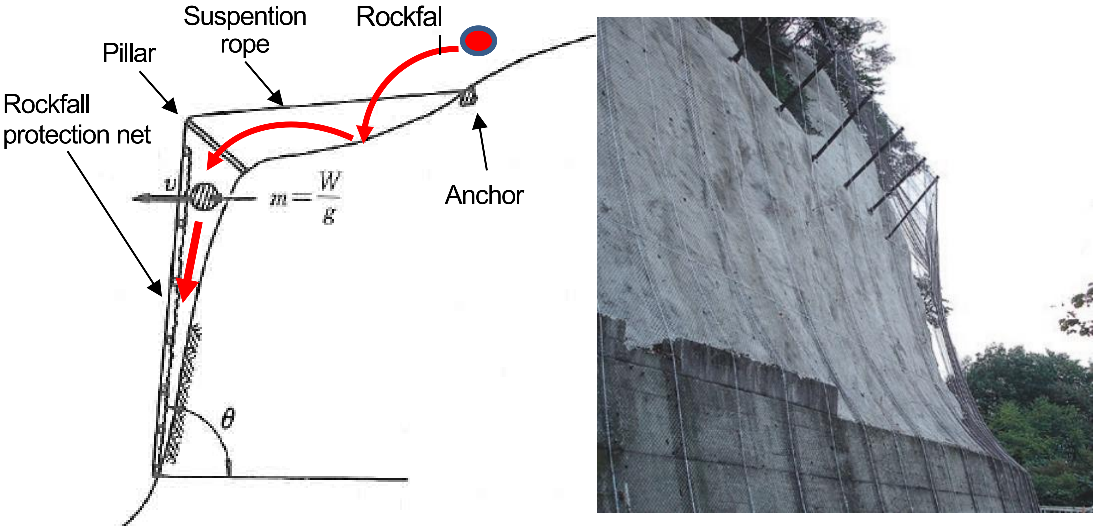
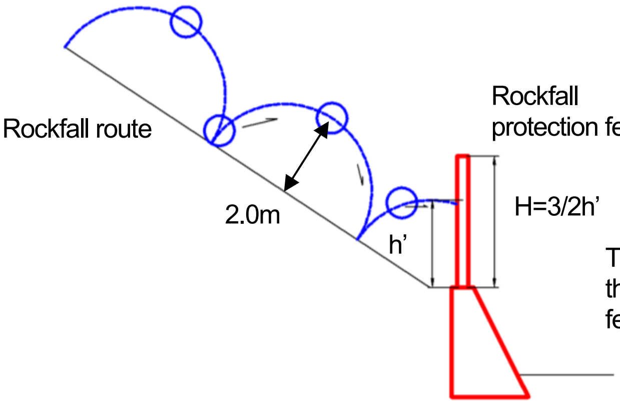


Figure 78　Case study of pocket type rockfall protecction net in Japan

(2) Rockfall protection fence work

It is a method to prevent rockfall by absorbing rockfall energy with wire rope, wire netting, posts, etc. It is installed at the middle or bottom of the slope, they are effective in preventing relatively small rockfalls. In case of long slopes, they may be placed in a multi-level configuration.

The height of the fence should be higher than the jumping height of the falling rocks. The component specifications must be capable of capturing the expected energy of falling rocks.



The height of the fence should be 3/2 times the height of the falling rock jump at the fence position.

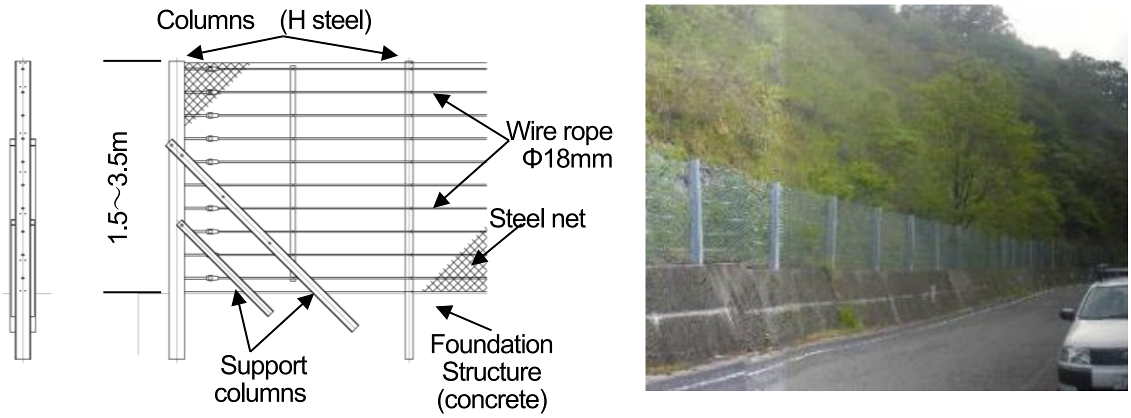


Figure 79 Case study of rockfall protecction fence in Japan

(3) High energy absorption type rockfall protection fence work

High energy absorption fence work is flexibly structured rockfall protection fences consisted of supports, wire ropes, nets, and reaction bodies. It is a construction method that can absorb high energy by the deformation of the net and the braking system of the wire rope. This method is available for Large energy rockfall of 2000kj.

In this construction method as well, member deformation occurs when capturing rockfall, so it is necessary to replace members by maintenance.

This method is avalable in Honduras

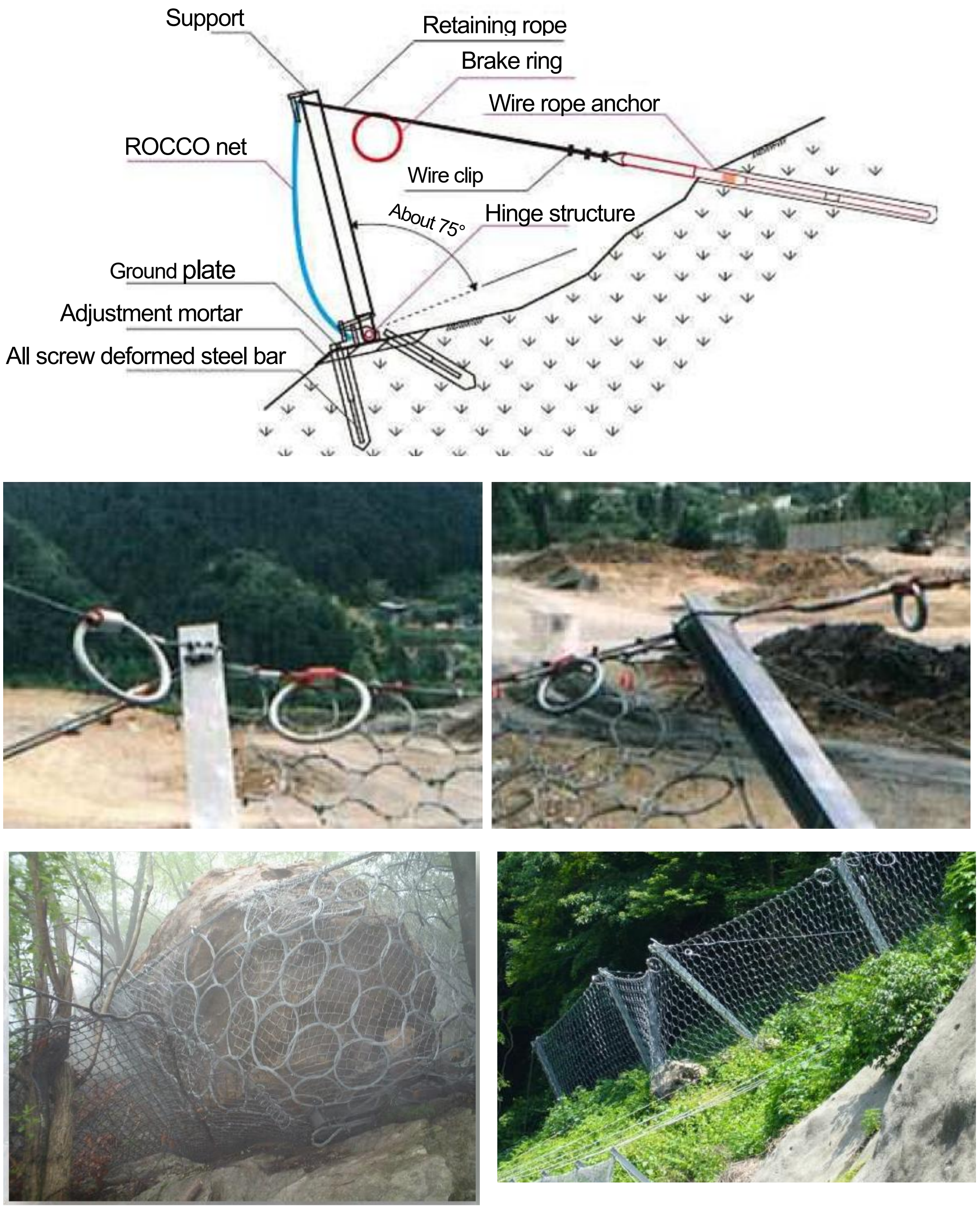


Figure 80 Case study of high energy absorption type rockfall protection fence work in Japan

(4) Rockfall protection wall work

A method of deterring the movement of rockfall by the rigidity of the wall body. Some structures are equipped with sand cushions or other buffer materials to absorb and disperse the impact, making it possible to handle large-energy falling rocks. Installed in the middle or bottom of a slope.

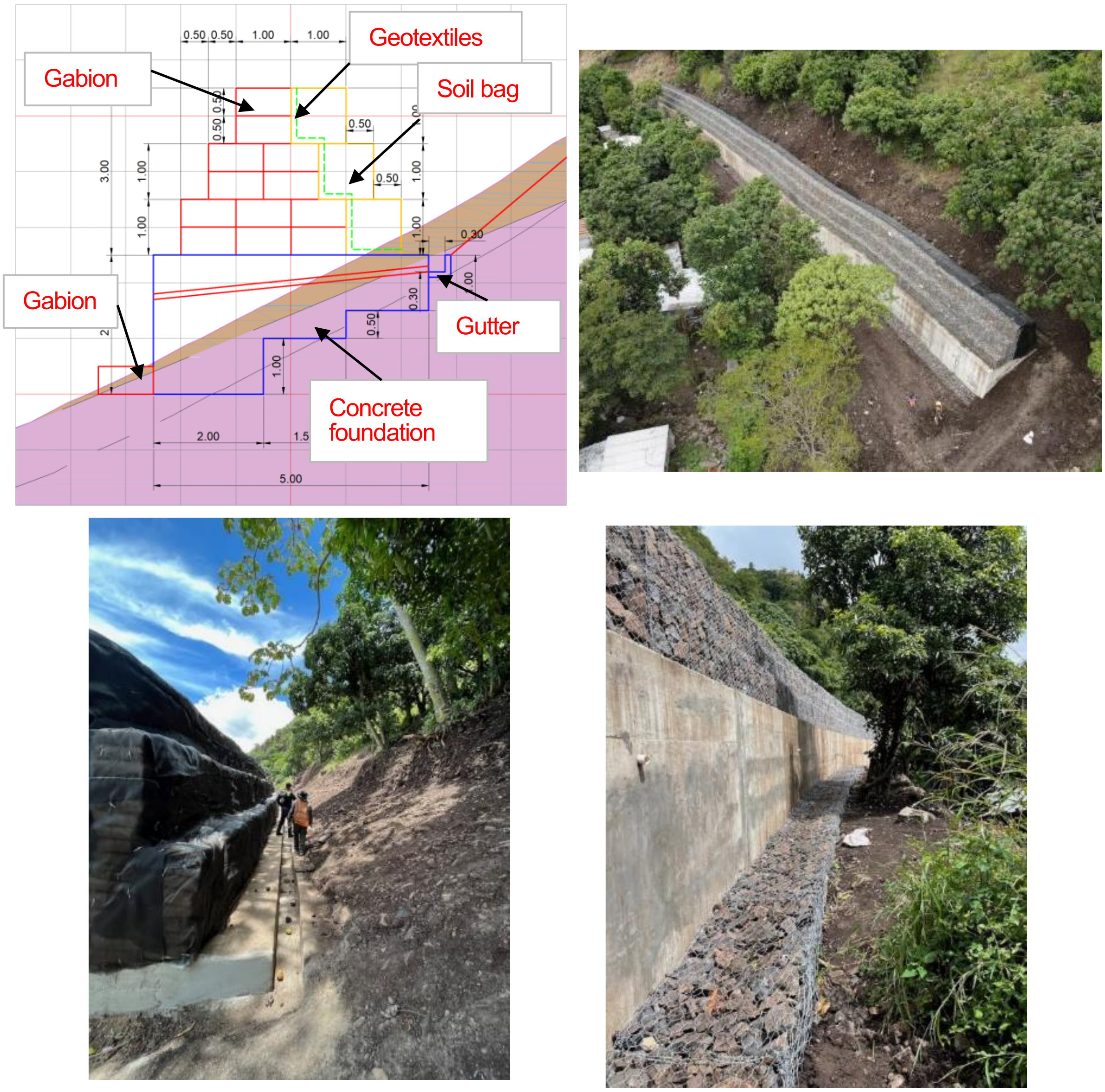


Figure 81　Case study of rockfill protection wall in Honduras (Fuerzas Unidas)

(5) Rock shed & Rockfall protection shelf work

1) Rock shed

It is a structure in which the road is covered by reinforced concrete or steel to provide direct protection from rockfall.

It is used in cases following

/There is no space for a retaining wall on the mountain side of a road directly under a steep slope,

/Rockfall energy is huge

/Rockfall protection fence can't capture rockfall. (because fence can't reach rockfall and rockfall jump over the fence.)

/Installing rockfall preventive work is difficult.

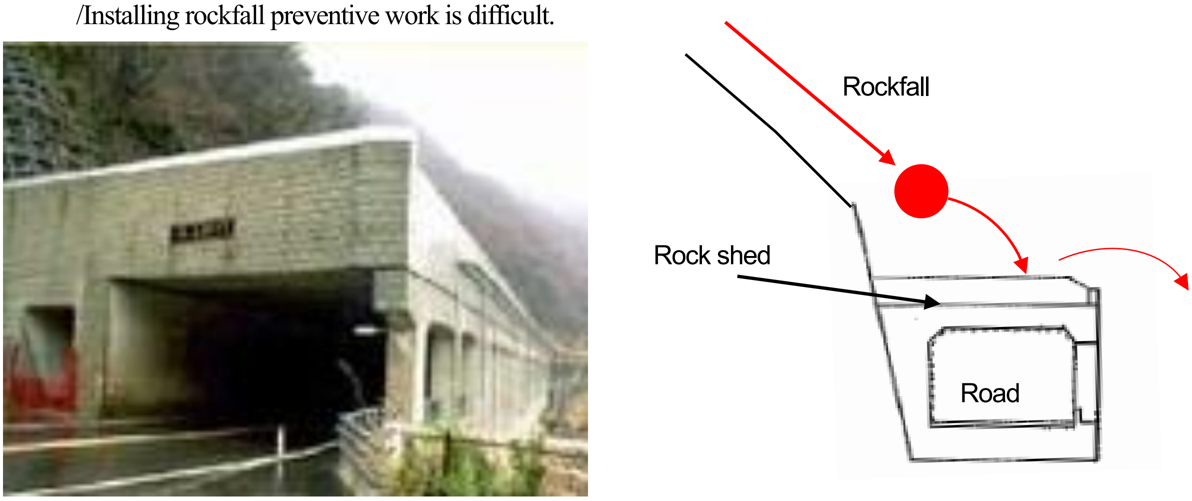


Figure 82　Case study of rock shed in Japan

2) Rockfall protection shelf

A steel or concrete eave-like structure to prevent rockfalls of a size that cannot be handled by rockfall protection fences.

This is applicable when the rockfall trajectory is limited to a limited area of the road. More economical and easier to construct than rock shed, but limited in terms of rockfall height, weight, etc.

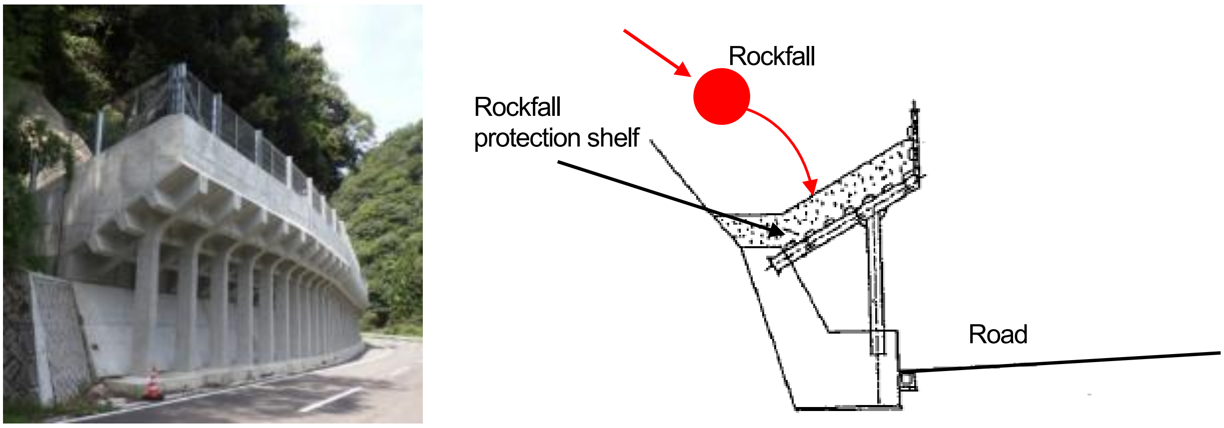


Figure 83　Case study of rockfall protection shelf in Japan

(6) Rockfall protection earth dyke / ditch

This is a method of deterring rockfalls by absorbing and dissipating the energy of rockfalls through the construction of banks and ditches in the area to be protected.

The condition for adoption is that there must be a space with a gentle slope at the target area.

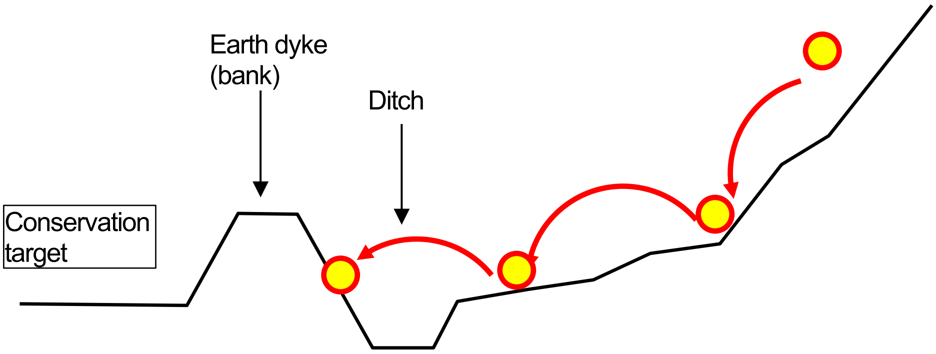


Figure 84 Image diagram of rockfall protection earth dyke / ditch

Annex 5

Manual for Supervise Countermeasure Construction of Small/Medium Size Slope Disasters Risk Sites

The Project for Control and Mitigation of Slope Disasters
in the Central District in Republic of Honduras

Manual for
Supervise Countermeasure Construction of
Small/Medium Size Slope Disasters Risk Sites

August 2023

AMDC
JICA Expert Team

Contents

Chapter 1. Introduction

1.1 Purpose of the manual

Construction supervision means the implemention management of construction work based on a construction methodlogy that has been developed by considering and formulating the best methods (labor, materials, construction methods, machinery, funds, and other means) to economically and safely construct the construction structure according to the design specifications and drawings within the construction period based on the contract requirements.

The main contents are (1) process managemennt, (2) dimension management, (3) quality management, (4) safety management, and (5) cost management.

Form dimension management means to control of dimension such as shape, size, and finish, while quality management means to control of quality such as strength of material by used and structures by constructed.

Methods and systems of construction supervision are different in detail depending on the country and the ordering authority, and are basically implemented based on the standards of the country and the ordering authority.

This manual summarizes the basic items of construction supervision, using the methods implemented in Japan as its subject matter.

We hope that this manual will be helpful in implementing construction supervision in Honduras in the future.

Chapter 2. Outline of construction supervision

2.1 Purpose of the supervision

Construction supervision is classified into management methods from the standpoint of the client and the contractor.

Construction supervision on the client's side is responsible for checking that the construction work is being performed as designed, with the required quality ensured, as per the process, and to prevent the quality and dimensional errors occurring and the delaying construction process before such a trouble occurring.

In other words, supervision on the client side is the task of managing the contractor to ensure that the construction work is performed as designed, with the required quality, safety and within the construction period.

Construction supervision on the contractor's side manages the construction process, required quality, safety, cost, structure dimension specified by drawing and technical specification to ensure that on-site construction proceeds smoothly.

In other words, the constructor's side is directly management of construction for ensuring that the construction work is implemented safely, according to the design, and with the required quality within the construction period.

Whether the client or the contractor is in the position of the contract, the management items and purposes are the same.

2.2 Contents of the supervision

In order to carry out construction work, contructor should prepare a construction methodlogy that mensioned clearly indicating the procedures, methods, machinery, mobilized labor, processes to be used to carry out the work and how the work will be managed.

The client and contractor should agree on this construction methodology, and the construction work will be carried out based on this construction methodology.

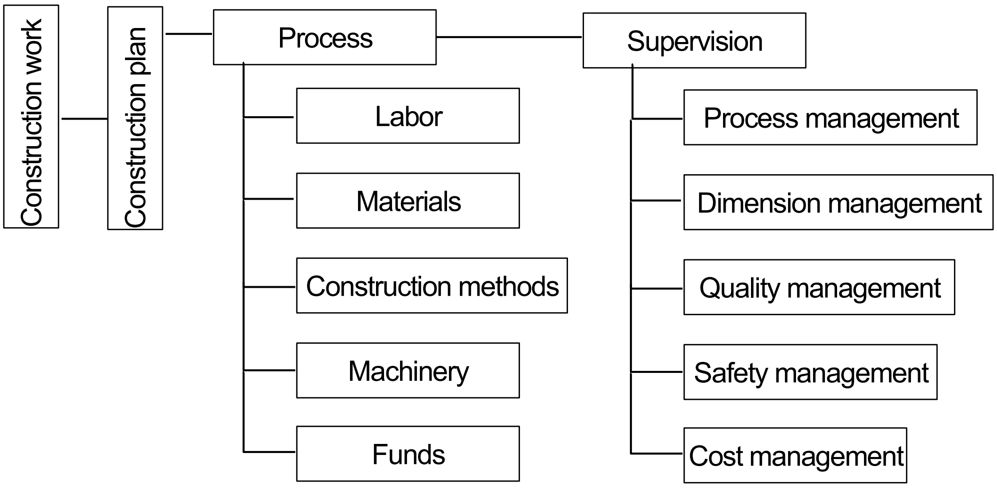


Figure 1 Concept of Construction Supervision

As described in the previous section, the items of construction supervision are (1) process managiment, (2) dimension managemant, (3) quality management, (4) safety management, and (5) cost management.

A summary of each management item is described below

(1) Process management

Process management means to compare the process planned at the beginning construction with the process actually in progress, if difference of progress is occured, to investigate and eliminate the causes of any difference of progress, to improve that work proceeds according to planned procces.

(2) Dimension management

1) Dimension management by direct measurement

Dimension management by direct measurement is to confirm that the constructed structure satisfies the shape and dimensions indicated in the design documents. (drawing, technical specification)

The shape and dimensions of the structure, reference height, centerline deviation, etc. are directly measured according to the construction sequence, and the results are recorded in a control chart or list of results each time, and the data are evaluated.

The dimension control is investigation the cause of any errors, take necessary measures.

2) Dimension management by photographing and recording

Dimension managemen by photographing and recording means to photograph and record the dimension based on the photographing standard, in order to confirm the form and quantity of underground buried structures and other parts that cannot be confirmed after construction, or to confirm the progress of each construction stage.

(3) Quality management

Quality management means to conduct physical and chemical tests based on "quality control standards" in order to build a structure that fully satisfies the quality standards indicated in the design documents (drawing, technical specification), and the results of these tests are then used to find problems and methods of improvement by using statistical methods, etc., and are controlled to ensure good quality.

In addition, quality management, as a part of construction management, is also conducted in combination with process management and dimension management to ensure quality, stable process, and appropriate dimension, which is the required of the construction.

(4) Safety management

Safety management means ensuring the safety of construction works under appropriate construction periods, methods, and costs by understanding the various conditions at each site, planning and preparing a system and environment for safe construction, and accurately responding to and managing changes in conditions that occur as the process progresses.

(5) Cost management

Cost control means that the contractor compares the planned cost calculated based on the working budget with the actual cost already incurred, and manages the construction work so that it will proceed without exceeding the planned cost by appropriate cost reduction.

(6) Relationship with each management

Process management, workmanship management, quality control, cost management, and safety management, though, should be managed accordingly,

These management contents are not independent, but are interrelated.

In construction work, it is known that quality, process, and cost have the following characteristics.

The relationship between process and cost is that as the process is speeded up and the construction quantity is increased, the cost per unit quantity becomes lower, but if the process is speeded up further and rush work is performed, the cost becomes higher.

The relationship between cost and quality is that poor quality items can generally be made at a lower cost, but good quality items cost become higher.

The relationship between quality and process is that good quality generally takes long time and slows down the process, if the process is speeded up and rush work is performed, the quality becomes lower.

As described above, quality, process, and cost are closely related.

The purpose of construction supervision is to coordinate these characteristics, plan the construction to keep quality and construction period, and reduce cost as much as possible, and to construct the project as planned.

Chapter 3. Construction methodlogy

3.1 Contents of construction methodology

Unless otherwise specified in the contract documents, the contractor shall determine all the means to complete the construction objectives at its own risk, and the contractor shall submit a construction plan on the procedures and methods necessary to complete the construction objectives before the commencement of construction.

In the preparation of the construction plan, the items specified in the contract and the design documents shall be included, except for minor items.

In the event of any significant changes to the construction plan, a revised construction plan shall be prepared and submitted prior to the commencement of work.

The Contractor shall describe the following in accordance with the following table of contents

1）Outline of construction works

2）Construction schedule

3）Organization chart

4）Machinery and equipment

5）Materials

6）Construction method (including main machinery, temporary facilities plan, construction site, etc.)

7）Construction management plan

8）Safety management

9）Emergency arrangements and response

10）Traffic management

11）Environmental measures

12）Improvement of working environment

13）Progress meetings

14）Progress reports

15）Others

3.2 Outline of construction works

As a minimum, the following items should be included in the construction summary

Contract name:

Construction site: location, address

Construction period: date of commencement and completion

Contract amount:

Client: name, address and telephone number

Contractor: name, address and telephone number

Scope of work:

Table 1 [Example] Scope of work

Construction classification	Type of work	Type	Particulars	Unit	Quantity	Remark
Road improvement	Road earthworks	Excavators	Excavation	m3	100.0	
	Retaining wall construction	Ready-made pile construction	Steel Pipe Piles	PC	25	

3.3 Construction Schedule

The planned construction schedule shall be prepared in the form of a network or a bar chart, etc., showing the beginning and end of the work for each type. In preparing the construction schedule, past data on weather conditions, especially rainfall and temperature, should be thoroughly studied and reflected in the progress plan.

(Notes)

1) In addition to being bound into the construction methodlogy, one copy of the planned construction schedule shall be prepared for progress control and maintained on site.

2) For construction types where weather, particularly rainfall and temperature, can have a significant impact on construction, the use of past data etc. must be fully investigated and reflected in the progress plan.

3) It must be consistent with the construction schedule attached to the contract.

4) It shall be ascertained whether the construction period for each type of work has been set appropriately, taking into account the volume and timing of construction.

Table 2 [Example] Scope of work

Name of contract:

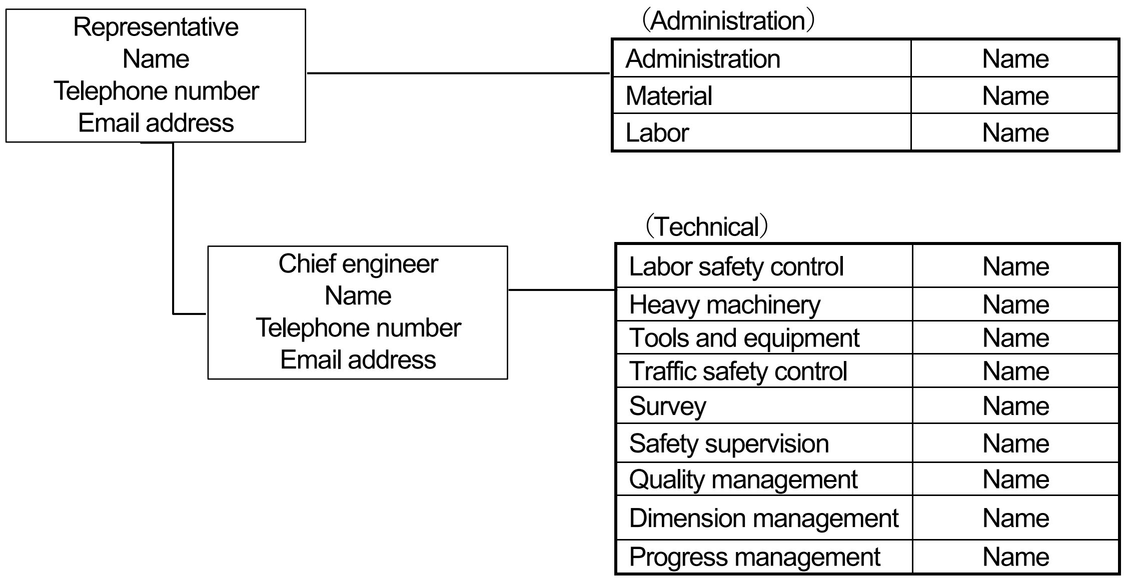
Date of contract:

Construction period: from XX/XX/XXXX to XX/XX/XXXX

Item		Unit	Quantity	August			September			Remark
Type of work	Type			10	20	30	10	20	30	
Retaining wall	Excavation	m3	100.0	━	━					
	Ready-made pile construction	PC	25.0			━	━	━	━	

3.4 Organization Chart

The site organization chart shall show the organization and chain of command and the division of work at the site, and for works where a specialist engineer is appointed, it shall be stated. The duties to be performed and the person in charge at the site shall be clearly indicated. It must be resubmitted if there are any changes to the organisation.



（Administration）

Administration	Name
Material	Name
Labor	Name

（Technical）

Labor safety control	Name
Heavy machinery	Name
Tools and equipment	Name
Traffic safety control	Name
Survey	Name
Safety supervision	Name
Quality management	Name
Dimension management	Name
Progress management	Name

Figure 2 (Example) Organization Chart on Site

3.5 Machinery and Equipment

The names, capacities and numbers of the main machineries to be used in the works shall be described. The items to be used of the machine should be clearly indicated in the list.

Table 3 (Example) Main machineries usage plan

Name	Standards	Unit	Quantity	Items to be used
Excavter	0.45m3	unit	1	Excavation
Drilling machine	3000Ps	unit	1	Piling

3.6 Material

The main materials to be used in the construction work shall be described in terms of quantity, method of quality certification and timing of material confirmation. The timing of the delivery of materials shall be consistent with the planned schedule.

This section describes the specified materials and main materials to be used in the construction work, the method of quality confirmation (material testing method, quality certificate, etc.) and the time of material confirmation.

It shall be ensured that there is no discrepancy between the timing of material deliveries and construction schedule.

Table 4 (Example) Main materials plan

Product name	Standard	Planned quantity	Manufacturers	Quality certification	Time of delivery			Summary
					Y	M	D	(Date of confirmation, etc.)
Deformed steel bars	D13	800 kg	Iron and steel	Mill sheet	2023	9	5	

3.7 Construction Methods

3.7.1 Work flow for the main works

Describe the work flow for each type of work and describe the following at each stage of work. It is better that explanations of each process is mentioned along the work flow.

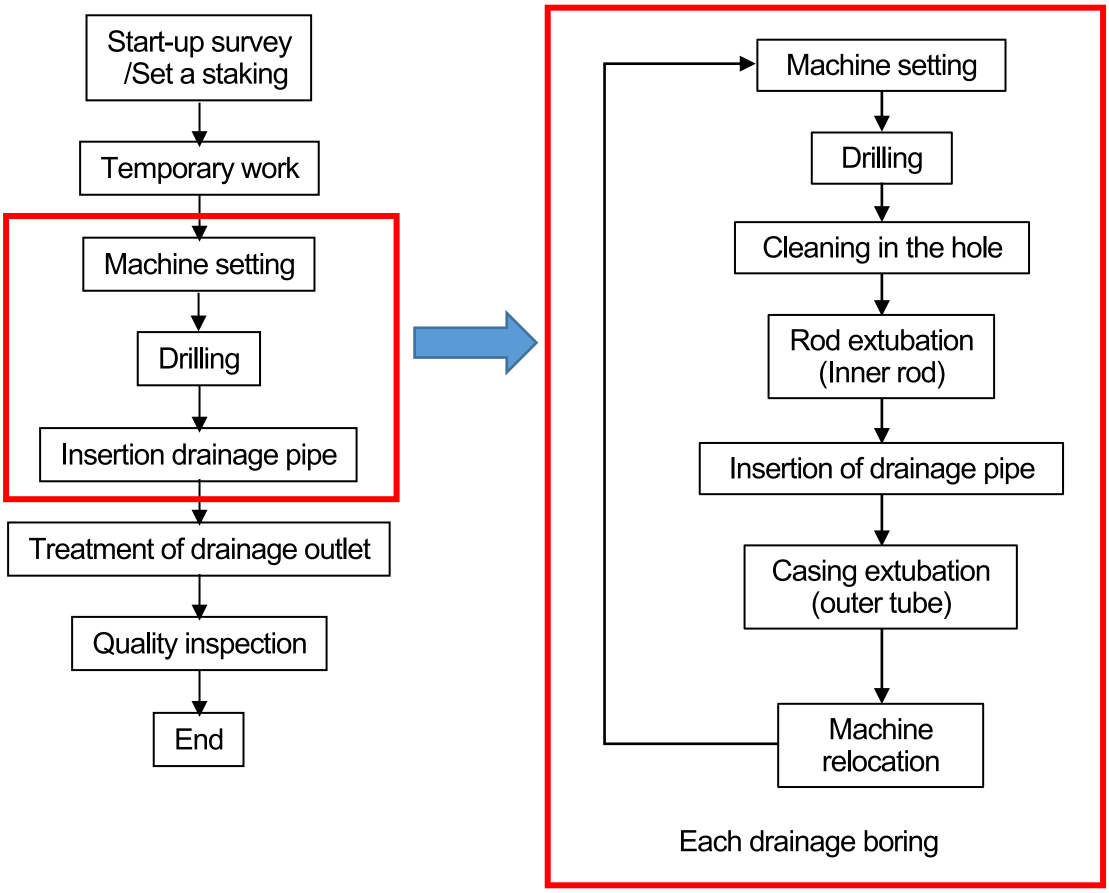


Figure 3 (Example) Work flow - (Horizontal drainage boring)

3.7.2 Notes on construction implementation and construction methods

Describe the working environment of the construction site (e.g. surrounding land use, natural environment, proximity to the site, etc.) and the timing of the construction of the main works (e.g. rainfall period, rainfall-drought period, etc.).

This is followed by a description of the main points to be kept in mind when carrying out the work, the main points of the construction method, the constraints (time of year, working hours, traffic restrictions, nature conservation, etc.) and the coordination with the relevant authorities.

It also describes the protection methods for reference points, underground installations and above-ground obstacles used in preparatory works

(Example) Notes on construction implementation and construction methods

1) The plan for the tranceportion method of construction equipment, the plan for temporary transportation routes, the plan for scaffolding, and the plan for the placement of materials and equipment, etc. are described.

When planning the temporary transportation route, avoid slope shape changes as much as possible (since the site is a landslide area and it has risk of slope instability due to topographic changes)

2) Clearly describe the installation method of the drillng machine (drilling location, direction, and height)
3) Clearly describe the installation method of the drillng machine (drilling location, direction, and height).
4) Clearly describe drilling procedures and drainage pipe insertion procedures.
5) Describe the method of drainage treatment after drilling and drainage pipe installation (Period of time untilinstall of catchment basin)..

3.7.3 **Temporary works**

The structure and layout plan of temporary facilities common to the entire construction work should be described in detail using location drawings, schematic drawings, etc. In addition, structural calculations and other methods to confirm safety should be included where possible. Other temporary facilities such as temporary buildings, temporary storage areas for materials and machinery, machinery and equipment for plants, transport routes, temporary drainage and temporary facilities for safety management should be described.

- Temporary buildings such as site offices, workers' quarters and warehouses
- Temporary storage or yards of materials, machinery etc.
- Plant and other machinery and equipment necessary for construction work
- Transportation routes (temporary roads, temporary bridges, repair of existing roads, etc.)
- Temporary drainage
- Construction sign boards, safety signs, traffic barriers, temporary facilities for safety control

3.8 Construction Management Plan

3.8.1 Process Management

Describe what management methods are used to manage the network, bar charts etc.

Explanation of Process Management is described in Chapter 4.

3.8.2 Quality management

Describe the quality control plan based on the quality control standard indicated in the technical specifications.

Explanation of Quality Management is described in Chapter 5.

3.8.3 Dimension management

Describe the dimension control plan based on the dimension control standard indicated in the technical specifications.

Explanation of Dimension Management is described in Chapter 6

3.8.4 Safety management

Describe the persons responsible for health and safety management and the policy for health and safety management activities. In the event of an accident, the method of contacting the relevant authorities, the affected person's home, etc., and emergency hospitals, etc., should also be described. The following items need to be described

(1) Construction safety management measures

Describe the person(s) responsible for health and safety management and the action plan for health and safety management.

(Example) Items to be included

1. Basic policy
    1) Safety targets and priority management items
    2) Safe construction system
    3) Basic safety measures
2. Health and safety management system
    1) Health and Safety Committee

2) Safety patrols
3) Safe working instructions
4) Safety management organisation

Each of these should be listed according to the person responsible as defined by Law in each country.

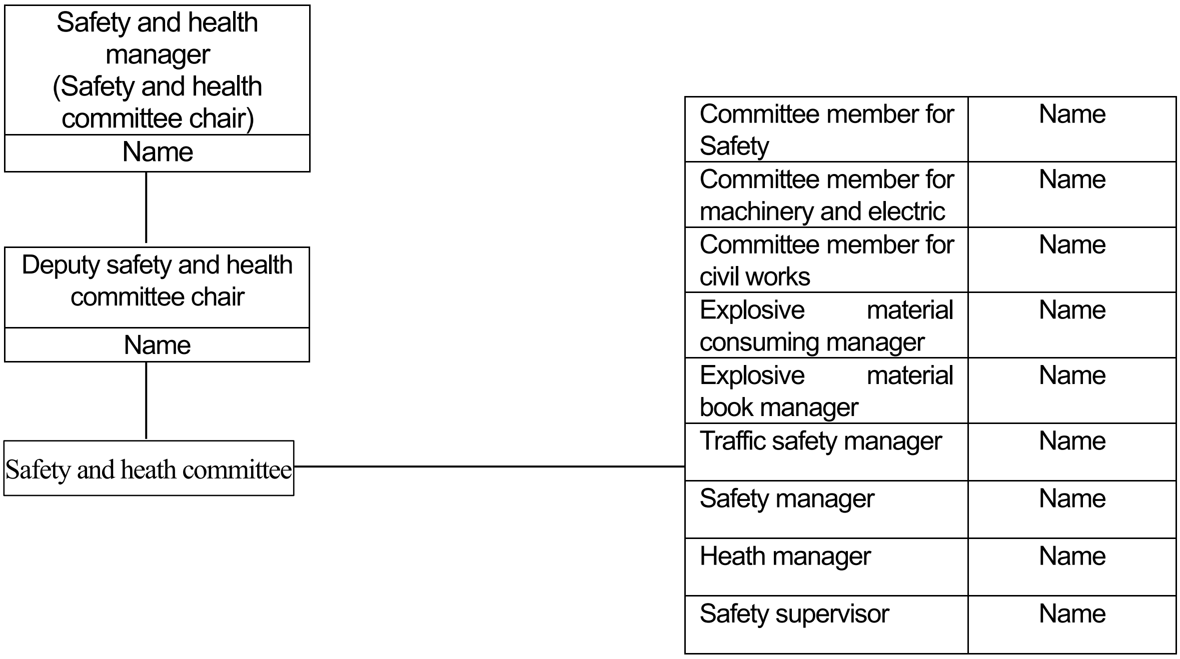


Figure 4 (Example) Safety organization chart

(2) Safety management measures for the third parties' facilities

This section describes measures to be taken when works are carried out in close proximity to third party facilities such as houses, shops, roads, railways, gas, electricity, telephone and water supply.

(3) Action plan on construction safety education and training

Describe the monthly safety education and training provided. In the safety management organisation, specify the system of site patrols and security personnel. Describe the requirements of relevant laws and regulations.

Table 5 (Example) Safety Management Action Plan

Name	Location	Who will attend	Frequency
Education for newcomers	Field office	Field operatives	On new entry
Morning assembly	On site	Field operatives	Every day before work
Hazard prediction activities	On site	Field operatives	Every day before work
Meeting the next day	Field office	head of staff	Every afternoon
Safety patrols	On site	Safety patrolman	Every day at any time
Safety training	Field office	Field operatives	Once a month

Safety Patrols	On site	Health and safety officer at the contractor's head office	Once a month
Health and Safety Council	Field office	Health and safety officers and foremen at contractors' headquarters	Once a month

(4) Excerpts from relevant laws, regulations, guidelines and other necessary and helpful information

Describe extracts from relevant laws and regulations of importance regarding health and safety.

(5) Emergency arrangements and response

Describe the organisational structure and communication system in the event of abnormal weather conditions such as heavy rain, strong winds, earthquakes, water quality accidents, construction accidents, etc.

In the event of abnormal weather conditions such as heavy rain, strong winds, etc., and the threat of a disaster, patrols of the site will be carried out as necessary to ensure vigilance.

1) Specify extreme weather requirements to be patrolled

(Example)

- Heavy rain: when the hourly rainfall reaches 50 mm and the continuous rainfall 250 mm.
- High winds: when the average wind speed over a 10-minute period reaches 10 m/sec.
- Earthquake: when the seismic intensity of 4 or higher occurs in the area including the site

2) Specify how to obtain weather information and what to do when requirements are reached

Table 6 (Example) Action Plan for Extreme Weather Events

Item	Heavy rain	High wind	Earthquake
Means to collect information	TV, radio, weather report, watching rivers/ stream, rain gauge,	TV, radio, weather report,	TV, radio
Action to be taken as per information			
Place of evacuation			

3) Specify the number of people and equipment that can be mobilised in the event of a disaster.

4) Clearly state the location and method of evacuation

5) Description of the communication system

Daytime and evening contact details for the following sections

- Client relations (office, project director, chief engineer, etc.)
- Contractor relations (head office, site representative, safety engineers, etc.)
- Relevant authorities (police station, fire station, emergency hospital, etc.)
- Others (e.g. electricity companies, telecommunication companies)

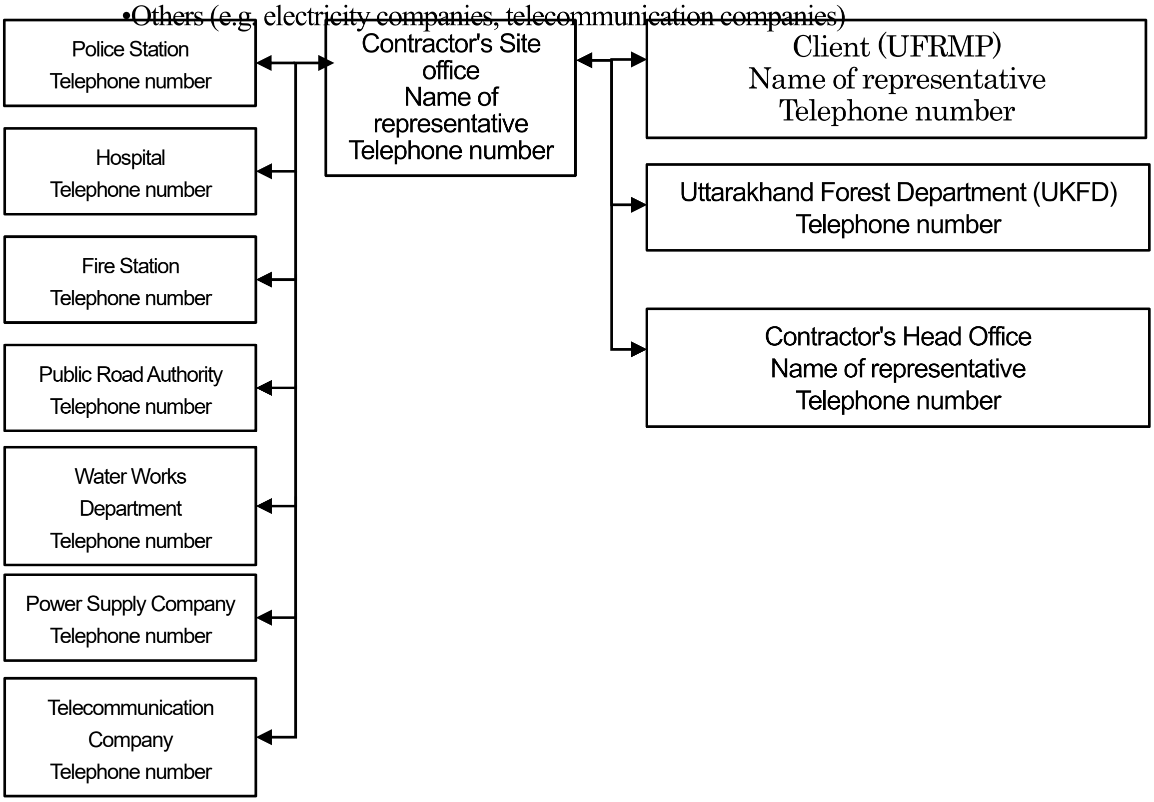


Figure 5 (Example) Communication system diagram

3.8.5 Traffic management

Describe the traffic treatment and traffic control measures associated with the works.

Where a diversion route is provided, a plan of the diversion route and the layout of safety facilities, guide signs and traffic control personnel should be described.

Specific plans for the layout of security facilities, measures for public roads and entrances/exits, routes for carrying in and out the main materials, measures to prevent overloading, etc. are to be described.

3.8.6 Environmental measures

For the purpose of preserving the living environment of the construction site area and ensuring smooth construction work, the following countermeasure plans are to be described in accordance with the relevant laws and regulations regarding environmental preservation measures.

1) Noise and vibration control
2) Water Pollution
3) Disposal of rubbish and dust
4) How to dispose of waste
5) Other

3.8.7 Progress meeting and report

With regard to the regular progress meetings with the client, the following items should be described

1) Date of the event
2) Attendees
3) Agenda
4) Minutes
5) Others

In relation to the preparation and submission of progress reports, please describe the following

1) Frequency and date of submission
2) Number of copies submitted
3) Items to be included (construction progress, stock of labour, materials and machinery, process management, health and safety management, environmental management, quality management, workmanship management, photographs, workmanship claims and payment management, etc.)
4) Others

3.8.8 Others

Describe other important matters as necessary.

1) Procedures with the public authorities (police, municipalities, road administrators)
2) Informing the local community
3) Holidays

Chapter 4. Process manegement

4.1 Purpose of process management

The purpose of process manegement is to manage the planning and implementation of the process within a specified construction period.

Since the quality and cost of construction are greatly affected by the speed of the process, process management is one of the most important items in construction management.

For the client side, process manegement is the management of the construction process to ensure that the work progresses appropriately and with sufficient quality and precision within the construction period.

On the contractor's side, adding a cost management factor to process control, the construction work is to be managed to maximize production at minimum cost with sufficient quality and precision.

The contractor controls the process for its own actions, while the client supervises the actions of the contractor.

4.2 Process Management Procedures

Process management is broadly classified into the control function in the "planning and implementation" stage and the improvement function in the "review and action" stage.

The process control procedure is t divided into the following steps: planning, do, check, and action (P→D→C→A).

The construction work is carried out based on the process chart. And the actual construction progress is recorded in the process chart on a daily, weekly, and monthly basis. And a comparison is made between the planned process and the actual process.

The actual progress is compared with the planned process, then the actual construction progress is managed to progress as much as possible in accordance with the plan.

However, if there is a large difference between the planned process and the actual progress (±10% of the plan), it indicates that there is a problem with the plan or the implementation system. Therefore, it is necessary to review the plan and take necessary measures.

Then, based on the re-planned process chart, each step of implementation(do), review(check), and action should be implemented again.

It is general process management procedure.

(1) Planning stage (P)

In order to make a process plan, based on the basic policy of construction methods and sequence of construction, etc., appropriate to the site, schedule plan and work procedures for each unit of work should be determined and a process chart should be prepared and a process chart should be prepared.

In this case, the use plan for labor, materials, machinery, and equipment must be fully considered. When preparing process plan, in addition overall process chart, it is also necessary to prepare a partial process chart for particularly important parts of the overall process for ensuring smooth progress of the overall process.

The general procedure for preparing a process plan is described below.

(1) Based on the construction category, determine the construction procedures for the construction items.

(2) Determine the appropriate construction period for each construction item.

(3) Coordinate the processes of each construction type with each other so that all construction work can be completed within the construction period.

(4) Coordinate the mobilization of labor, materials, and machinery throughout the entire construction period to avoid overly concentrated work and waiting time.

(5) Prepare process charts.

(2) Implemantaion stage (D)

Arranges labor, materials, machinery and equipment, etc., in according to the schedule plan and work procedures in the process schedule, and directs and supervises the construction work.

(3) Review(check) stage (C)

The progress of the construction process is monitored, and construction progress is managed by comparing the planned process with the actual process.

The contractor shall report the progress of the construction process to the cliant side superviser as necessary.

(4) Action stage (A)

If the actual progress of the construction differs from the planned schedule or is not stable, corrective actions should be taken, such as improving work methods to speed up the process.

In some cases, the process plan is reviewed again, for example, by rearranging the process chart.

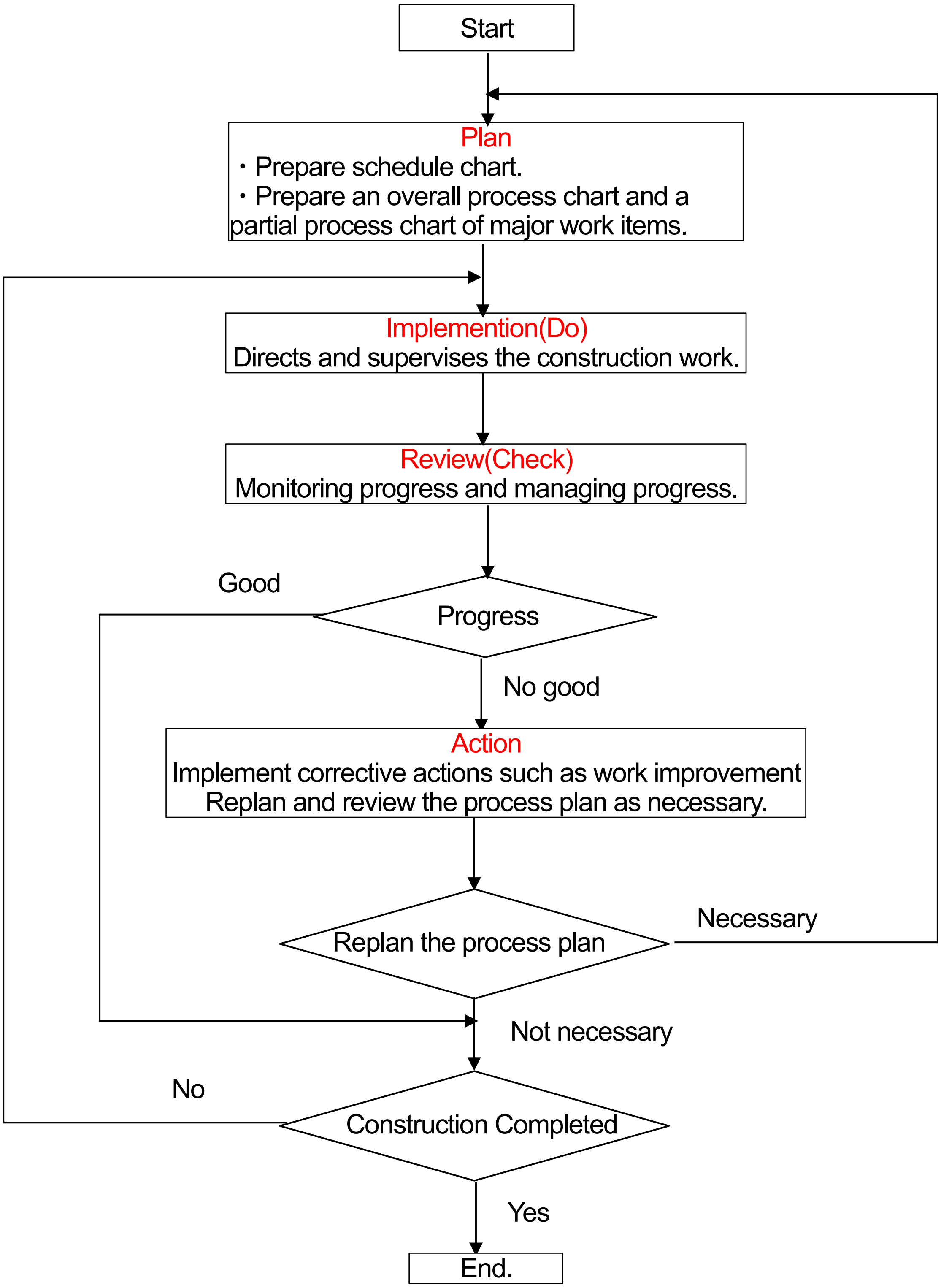


Figure 6 Process Management Flowchart

4.3 Types and Characteristics of Process Charts

Currently, there are four types of process management methods in general use: bar chart type, coordinate type, curve type, and network type. The advantages and disadvantages of each are shown in following table.

Table 7 Types of Process Charts

Item	Advantage	Disadvantage
Bar chart type	・Easy to handle ・Progress is directly visible ・Easy to revise	・Interrelationships between works are unclear. ・When parts of the work are changed, it is difficult to understand the effect on the overall work. ・Unclear factors are likely to be included. ・The schedule is rough estimate.
Coordinate type	・When progress is indicated only by distance, as in the case of tunnel construction, all types of work can be indicated within the schedule chart. ・The construction sequence, schedule gaps, etc., can be visually indicated. ・The progress status of the construction position and process can be visually indicated.	・Interrelationships between works are unclear. ・When parts of the work are changed, it is difficult to understand the effect on the overall work. ・Unclear factors are likely to be included. ・The schedule is rough estimate. (When used in combination with bar charts, these disadvantages can be avoided to some extent.)
Curve type	・Management is based on amount of work(amount of money) completed, so it is easy to understand the progress of the work.	・Work procedures are unclear ・Difficult to understand the required days for the work and the work that will affect the construction period. (When used in combination with bar charts, these disadvantages can be avoided to some extent.)
Network type	・Interrelationships between each work are clear. ・When there is a partial change, the impact on the overall project can be understood quantitatively. ・It is suitable for overall management of complex projects. ・Capable of focused management	・Takes a lot of time to create ・It takes time to understand the method ・Difficult to assemble a network ・Relatively difficult to revise

A process chart may be divided into an overall process chart and a partial process chart (detailed process chart).

The overall process chart is prepared to indicate the overall construction schedule by classifying each major process and combining the construction sequence, and is used to determine the progress of the overall construction project or the critical path in the overall process.

The partial process chart is used to select only the critical processes in the overall process, prepare a detailed schedule for that process, and perform focused management to ensure that the overall process progresses smoothly as planned.

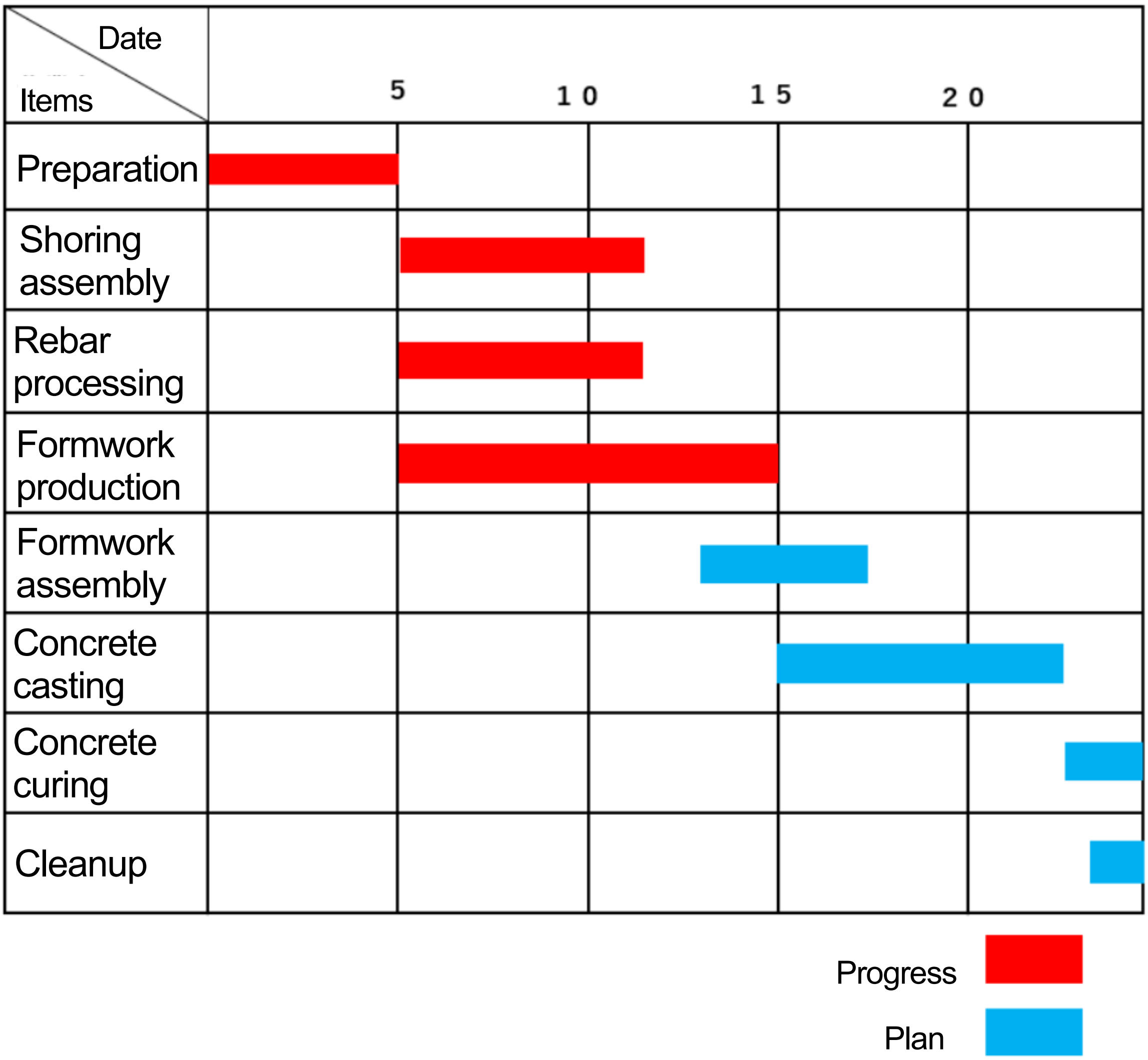


Figure 7　(Example) Process chart：Bar chart type

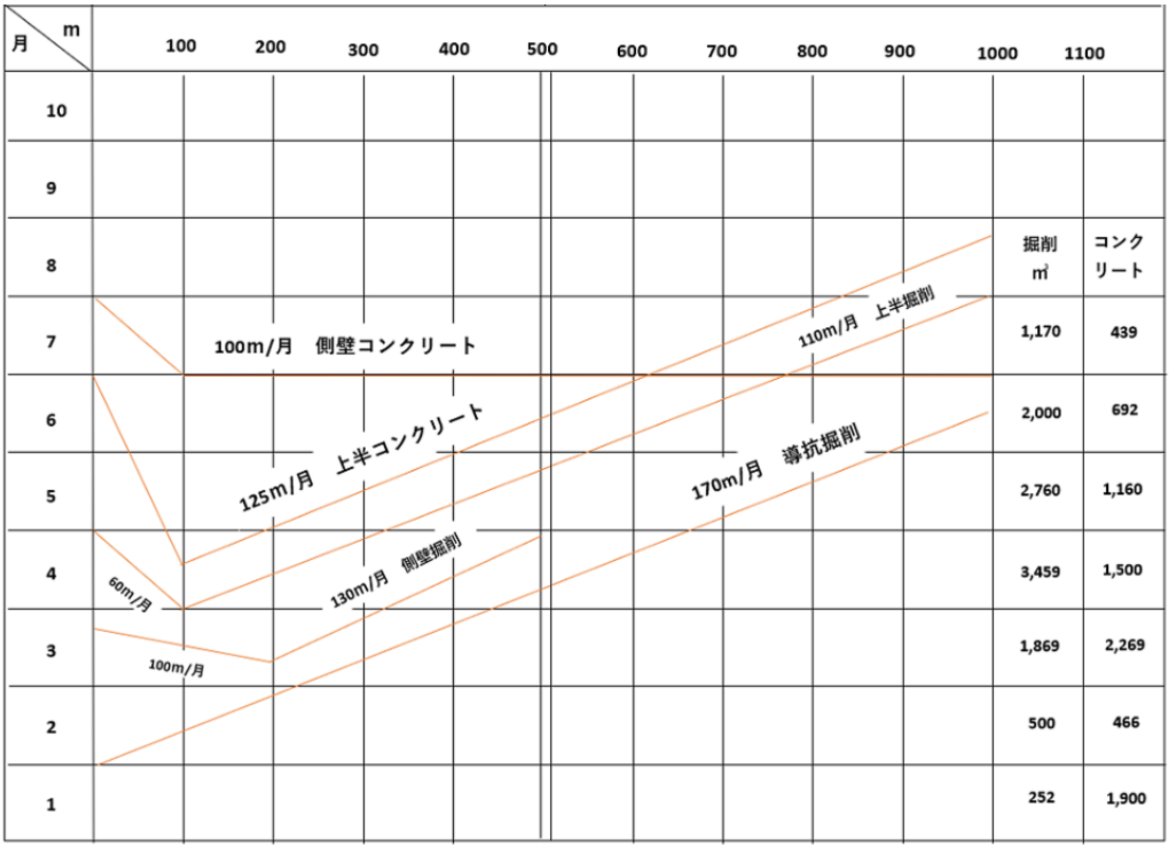


Figure 8　 (Example) Process chart：Coordinate type

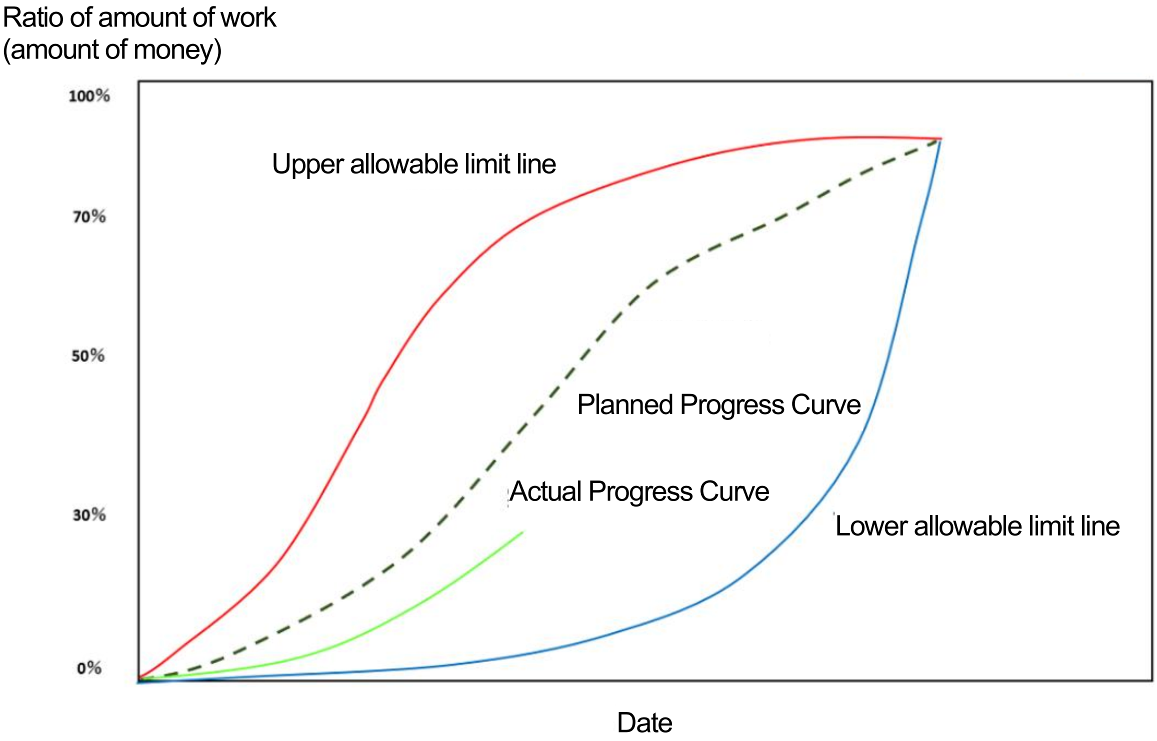


Figure 9　 (Example) Process chart：Curve type

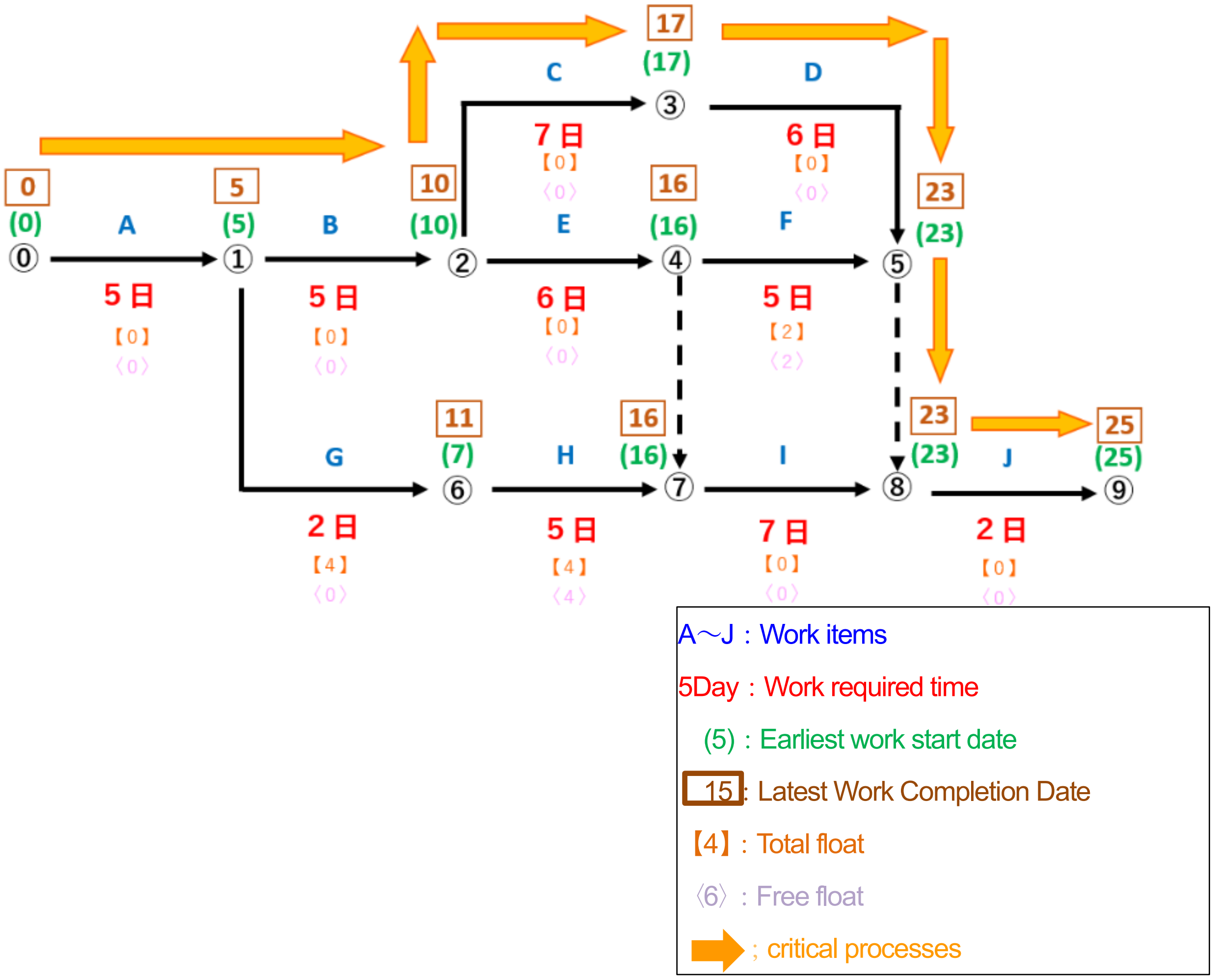


Figure 10 (Example) Process chart：Network type

Chapter 5. Quality management

5.1 Purpose of quality management

Quality management is performed in combination with process management and dimension management as part of construction management, and statistical methods are used to identify problems and improvement methods to secure the desired quality, stable process, and proper dimensioning of the work.

5.2 Quality management procedures

5.2.1 Items required to implement quality management

Determine the quality characteristics to be managed and the values of those characteristics.

(1) Quality characteristics

Determine the quality characteristics to be managed and the values of those characteristics.

1) Selection condition

- The characteristic that totally indicate the state of the process
- The characteristic that have an important effect on the quality of the product.
- Substitute characteristics (characteristics that are closely related to the true characteristics to be required and used in place of the true characteristics)
- The characteristic should be easy to measure
- The characteristic should be easy to take action against the process.

2) Examples of quality characteristics

Compressive strength of concrete σck = 18 KN/mm2

(2) Quality standard

The quality standard should be achievable and of a character indicated by the average of the quality and the range of variation. It should also match the standard specified in the design documents.

1) Determination of quality standard

- Target value of quality to be achieved
- Target value of quality with a margin to allow for "variation" in quality
- Setting an initial rough standard based on existing data, etc., and revising the standard according to the construction process.

2) Example of quality standard

Concrete slump (8 cm) 8 cm ± 2.5 cm

(3) Work standards (work methods)

In order to secure the quality standard, standards, etc. concerning work methods, work sequence, cautions for equipment used, etc., shall be determined as work standards.

1) How to decide the work standards

- Work standards shall be determined based on past performance, experience, etc.
- Procedures are to be determined so that management can be carried out throughout the overall process.
- Determine procedures to secure stable processes even when abnormalities occur in the processes.
- The standards are documented and shared.

2) Examples of work standards

Concrete shall be compacted using a high-frequency vibrator for approximately ○○ seconds at ○○ m intervals, and compacted carefully to integrate with the previously placed concrete

(4) Testing and inspection methods

Testing and inspection methods shall be determined.

As described above, in order to secure quality standards, work, inspection, and testing must be performed in accordance with the established methods.

5.2.2 Quality management procedures

The Quality management procedures is as follows, and a workflow is shown in the figure below.

1) Determine "quality characteristics" to manage the process.

(Example) Compressive strength σck = 18 N/mm2

2) Determine "quality standards.

The "quality standard" shall be in accordance with the standard specified in the design documents, and shall be indicated in the average of the quality and the range of variation.

3) Determine "work standard" in order to ensure the quality standard . (To be described in the construction methodology.)

4) Conduct construction work according to the work standards and collect data.

5) Judge whether each data satisfies the quality standard with sufficient margin by using "histogram", etc.

6) If each data satisfies the quality standard, the stable state of the process is judged by using "control chart".

7) If the quality standard is not satisfied or an abnormality occurs in the process, the cause is

investigated and measures are taken to prevent recurrence.

8) If the process is in a stable state, then the management limit is kept and the work is continued.

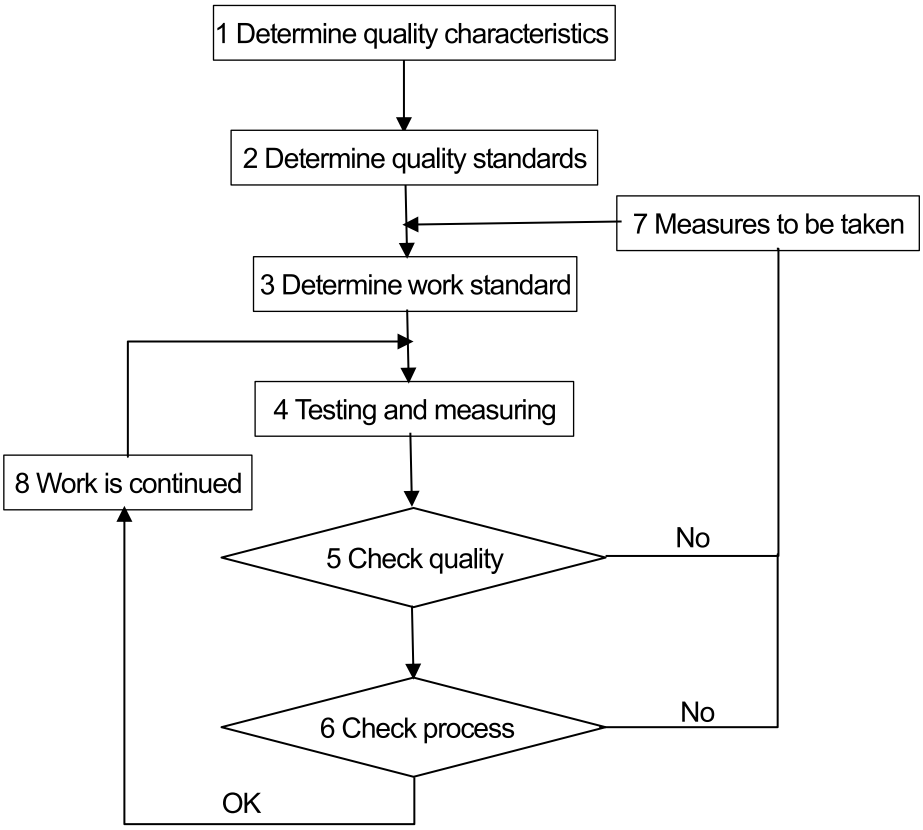


Figure 11　Work flow of quality management

Chapter 6. Dimension management

6.1 Purpose of the dimension management

It is necessary to examine how the objects structures are constructed against the required conditions (Various dimensions and positions, including size, position, thickness and depth, etc.) shown by contract doqument and drawings, and if any unsatisfactory conditions are found, to pursue the causes and make improvements. This action is called dimention management.

6.2 Method of the dimension management

(1) Dimension management by direct measurement

Dimension management by direct measurement is to confirm that the constructed structure satisfies the shape and dimensions indicated in the design documents. (drawing, technical specification)

The shape and dimensions of the structure, reference height, centerline deviation, etc. are directly measured according to the construction sequence, and the results are recorded in a control chart or list of results each time, and the data are evaluated.

The dimension control is investigation the cause of any errors, take necessary measures.

(2) Dimension management by photographing and recording

Dimension managemen by photographing and recording means to photograph and record the dimension based on the photographing standard, in order to confirm the form and quantity of underground buried structures and other parts that cannot be confirmed after construction, or to confirm the progress of each construction stage.

6.3 Dimension management plan

Dimension management should be carried out based on a management plan prepared in advance that specifically defines the control measuring points, dimensioning positions, photographic positions, number of times, and types of control charts.

It is also important to prepare a check system and to check whether the work is progressing according to the management plan.

Points to be noted in preparing the plan are as follows.

(i) Measurements should be taken at the locations and by the methods specified in the technical specifications.

(ii) Photographs should be taken at the same locations as the dimension management points.

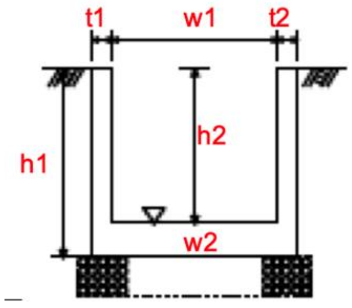
(iii) Management charts and other charts should be prepared in accordance with their purpose.

For example, mainly used to confirm the quantity of workpiece should be shown on a development plan, etc.

In while requiring allowance in standards should be shown on a as build drawng, workpiece chart, process capability chart, histogram, etc.

(iv) An example of a management plan table is shown as following.

Table 8　(Example) Dimension management plan table

Management Category		Scope of as-built dimension control management by the Contractor					Method of supervision by the Engineer
Category	Item	Measureing item	tolerance	Measuring interval	Archive	Measuring position	
Concrete channel	Cast in place	Formation level	±30mm	Every 40m completed length. If total length is not more than 40m, 2 points shall be measured.	Keeping record with photo in the file for inspection		Inspection for measurement by the Contractor
		Thickness: t1, t2	-20mm				
		Width: w1,w2	-30mm				
		Height: h1, h2	-30mm				
		Length	-200mm				

6.4 Procedures of dimension management by direct measurement

(1) Selection of measuring points to be controlled

Management points are generally selected based on a 'Dimension management plan'. In this case, control points shall be selected taking into account the topography and structural change points.

(2) Management reference values and standard values

The management reference values are reference values set at the construction control stage to ensure that the values fall within the range of the 'standard values'.

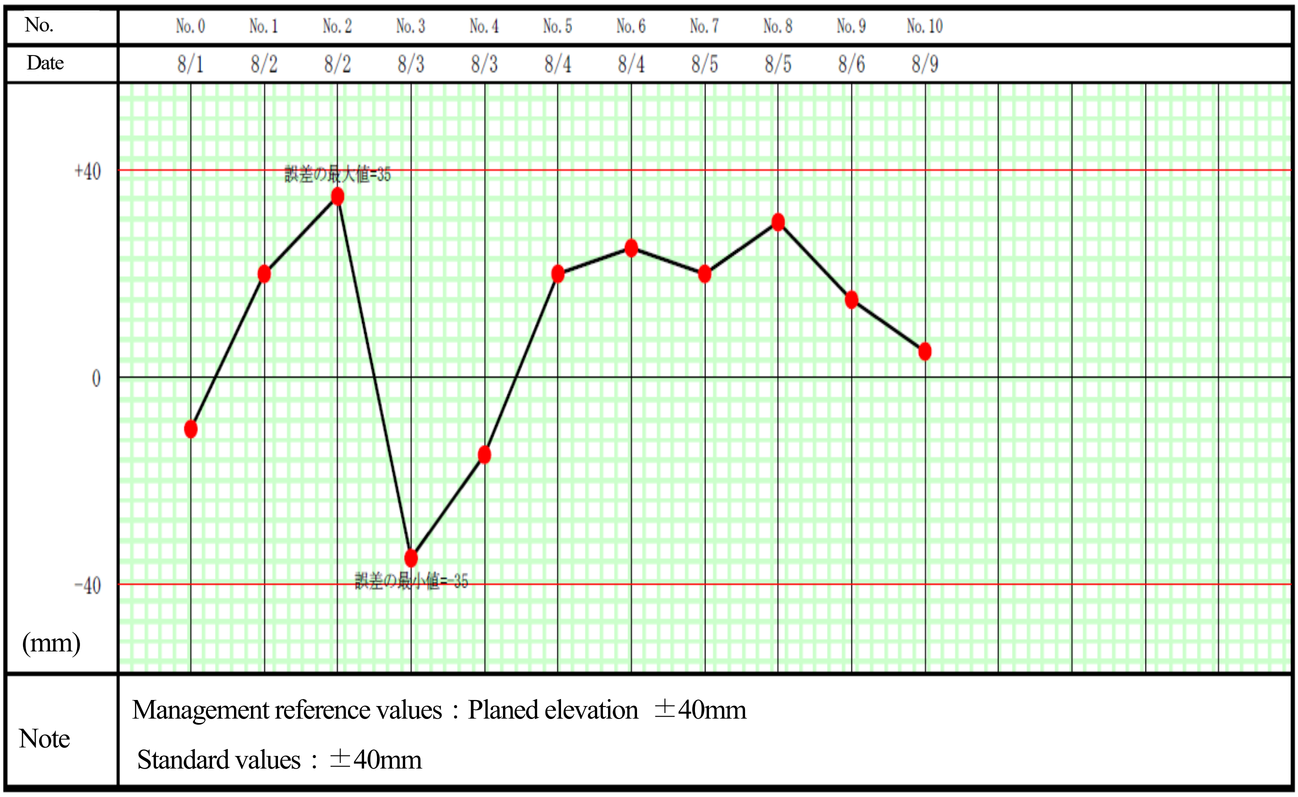
The standard values are the limits of the difference between the design values and the workmanship.

In cases where company management standard values are separately established to ensure higher quality, it is to be checked whether they are managed using the company's management standard values.

(3) Management method

Dimension management is carried out for two purposes: to provide " allowance" against the standard values and to confirm the quantity of workmanship, and is necessary as data for handing over the construction work to the client after completion of the construction work.

Management methods include the following



Management reference values：Planed elevation ±40mm

Standard values：±40mm

Figure 12　（Example）Management charts

Table 9　(Example) Dimension management result list

Items	Elevation 1			Elevation 2			Thickness		
Standard value	-40 ～ +40			-40 ～ +40			-25 ～		
Company management standard values	-20 ～ +20			-20 ～ +20			-13 ～		
Position	Design value	Measured value	Difference	Design value	Measured value	Difference	Design value	Measured value	Difference
No.1	100.000	99.990	-0.010	100.000	99.990	-0.010	20	21	+1
No.2	110.000	110.020	+0.020	110.000	110.020	+0.020	20	22	+2
No.3	120.000	120.035	+0.035	120.000	120.035	+0.035	20	24	+4
No.4	130.000	129.965	-0.035	130.000	129.965	-0.035	20	32	+12

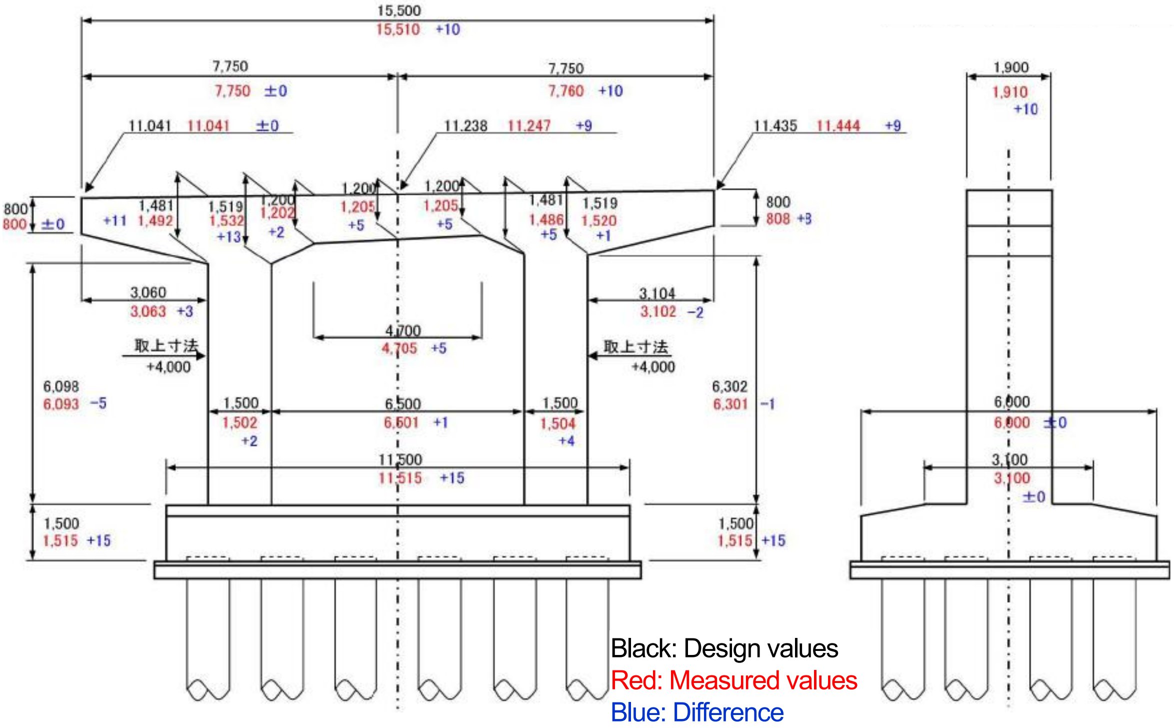


Figure 13　（Example）Description on structural drawings

6.5 Procedures of Dimension management by photographing and recording

(1) Selection of measuring points to be managed

The number of points to be photographed shall be in accordance with the 'management plan', but as a rule, the selection of photographing locations shall be the same as in the case of dimension management by direct measurement.

When taking photographs, it is necessary to take photographs in such a way that the information to be obtained is clear, based on a thorough understanding of the management plan and the site situation.

(2) Basic components of photo management

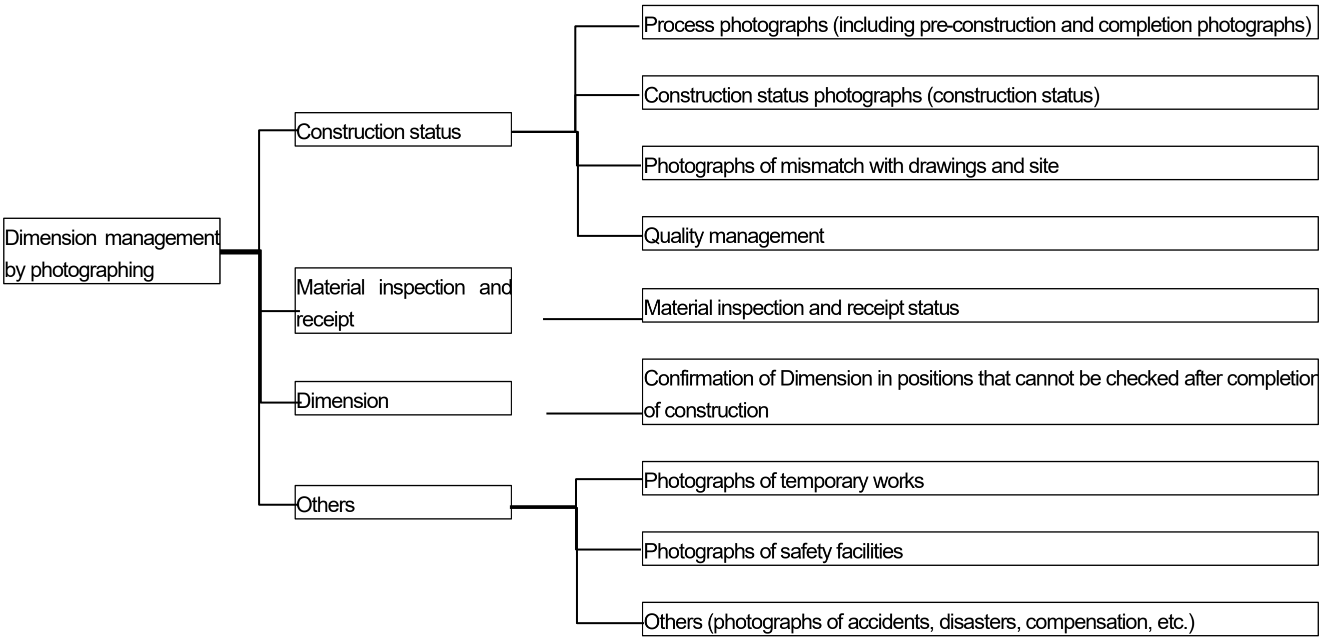


Figure 14 Basic components of photo management

(3) Organisation of photographs

1) General organisation

Photographs should be classified by construction type and measuring points, and organised according to the sequence of construction, with titles and supplementary drawings attached to clarify what was photographed and where.

For contents related with the management chart, the measuring positions on the management chart and the photographic positions, as well as the dimensions of the management chart and the dimensions of the photographs, should be consistent.

2) Editing sequence

The sequence of editing varies slightly depending on the size, type and volume of construction work, but in general the sequence is as follows.

(i) Situation photographs

(a) Photographs of the process (including pre-construction and completion)

(b) Status photographs of construction work .... construction sequence

(c) Photographs of discrepancies between drawings and site

(d) Quality control .... per test item

(ii) Material acceptance inspection photos .... by inspection date and order or by material

(iii) Photographs of confirmation of dimension .... organise the workmanship dimensions by construction type and measuring points in the order of construction.

(iv) Other photographs

(a) Temporary construction status photos .... by type

(b) Safety facility photographs .... by facility

(c) Others .... Organise the details of factors that may change the contract conditions
(e.g. changes in geology, emergence of groundwater, etc.)

Chapter 7. Safety management

7.1 Purpose of the safety management

The purpose of safety management is taking measures to prevent accidents on construction sites where hazards are present. Safety measures are important not only for the workers on the construction site, but also for third parties.

Safety management means ensuring the safety of construction works under appropriate construction periods, methods, and costs by understanding the various conditions at each site, planning and preparing a system and environment for safe construction, and accurately responding to and managing changes in conditions that occur as the process progresses.

7.2 Contents of the safety management

This section presents guidelines for safety management as implemented in Japan. Reference should be made according to the size of the works and the contracting and execution system in Honduras.

(1) Prime contractor's responsibility

Depending on the size of the construction project, it is often carried out by a corporate entity consisting of a prime contractor and subcontractors.

The prime contractor is responsible for setting up a management and implementation system for safety measures, while the subcontractors follow this safety management system and carry out safe construction work.

Safety management to be carried out by the prime contractor is shown below.

1) Prepare a health and safety management plan

Prepare a health and safety management plan that includes basic policies for health and safety management at construction sites, health and safety objectives and priority items for work accident prevention measures.

2) Subcontracting contracts with appropriate work content

Subcontracting according to the quality of the subcontractor

3) Clarify who implements measures to prevent work accidents and who is responsible for the costs of such measures in the contract

Clarify the burden of costs to safety measures and clarify the responsibilities of subcontractors and prime contructor by specifying safety measure items and amounts in the contract.

4) Understand information (workers, equipment, etc.) of subcontractors by the prime contractor

In order to carry out health and safety guidance to subcontractors appropriately, the prime contractor shall have the following items etc. notified by the subcontractor to the prime contractor and understand them.

(i) The name of the subcontractor, the details of the contract and the name of the person responsible for safety and health,

(ii) A list of workers, whether or not they have obtained a work licence for health and safety and whether or not they have attended safety education, etc.

(iii) Information on the safety and health manager of the subcontractor (whether or not on-site at the construction site).

(iv) Machinery and equipment to be brought to the construction site

5) Preparation of work procedure manuals

The prime contractor shall instruct subcontractors to prepare work procedure manuals that takes into account the prevention of work accidents.

And the prime contractor has the subcontractors work in accordance with the Work procedure manuals.

6) Setting up and operating safety councils

The prime contractor, together with all subcontractors, sets up a safety council to raise awareness of safety measures.

7) Patrols of the work area

The safety manager of the prime contractor carries out daily patrols of all work

8) Training of new assigned workers

Give instructions and support to subcontractors to carry out sufficient training for newly assigned workers.

9) Health and safety meetings before work starts

The prime contractor shall instruct the subcontractor to gather its workers every day and hold a health and safety meeting before work starts.

(2) Specific safety measure items.

1) Checking the health of workers

Checking the health of workers is an important part of safety management on construction sites.

2) Regularly inspect equipment

Regular equipment inspections are important for safety management on construction sites. Inspections should be carried out regularly to check for any changes in the performance or structure of the equipment and machinery used.

In addition, it is a desirable practice to inspect equipment before the start of work and at the end of each workday. In the event of a storm or earthquake, it is also a desirable practice to check for any abnormalities in machinery and equipment when work is restarted.

3) Preventing accidents under suspended loads

To prevent accidents under suspended loads, it is important to strictly prohibit access to the vicinity of the suspended load.

4) Be careful when working at the same time in the upper and lower positions

Special care should be taken when working at the same time in the upper and lower positions due to the risk of falling objects.

When working at the same time in the upper and lower positions, install a protection facility to catch falling objects and prepare a work procedure manual to ensure that the rules for working at the same time in the upper and lower positions are strictly enforced and safety measures are taken.

5) Carrying out work in accordance with the work procedure manual

All workers must carry out the work in accordance with the work procedure manual prepared in consideration of safety measures. It is important to check and inform the workers about the work procedures before the work is carried out.

6) Preventing falls

Preventing falls is an important safety practice on construction sites. On construction sites, make sure that there are safe passageways to avoid tripping and slipping.

It is important to ensure that work areas are organised and kept clean in order to prevent falls

7) Take season-specific safety measures

It is very important to take season-specific safety precautions. Each season requires different precautions, so it is necessary to be aware of them and manage safety accordingly. The physical condition of workers also requires different attention in different seasons.

▪ Bad weather conditions

Firstly, in bad weather, the site can become slippery due to rain. Furthermore, in the case of strong winds such as hurricanes, there is a high risk of workers falling over and materials and equipment being blown away.

If the site is close to a river or bay, attention should be paid to material spills and flooding.

▪ Summer heat protection

Heat stroke prevention should be particularly careful.

First of all, it is necessary to have an environment in which people can replenish water and salt frequently.

Site supervisors should be aware of the physical condition of their workers.

8) Measures for working at height

It is very important to install safety belts for working at height.

If the work area is at a height of 2 m or more, protective fences or other equipment must be installed to prevent falling. If the height or depth exceeds 1.5 m, facilities must also be installed to enable workers to safely climb up and down.

Chapter 8. Case study of construction supervision (Horizontal drainage boring)

Horizontal drainage boring is an effective method of landslide prevention work in Honduras, and it is hoped that it will be established in the future.

This chapter describes points to be considered in the construction supervision of Horizontal drainage boring.

8.1 Outline of Horizontal drainage boring

Horizontal drainage boring is a method for draining groundwater that triggers landslide activity and lulling landslide activity.

As shown in the diagram, this is a simple method of drilling a hole 5-10° upwards with a drilling machine and inserting a drainage pipe.

The collected groundwater is then drained out of the landslide site via a channel.

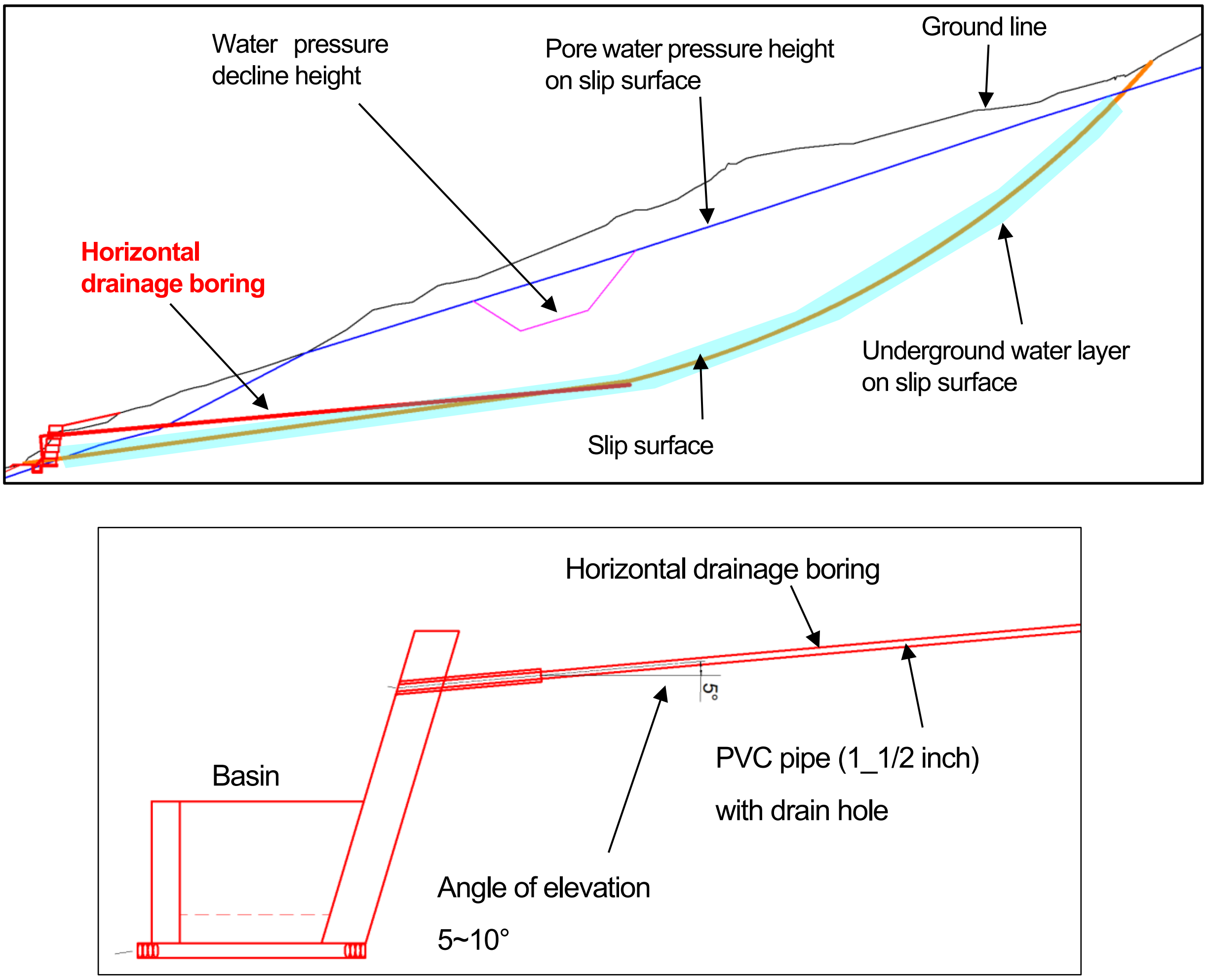


Figure 15 Reference drawing of Horizontal drainage boring

Drilling situation Drainage pipe installation

Completion status Drainage situation

Figure 16 Horizontal drainage boring in Campo Cielo

8.2 Points to note in process management

(1) Time of process management

As explained in the previous chapter, the purpose of process manegement is to manage the planning and implementation of the process within a specified construction period.

Process management should not be conducted only during construction, but should also be considered during the design and order preparation stages.

It is necessary to select the drilling method (selection of drilling machine) according to the site construction conditions at the design stage.

It is difficult to install large machines when the construction yard is small, and it may also be difficult to install multiple machines and simultaneously construct multiple types of work.

It is essential to consider construction procedures, selection of machines to be used, and temporary construction methods at the design stage, and this planning has a significant impact on process management during construction.

At the order preparation stage, it is necessary to estimate construction costs and set the construction period according to the construction method, construction machinery, and temporary construction method considered at the design stage.

If the construction schedule is set without regard to the construction method and procedures, it will place a heavy burden on process management during construction, and have a significant impact not only on process management, but also on safety management, quality management, and dimension management.

(2) Selection of drilling machine

The most important factor in process management of horizontal drainage boring is the selection of the drilling machine.

Drilling machines can be classified into the following two major types

Rotary Drilling Machine

Small type

For horizontal drilling

Rotary Percussion Drilling Machine

Crawler type

Skid type

Figure 17 Drilling machine for Horizontal drainage boring

○Rotary Drilling Machine

Drilling by rotation. Drilling speed is slower.

Work space required is smaller.

Drilling speed can be speeded by installing an air hammer.

No suitable for drilling hard rock.

○Rotary Percussion Drilling Machine

Drilling by rotation and blow. Drilling speed is faster.

Work space required is larger.

Suitable for drilling hard rock.

It should be selected type of drilling machine base on the geological condition and situation of work space.

If the process is delayed, it should be considered changing the drilling machine and adding a machine.

8.3 Points to note in dimension management

Dimension control items for horizontal drainage boring are as follows

- Location, direction, and height of drilling point
- Drilling angle
- Length of drilling hole
- Length of installed pipe

The following is an explanation of how to manage these control items in the construction process.

(1) Management for Location, direction, and height of drilling point

Before construction, the location of the drilling point should be clearly indicated on site by start-up survey. (See the figure below).

The contractor shall specify the location, direction, and height of drilling point for each horizontal drainage boring. The supervisor on the client side confirms that there is no difference from the position, direction, and height indicated in the design documents.

After approval by the supervisor on the client side, the construction work is started.

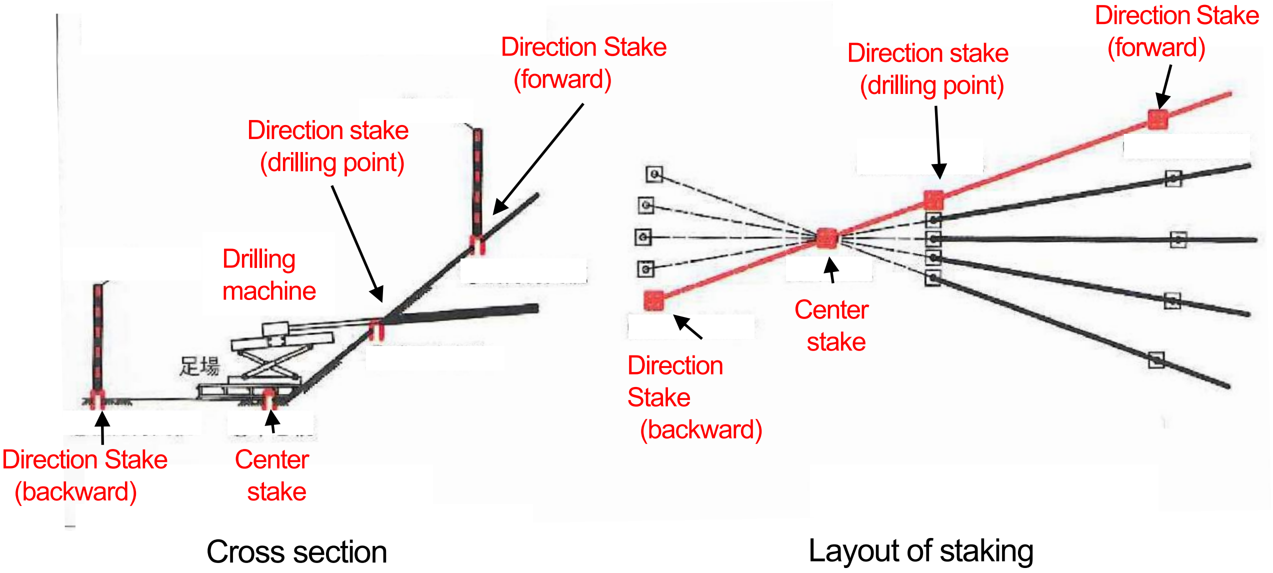


Figure 18 Case study of start-up survey for indicating drilling point

In the construction stage, the drilling machine is set in accordance with the location, direction, and height of drilling point indicated in the start-up survey, and excavation is started.

When the machine is set, the supervisor on the side of the client checks that the set position is correct.

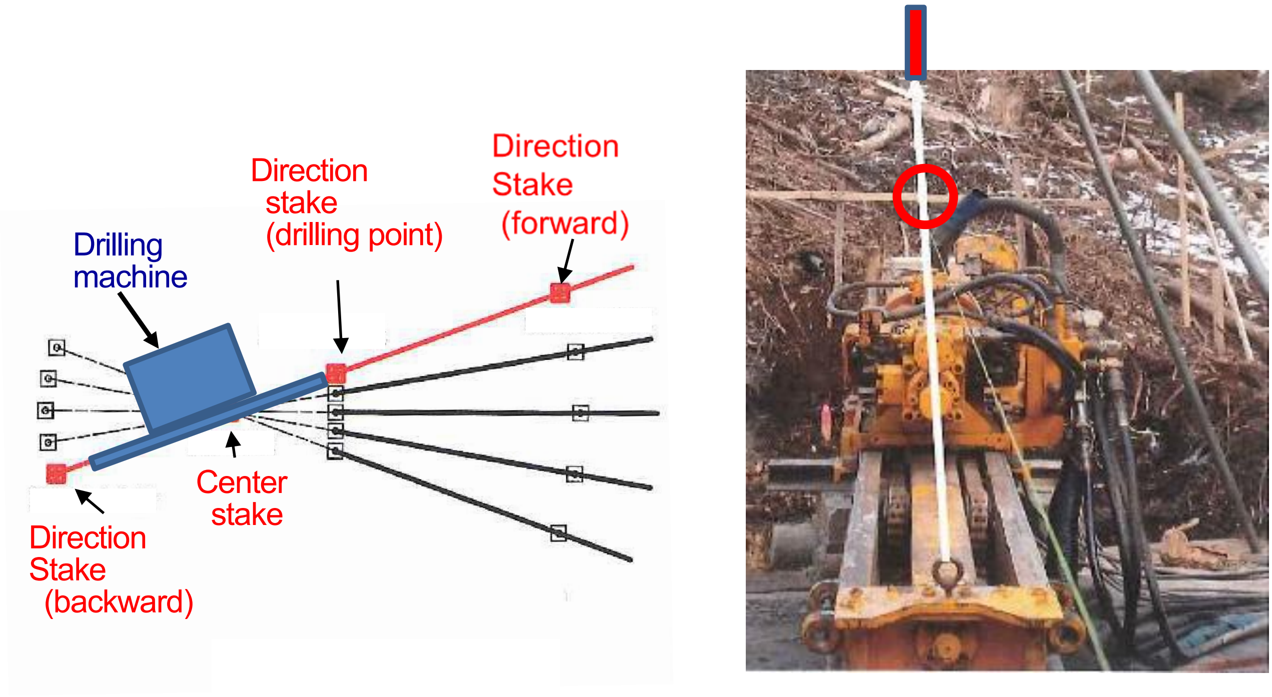


Figure 19 Case study of machine setting

(2) Management for Drilling angle

After setting the drilling machine based on the start-up survey, the drilling angle (elevation angle) is set.

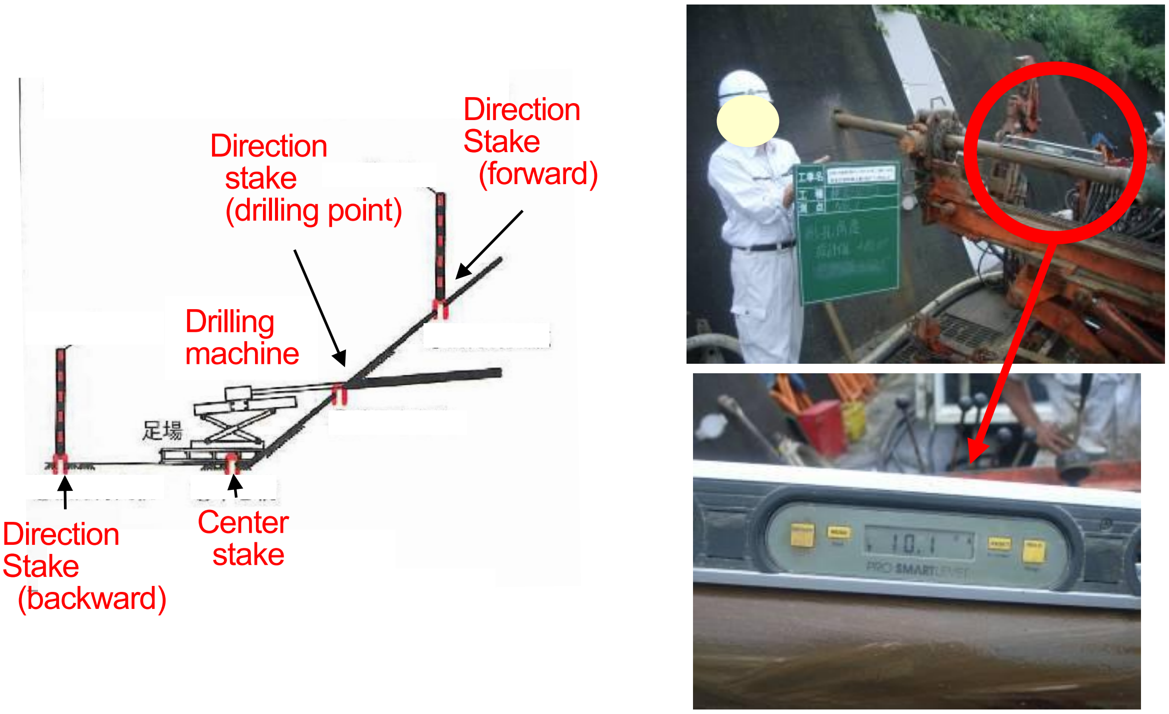
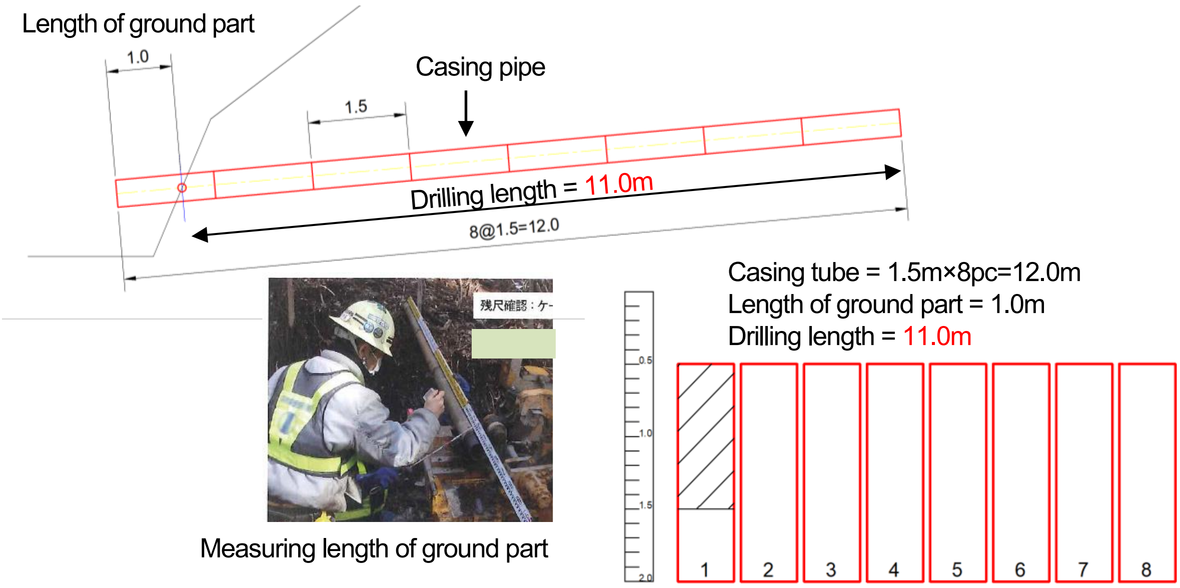


Figure 20 Case study of drilling angle setting

(3) Management for Drilling length

Drilling length is managed by the number of casing pipes. (See figure below).



Casing tube = 1.5m×8pc=12.0m
Length of ground part = 1.0m
Drilling length = 11.0m

Measuring length of ground part

Figure 21　Case study of drilling lemgth management

(4) Management for Length of installed drainage pipe

Drainage pipe length is managed by the number of drainage pipes. (See figure below).

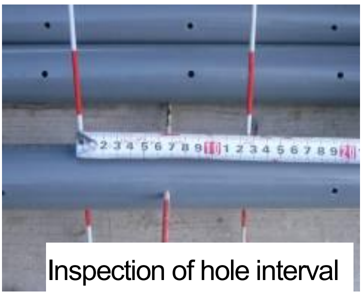
Drainage pipes are inserted by connecting pipes that have been divided into approximately 3 m lengths.

Before inserting a pipe, check the length and number of pipes to be inserted. At the same time, check the diameter of the pipe, the diameter of the drainage hole, and the spacing between them.

During insertion, make sure that all the pipes are inserted.

Insertion length is checked from the number of pipes inserted and the length of the ground surface as well as excavation length management.

Inspection of drainage pipe
(length, number, diameter)

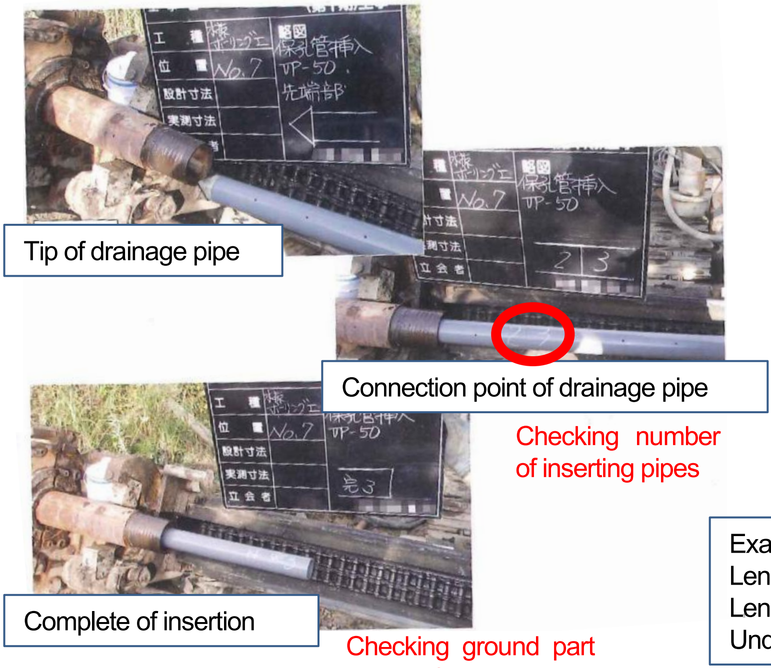


Inspection of hole interval

Inspection of drainage hole diameter

Figure 22 Case study of drainage pipe lemgth management

Insertion of drainage pipe



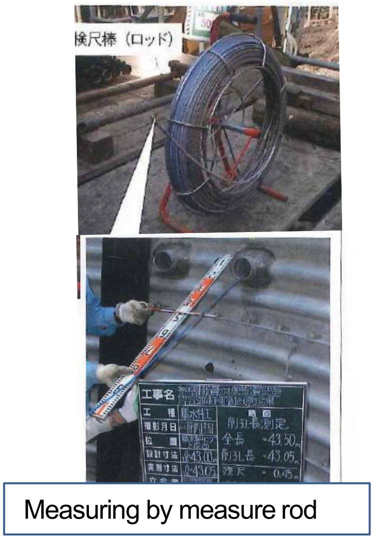
Tip of drainage pipe

Connection point of drainage pipe

Checking number of inserting pipes

Complete of insertion

Checking ground part length of pipe



Measuring by measure rod

Example
Length of pipe = 4.0m×3pc=12.0m
Length of ground part = 1.0m
Underground length = 11.0m

Figure 23 Case study of drainage pipe installing lemgth management

Dimension management requires visual confirmation by the supervisor as well as photo recording.

8.4 Points to note in quarity management

Quality control items in horizontal drainage boring correspond to quality control of materials used.

The applicable materials are as follows

PVC pipe: Using material approved by supervisor (client)

Mill Test Report of products

Concrete for basin: strength, materials, and mixtures etc.

8.5 Points to note in safety management

The most common accidents in boring construction are as follows

- Caught in machines, (rotating parts such as rods and casings)
- Pinching accidents, (at joints of rods and casings, guide rails, etc.)
- Falling accidents from scaffolds
- Falling accident of suspended load during loading/unloading

The following is contents of measures to be taken to avoid each accident.

(1) Satfey Management for being caught in machines

There have been confirmed cases of people getting caught in the casing rod as a result of accidents during drilling.

To avoid accidents, the following points should be considered

- Stay away from the rotating parts of the drilling machine when it is spinning.
- Keep the work floor tidy (to prevent contact with the rotating parts due to tripping and falling).
- Don't wear nylon rain gear (wet nylon rain gear tends to stick to the rod, and caught accidents have occurred).

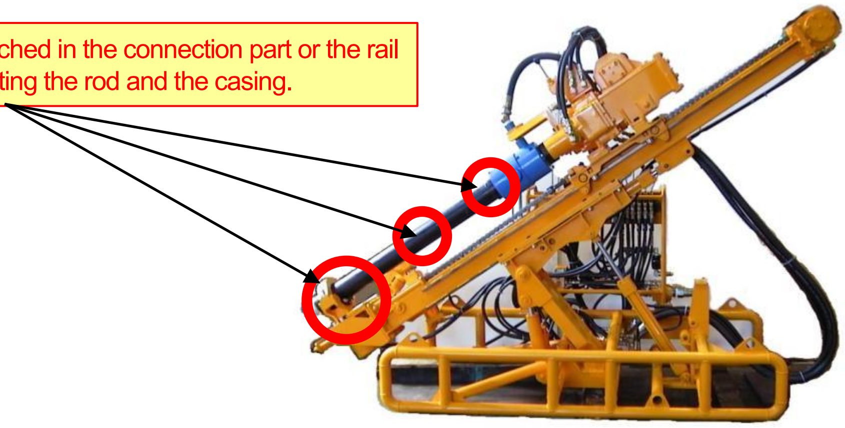
Figure 24 Case study of accident by caught in a spinning rod

(2) Satfey Management for pinching accidents

An accident that hand is pinched in the connection part or the rail has occurred, when connecting the rod and the casing.

To avoid accidents, the following points should be considered

- Observe the work procedure and confirm the signal with operator and worker.
- Keep your hand away from the connection part and the gap between the rail and the casing.



An accident that hand is pinched in the connection part or the rail has occurred, when connecting the rod and the casing.

Figure 25　Case study of pinching accidents

(3) Satfey Management for falling accidents from scaffolds

Accident that workers falling from scaffolds and and falling materials from scaffolds have resulted in human and property damage.

To avoid accidents, the following points should be considered

- Scaffolding should be safe for the weight of the boring machine.
- Install handrail and baseboard as shown in the figure on the right to prevent falling.
- Do not make any openings in the floor.

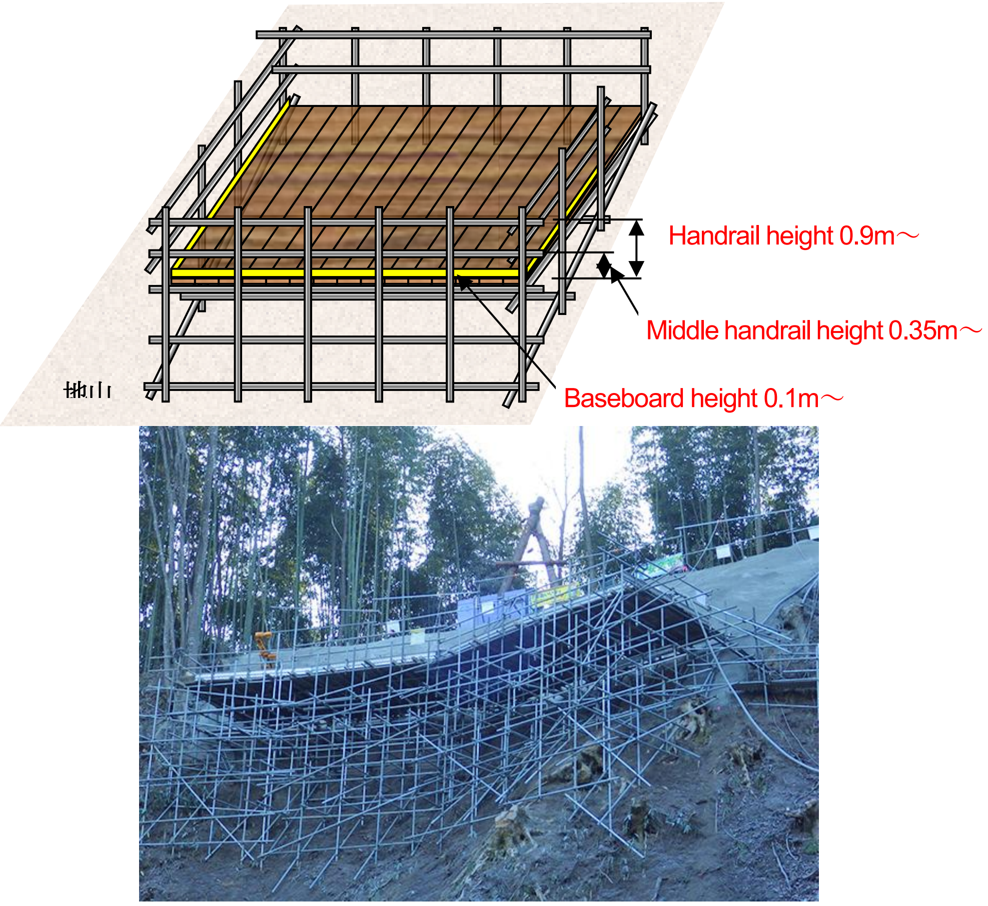


Figure 26　Case study of safety measure for falling accidents from scaffolds

(4) Satfey Management for Falling accident of suspended load during loading/unloading

Falling of suspended loads is often caused by the following

- Cutting of sling wire
- Misconnection of the sling wire
- Suspension of a load over the rated load

To avoid accidents, the following points should be considered

○Cutting of sling wire

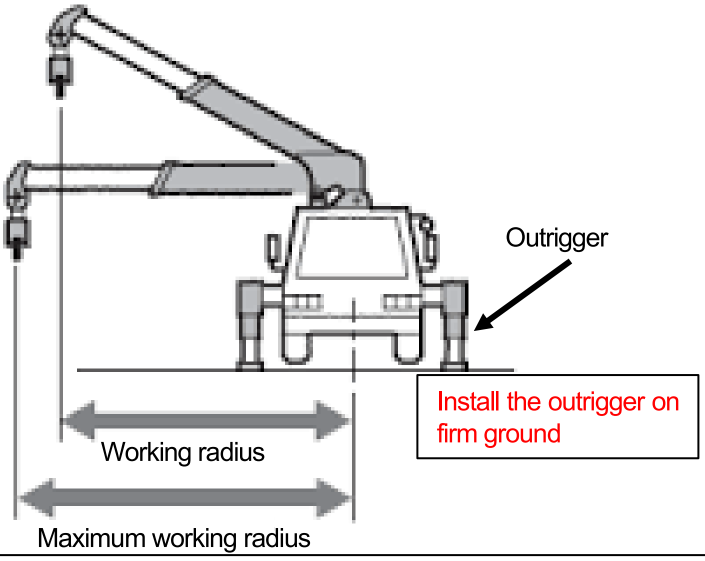
- Suspension of a load with less than the rated load of the wire.
- Check the wire and do not use defective wire.

○Misconnection of the sling wire

- Check the center of gravity of the load, suspending of load at good balance.
- Make sure that the wire attached to the load does not slip and come off.
- Suspension of a load with less than the rated load of the wire.
- Do not get close to the bottom of the suspension of load.

○Suspension of a load over the rated load of crane

- Suspending a load should be less than the rated load of the crane
- Install the outrigger on firm ground
- Stay away from under the suspended load
- Check the signal of the operator and the worker, and work according to the signal
- Do not work in strong winds.



Install the outrigger on firm ground

The rated load is determined by the working radius and the outrigger overhang width.

Figure 27 Crane load ratings and crane installation conditions

Annex 6

Manual for Monitoring and Maintenance of Countermeasure Structures of Small/Medium Size Slope Disasters Risk Sites

The Project for Control and Mitigation of Slope Disasters
in the Central District in Republic of Honduras

Manual for Monitoring and Maintenance of Countermeasure Structures of Small/Medium Size Slope Disasters Risk Sites

August 2023

AMDC
JICA Expert Team

Contents

Chapter 1. Introduction

1.1 Purpose of the manual

Slope stabilization facilities (countermeasure works) are facilities that contribute to slope stability, and if the function of the facilities decrease, it will not be possible to ensure slope stability.

It is important to maintain the facilities in order to maintain slope stability.

In maintaining the facility, it is important not only to confirm the condition of the facility and make repairs, but to check the condition of the target slope.

This manual describes the contents regarding to the confirmation of facility's condition (monitoring of facility) and maintenance of facility, as well as the confirmation of slope condition (monitoring slope), and describes the monitoring and maintenance methods that effectively link these two targets (facility and slope).

1.2 Monitoring concept

Slope stability can be kept by the health functioning of the installed facilities.

Likewise, the facilities of countermeasure that have been installed will gradually deteriorate and functions of countermeasure will gradually become reduce.

If a change in the slope condition occurs, it is necessary to determine whether the cause is due to a reduce in the function of the installed countermeasures or a change in the slope conditions, and to investigate and take action to the cause.

Especially in the case of landslide countermeasures, it is important to conduct monitoring of slope condition and facility functions in parallel in order to confirm each condition.

For monitoring of slope condition, the monitoring (groundwater level, tilt meter in borehole, etc.) and visual inspection is periodically conducted. (This monitoring method is shown in the investigation manual in Output 1.)

This manual describes the monitoring and maintenance methods for the installed facilities of countermeasure.

It also explains how to verify the result of slope condition monitoring and the monitoring results of the facility, and the maintenance to be implemented based on the results.

Chapter 2. Outline of facility monitoring

2.1 Facility monitoring procedure

Facility monitoring procedure is shown as following

It is important to conduct monitoring of slope condition and facility functions in parallel in order to confirm and verify each condition.

Then base on the result of verify, it should be implement repair (countermeasure) and continue to monitoring.

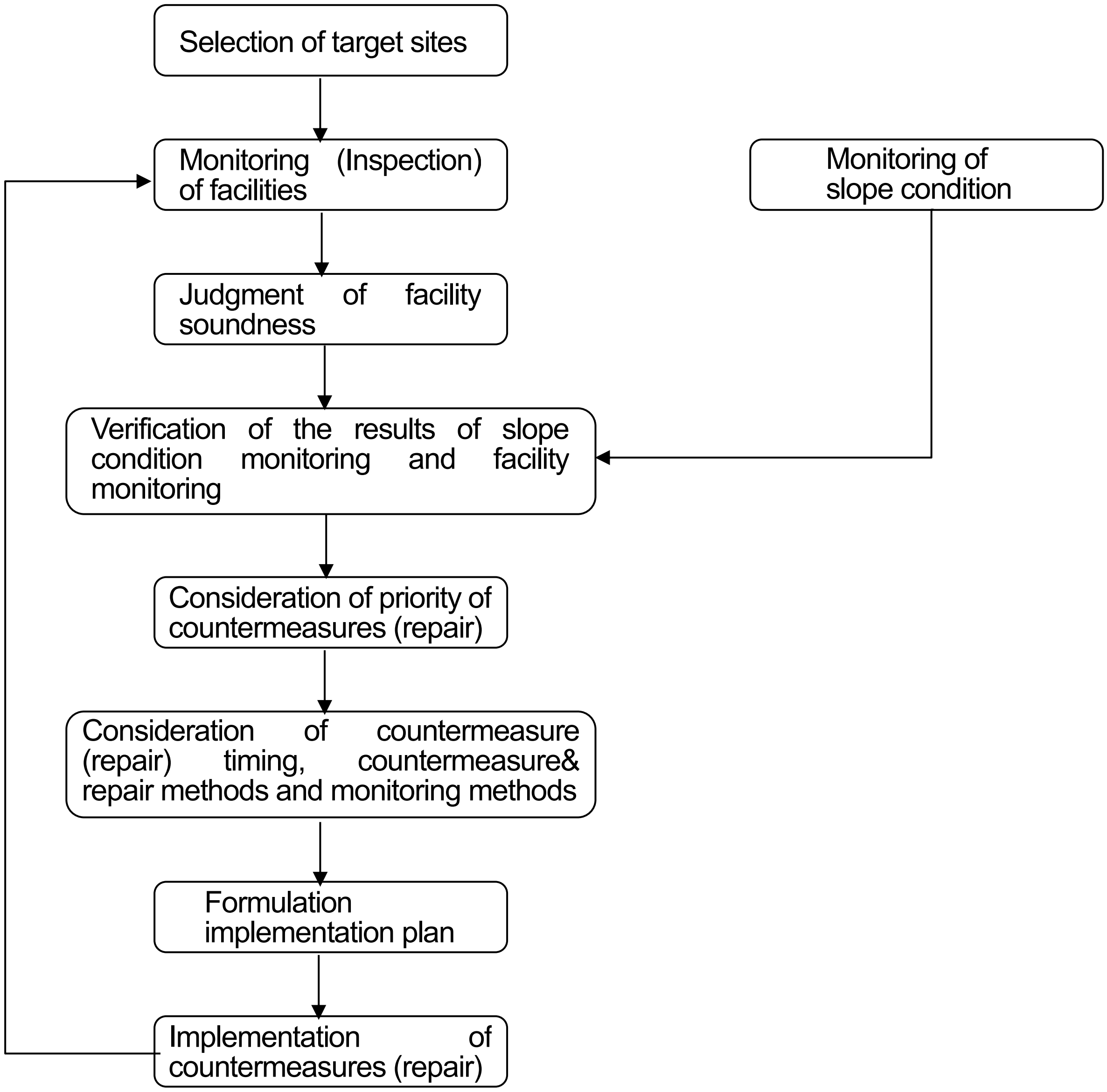


Figure 1 Facility monitoring procedure

2.2 Facility ledger

In order to implement monitoring and maintenance, it is should to select the target facilities.

In order to select facilities, it is essential to prepare a ledger of facilities that have been constructed in the past and to understand that what kind of facilities and where are located and their structures, etc.

The following points should be described and organized in the ledger

- General conditions of the target area
  (location, extent, landowner information, project process, disaster record, etc.)
- Location of installed facilities
  (plan view, longitudinal section, etc.)
- Information on each facility
  (construction type, size, construction year, structural drawings, photographs, etc.)

It is useful to organize this information using GIS in order to manage this ledger.

In addition, it is important to manage a ledger with the following information for maintenance

- Monitoring results : timing, results, and evaluation
- Repair plan based on the monitoring : repair, maintenance, renewal, etc.
- Repair results

It is important that this information be consolidated and used and updated in monitoring and maintenance execution.

Japanese case studies of facility ledger in Landslide prevention project are shown as following pages.

In Japan, when implementing landslide countermeasures, it is necessary to designate as landslide prevention zone by law the landslide block, the surrounding area where damage is expected, and the location where countermeasure works are to be constructed.

Therefore, it is necessary to organize the information on the designated landslide prevention zone in a ledger.

Following information are recorded in the ledger.

- General information of landslide
- Information of countermeasure works
- Information of lands set in the landslide control area and their landowners
- Information of sales/leases of lands that is provided for the implementation of countermeasure works.

Table 1 Case study of landslide prevention zone ledger (General contents)

Office name :

Landslide Prevention Zone Ledger

Ledger No. 1

Name of Landslide zone			○ ○ ○ ○				Location		○○State △△City □□			
Date of legal designation			2024/9/10				Zone No.		1			
Area of landslide prevention project zone (Area designated by law)			10.5			ha	Impact on River		○○River			
Outline of landslide prevention zone			Type of land				Building		Public Facilities			
			Cultivated land (ha)	Forest land (ha)	Residential land (ha)	Other (ha)	Private House (unit)	Other	Road	River	School, hospital, church	Other
	Inside of the zone	Landslide block area	2.0	1.0	4.0	1.5	30	5	200m		School 1 Hospital 1	
		Other area		2.0						○○river 300m		
	Outside of the zone	Preferred Area of Damage				0.5						
	Total		2.0	3.0	4.0	2.0						
	Landslide status		Current activity		Past activity		Depth of landslide		Slope gradient		Geological information	
			Active		Private houses and roads damaged on 1968/1/19		10m		10°		Tuff	
Relation to other legal designations			Not applicable									
Situation of disaster occurrence	Date of disaster	Name of the unusual weather event as triger of disaster	Fatalities	Injuries	Damaged houses (unit)	Activity situation (size)			Rainfall amount			Weather station
						Slope length (m)	Slope wide (m)	Amount of landslide soil (m3)	Continuous rainfall	Maximum daily rainfall	Maximum hourly rainfall	
	2022/9/25	Hurricane ○○	0	0	10	150	30	45000	200	150	50	○○city

Table 2 Case study of landslide prevention zone ledger (Facilities list)

Landslide Prevention Zone Ledger

Zone No.	1
Name of Landslide zone	○○

Landslide Prevention Facilities									
Location（Block）	Type of countermeasure	Name of facility	Administrator	Owner	Structure	Amount	Completion date	Whether or not the construction location is in a zone regulated by	Remark
A block	Horizontal drainage boring	HDB-1	AMDC	Tegucigalpa city	φ90mm L=30～40m	10pc	2024/1/20	NA	Gabion wall Catchment basin
A block	Horizontal drainage boring	HDB-2	AMDC	Tegucigalpa city	φ90mm L=30～50m	8pc	2024/2/20	NA	Gabion wall Catchment basin
A block	Channel	CH-1	AMDC	Tegucigalpa city	Concrete channel	45m	2024/3/12	NA	
B block	Horizontal drainage boring	HDB-3	AMDC	Tegucigalpa city	φ90mm L=40～45m	12pc	2023/9/20	NA	Gabion wall Catchment basin
B block	Horizontal drainage boring	HDB-4	AMDC	Tegucigalpa city	φ90mm L=25～40m	10pc	2023/10/30	NA	Gabion wall Catchment basin
B block	Channel	CH-2	AMDC	Tegucigalpa city	Concrete channel	45m	2023/11/19	NA	
B block	Gabion wall	RW-1	AMDC	Tegucigalpa city	H=3.0 W=1.5m	25m	2023/10/20	NA	
B block	Gabion wall	RW-2	AMDC	Tegucigalpa city	H=4.0 W=1.5m	35m	2023/11/15	NA	
B block	Gabion wall	RW-3	AMDC	Tegucigalpa city	H=3.0 W=1.5m	20m	2023/11/30	NA	
B block	Cutting slope		AMDC	Tegucigalpa city		100m2	2024/12/20	NA	Include Hydroseeding

In addition, a plan view and longitudinal section showing the countermeasure works and landslide profile (block, slip surface, etc.), a structural drawing of each countermeasure work, and a photograph of the completed work should be attached to the ledger.

Table 3 Case study of landslide prevention zone ledger (Construction History)

Landslide prevention work ledger

Zone No.	
Name of Landslide zone	○○

Year		Master plan			2020			2021			2022			2023			2024		
Project cost		HNL 50,000,000			HNL 8,400,000			HNL 8,900,000			HNL 10,900,000			HNL 10,900,000			HNL 10,900,000		
Construction cost		HNL 30,000,000									HNL 10,000,000			HNL 10,000,000			HNL 10,000,000		
Incidental construction cost		HNL 1,500,000									HNL 500,000			HNL 500,000			HNL 500,000		
Surveying, investigation, and design costs		HNL 10,000,000			HNL 8,000,000			HNL 2,000,000											
Land acquisition cost		HNL 5,000,000						HNL 5,000,000											
Compensation cost		HNL 1,500,000						HNL 1,500,000											
Administrative cost		HNL 2,000,000			HNL 400,000			HNL 400,000			HNL 400,000			HNL 400,000			HNL 400,000		
Contructor					○○Consultants			□□Consultants			○○Construction&Built ltd.			○○Construction&Built ltd.			○○Construction&Built ltd.		
Completion date					2020/12/20			2021/8/10			2022/12/15			2023/12/20			2024/12/10		
		Name of facility	Quantity	Unit	Name of facility	Quantity	Unit	Name of facility	Quantity	Unit	Name of facility	Quantity	Unit	Name of facility	Quantity	Unit	Name of facility	Quantity	Unit
Work item	Horizontal drainage boring			PC			PC			PC	HDB-1	10	PC			PC			PC
	Horizontal drainage boring			PC			PC			PC	HDB-2	8	PC			PC			PC
	Horizontal drainage boring			PC			PC			PC			PC	HDB-3	12	PC			PC
	Horizontal drainage boring			PC			PC			PC			PC	HDB-4	10	PC			PC
	Channel			m			m			m	CH-1	45	m			m			m
	Channel			m			m			m			m	CH-2	45	m			m
	Gabion wall			m			m			m			m			m	RW-1	25	m
	Gabion wall			m			m			m			m			m	RW-2	35	m
	Gabion wall			m			m			m			m			m	RW-3	20	m
	Cutting slope			m2			m2			m2			m2			m2		100	m2
Remark					Geological Survey Boring, Analysis, Design, Surveying			Land acquisition Relocation of Residence											

Table 4 Case study of landslide prevention zone ledger (Land for facility use list)

Landslide prevention facility site ledger

Zone No.	1
Name of Landslide zone	○○

Address	Category of land	Area (m2)	Date of Contract	Contractor		Contents of Contract	Date of registration	Remark
				Name of landowner	Address			
○○3-3	Forest	50.0	2021/10/10			Land Lease Agreements		
○○5-1	Wildlands	50.0	2021/10/15			Land Lease Agreements		
○○1-15	Cultivated land	30.0	2021/9/25			Land sale contract	2021/12/5	
○○3-1	Cultivated land	30.0	2021/9/25			Land sale contract	2021/12/5	
○○3-2	Residenti al land	50.0	2021/11/3			Land sale contract	2021/12/5	
○○4-1	Residenti al land	50.0	2021/11/3			Land sale contract	2021/12/5	
○○6-1	Residenti al land	50.0	2021/11/3			Land sale contract	2021/12/5	

Table 5 Case study of landslide prevention zone ledger (Prevention zone list)

Landslide Prevention Zone Land Ledger

Zone No.	1
Name of Landslide zone	○○

State	City	District	Address No.
Francisco Morazan	Tegucigalpa	○○	1-1,2-1,3,7-1,8,8-1,8-2,8-3,9-1,9-2,9-3
		□□	1-13,2-2,2-4,2-7,2-8,2-9,2-10,2-11,2-12,3-1,3-2,3-3,3-4,3-5,3-8,3-9
		△△	1-4,2-3,3,7-5,8,8-1,8-2,8-3,9-1,9-2,9-3
		※※	1-1,2-1,3,7-1,8,8-1,8-2,8-3,9-1,9-2,9-3
Remark			

It should be attached cadastral map of the area designated as a landslide prevention zone

2.3 Outline of monitoring

2.3.1 Monitoring type and timing

The types of monitoring is classified into four categories

< Daily monitoring >

During the daily management of landslide prevention facilities (patrols), it is conducted to check whether deformation of the facilities or not (due to aging, slope deformation, or other factors) is checked visually.

It is effective to conduct this monitoring during landslide observation (groundwater level, inclinometer in borehole, etc.)

Monitoring should be conducted during daily patrols and landslide monitoring

< Periodic monitoring >

It is conducted to check each facilities by visually inspect whether is deformation, aging, etc or not, and level of deformations.

It is confirmed and judged future risks that may be caused by deformation, etc.

Checking items are set based on the characteristics and purpose of the structure.

Monitoring is conducted once every 5 to 10 years. However, for facilities that are judged to be need observation or countermeasures in the soundness level evaluation of facilities, monitoring should be conducted at intervals of 5 years or less.

< Emergency monitoring >

After abnormal rainfall or earthquakes, it is conducted to check whether is deformation, aging, etc or not, and level of deformations.

Check contents is same as periodic monitoring

< Detailed monitoring >

It is conducted to confirm in more detail the level and causes of deformations confirmed in periodic and emergency monitoring. (In case that it is judged neccesarry to detailed monitoring in periodic and emergency monitoring)

Based on the monitoring results, it is judged whether or not to repair or renew the facilities.

2.3.2 Way of monitoring (Periodic and emergency monitoring)

For periodic and emergency monitoring, the appearance of the facility and the conditions surrounding the facility shall be checked and recorded on the monitoring form.

If any abnormality is found in the facility (except for minor ones), it shall be checked by method such as measurement, hammering test, observation, etc., adapted to the situation, if necessary. (Refer to chapter 3: Facility monitoring method)

During monitoring, the following points should be taken into consideration

1. In principle, it is checked for any problems in the facility and recorded them.
2. Photographs should be taken from the same angle and within the same range, etc., in order to grasp changes with the situation compared to the previous survey.
3. When taking photographs of deformation, it is better to use a measuring tape, pole, etc. to determine the extent of the deformation.
4. It is better to use a hammer or other simple instrument to check the situation, depending on the abnormality situation (hammer test etc.).

Hammer test is method of checking internal problems by hitting a structure with a hammer and determining the difference in sound.

It is used to check the internal problems of reinforced concrete, etc.

Examples of hammer test judgments are shown below

Table 6 Examples of hammer test judgments

Result of hammering sound	Assumed condition of concrete structure
High-pitched, clear sound is sounded during hammering (clear sound)	Sound (No abnormality)
Dull sound such as thumping, thudding, etc. （Dull sound)	Deteriorated, hollow near the surface.
Sounds of thinness (peel off) Commonly observed in Shotcrete deformations	Sound of separation (floating).

5. It is recorded the situation of the found abnormality, including its location, on the monitoring sheet. and photographs should also be attached to the monitoring sheet.
6. It is better to mark or rivet the measurement points where an abnormality is found in order to observe progress of abnormality. In monitoring, it is better to be measured of abnormal positions (change in distance between points of marking or rivet) and understood progress of abnormality quantitatively.

7. During the monitoring, it is better to carry as build drawing and the previous monitoring sheets to confirm the situation of abnormality and their progress.

The detail way of monitoring is described Chapter 3, taking into account the characteristics of each facility.

2.3.3 Monitoring items

Monitoring items for landslide protection works are as shown below. (It is focused on work items installed on the project in Honduras)

Details of monitoring items for each construction item and examples of deformities will be explained later.

Table 7 Monitoring items list

Work items	Part of facility	Damage (deformation) to be focused on	Considerations when monitoring
Horizontal drainage boring	Drainage pipe	Deterioration / corrosion, Damage / deformation	・It is checked the status of corrosion (steel) and deterioration (plastic) of drainage pipes due to aging. ・It is checked the status of damage and deformation of water drainage pipes due to landslide activity, etc.
		Pipe blockage	・It is checked for blockages (iron, bacteria, mud, algae) on the drainage pipe.
	Catchment basin	Deterioration / corrosion, Damage / deformation	・It is monitored visually whether is any deformation or not. ・It is better to measure and record the drainage amount from the drainage pipes. ・It is checked the status of corrosion of steel materials and deterioration of concrete and other materials due to aging. ・It is checked the status of damage and deformation of drainage pipe protection works and catchment basins due to landslide activity, etc.
		Deposit of sediment	・It is checked for deposits of sediment, etc. in the catch basin.
Drainage well	Main body	Deterioration / corrosion, Damage / deformation	・It is checked and record the location, size, and direction of any damage or deformation by going inside drainage well. ・During entry into drainage well for monitoring, it should be implement monitoring after securing safety for risk of oxygen deficiency, toxic gases, falls, etc. ・If not entry the interior, it is checked visually the main body for damage, rupture, or tilting, for waterlogging, and condition of the drainage pipe outlet clogging. ・It is better to measure and record the drainage amount of the drainage pipe (horizontal drainage boring in the well). ・It is recorded the location, scale, and direction of deformation and damage in the main body. In particular, the location and the direction of crack and deformation should be

			recorded, since they are important information for estimating how force is acted. ・It is recorded the location and scale of corrosion (steel material) and deterioration (concrete material) in the main body due to aging.
	Drainage pipe (Horizontal drainage boring)	Deterioration / corrosion, Damage / deformation	・It is checked the status of corrosion (steel) and deterioration (plastic) of drainage pipes due to aging. ・It is checked the status of damage and deformation of drainage pipes to well due to landslide activity, etc.
		Pipe blockage	・It is checked for blockages (iron bacteria, mud, algae) on the drainage pipe.
	Drainage pipe from well	Deterioration / corrosion, Damage / deformation	・It is checked the status of corrosion (steel) and deterioration (plastic) of drainage pipes due to aging. ・It is checked the status of damage and deformation of drainage pipes from well due to landslide activity, etc. ・It is checked waterlogging of well due to blockage of drainage pipe from well. ・The presence or absence of water leakage from the drainage pipe can be confirmed by comparing the amount of water at the inlet and outlet of the drainage pipe.
		Pipe blockage	・It is checked for blockages (iron, bacteria, mud, algae) on the drainage pipe from well.
	Safety facilities (Ladder, canopy, fence, doors, etc.)	Deterioration / corrosion, Damage / deformation	・It is checked the situation of corrosion, deterioration, damage, deformation, etc. of the facility.
Channel	Channel, catchment basin, drop work	Deterioration / corrosion, Damage / deformation	・It is checked visually for deformation. ・It is checked for corrosion of steel materials and deterioration of concrete and other materials due to aging. ・It is checked for damage and deformation of channel, catchment basin, and drop work due to landslide activity, etc.
		Deposit of sediment	・It is checked the condition of deposits of sediment (include trash, fallen tree, leaves, etc.) in channels, catchment basins, and drop works. (Confirm for sediments are not obstructing water flow or causing overflow.)
Retaining wall		Deformation, collapse, erosion, etc.	It is checked cracks / damage / deformation of structure and settlement / spring water / erosion at the foundation.
Slope protection work		Shotcrete	Deformation, collapse, cavity, etc. Slope condition

2.3.4 Soundness assessment procedure base on the monitoring result

Following figure shows the sequence of events from the implementation of monitoring to the determination of the soundness of the facility.

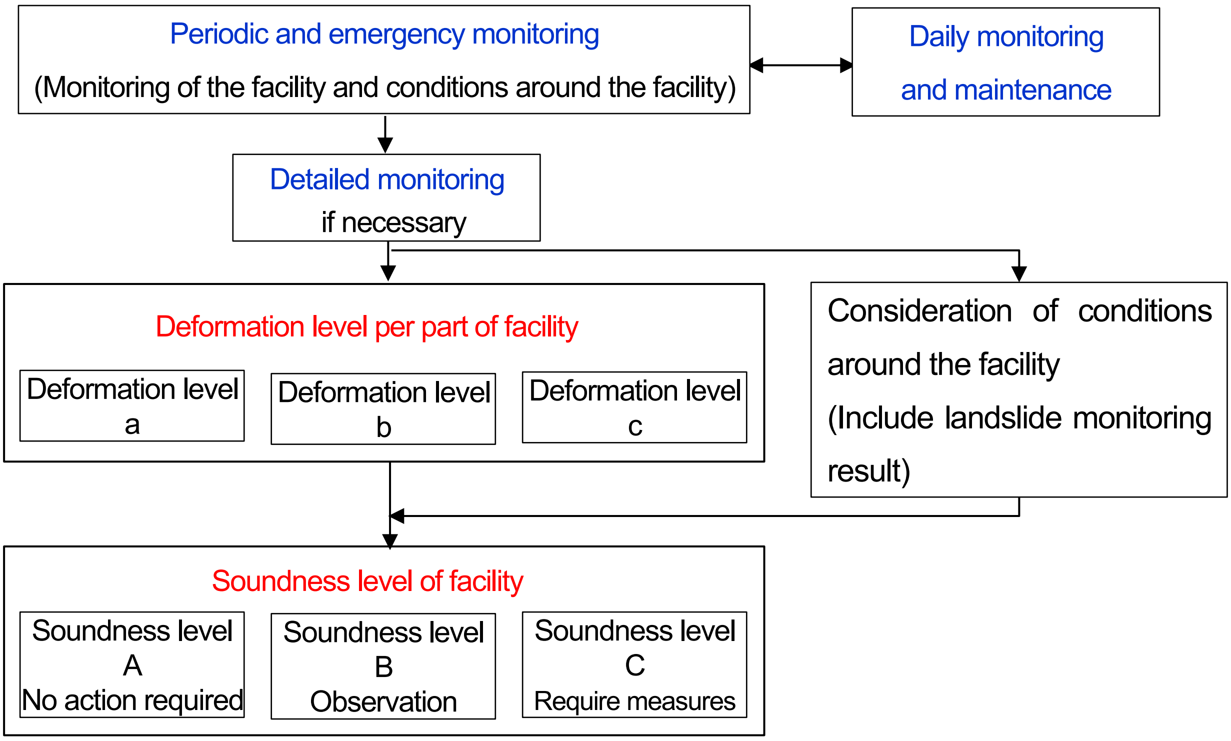


Figure 2 Work flow of monitoring

This flow shows the following work flow.

- Determine the level of deformation of each part of the facility based on various monitoring results.
- Base on the evaluation of deformation level, determine the soundness of the facility considering conditions around the facility and future risk of the target slope and landslide monitoring result.

The following is a guideline for the level of deformation and soundness.

Table 8 Judgment index of deformation level (subject part of facility)

Deformation level	Deformation condition
a	No damage or minor damage has occurred in the subject part, but there is no loss of performance due to the damage, and no countermeasures are required.
b	Damage has occurred in the subject part, but no significant deterioration in performance has occurred. Although there is currently no need to take immediate countermeasures, it is necessary to monitor the progress of the damage through periodic monitoring and emergency monitoring.
c	Due to damage has occurred to the subject part, there is loss of performance, or there is concern that the decrease of performance and strength.

Table 9 Judgment index of Soundness level

Soundness level	Deformation condition
A No action required	No damage has occurred to the facility, or minor damage has occurred but there is no loss of function or performance of the facility due to the damage, and no countermeasures are required.
B Observation	Although damage has occurred to the facility, there has been no loss of function or performance that would be a problem. Although there is no need to take measures at present immediately, there is a possibility that measures may be required in the future, so the progress of damage should be monitored through periodic or occasional monitoring, or measures should be taken from the viewpoint of preventive maintenance.
C Required measures	Due to damage of each part, performance and strength of facility is loss or decrease.

The functional decline is determined by considering the results of landslide monitoring (groundwater level, etc.), the deformation of the surrounding slopes, and structural stability.

Chapter 3. Facility monitoring method

3.1 Horizontal drainage boring

3.1.1 Structure of horizontal drainage boring

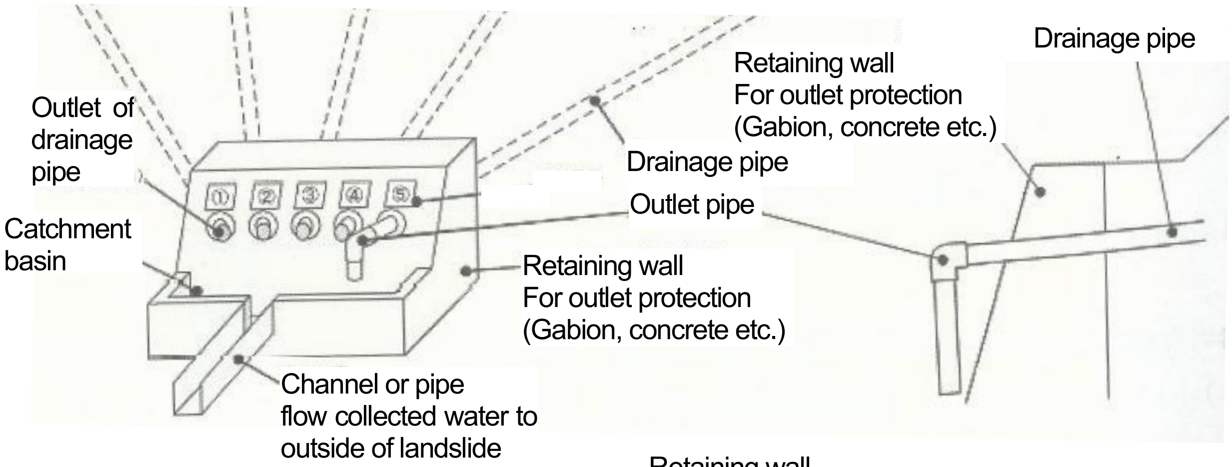


Figure 3 Case study in Honduras (Campo Cielo)

Table 10 Structure of horizontal drainage boring

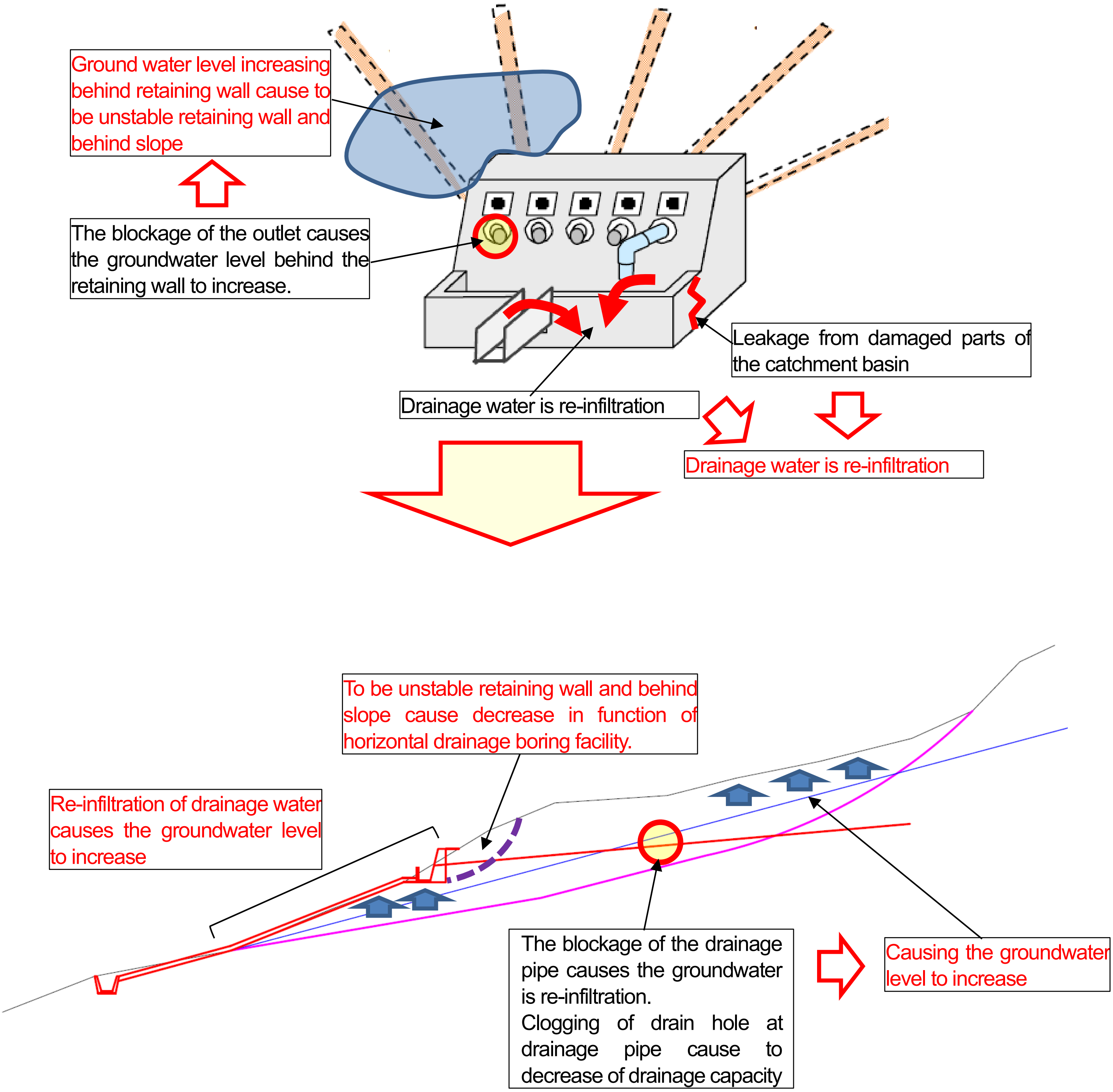
Item	Explanation
Drainage pipe	・Drilling into a landslide body and inserting a pipe with a diameter of 40 to 100 mm to drain groundwater. ・PVC pipes with strainers are often used.
Outlet pipe	・To led collected groundwater to the catch basin. ・PVC pipes are often used.
Retaining wall for outlet protection	・Retaining wall to protect the outlet of the drainpipe ・Generally used in concrete or gabion construction.
Catchment basin	・A facility for water drainaged from drainage pipes and leading it to channels and pipes. ・Generally this is attached with retaining wall for protection of outlets.
Channel, pipe	・Facilities that connect to main water channels, etc., in order to lead the water collected in the catchment basin out of the landslide area.

3.1.2 Decline in the function of horizontal drainage boring and its causes

The items that cause a decline in function and their impact on landslides are shown below.

Table 11 Decline in the function of horizontal drainage boring and its causes

Effectiveness and functions as a landslide countermeasure method	・Reduction of pore water pressure acting on the slip surface (including the effect to drain groundwater in the landslide body that is suplied to slip surface)				
Types of functional decline	・Decrease in water collection capacity (Drainage pipe) ・Decrease in flow capacity (Drainage pipe) ・Decrease in drainage capacity (Basin, channel, pipe)				
Phenomenon Indicating functional decline	Item	Damage, cutting, deterioration, deformation of drainage pipes.	Blockage of drainage pipe, clogging of drain hole at drainage pipe.	Deformation, blockage, and buried of retaining wall, catchment basin, channel, pipes, etc.	Ground moisture and spring water occur around the facility.
	Content	Damage of pipe caused by landslide activity, deformation due to aging or corrosion of pipe.	Decrease in water collection capacity due to clogging of drainage holes, decrease in flow capacity due to blockage of drainage pipes.	Small collapses of surrounding slopes due to water leakage, deformation and tilting of facilities due to scouring of the facility foundation. Reduction in flow capacity due to deposit soil in the catchment basin and channel.	Due to the deterioration of the facility, the groundwater level in the surrounding area increase.
Conditions that may occur due to functional decline	The drainage pipe's function of collecting and draining groundwater is reduced. Leakage and re-percolation of the water collected in the pipe due to blockage and broken of pipe.			The collected water leaks and re-percolates into the landslide body.	
Impacts on landslides	Reduction drainage capacity by blockages and leaks in drainage pipes and the leakage and re-percolation of collected water lead to an increase in the groundwater level, which in turn leads to a decrease in the stability of landslides.				



Ground water level increasing behind retaining wall cause to be unstable retaining wall and behind slope

The blockage of the outlet causes the groundwater level behind the retaining wall to increase.

Leakage from damaged parts of the catchment basin

Drainage water is re-infiltration

Drainage water is re-infiltration

To be unstable retaining wall and behind slope cause decrease in function of horizontal drainage boring facility.

Re-infiltration of drainage water causes the groundwater level to increase

The blockage of the drainage pipe causes the groundwater is re-infiltration.
Clogging of drain hole at drainage pipe cause to decrease of drainage capacity

Causing the groundwater level to increase

Figure 4　The impaction to landslide stability by decrease in functionality of facility.

3.1.3 Evaluation criteria for deformation level (Periodic and emergency monitoring)

The items that cause a decline in function and their impact on landslides are shown below.

Table 12 Evaluation criteria for deformation level (Horizontal drainage boring)

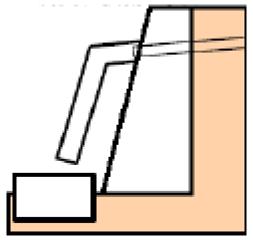
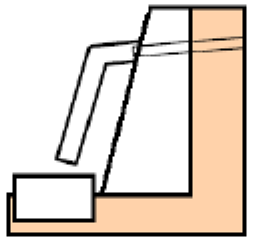
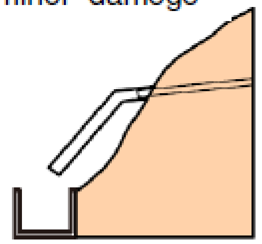
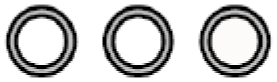
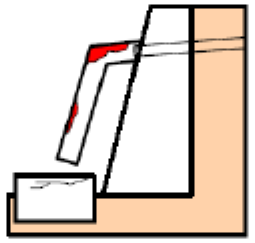
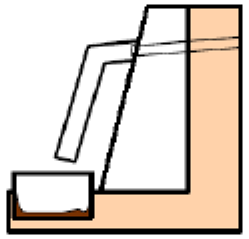
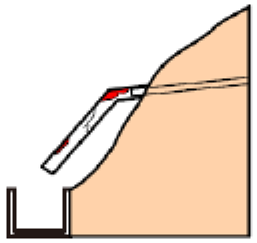
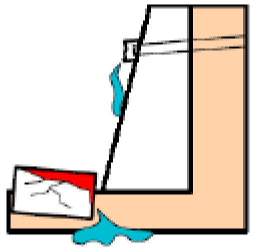
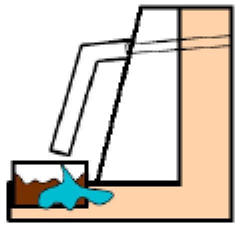
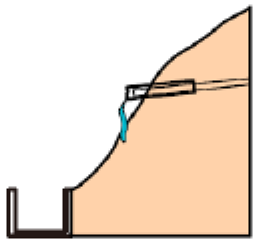
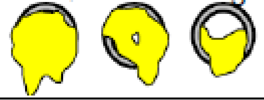
Deformation level		Horizontal drainage boring			
		Deformation of retaining wall, catchment basin, channel and pipe	Sedimentation of catchment basin and channel	Deformation of outlet pipe	Blockage of drainage pipe
a	Minor or no damage	No or minor damege 	No sedimentation 	No or minor damege 	･No blockages ･Small amount blockage at the oultet of drainage pipe ･Groundwater drainage has been confirmed 
b	There is damage, but it has not resulted in a decline in function or performance	Some dameges, no leaking 	Some sedimentation, no overflow 	Some dameges, no leaking 	･Blockage in most of the drainage pipes (generally less than 25% of outlet area of each drainage pipe) ･Groundwater drainage has been confirmed 
c	There is a decrease in function or performance	Leaked due to dameges 	Overflow due to sedimentation 	Most of them are damaged 	･Largr amount blockage in most of the drainage pipes (generally more than 25% of outlet area of each drainage pipe) ･It seems that groundwater drainage stopped due to blockage 
Evaluation Points		･Decrease of drainage capacity, leakage of drainage water, and overflowing water cause to increase the groundwater level and to be unstable of landslides. ･Data of groundwater observation and groundwater drainage volume observation is useful information for evaluating the soundness of facility.			
		There is a risk that the drainage water from the horizontal drainage system may not be collected or that the collected water may leak.	There is risk of re-infiltration into landslide body of overflowing water.	There is risk that it is impossible to collect drainage water into the catchment basin.	Blockage of the drainage pipe causes a decrease in drainage capacity and re-infiltrate drained groundwater.
Points to note for monitoring		･Check for any changes by visual inspection. ･It is desirable to record the drainage volume.			
		･Check the condition of corrosion of steel materials and deterioration of concrete and other materials due to aging. ･Check the condition of damage and deformation of retaining walls and catchment basins due to landslide activity,	･Check the condition of sedimentation of soil, plant remains, trash,etc. in the catchment basin.	･Check the condition of corrosion of steel materials and deterioration of concrete and other materials due to aging. ･Check the condition of damage and deformation of retaining walls and catchment basins due to landslide activity,	･Check for blockages situation in the water outlet.

Table 13　Monitoring Case Studiy (Outlet drainage pipe)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No blockages ・Small amount of blockage at the oultet of drainage pipe ・Groundwater drainage has been confirmed	
b There is damage, but it has not resulted in　decline in function	・Blockage in most of the drainage pipes (generally less than 25% of outlet area of each drainage pipe) ・Groundwater drainage has been confirmed	
c There is decrease infunction	・Largr amount blockage in most of the drainage pipes (generally more than 25% of outlet area of each drainage pipe) ・It seems that groundwater drainage stopped due to blockage	

Table 14　Monitoring Case Studiy (Catchment basin)

Deformation level	Points to note for monitoring	Situation phot
a Minor or no damage	No sedimentation	
b There is damage, but it has not resulted in　decline in function	Some sedimentation, no overflow	
c There is decrease infunction	Overflow due to sedimentation	

3.1.4 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Table 15 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Soundness level	Deformation condition	Countermeasure
A No action required	No damage	・Continue to monitor
B Observation	In case that although more than one case level b deformation is observed in the drainage pipe, retaining wall, catchment basin, or surrounding slope, but there is no relationship between the each deformations or progressive and it is judged that there is no functional decrease at present.	・During periodic monitoring, it is monitored the progress of any deformations. ・In some cases, it is considered the frequency and timing of periodic monitoring.
C Required measures	・Deformation level is c. ・There are multiple deformation level b and these deformations are caused by the same factor or these deformation is progressing.	Necessary detailed monitoring is conducted, and repair work and emergency measures are considered and implemented.

During judgment of soundness, it is important to consider result of landslide monitoring (groundwater level, rainfall amount, inclinometer, drainage water amount etc.)

Table 16 Case study of monitoring sheet (Periodic and emergency monitoring)

Site		Campo Ciero	Landslide Block	L-1
Construction year		2002	Structure No.	No.1
Structure specifications	Drainage pipe	PVC pipe	Report No.	1
	Retaining wall	Gabion	Monitoring date	2024/11/11
	Catchment basin	Concrete	Organization conducting monitoring	JET
	Outlet Channel	Flexble pipe	Name of person conducting monitoring	Hotaka Aoki

Item		Deformation	Comment
Drainage pipe	Blockage	c	6pc pipe are blockaged at outlet(over 50% area of pipe outlet)
	Breakage	a	No damege
Retaining wall	Breakage	a	No damege
Catchment basin	Breakage	a	No damege
	Blockage	b	Some sedimentation, no overflow
Channel(Pipe)	Breakage	a	No damege
	Blockage	a	No sedimentation
Surround slope	Breakage	a	No deformation

		Comment
Judgement	A : No action required	Due to the significant blockage of the drainage pipe outlet, detailed monitoring will be carried out in order to determine the need for cleaning work or other repairment. No deformation was observed in other parts, and daily monitoring will continue to be carried out.
	B : Observation	
	[✓ C : Reruired measures]	

Drawing & Photo


Outlet blockage


Outlet blockage

3.1.5 Detail monitoring

Items that can be checked during periodic monitoring (described in the section 3.1.3) are limited to those that can be seen with the visual range of the ground surface.

The purpose of the detailed monitoring of the horizontal drainage boring is to check for any deformation (blockage, clogging, breaking, etc.) in the drainage pipe.

This content introduce the methods of detailed surveys conducting in Japan.

The following methods are used for monitoring.

Visual inspection : Checking the stuation of blockage at the drainage pipe outlet. (Same as periodic and emergency monitoring)

Measuring by measurement rod : Inserting a measuring rod into the drainage pipe to check for blockage or rupture and the depth of any blockage or rupture.

Borehole camera survey : A small CCD camera is inserted into the pipe to take photographs of the inside to check for blockages and breaks.

Drainage rate measurement : The drainage rate of groundwater drainaged through the drainage pipe is checked. When cleaning inside of pipe is to be carried out, this data is used to compare the amount of wastewater before and after cleaning.

In general, if it becomes necessary to check the internal condition of the pipe in more detail as a result of measuring by measuring rod, a borehole camera survey is carried out.

Here, it is explained measuring by measurement rod and borehole camera survey.

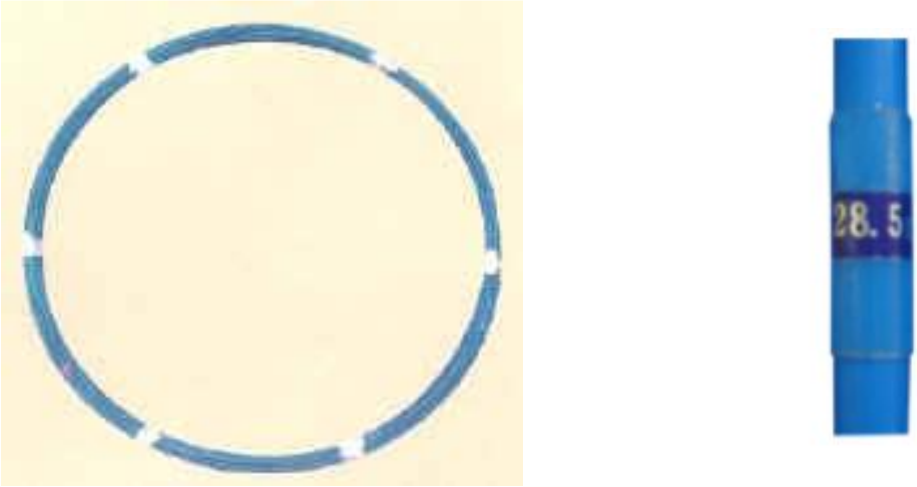
（1）Measuring by measurement rod

Measuring by measurement rod is a method of inserting a measurement rod into the drainage pipe and checking whether it can be inserted to the planned depth.

It is also used to check the depth at which insertion becomes difficult or impossible due to blockage

In Japan, measurement rods are prepared for borehole surveys, and monitoring is generally carried out using these rods.

Measurement rod prepared in Japan is shown following.



Measurement rod (storage) Scale at the rod

Figure 5 Measurement rod prepared in Japan

Measurement rods are made of glass fiber and are around 6mm in diameter

The standard length is 100m (maximum 200m), and as shown in the photo above, it has a scale marked in 50cm increments, so it is possible to measure the depth of insertion of the rod

When stored, it can be coiled as shown in the photo, making it easy to transport.

The monitoring method is inserting a measurement rod into the drainage pipe to check the depth to which it can be inserted

Before insertion, it is necessary to know the length of each drainage pipe

If it is not possible to insert the rod to the planned depth, it is judged that there is a problem due to blockage or breaking of the pipe.

If it is felt friction when inserting due to a blockage of slime, record the depth.

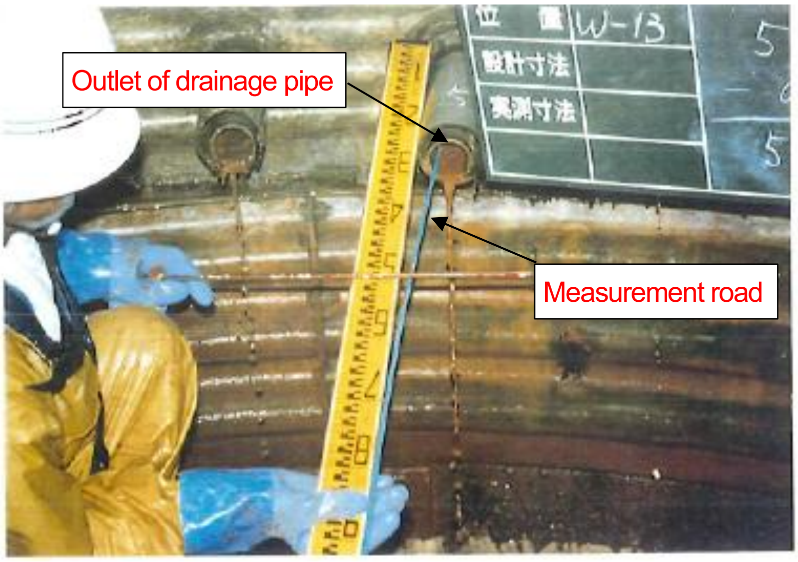
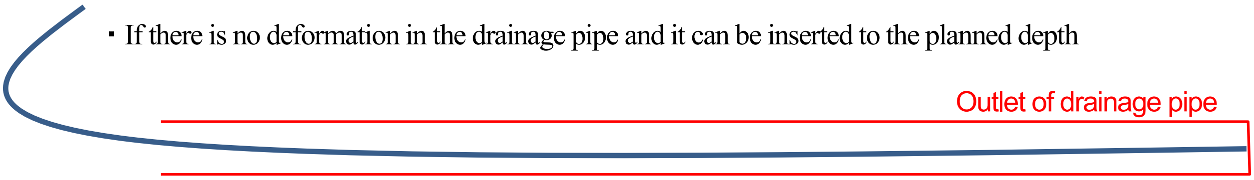
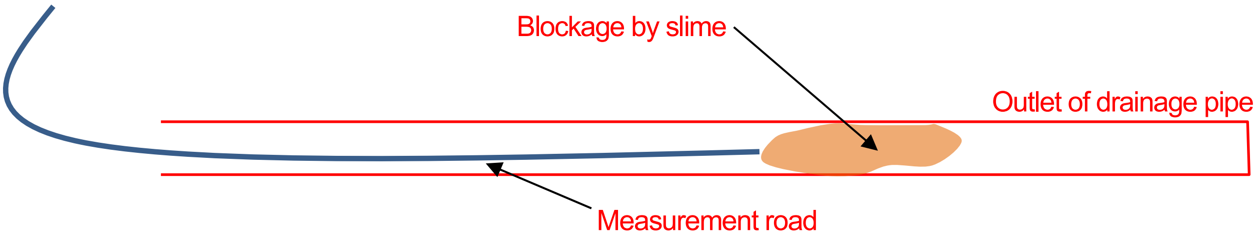


Figure 6　Monitoring situation (Case study of horizontal dranage boring in drainage wel)

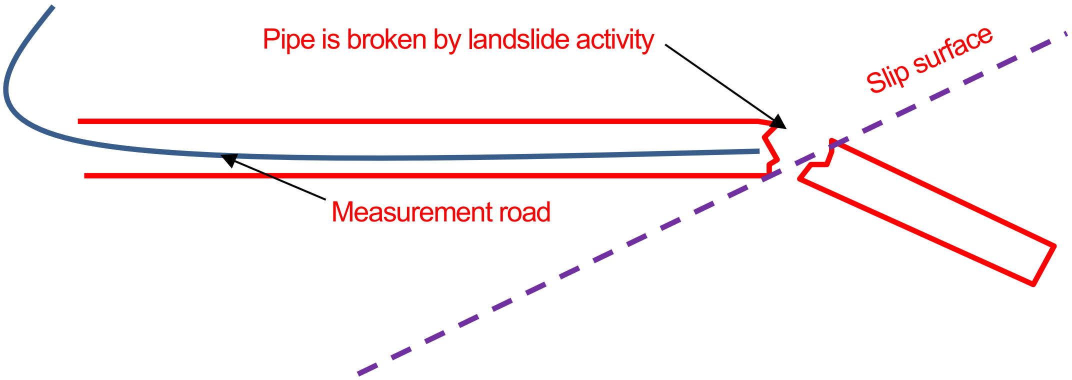
- If there is no deformation in the drainage pipe and it can be inserted to the planned depth



- If it is blocked by slime, it may be difficult to insert or impossible to insert.
  Record the depth at which it is impossible to insert or difficult to insert.
  If it is difficult to insert, try to insert to the planned depth if possible.



- If it breaks, it will clearly be impossible to insert (the feeling when inserting is different from slime blockage)



（2）Evaluation of the results of the detailed monitoring

During detailed monitoring, monitoring of the drainage pipe outlet (blockage, damage) and monitoring inside the drainage pipe will be carried out.

Evalution of monitoring result is shown the following tables.

○Outlet of drainage pipe　(Visual inspection)

Table 17　Deformation evalution of each drainage pipe (Outlet)

Deformation level		Situation of deformations
Blockage at outlet of drainage pipe	Level 1	No blockage
	Level 2	Small amount slime at outlet of drainage pipe.
	Level 3	Blockage of the drainage pipes (less than 25% area of outlet of drainage pipe)
	Level 4	Blockage of the drainage pipes (25～50% area at outlet of drainage pipe)
	Level 5	Blockage of the drainage pipes (50% or more area at outlet of drainage pipe)
Deformation at outlet of drainage pipe	Level 1	No damage
	Level 2	Minor damage
	Level 3	Significant damage

Table 18 Deformation evalution of each drainage pipe group (Outlet)

Deformation level		Evalution of deformations
Blockage at outlet of drainage pipe	a	If the deformation of all the pipe outlets in the group is Level 1 to 3
	b	If the number of deformation level 4 or 5 pipe outlets are less than 50% of the total number in the group.
	c	If the number of deformation level 4 or 5 pipe outlets are 50% or more of the total number in the group.
Deformation at outlet of drainage pipe	a	If the deformation of all the pipe outlets in the group is Level 1 to 2
	b	If the number of deformation level 3 pipe outlets are less than 50% of the total number in the group.
	c	If the number of deformation level 3 pipe outlets are 50% or more of the total number in the group.

○Drainage pipe (Measuring by measurement rod)

Table 19 Deformation evalution of each drainage pipe (Inner of pipe)

Deformation level		Situation of deformations
Blockage at inner of drainage pipe	Level 1	If there is no deformation in the drainage pipe and it can be inserted to the planned depth
	Level 2	It can be inserted to the planned depth, but it is felt friction when inserting due to a blockage of slime.
	Level 3	If it is not possible to insert the rod to the planned depth

Table 20 Deformation evalution of each drainage pipe group (Inner of pipe)

Deformation level		Evalution of deformations
Blockage at inner of drainage pipe	a	If the deformation of all the pipe outlets in the group is Level 1 or 2
	b	If the number of deformation level 3 pipes are less than 50% of the total number in the group.
	c	If the number of deformation level 3 pipes are 50% or more of the total number in the group.

If pipes with Level 2 or 3 evaluations are confirmed, it is desirable to conduct monitoring using borehole camera survey.

(3) Momitoring by borehole camera

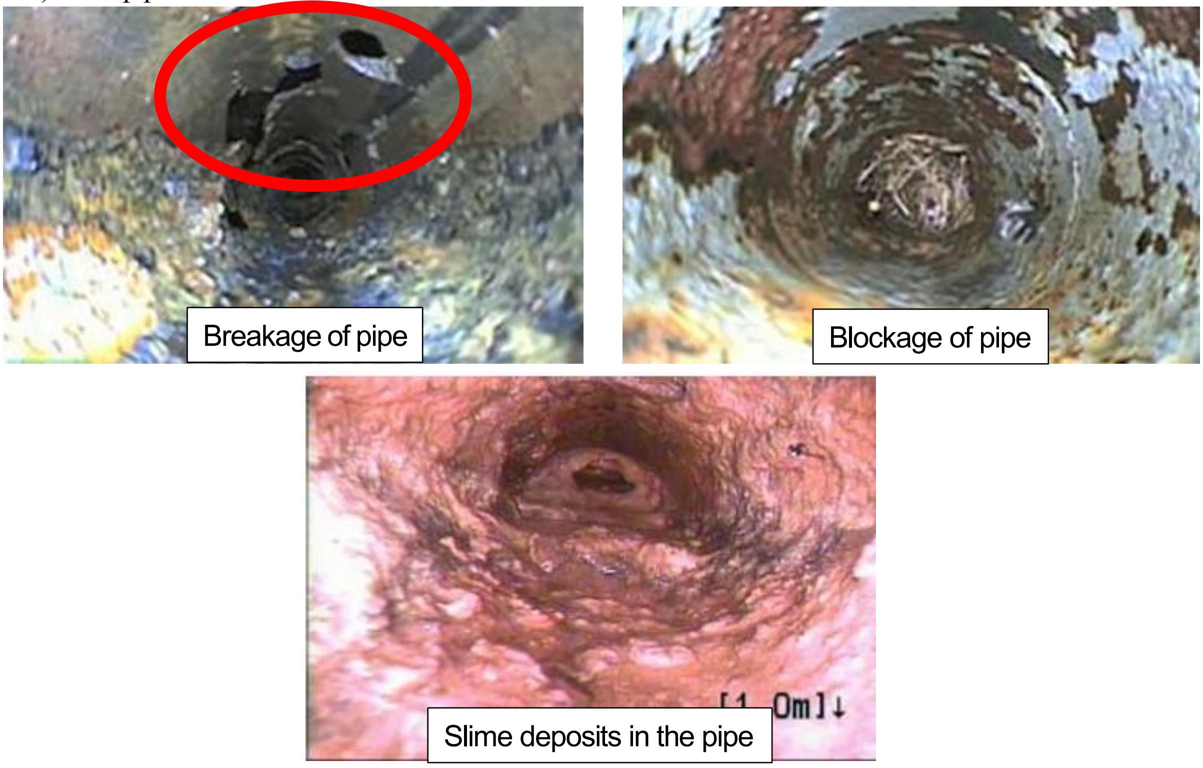
The borehole camera survey directly confirms the blockage and breakage conditions inside the drainage pipe using images from the borehole camera.

It is sometimes carried out before and after the drainage pipe cleaning work to check the effectiveness of the cleaning work.

The following are examples of deformation monitoring using an borehole camera in Japan.

Figure 7 CCD camera for borehole monitoring

A CCD camera with a scale on the cable or CCD camera with measuring system attached cable drum is inserted into the drainage pipe to check and record any deformation (slime deposits, blockages, breakages, etc.) in the pipe.



Breakage of pipe

Blockage of pipe

Slime deposits in the pipe

Figure 8 Monitoring result

○Evaluation of monitoring result by borehole camera

Table 21 Deformation evalution of each drainage pipe (Borehole camera)

Deformation level	Situation of deformations
Level 1	No deformation or minor deformation
Level 2	Slime deposits and pipe blockages caused by slime have been confirmed, but it is expected that the function can be restored by cleaning.
Level 3	Blockage by plant roots is observed, but there is no damage to the pipe. Sediment inflow from the drainage hole of pipe is significant, and functional restore by cleaning cannot be expected for a long period of time.
Level 4	Blockage or damage due to corrosion of the pipe, etc. is confirmed. Damage to the pipe due to plant roots, etc. is confirmed.
Level 5	The pipe is broken due to landslide activity.

Table 22 Deformation evalution of each drainage pipe group (Borehole camera)

Deformation level	Situation of deformations
a	Only level 1
b	If the number of deformation level 2,3 pipes are less than 50% of the total number in the group. If the number of deformation level 4,5 pipes are less than 20% of the total number in the group.
c	If the number of deformation level 2,3 pipes are 50% or more of the total number in the group. If the number of deformation level 4,5 pipes are 20% or more of the total number in the group.

(4) Overall evaluation

Table 23 Overall evaluation and measure in monitoring of horizontal drainage boring.

Deformation level	Overall evaluation	Measures
A	In case that all evaluation is level a	Continue periodic monitoring
B	In case that evaluation level is b or a	<Follow-up observation> Increase the frequency of periodic monitoring. Conduct detailed inspections during periodic monitoring to check for any progression of deformations.
C	In case that evaluation level c is include	<Take measures> Consider and implement repair work and emergency measures.

Judgment of implememtain of repair or reinstallation (include cleaning) should to be considered with monitoring result pf landslide activity (groundwater level, rain amount, borehole inclinometer, etc.)

Refer to chapter.4

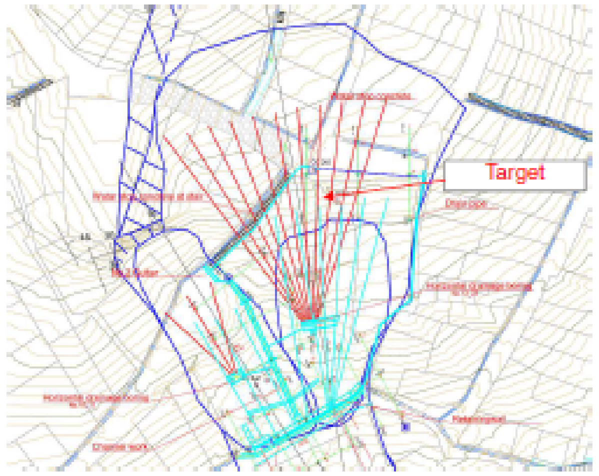
Case study of the detailed monitoring results and evaluation table for horizontal drainage boring is shown at next page.

Table 24 Case study of monitoring sheet (Detailed monitoring)

<table>
<tr><td>Site</td><td>Campo Ciero</td><td>Landslide Block</td><td>L-1</td><td>Structure No.</td><td>No.1</td></tr>
<tr><td>Construction year</td><td colspan="3">2022</td><td>Report No.</td><td>1</td></tr>
<tr><td rowspan="4">Structure specifications</td><td>Drainage pipe</td><td colspan="2">PVC pipe</td><td>Drainage pipe size</td><td>2 inch</td></tr>
<tr><td>Retaining wall</td><td colspan="2">Gabion</td><td>Monitoring date</td><td>2024/11/11</td></tr>
<tr><td>Catchment basin</td><td colspan="2">Concrete</td><td>Organization conducting monitoring</td><td>JET</td></tr>
<tr><td>Outlet Channel</td><td colspan="2">Flexble pipe</td><td>Name of person conducting monitoring</td><td>Hotaka Aoki</td></tr>
</table>

<table>
<tr><td rowspan="2">Structure items</td><td rowspan="2">Monitoring items</td><td rowspan="2">No.,
length
Evaluation items</td><td>No.1</td><td>No.2</td><td>No.3</td><td>No.4</td><td>No.5</td><td>No.6</td><td>No.7</td><td>No.8</td><td>No.9</td><td>No.10</td><td colspan="11" rowspan="2">Evaluation of deformation level</td></tr>
<tr><td>50m</td><td>50m</td><td>50m</td><td>50m</td><td>50m</td><td>50m</td><td>50m</td><td>50m</td><td>50m</td><td>50m</td></tr>
<tr><td rowspan="4">Outlet of pipe</td><td rowspan="4">Visual inspection</td><td>Blockage level</td><td>1</td><td>2</td><td>2</td><td>3</td><td>4</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td rowspan="2">Blokege level total</td><td>Level 1</td><td>Level 2</td><td>Level 3</td><td>Level 4</td><td>Level 5</td><td>Amount of level 4,5</td><td>Ratio</td><td>Deformation level(group)</td><td></td><td></td></tr>
<tr><td>Blockage material</td><td></td><td colspan="8">Reddish-brown slime</td><td></td><td>1 pc</td><td>3 pc</td><td>2 pc</td><td>2 pc</td><td>1 pc</td><td>3</td><td>30%</td><td>b</td><td></td><td></td></tr>
<tr><td>Deformation level</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td rowspan="2">Deformation level total</td><td>Level 1</td><td>Level 2</td><td>Level 3</td><td></td><td></td><td>Amount of level 3</td><td>Ratio</td><td>Deformation level(group)</td><td></td><td></td></tr>
<tr><td>Deformation situasion</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>10 pc</td><td>0 pc</td><td>0 pc</td><td></td><td></td><td>0</td><td>0%</td><td>a</td><td></td><td></td></tr>
<tr><td rowspan="7">Inner of pipe</td><td rowspan="2">Drainage amount measurement</td><td>During monitoring (L/min)</td><td>0.1</td><td>0.2</td><td>0.3</td><td>0.2</td><td>0.4</td><td>0.6</td><td>0.6</td><td>0.2</td><td>0.1</td><td>0.1</td><td rowspan="2">Drainage amount total</td><td>2.8</td><td>L/min</td><td colspan="8" rowspan="2">After inner pipe cleaning, measuring drainage amount will be implemented.</td></tr>
<tr><td>After creaning (L/min)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>0.0</td><td>L/min</td></tr>
<tr><td rowspan="3">Measuring by measurement rod</td><td>Insert length (m)</td><td>50m</td><td>50m</td><td>50m</td><td>50m</td><td>40m</td><td>45m</td><td>38m</td><td>40m</td><td>50m</td><td>50m</td><td rowspan="3">Blokege level total</td><td>Level 1</td><td>Level 2</td><td>Level 3</td><td></td><td></td><td>Amount of level 3</td><td>Ratio</td><td>Deformation level(group)</td><td></td><td></td></tr>
<tr><td>Blockage level</td><td>1</td><td>2</td><td>2</td><td>2</td><td>3</td><td>3</td><td>3</td><td>3</td><td>2</td><td>1</td><td>1 pc</td><td>1 pc</td><td>3 pc</td><td></td><td></td><td>4</td><td>40%</td><td>b</td><td></td><td></td></tr>
<tr><td>Feeling when inserting</td><td></td><td>felt friction 22m～</td><td>felt friction 15m～</td><td>felt friction 25m～</td><td>felt friction 12m～</td><td>felt friction 8m～</td><td>felt friction 11m～</td><td>felt friction 15m～</td><td>felt friction 18m～</td><td></td><td colspan="10">Because the blockage caused by slime was significant, it's checked inside of the pipe using borehole camera.</td></tr>
<tr><td rowspan="2">Borehole camera</td><td>Blockage level</td><td>1</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>2</td><td>1</td><td rowspan="2">Blokege level total</td><td>Level 1</td><td>Level 2</td><td>Level 3</td><td>Level 4</td><td>Level 5</td><td>Amount of level 2,3</td><td>Ratio</td><td>Amount of level 4,5</td><td>Ratio</td><td>Deformation level(group)</td></tr>
<tr><td>Situation</td><td></td><td></td><td></td><td></td><td colspan="4">Due to the distribution of slime, it is not possible to insert a camera at depths more than 38～45m.</td><td></td><td></td><td>2 pc</td><td>8 pc</td><td>0 pc</td><td>0 pc</td><td>0 pc</td><td>8</td><td>80%</td><td>0</td><td>0%</td><td>c</td></tr>
</table>

Drawing & Phot



<table>
<tr><td rowspan="3">Overall evaluation</td><td>A Continue periodic monitoring</td><td rowspan="3"><Comments>
There is no confirmed breakage at the pipe or surrounding facilities.
As there is a lot of slime distributed inside the pipe, it is necessary to carry out inner pipe cleaning.
When carrying out the cleaning, it's proposed comparing the amount of drainage and comparing the groundwater level, before and after the cleaning.</td></tr>
<tr><td>B Follow-up observation</td></tr>
<tr><td>[✓ C Take measure]</td></tr>
</table>

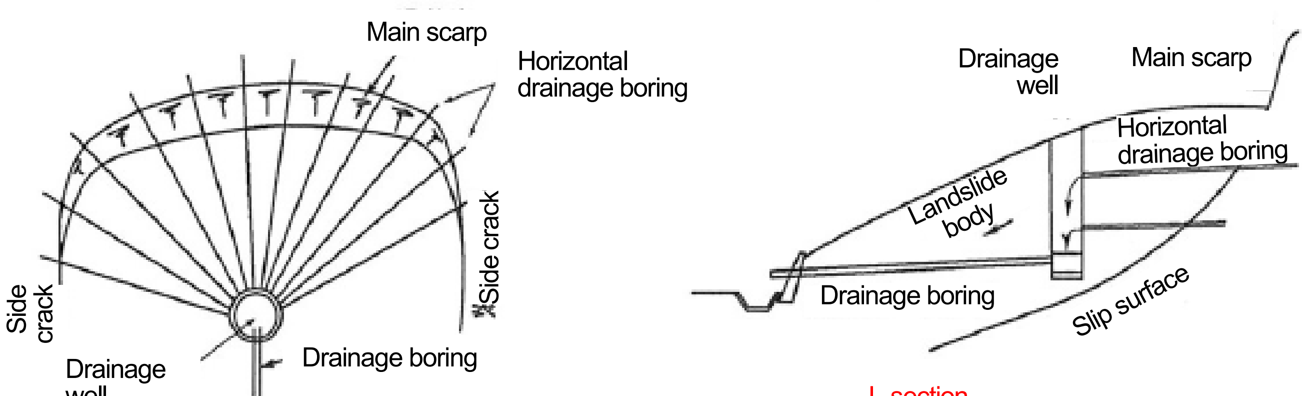
3.2 Drainage well

3.2.1 Structure of drainage well

The structure of the facility is explained below.

Table 25 Structure of Drainage well

Items		Material	Explanation
Mainbody of wel	Well body	Steel	Steel sheet earth retaining plate (liner plate) assembled in a cylindrical shape. Liner plate is that thin steel sheet is processed into a corrugated shape.
	Reinforcement ring	Steel	Circular H-shaped steel that is installed along the inner wall (liner plate) of the well as a reinforcing material.
	Vertical stiffener	Steel	H-shaped steel that is installed vertically inside the well as a reinforcing material.
	Lateral strut	Steel	H-shaped steel that is installed horizontally inside the well as a reinforcing material.
	Base concrete	Concrete	A concrete catchment basin at the bottom of the drainage well. It is to prevent weathering of well basement and to prevent leakage.
Fixed concrete (ground surface)		Concrete	Concrete is placed on the surface to fix the well top and to prevent surface water from flowing into the behind well wall.
Horozontal drainage borring		PVCpipe	A facility for drainage groundwater by drilling into the ground radially from within a well and inserting a drainage pipe. PVC pipes with strainers are widely used.
Drainage borring		Steel	It is facility that drain groundwater collected from the well wall and horizontal drainage borings to outside of drainage well. Steel pipes are mainly used..
Others	Roof canopy	Steel	It is made of circularly-shaped steel plates or expanded metal. It has hatch for maintenance (hatch for entering and exiting).
	Ladder	Steel	It is installed along the well wall to the bottom of the drainage well for maintenance purposes.
	Fence	Steel	A fence to secure safety is set up around the drainage well to prevent outsiders from entering.



Plan view

L-section

Exterior

In side of drainage well

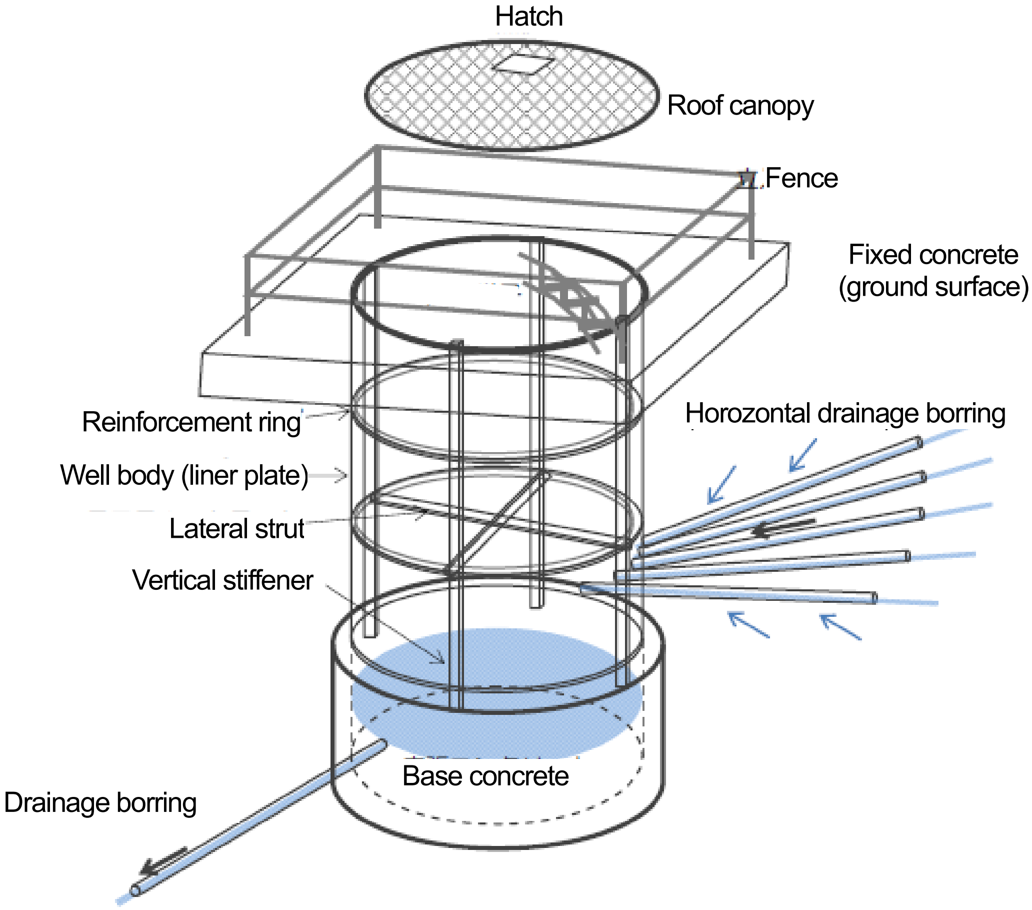


Figure 9 Image drawing of drainage well.

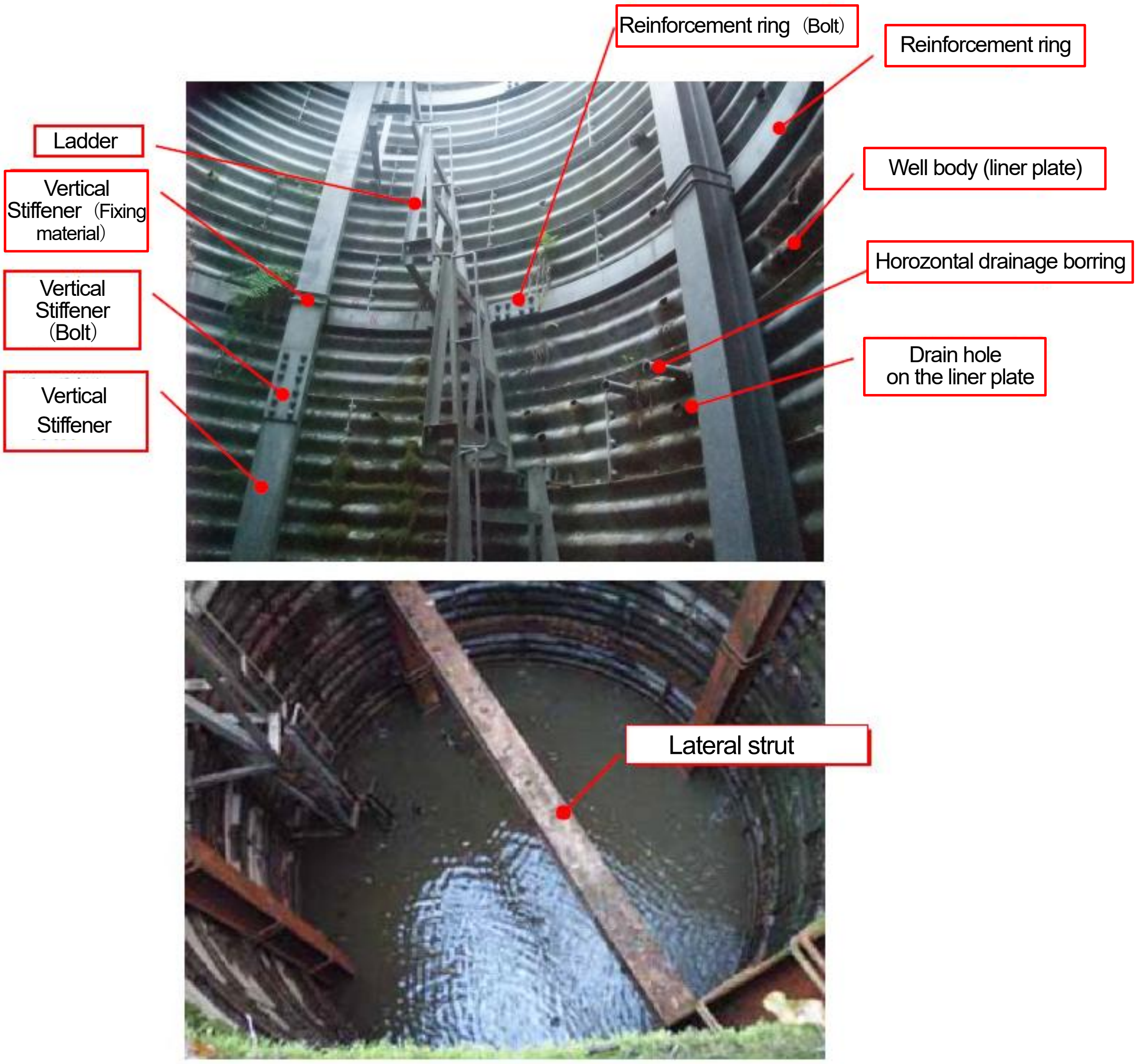


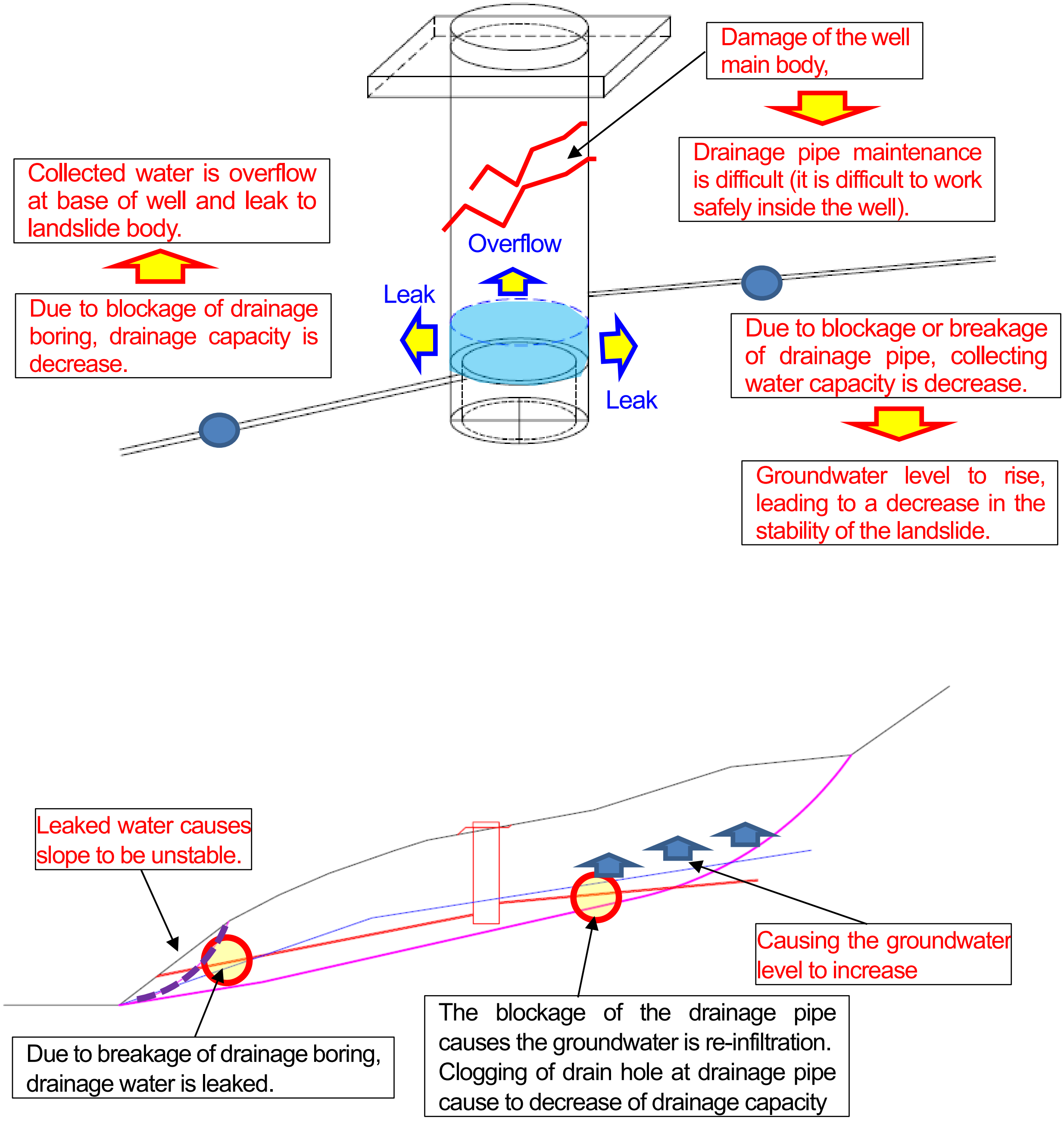
Figure 10　Case study photo of drainage well.

3.2.2 Decline in the function of drainage wel and its causes

The items that cause a decline in function and their impact on landslides are shown below.

Table 26 Decline in the function of drainage well and its causes

Effectiveness and functions as a landslide countermeasure method		･Reduction of pore water pressure on the slip surface (Deep layer groundwater is drained from the landslide area)		
Types of functional decline		・Decrease in water collection capacity (Horizontal drainage boring) ・Decrease in flow capacity (Horizontal drainage boring) ・Decrease in drainage capacity (Drainage boring, Well mainbody)		
Phenomenon Indicating functional decline	Item	Damage of the well main body, displacement or deformation, corrosion or deterioration.	Blockage and breakage of the drainage pipe(Horizontal drainage boring).	Soil moistening or spring water around the facility.
	Content	Damage or deformation of well body caused by landslide activity, deterioration, corrosion of materials.	Decrease in water collection capacity due to clogging of drainage holes of drainage pipe, decrease in flow capacity due to blockage of drainage pipes.	The groundwater collection and drainage capacity is reduced due to clogging, corrosion or damage of drainage pipe and well body, and the underground water level increase.
Conditions that may occur due to functional decline		Groundwater cannot be sufficiently collected, drained, or drainaged. There is leakage or re-percolation of collected water.		
Impacts on landslides		A decrease in the water collection capacity due to blockages in the drainage pipe (Horizontal drainage boring), overflow and leakage of catchment basin at the bottom of well due to blockages in the drainage pipes (Drainage boring), and leakage due to cracks in the bottom concrete (catchment basin) can all cause the groundwater level to increase, leading to a decrease in the stability of the landslide.		



Damage of the well main body,

Drainage pipe maintenance is difficult (it is difficult to work safely inside the well).

Collected water is overflow at base of well and leak to landslide body.

Due to blockage of drainage boring, drainage capacity is decrease.

Due to blockage or breakage of drainage pipe, collecting water capacity is decrease.

Groundwater level to rise, leading to a decrease in the stability of the landslide.

Leaked water causes slope to be unstable.

Causing the groundwater level to increase

Due to breakage of drainage boring, drainage water is leaked.

The blockage of the drainage pipe causes the groundwater is re-infiltration. Clogging of drain hole at drainage pipe cause to decrease of drainage capacity

Figure 11 The impaction to landslide stability by decrease in functionality of facility

3.2.3 Evaluation criteria for deformation level (Periodic and emergency monitoring)

The items that cause a decline in function and their impact on landslides are shown below.

Table 27 Evaluation criteria for deformation level (Drainage well)

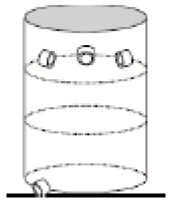
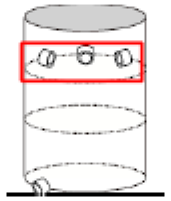
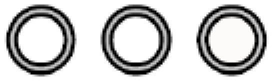
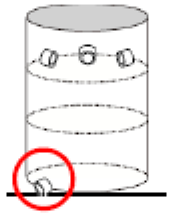
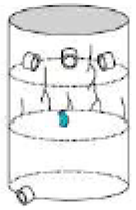
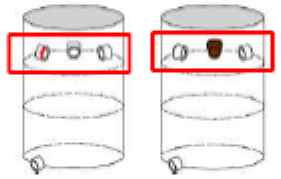
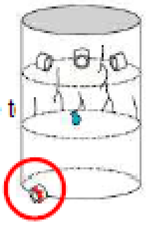
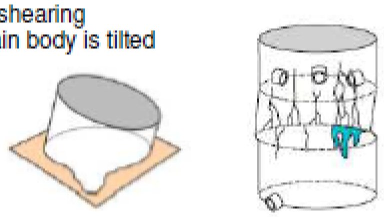
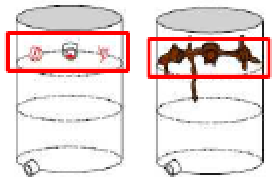
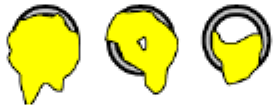
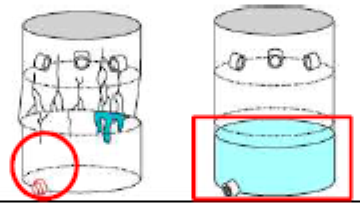
Deformation level		Drainage well			
		Deformation of well mainbody	Corrosion, deterioration, damage and deformation of drainage pipes (Horizontal drainage boring)	Blockage of drainage pipe (Horizontal drainage boring)	Corrosion, deterioration, damage and deformation of drainage pipes (Drainage boring)
a	Minor or no damage	･No or minor damege 	･No or minor damege 	･No blockages ･Small amount of blockage at the oultet of drainage pipe ･Groundwater drainage has been confirmed 	･No or minor damege 
b	There is damage, but it has not resulted in a decline in function or performance	･There is damage or deformation due to shearing, etc. ･Some parts of the main body are damaged due to corrosion or deterioration. 	･Some of the drainage pipes are broken or blocked. 	･Blockage in most of the installed drainage pipes (generally less than 25% of outlet area of each drainage pipe) ･Groundwater drainage has been confirmed 	･The cross-sectional area of the drainage pipe is decreased due to damage or deformation ･The drainage pipe is deformed due t corrosion or deterioration ･Drainage is confirmed (Comfirm at the outlet) 
c	There is a decrease in function or performance	･Most of the main body is damaged due to corrosion, deterioration, damage or deformation ･The main body is broken due to damage or deformation such as shearing The main body is tilted 	･Most of the drainage pipes are broken or blocked. 	･Large amount blockage in most of the installed drainage pipes (generally more than 25% of outlet area of each drainage pipe) ･It seems that groundwater drainage stopped due to blockage 	･Due to corrosion, deterioration, damage and deformation, drainage pipes is broken and collected water is leakage. ･ Due to blockage of drainage pipe, collected water is overflowed from basin at bottom of well and leakage from well wall. 
Evaluation Points		･Decrease of drainage capacity, leakage of drainage water, and overflowing water cause to increase the groundwater level and to be unstable of landslides. ･Data of groundwater observation and groundwater drainage volume observation is useful information for evaluating the soundness of facility.			
		･If damege or deformation of the main body is progress due to landslide activity, it will eventually be broken. ･If corrodion, deterioration, damage or deformation of main body, and the main body is progress, main body will be broken and there is a risk that the collected water will leak or not be collected.	･If deterioration, corrosion, damage or deformation progresses, there is a risk that the drainage pipes will be unable to collect water.	･Blockage of the drainage pipe causes a decrease in drainage capacity and re-infiltrate drained groundwater.	･If overflow occure and water level is increase more upper the outlet of drainage pipe (Horizontal drainage boring), drainage water from pipe is difficult. ･If collected water is overflowed from basin at bottom of well, there is a risk of leakage from well wall.
Points to note for monitoring		･Monitoring should be carried out by entering the inside of the drainage well to record the position, scale and direction of any damage or deformation. ･When entering the inside of the well for monitoring, there is a risk of anoxia, toxic gas, or falling etc., so it should be made sure it is safe before entering. ･If monitoring is implemented without entering the inside, it should be visually inspected the main body for damage, breakages, tilting, water overflow, and situation of drainage pipe outlet. ･It is desirable to record the drainage situation (amount) from the drainage pipe (Horizontal drainage boring).			
		･Record the location, scale and direction of deformation of the main body. In particular, the location of cracks and the direction of deformation are important information for estimating the direction of force, so record them appropriately. ･Record the location and scale of corrosion (steel members) and deterioration (concrete members) of the main body due to aging.	･Check the condition of the corrosion (steel) and deterioration (plastic) of the drainage pipes due to aging. ･Check the condition of the damage and deformation of the drainage pipes due to landslide activity, etc.	･Check for blockages situation in the drainage pipe outlet.	･Check the condition of the corrosion (steel) and deterioration (plastic) of the drainage pipes due to aging. ･Check the condition of the damage and deformation of the drainage pipes due to landslide activity, etc. ･Check whether there is collected water overflow from basin at bottom of well due to a blocked drainage pipe. ･It is checked whether there is a leak from the drainage pipe by comparing the amount of water in the drainage pipe's inlet and outlet, etc.

Table 28 Evaluation criteria for deformation level (Drainage well)

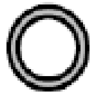
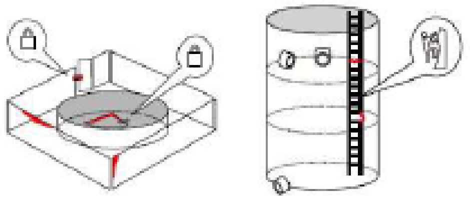
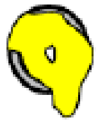
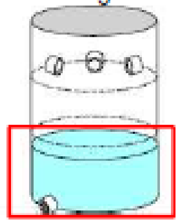
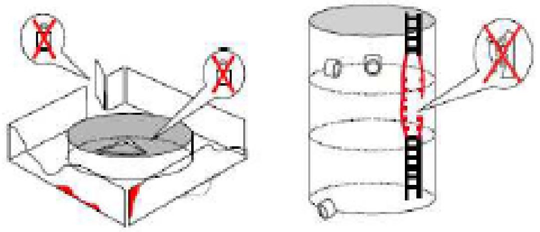
Deformation level		Drainage well			
		Blockage of drainage pipe (Drainage boring)	Safety equipment (canopies, fences, hatchs, locks, stairs, ladders, etc.)		
a	Minor or no damage	・No blockages ・Small amount of blockage at the oultet of drainage pipe ・Collected water drainage is confirmed 	・No or minor damege. ・There are corroded, deteriorated, damaged, deformed, but they are usable. 		
b	There is damage, but it has not resulted in a decline in function or performance	・Blockage in the installed drainage pipe (generally less than 25% of outlet area of drainage pipe) ・Collected water drainage is confirmed 			
c	There is a decrease in function or performance	・Large amount blockage in the installed drainage pipe (generally more than 25% of outlet area of drainage pipe) ・Due to blockage of drainage pipe, collected water is overflowed from basin at bottom of well and leakage from well wall.  	・Due to corrodion, deterioration, damage, deformtion, they are not functioning and usable. 		
Evaluation Points		・Decrease of drainage capacity, leakage of drainage water, and overflowing water cause to increase the groundwater level and to be unstable of landslides. ・Data of groundwater observation and groundwater drainage volume observation is useful information for evaluating the soundness of facility.			
		・If drainage pipe is blockage, collected water can't be discharged, basin at the bottom of well is overflow and there is a risk of leakage from well wall.	・If damage, etc. progresses, it will cause problems with safety management, such as accidents due to people other than those involved entering or falling into bottom of well. ・If damage, deformation, corrosion, or deterioration of safety facilities progresses, it will cause problems with implementation of monitoring work with safety.		
Points to note for monitoring		・Monitoring should be carried out by entering the inside of the drainage well to record the position, scale and direction of any damage or deformation. ・When entering the inside of the well for monitoring, there is a risk of anoxia, toxic gas, or falling etc., so it should be made sure it is safe before entering. ・If monitoring is implemented without entering the inside, it should be visually inspected the main body for damage, breakages, tilting, water overflow, and situation of drainage pipe outlet. ・It is desirable to record the drainage situation (amount) from the drainage pipe (Horizontal drainage boring).			
		・ Record the drainage situation (volume) of the drainage pipe. ・ Check the blockage of inlet and outlet of the drainage pipe.	・Check the condition of the facility for corrosion, deterioration, damage, deformation, etc.		

Table 29　Monitoring Case Studiy (Well main body)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No or minor damage	
b There is damage, but it has not resulted in　decline in function	・Some parts of the main body are damaged due to corrosion or deterioration.	
c There is decrease infunction	・Most of the main body is damaged due to corrosion, deterioration, damage or deformation	

Table 30　Monitoring Case Studiy (Well main body)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No or minor damage	
b There is damage, but it has not resulted in　dec line in function	・There is damage or deformation due to shearing, etc.	
c There is decrease infunction	・Most of the main body is damaged due to corrosion, deterioration, damage or deformation ・The main body is broken due to damage or deformation such as shearing ・The main body is tilted	

Table 31 Monitoring Case Studiy (Horizontal drainage boring)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No blockages ・Small amount of blockage at the oultet of drainage pipe ・Groundwater drainage has been confirmed	
b There is damage, but it has not resulted in decline in function	・Blockage in most of the installed drainage pipes (generally less than 25% of outlet area of each drainage pipe) ・Groundwater drainage has been confirmed	
c There is decrease infunction	・Large amount blockage in most of the installed drainage pipes (generally more than 25% of outlet area of each drainage pipe) ・It seems that groundwater drainage stopped due to blockage	

Table 32 Monitoring Case Studiy (Drainage boring)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No blockages ・Small amount of blockage at the oultet of drainage pipe ・Collected water drainage is confirmed	
b There is damage, but it has not resulted in decline in function	・Blockage in the installed drainage pipe (generally less than 25% of outlet area of drainage pipe) ・Collected water drainage is confirmed	
c There is decrease infunction	・Large amount blockage in the installed drainage pipe (generally more than 25% of outlet area of drainage pipe) ・Due to blockage of drainage pipe, collected water is overflowed from basin at bottom of well and leakage from well wall.	

Table 33 Monitoring Case Studiy (Safety facilities)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no d amage	・No or minor damage. ・ There are corroded, deteriorated, damaged, deformed, but they are usable.	
b There is damage, but it has not resulted in dec line in func tion		
c There is decrease infunction	・ Due to corrodion, deterioration, damage, deformtion, they are not functioning and usable.	

3.2.4 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Table 34 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Soundness level	Deformation condition	Countermeasure
A No action required	No damage	・Continue to monitor
B Observation	In case that although more than one case level b deformation is observed in the well main body, drainage pipe (Horizontal drainage boring & drainage boring), safety facilities or surrounding slope, but there is no relationship between the each deformations and progressive and it is judged that there is no functional decrease at present.	・During periodic monitoring, it is monitored the progress of any deformations. ・In some cases, it is considered the frequency and timing of periodic monitoring.
C Required measures	・Deformation level is c. ・There are multiple deformation level b and these deformations are caused by the same factor or these deformation is progressing.	Necessary detailed monitoring is conducted, and repair work and emergency measures are considered and implemented.

During judgment of soundness, it is important to consider result of landslide monitoring (groundwater level, rainfall amount, inclinometer, drainage water amount etc.)

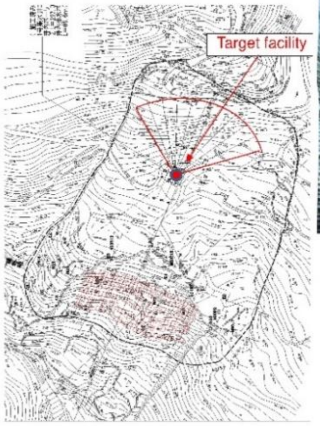
Table 35 Case study of monitoring sheet (Periodic and emergency monitoring)

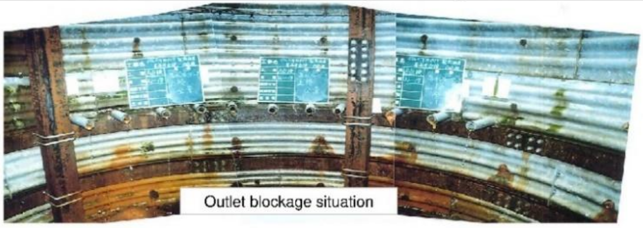
Site		Jawadi	Landslide Block	L-1
Construction year		2012	Structure No.	No.1
Structure specifications	Well main body	Liner plate φ3.5mL=20.0m	Report No.	1
	Horizontal drainage boring	PVC pipe	Monitoring date	2024/11/11
	Drainage boring	Gas pipe (Steel)	Organization conducting monitoring	JET
	Outlet Channel	Flexble pipe	Name of person conducting monitoring	Hotaka Aoki

Item			Deformation level	Comment
Well main body	Well body	Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
	Reinforcement ring	Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
	Vertical stiffener Lateral strut	Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
Horizontal drainage boring		Blockage	b	･Blockage of some drainage pipes (generally less than 25% of outlet of drainage pipe) ･Groundwater discharge has been confirmed
		Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
Drainage boring		Blockage	a	No damege
		Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
Base concrete		Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
Fixed concrete (Ground surface)		Damage Deformation	a	No damege
Others	Roof canopy	Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
	Ladder	Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
	Fence	Damage Deformation	a	No damege
		Corrosion, Deterioration	a	No damege
Surround slope			a	No deformation

		Comment
Judgement	A : No action required	･Blockage of some drainage pipes (generally less than 25% of outlet of drainage pipe) ･Groundwater discharge has been confirmed ･During periodic monitoring, it is monitored the progress of any deformations. ･In some cases, it is considered the frequency and timing of regular inspections. ･No deformation was observed in other parts, and daily monitoring will continue to be carried
	[✓ B : Observation]	
	C : Reruired measures	

Drawing & Photo





3.2.5 Detailed monitoring

The detailed monitoring is conducted to check the condition of the facilities in detail, and is carried out when deterioration or damage is confirmed during periodic monitorings.

The items subject to detail monitoring are as follows

○Well body

The condition of deterioration and damage is determined by directly observing and measuring the deformation of the well wall. The items to be checked are as follows

Damage and deformation of the wall material (include reinforcement ring, vertical stiffener, lateral strut) :

Check for the existence and degree of cracks, breaks, bulging, bending, displacement, and tilting, etc.

Deterioration and corrosion of the wall material(include reinforcement ring, vertical stiffener, lateral strut) :

Check for the existence and degree of rust, thickness, and perforations.

○Horizontal drainage boring

Check the same items as for horizontal drainage boring on the ground. (Breakage, blockage of drainage pipes)

○Drainage boring

The purpose of this monitoring is to check that the drainage pipe is draining the collected water properly.

At first, it should be checked that the basin at the bottom of the well is not overflowing.

If it is overflowing, there is a possibility that the drainage pipe is not functioning, so check for blockages and breakages in the same way as for the horizontal drainage boring.

○Base concrete

The purpose is to check that the basin store the collected water and the water is drained by drainage pipe properly.

It should be checked for the presence and degree cracks, tilting, deterioration of basin and sedimentation in the basin.

○Safety facilities

It should be checked for corrosion, deterioration, deformation, and breakage of the roof canopy and ladder.

(1) Points to note for safety when monitoring

When entering the well, it is necessary to take sufficient measures to prevent oxygen deficiency, toxic gases, and falls, and to be careful about safety.

○Countermeasures against oxygen deficiency and toxic gases

In order to carry out safe work in a well, it is necessary to prepare an environment with an **oxygen concentration of more than 18% and hydrogen sulfide of less than 1ppm.**

When working, it is necessary to constantly measure the oxygen and gas concentration with a meter to check that the environment is being maintained as specified.

In order to maintain the specified environment (oxygen more than 18%, hydrogen sulfide less than 1 ppm), it is essential to ventilate the well at all times using a air blower, as shown in the figure below.

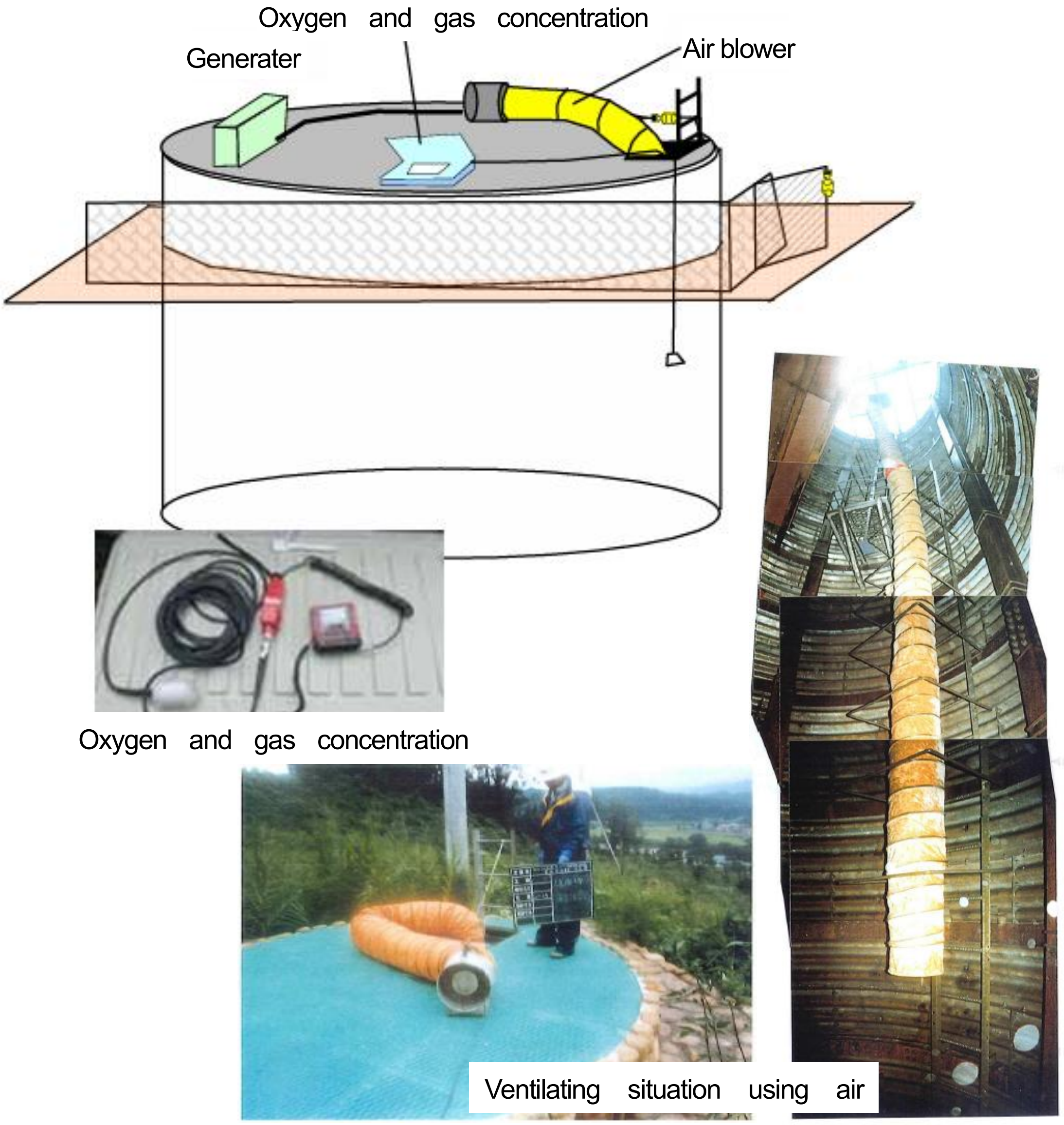


Figure 12 Case study of countermeasures against oxygen deficiency and toxic gases

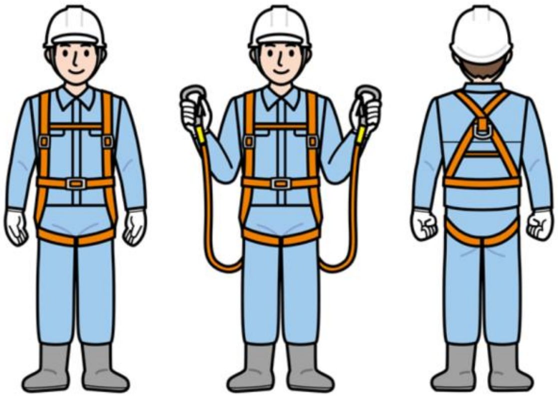
○Measures against falling

As the work will be carried out at a height, it is essential to take measures to prevent falls.

Basically, the work will be carried out using a ladder, but there is case that the ladder itself will deteriorate and it will be difficult to ensure safety during the work.

So it is necessary to use a safety harness and safety rope to ensure the safety of the workers.

Safety rope



Safety harness

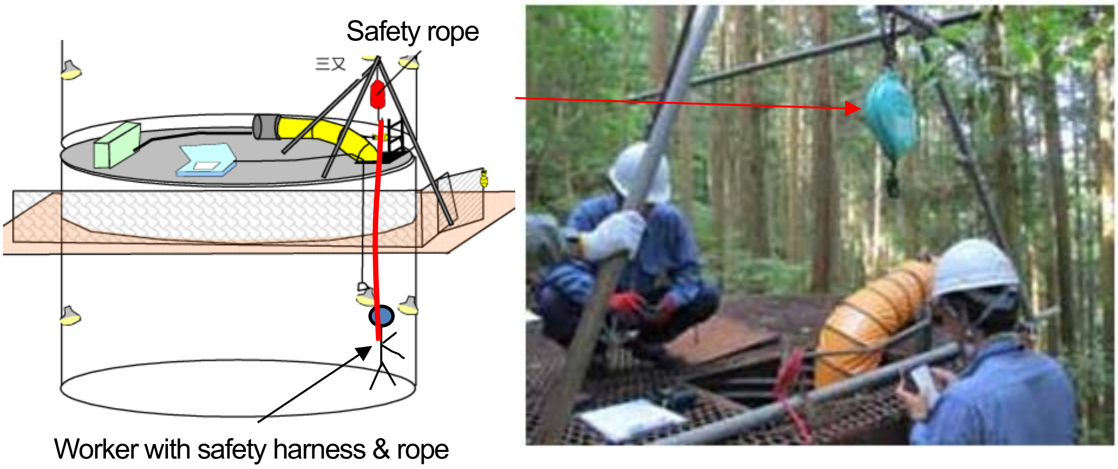


Figure 13　Case study of measures against falling

(2) Detail monitoring of well body

The main monitoring items are as follows

- Check of the well wall condition (prepare layout drawing of monitoring result)
- Hammer test of the well wall
- Measurement of the thickness of well wall material (liner plate)
- Measurement of the plumb bob

○Check of the well wall condition (prepare layout drawing of monitoring result)

Check items include the distribution of rust & corrosion, the distribution of slime adhesion, the location, extent and degree of deformation, water flow traces, the distribution of plant growth, etc.

The position of water trace (spring water position), and the area around the horizontal drainage boring are carefully checked because rust and corrosion tend to progress easily in these areas.

The results of the investigation of the well wall conditions are organized as a layout drawing.

It is possible to understand objectively situation inside the drainage well by taking photo of well wall and organizing layout photo and contrasting with layout drawing.

The following is an example of a layout drawing and layout photo.

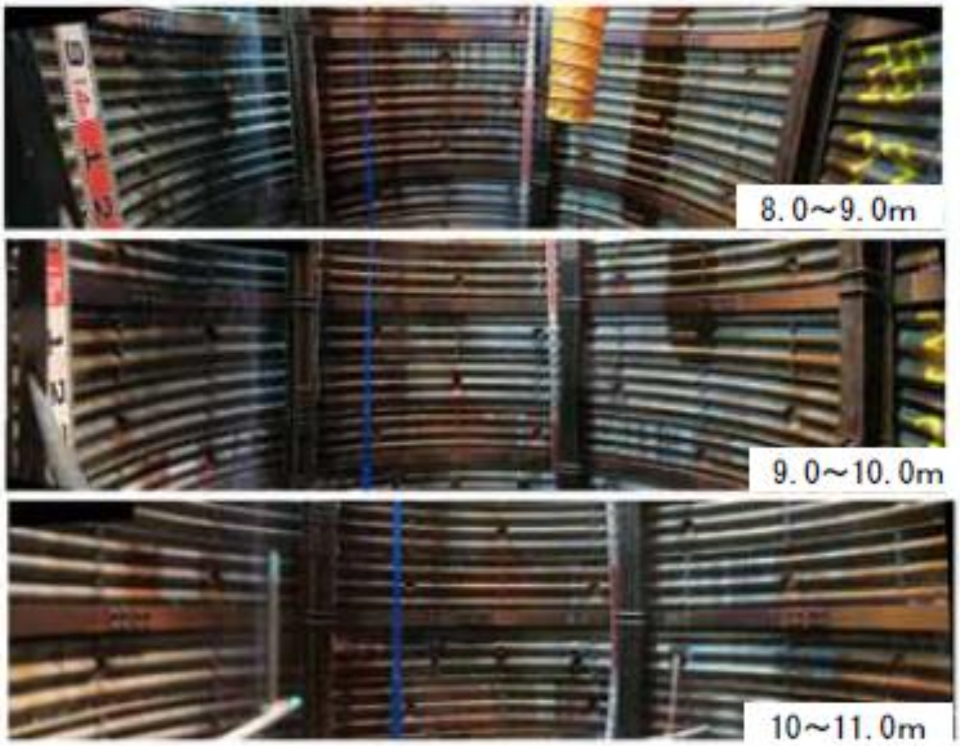


Figure 14　Case study of layout photo

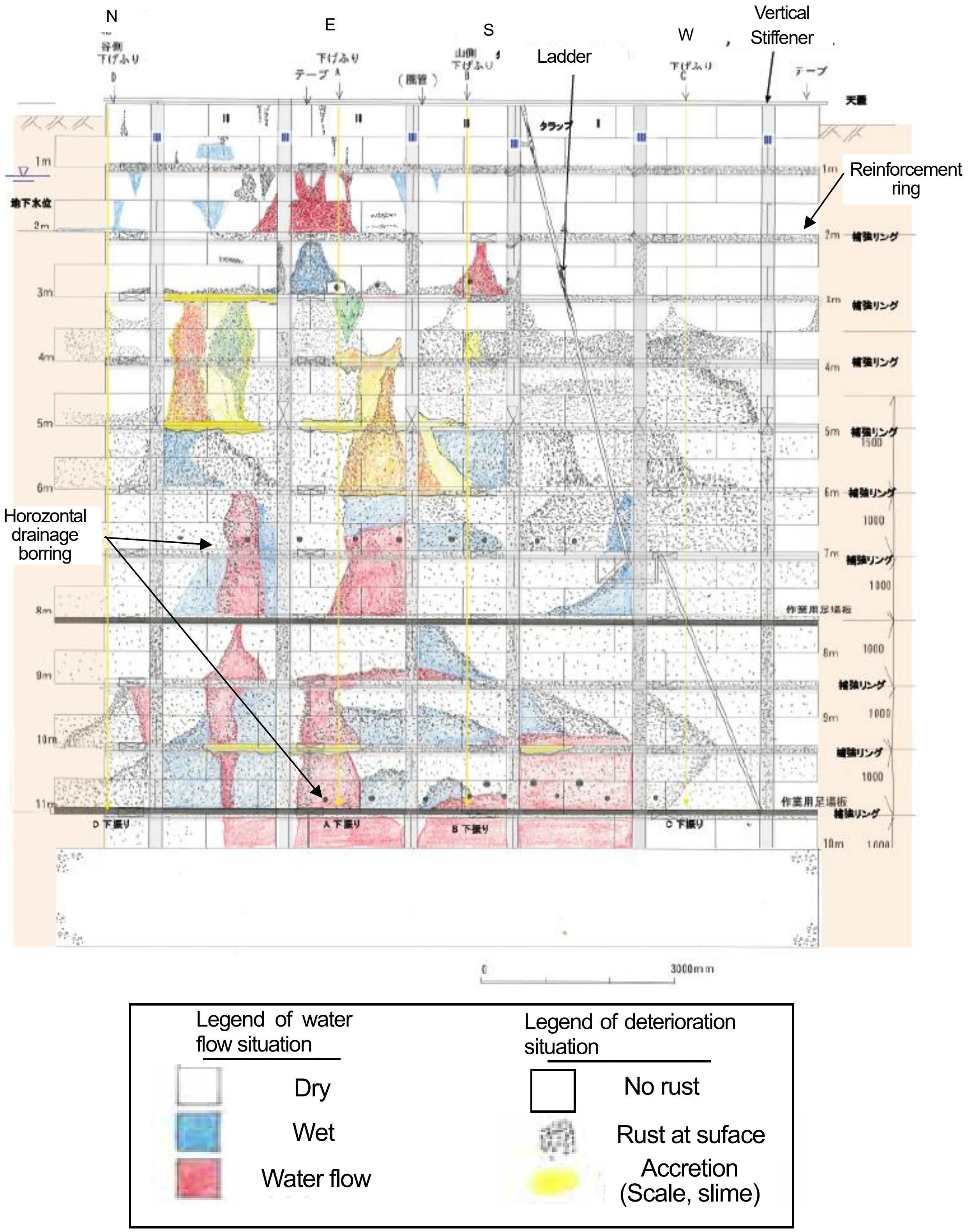


Figure 15 Case study of layout drawing

If deformation or breakage of the wall is confirmed, the location, extent and degree of damage should be noted. In addition, detailed photographs and sketches should be attached.

○Hammer test of the well wall

As explained on page 10, the hammer test is a method for estimating the internal conditions of a structure by listening to the differences in the sound of the hammer hitting the structure.

It is generally used for concrete structures, but it is also used to determine the deterioration of Linerplate (steel).

However, the sound changes depending on the condition of the back of the wall (whether it is hollow, whether it is filled, and whether it is in contact with the ground).

In addition, since corrosion and deterioration start in a small area, it is difficult to judge accurately based on the sound of hammering alone.

Table 36　Comparison of hammer test sound and deterioration (rough guide)

Result of hammering sound	Assumed condition of concrete structure
High-pitched metallic sound	Sound (No abnormality)
Somewhat low metallic sound	Suspected of beginning to deteriorate
Dull metallic sound	Suspected of deteriorating

○Measurement of the thickness of well wall material (liner plate)

This measurement is carried out to check whether the wall material (liner plate) is reduced in cross-sectional thickness due to deterioration such as rust.

・The thickness of the liner plate is measured at position of the drainage hole.

・In principle, one measurement is taken at a depth of 1m.

・Since accretion (rust, scale, slime) adhere to the surface of the liner plate, that is polished to the extent that it does not affect the remaining thickness of liner plate.

・In order to calculate the amount of corrosion, it is necessary to collect data on the design material(liner plate) thickness.

Figure 16　Measuring situation of remaining thickness of materials

○Measurement of the plumb bob

This is a measurement to check the deformation of the well body.

The plumb bob is suspended from the top of the well, and the distance of the plumb bob from the wall is measured at each depth to measure the tilting and bending of the well body.

The image of the measurement is as shown in the figure below.

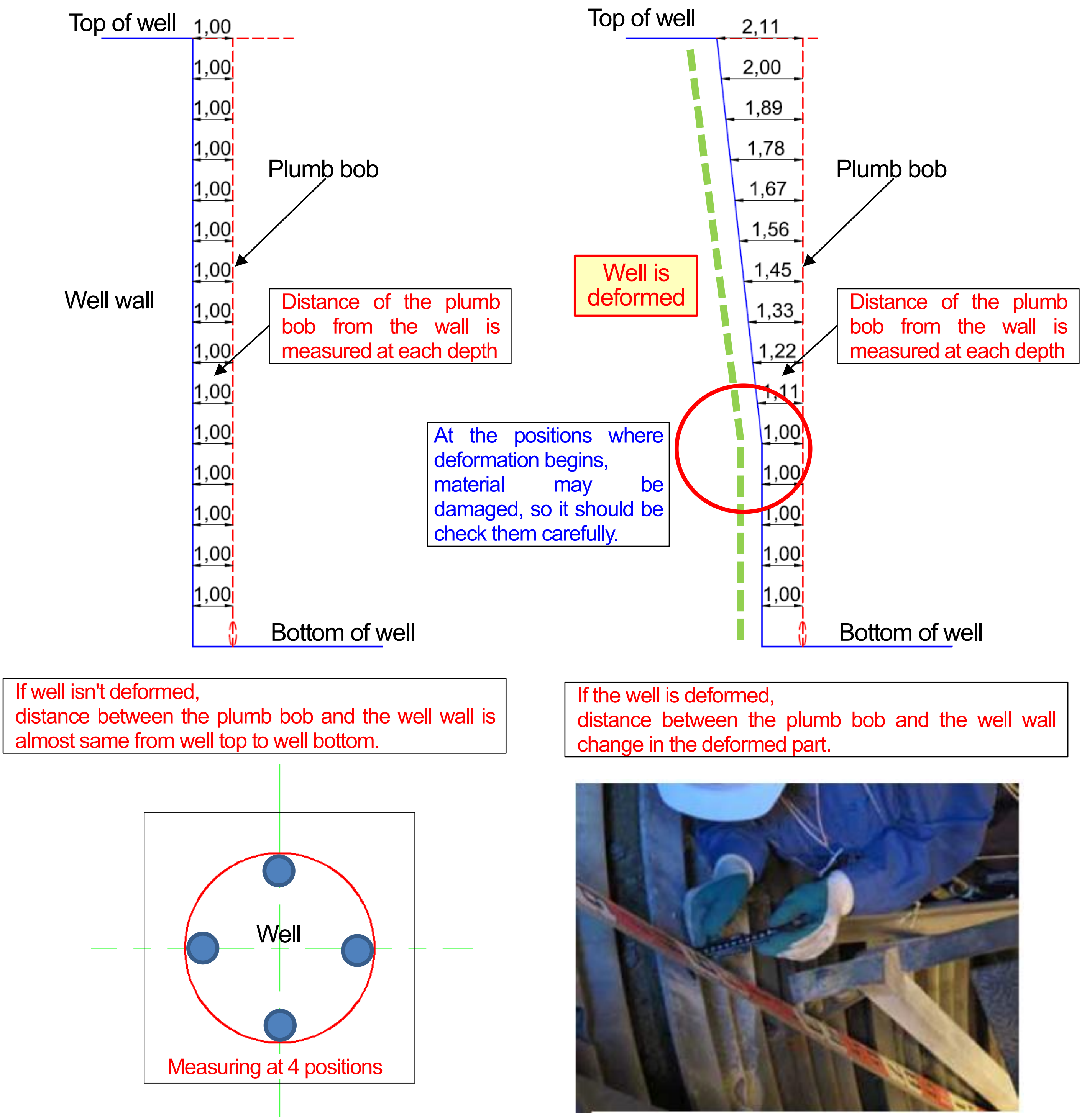


Figure 17　Image drawing of the plumb bob measurement

○Case study of detail monitoring (well body)

The following are examples of the results of well body detail monitoring.

The deformation levels a, b, and c are corresponds from top to down in each table.

Table 37　Case study of detail monitoring (well body)

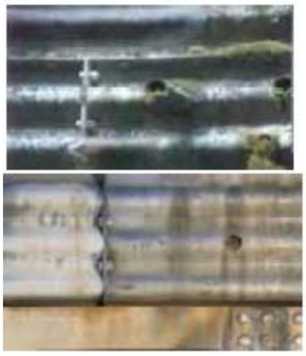
Hammer test	Liner plate		Reinforcement ring	
High-pitched metallic sound	No damage or only minor spot rust, including localized brownish-red discoloration.		No damage or only minor spot rust, including localized brownish-red discoloration.	
Somewhat low metallic sound It is a sharp metallic sound, but it is slightly muddy sound (it includes the peeling sound of rust on the surface).	Minor surface expansion due to rust. The surface is rough overall, with some peeling.		Minor surface expansion due to rust. The surface is rough overall, with some peeling.	
Dull metallic sound Muffled sound and a metallic sound are mixed together.	Surface expansion and thinning due to rusting. Decreased strength. Easily peels off from the surface layer. Defects and damage.		Surface expansion and thinning due to rusting. Decreased strength. Easily peels off from the surface layer. Defects and damage.	

Table 38 Case study of detail monitoring (well body)

Hammer test	Vertical stiffener Lateral strut		Bolt and Nut	
High-pitched metallic sound	No damage or only minor spot rust, including localized brownish-red discoloration.		No damage or only minor spot rust, including localized brownish-red discoloration.	
Somewhat low metallic sound It is a sharp metallic sound, but it is slightly muddy sound (it includes the peeling sound of rust on the surface).	Minor surface expansion due to rust. The surface is rough overall, with some peeling.		Minor surface expansion due to rust. The surface is rough overall, with some peeling. Wrench tightening is possible.	
Dull metallic sound Muffled sound and a metallic sound are mixed together.	Surface expansion and thinning due to rusting. Decreased strength. Easily peels off from the surface layer. Defects and damage.	 	Surface expansion and thinning due to rusting. Decreased strength. Easily peels off from the surface layer. Defects and damage. Wrench tightening is impossible.	

（3）Horizontal drainage boring

Check the same items as for horizontal drainage boring on the ground. (Breakage, blockage of drainage pipes)

See page 24 for details about how to monitor.

（4）Drainage boring

At first, it should be checked that the basin at the bottom of the well is not overflowing.

If the water level is higher than the drainpipe opening, there is a high possibility that there is a blockage or other problem with the drainpipe.

If the amount of water draining from the outlet is less than the amount draining from the inlet, it is possible that there is a leak from the drainpipe.

It is also possible that the amount of groundwater drained from the horizontal drainage boring or the well body has exceeded the capacity of the drainage boring (which is set based on the borehole diameter and gradient). In this case, it is necessary to consider adding more drainage boring

Check the same items as for horizontal drainage boring on the ground. (Breakage, blockage of drainage pipes)

See page 31 for details about how to monitor.

（5）Base concrete

Check the sedimentation of soil in the basin, cracks in the concrete, and tilting.

Measure and record the location, depth, width, and length of cracks.

In some cases, drain the water in the basin using a pump, etc., and inspect it.

（6）Safety facilities

It should be checked for corrosion, deterioration, deformation, and breakage of the roof canopy and ladder.

The following are examples of the results of safety facilitiesdetail monitoring.

The deformation levels a, b, and c are corresponds from top to down in the table.

Table 39　Case study of detail monitoring (safety facilities)

Roof canopy		Ladder	
No damage or only minor spot rust, including localized brownish-red discoloration.		No damage or only minor spot rust, including localized brownish-red discoloration.	
Minor surface expansion due to rust. Rough surface overall, with some peeling.		Minor surface expansion due to rust. Rough surface overall, with some peeling.	
Partial loss of parts or thinning has occurred, there is part that is not secured functioning properly.	 	Partial loss of parts or thinning has occurred, there is part that is not secured functioning properly. .	 

（7）Evaluation of the results of the detailed monitoring

It is shown the evaluation of the level of deformation for each part of the drainage well as followings.

○Mainbody

Table 40　Deformation evalution of mainbody

Deformation level		Evalution of deformations
Deformation	a	・No or minor damage
	b	・There is damage and deformation such as shearing etc, but it does not affect the stability of the main body as a whole.
	c	・The majority of the main body is damaged or deformed. ・The main body is broken due to shear or other damage or deformation. ・The main body is deformed by tilting. ・The damage or deformation is minor, but monitoring has confirmed clear cumulative displacement.
Corrosion, deterioration	a	・No or only minor corrosion, deterioration
	b	・Medium-level deterioration/corrosion is observed in less than 70% of the main body. ・Significant deterioration/corrosion is observed in less than 10% of the main body. ・Although some deterioration and corrosion are confirmed, the steel material is not expanded on the surface or decreased in thickness.
	c	・Medium-level deterioration/corrosion is observed in more than 70% of the main body. ・Significant deterioration/corrosion is observed in more than 10% of the main body. ・Causing by deterioration and corrosion, the steel material is expanded on the surface or decreased in thickness and breakage of the parts is confirmed.

○Baseconcete

Table 41　Deformation evalution of Baseconcrete

Deformation level		Evalution of deformations
Deformation	a	・No or minor damage
	b	・Although some damage is confirmed, there is no loss of water storage function.
	c	・There is damage such as cracks to cause water leakage at the bottom. ・The basin is tilted and deformed. The majority of the main body is damaged or deformed.
Sedimentation	a	・No or only minor sedimentation
	b	・Sedimentation of less than 50% of the basin volume, and the inlet of the drainage pipe is not blocked by sedimentation
	c	・Sedimentation of more than 50% of the basin volume, ・The inlet of the drainage pipe is blocked by sedimentation

○Safety facilities

Table 42　Deformation evalution of Safety facilities

Deformation level		Evalution of deformations
Deformation	a	・No or minor damage
	b	・There are some deformed or damaged parts at roof canopy and ladder, however no functional loss is confirmed.
	c	・There are some deformed or damaged parts at roof canopy and ladder, then functional loss and risk of function loss is confirmed.
Corrosion, deterioration	a	・No or only minor corrosion, deterioration
	b	・It is comfirmed minor surface expansion due to rust, rough surface overall and with some peeling, at the each facilities.
	c	・Partial loss of parts or thinning has occurred by rust and corrosion, there is part that is not secured functioning properly.

○Horizontal drainage boring

Evalute the same items as for horizontal drainage boring on the ground. (Breakage, blockage of drainage pipes)

See page 31 for details about how to evalute.

○Drainage boring

Evalute the same items as for horizontal drainage boring on the ground. (Breakage, blockage of drainage pipes)

Table 43 Deformation evalution of drainage boring

Deformation level		Evalution of deformations
Deformation, corrosion, deterioration and blockage (inlet and outlet)	a	・No or minor damage
	b	・There are some deformed or damaged parts at roof canopy and ladder, however no functional loss is confirmed.
	c	・There are some deformed or damaged parts at roof canopy and ladder, then functional loss and risk of function loss is confirmed.
Measuring by measurement rod	a	If there is no deformation in the drainage pipe and it can be inserted to the planned depth
	b	It can be inserted to the planned depth, but it is felt friction when inserting due to a blockage of slime.
	c	If it is not possible to insert the rod to the planned depth
Monitoring by Borehole camera	a	No deformation or minor deformation
	b	There is a deposition of slime in the pipe, but it is not blocking the pipe.
	c	・Due to deposition of slime in the pipe, it is blocking the pipe. ・The pipe is damaged due to stress caused by landslide activity, corrosion and deterioration.

If the basin is overflowing in spite of that above mentioned problems are not present, it is possible that the drainage pipe capacity is insufficient (drainage pipe bore, installation gradient).

In cace that, taking into account the drainage amount from the horizontal drainage boring, the drainage amount from the well wall, and the drainage amount from the continuous well upstream, it should be checked the drainage capacity of the current drainage pipe and considered to install additional drainage boring.

○Overall evaluation

Table 44　Overall evaluation and measure in monitoring of drainage well.

Deformation level	Overall evaluation	Measures
A	If there is case of level a	Continue periodic monitoring
B	If there is case of level b	<Follow-up observation> Increase the frequency of periodic monitoring. Conduct detailed inspections during periodic monitoring to check for any progression of deformations.
C	If there is case of level c	<Take measures> Consider and implement repair work and emergency measures.

Judgment of implememtain of repair or reinstallation (include cleaning) should to be considered with monitoring result pf landslide activity (groundwater level, rain amount, borehole inclinometer, etc.)

Refer to chapter.4

Case study of the detailed monitoring results and evaluation table for drainage well is shown at next page.

Table 45　Case study of monitoring sheet (Detailed monitoring)

Site	Ulloa	Landslide Block	Ⅲ	Structure No.	No.2	Construction year	2015	Report No.	1-1
Drainage well depth	GL-18.0m	Mterial of mainbody	Steel	Monitoring date	2024/11/11	Organization conducting monitoring	JET		
Drainage well diameter	3.50m					Name of person conducting monitoring	Hotaka Aoki		

Position-specific deformation record

Depth (m)	Deformation level	Corrosion level	Measurement of the thickness (mm)				Measurement of the plumb bob (mm)				Hammer test (Presence/absence of abnormality)		Comment
0 ～ 1	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
1 ～ 2	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
2 ～ 3	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
3 ～ 4	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
4 ～ 5	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
5 ～ 6	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
6 ～ 7	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
7 ～ 8	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
8 ～ 9	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
9 ～ 10	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
10 ～ 11	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
11 ～ 12	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
12 ～ 13	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
13 ～ 14	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
14 ～ 15	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
15 ～ 16	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
16 ～ 17	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
17 ～ 18	a	a	27.0	27.0			0.0	0.0	0.0	0.0	Yes	[✓ No]	
18 ～ 19											Yes	No	
19 ～ 20											Yes	No	
20 ～ 21											Yes	No	
21 ～ 22											Yes	No	
22 ～ 23											Yes	No	
23 ～ 24											Yes	No	
24 ～ 25											Yes	No	
25 ～ 26											Yes	No	
26 ～ 27											Yes	No	
27 ～ 28											Yes	No	
28 ～ 29											Yes	No	
29 ～ 30											Yes	No	

Vertical stiffener	Reinforcement ring	Lateral strut	Safety facilities
Comments	Comments	Comments	Comments

Evaluation by part

Items		Monitoring items	Evaluation	Comment
Mainbody	Linerplate	Deformation level	a	
		Corrosion level	a	
	Reinforcement ring	Deformation level	a	
		Corrosion level	a	
	Vertical stiffener	Deformation level	a	
		Corrosion level	a	
	Lateral strut	Deformation level	a	
		Corrosion level	a	
Base concrete		Deformation level	a	
		Corrosion level	a	
		Sedimentation	a	
Safety facilities	Roof canopy	Deformation level	a	
		Corrosion level	a	
	Ladder	Deformation level	a	
		Corrosion level	a	
	Safety fence	Deformation level	a	
		Corrosion level	a	

Photo & Drawing

Overall evaluation

[✓ A]	Continue periodic monitoring	Comments
B	Follow-up observation	
C	Take measures	

Table 46 Case study of monitoring sheet (Detailed monitoring)

Site	Ulloa	Landslide Block	Ⅲ	Structure No.	No.2	Construction year	2015	Report No.	1-1
Structure specifications	Drainage pipe	PVC pipe	Drainage well depth	GL-18.0m		Monitoring date	2024/11/11	Organization conducting monitoring	JET
	Pipe size	2 inch	Installation depth of HDB	GL-15.0m				Name of person conducting monitoring	Hotaka Aoki

Structure items	Monitoring items	No., length Evaluation items	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	No.10
			50m	50m	50m	50m	50m	50m	50m	50m	50m	50m
Outlet of pipe	Visual inspection	Blockage level	1	2	2	3	4	5	4	3	2	1
		Blockage material		Reddish-brown slime								
		Deformation level	1	1	1	1	1	1	1	1	1	1
		Deformation situasion										
Inner of pipe	Drainage amount measurement	During monitoring (L/min)	0.1	0.2	0.3	0.2	0.4	0.6	0.6	0.2	0.1	0.1
		After creaning (L/min)										
	Measuring by measurement rod	Insert length (m)	50m	50m	50m	50m	40m	45m	38m	40m	50m	50m
		Blockage level	1	2	2	2	3	3	3	3	2	1
		Feeling when inserting		felt friction 22m～	felt friction 15m～	felt friction 25m～	felt friction 12m～	felt friction 8m～	felt friction 11m～	felt friction 15m～	felt friction 18m～	
	Borehole camera	Blockage level	1	2	2	2	2	2	2	2	2	1
		Situation					Due to the distribution of slime, it is not possible to insert a camera at depths more than 38～45m.					

Evaluation of deformation level

Blokege level total	Level 1	Level 2	Level 3	Level 4	Level 5	Amount of level 4,5	Ratio	Deformation level(group)		
	1 pc	3 pc	2 pc	2 pc	1 pc	3	30%	b		
Deformation level total	Level 1	Level 2	Level 3			Amount of level 3	Ratio	Deformation level(group)		
	10 pc	0 pc	0 pc			0	0%	a		
Drainage amount total	2.8 L/min	After inner pipe cleaning, measuring drainage amount will be implemented.								
	0.0 L/min									
Blokege level total	Level 1	Level 2	Level 3			Amount of level 3	Ratio	Deformation level(group)		
	1 pc	1 pc	3 pc			4	40%	b		
	Because the blockage caused by slime was significant, it's checked inside of the pipe using borehole camera.									
Blokege level total	Level 1	Level 2	Level 3	Level 4	Level 5	Amount of level 2,3	Ratio	Amount of level 4,5	Ratio	Deformation level(group)
	2 pc	8 pc	0 pc	0 pc	0 pc	8	80%	0	0%	c

Overall evaluation

A Continue periodic monitor

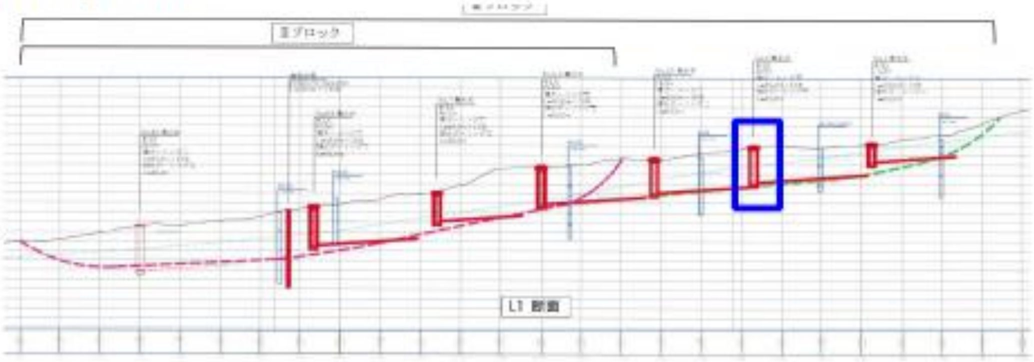
B Follow-up observation

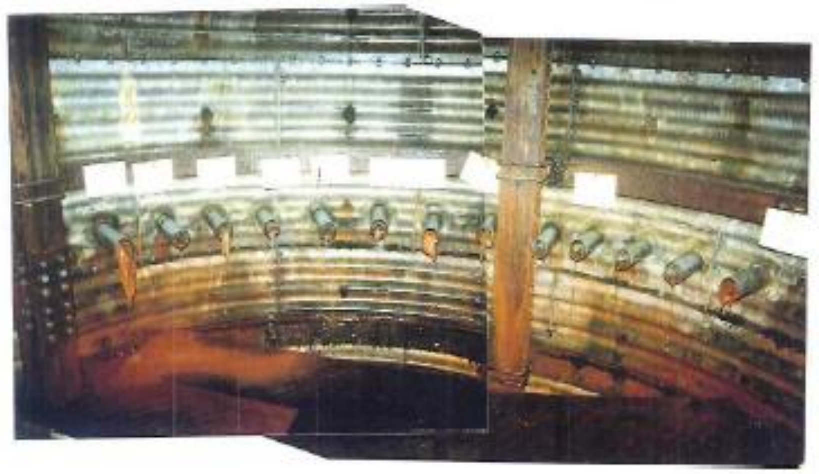
[✓ C Take measure]

<Comments>

- There is no confirmed breakage at the pipe or surrounding facilities.
- As there is a lot of slime distributed inside the pipe, it is necessary to carry out inner pipe cleaning.
- When carrying out the cleaning, it's proposed comparing the amount of drainage and comparing the groundwater level, before and after the cleaning.

Drawing & Phot





<Drainage boring>

No.	Length (m)	Deformation of inlet & outlet	Corrosion, deterioration of inlet & outlet	Drainage amount (l/min)	Blockage(%)		Measuring rod (m)	Borehole camera		Over flow of Basin
					inlet	outlet		Blockage	Breakage	
1	40	No	No	3.5	0	0	40	No	No	No
Evaluation		a	a		a	a	a	a	a	a

Drainage amount of HDB (l/min)	2.8	Drainage amount at inlet (l/min)	
Drainage amount of DB (l/min)	3.5	Drainage amount of outlet (l/min)	

Overall evaluation

[✓ A Continue periodic monitor]

B Follow-up observation

C Take measure

<Comments>

3.3 Channel

3.3.1 Structure of channel

(1) Surface water control work (channel work)

The structure of the facility is explained below.

Table 47 Structure of surface water control work (channel work)

Items		Material	Explanation
Channel work		Concrete	This facility collects surface water such as spring water and rainwater, and drainage water from horizontal drainage boring. This facility removes the water that causes landslides out of the landslide area.。
		Steel	
		PVC	
Ancillary facility	Catchment basin	Concrete	It works as a channel connection, earth retaining, hydraulic jump prevention, and drop work. It also catches groundwater collected by drain work. They are installed at the junction, bends, and slope change points of channels.
		Steel	
	Drop work	Concrete	It is installed at steps or steep slopes in channels. By it is installed to reduce the gradient of the channel, it makes to reduce waterflow speed or to secure stabilty of channel.
Terminal facility		Concrete	A structure installed at the end of channel to prevent slope collapse and erosion at end of channel.
		Boulder	

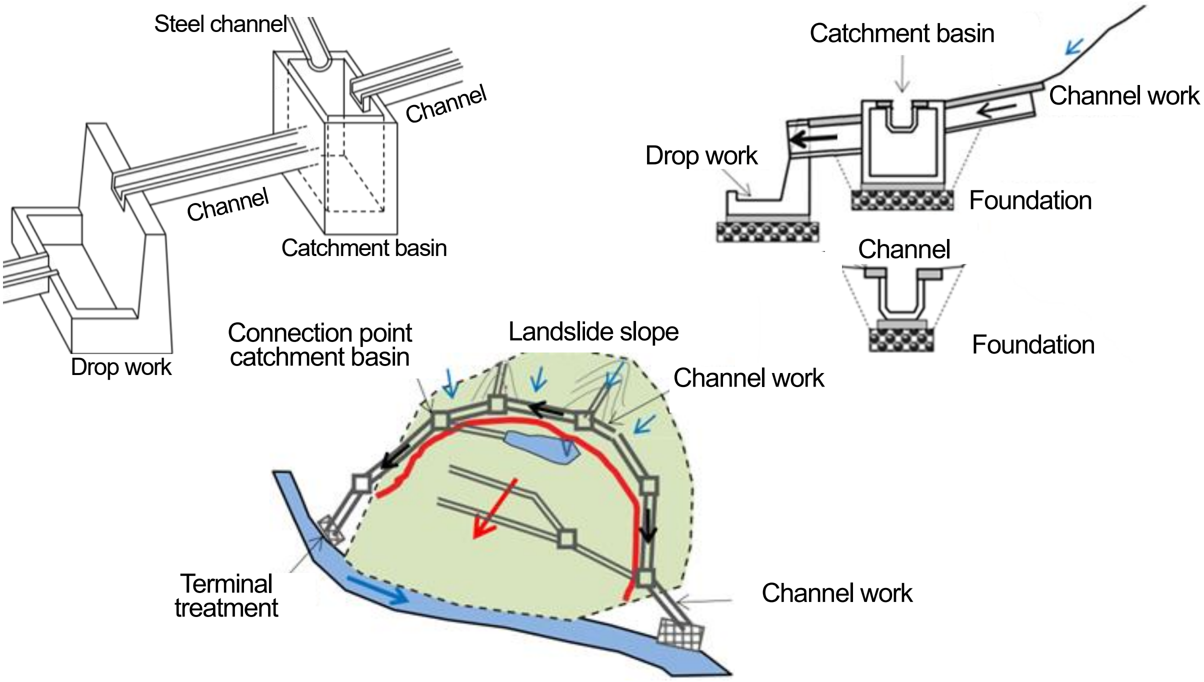


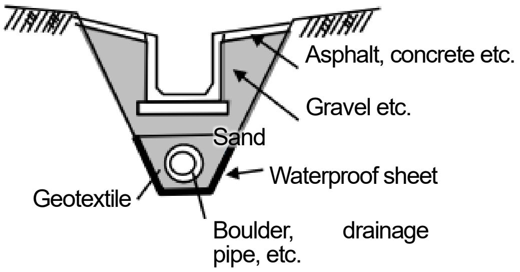
Figure 18 Image drawing of surface water control work

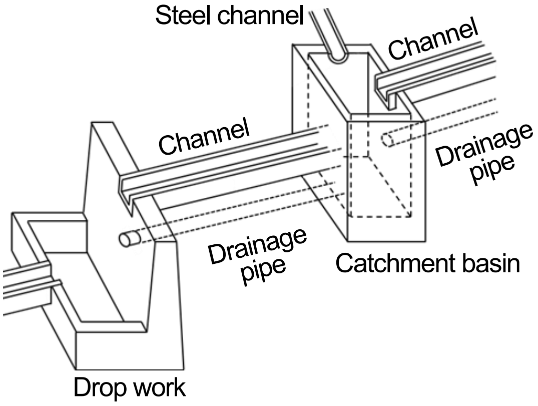
（2）Shallow ground water control work

Table 48　Structure of shallow ground water control work

Items			Material	Explanation
Drain work	Drain part	Drainage pipe	PVC, PE, etc.	A facility for drainage shallow groundwater. Highly permeable material is continuously installed in areas with high groundwater level.
		Boulder	Boulder with steel wire	
Channel and drain combined work	Drain part	Drainage pipe	PVC, PE, etc.	Drain work is placed under the channel, and form a channel and drain combined structure. Generally, the drainage pipe is covered with crushed stone. It also has the function of preventing erosion of the channel bottom.
		Boulder	Boulder with steel wire	
	Channel part		Concrete	This facility collects surface water such as spring water and rainwater, and drainage water from drain work. And it drains to outside of landslide area.
			Steel	
			PVC	
Ancillary facility	Catchment basin		Concrete	It works as a channel connection, earth retaining, hydraulic jump prevention, and drop work. It also catches groundwater collected by drain work. They are installed at the junction, bends, and slope change points of channels.
			Steel	
	Drop work		Concrete	It is installed at steps or steep slopes in channels. By it is installed to reduce the gradient of the channel, it makes to reduce waterflow speed or to secure stabilty of channel.

Channel work





Channel and drain combined work

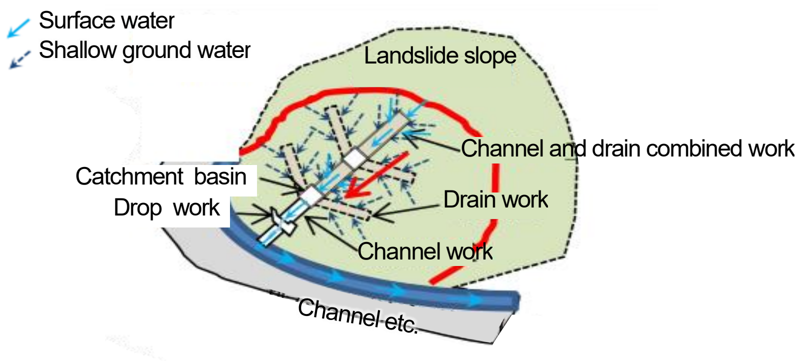


Figure 19　Image drawing of shallow ground water control work

Surface water control work (Channel work)

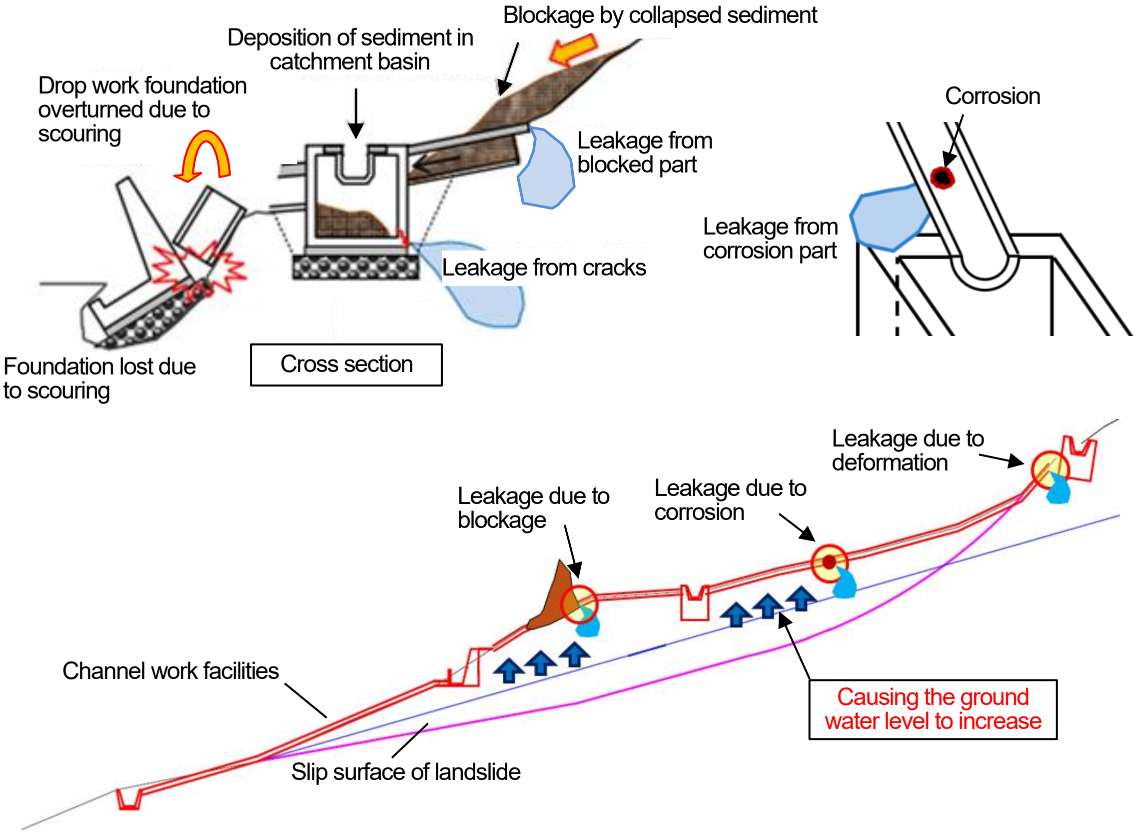
Shallow ground water control work
(Drain work)

3.3.2 Decline in the function of channel work and its causes

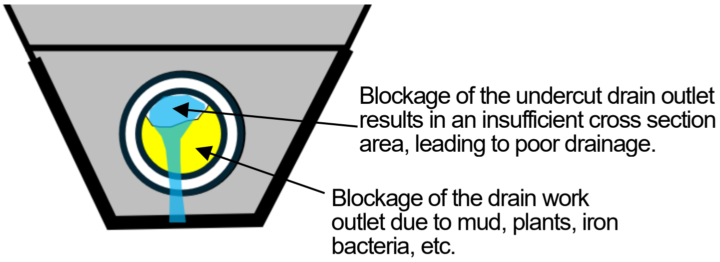
The items that cause a decline in function and their impact on landslides are shown below.

Table 49 Decline in the function of surface water and shallow ground water control work

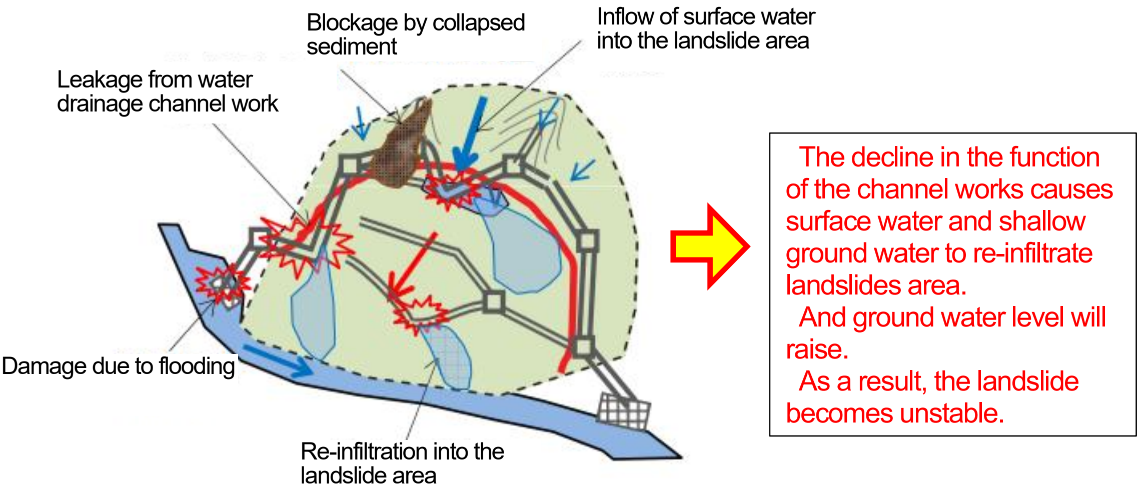
Effectiveness and functions as a landslide countermeasure method		In order to reduce the pore water pressure of the groundwater acting on the slip surface, it is drained surface water and shallow ground water to outside of the landslide area and controled infiltration into the landslide body.				
Types of functional decline		･Decrease in water collection capacity ･Decrease in flow capacity ･Decrease in discharge capacity				
Phenomenon indicating functional decline	Item	Corrosion, deterioration, damage, and deformation of components	Accumulation of sediment in channels (blockage, burial)	Leakage (possibility of leakage based on comparison of upstream and downstream flow rates)	Wetlands and springs have appeared in the ground around the facility.	Blockage of drainage pipe
	Content	Channels are damaged or deformed because of landslide activity, erosion of the sides of channels, deterioration of materials, etc.	The cross sectional area of flow decreases, due to the accumulation of sediment and fallen leaves in the channel.	Water leaks from cracks, joints, and connections, causing soil suction and foundation erosion.	Due to the infiltration of water (leakage, etc.) from the channel, wetlands and springs occur around the facility.	Drainage pipe is blocked by slime.
Conditions that may occur due to functional decline		Water leaks from dameged positions of the facility and re-infiltrates into the landslide body.	Running water overflows at the buried point and re-infiltrates into the landslide body.	Leakaged water re-infiltrates into the landslide body.	Re-infiltrate into the landslide body from wetlands, springs, etc.	It causes a decrease in the drainage function of shallow groundwater.
Impacts on landslides		Overflow and leakage from channels cause surface water to re-percolate into the landslide body. As result, it is increased the groundwater level (increase the pore water pressure of the groundwater acting on the slip surface) and caused decrease in landslide stability.				



Function decline of surface water control work



Function decline of shallow ground water control work (drain work)



The decline in the function of the channel works causes surface water and shallow ground water to re-infiltrate landslides area.
And ground water level will raise.
As a result, the landslide becomes unstable.

Figure 20　The impaction to landslide stability by decrease in functionality of channel works

3.3.3 Evaluation criteria for deformation level (Periodic and emergency monitoring)

Points of focus in monitoring are shown as following

①Mainbody of channel work (channel, catchment basin, drop work)

- Breakage

  Missing, cracks, abrasion

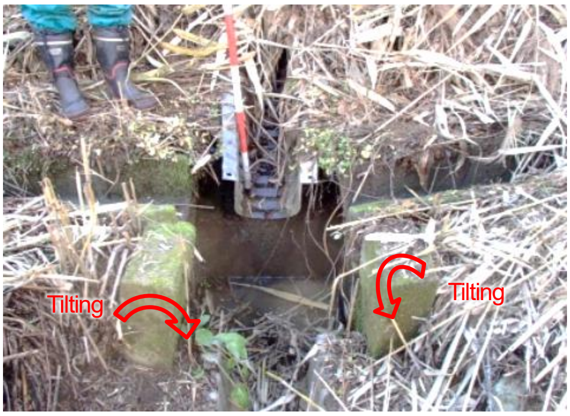
Crack in channel

Cracks and missing in drop work

- Deformation

  Shift between joints, subsidence, tilting, inversion of channel gradient

Subsidence and tilting in channel



Tilting in catchment basin

- Corrosion

  Rust (Steel channel can cause leakage)

Rust in steel channel

- Blockage, burial

  Accumulation of sediment and fallen leaves etc., plant invasion

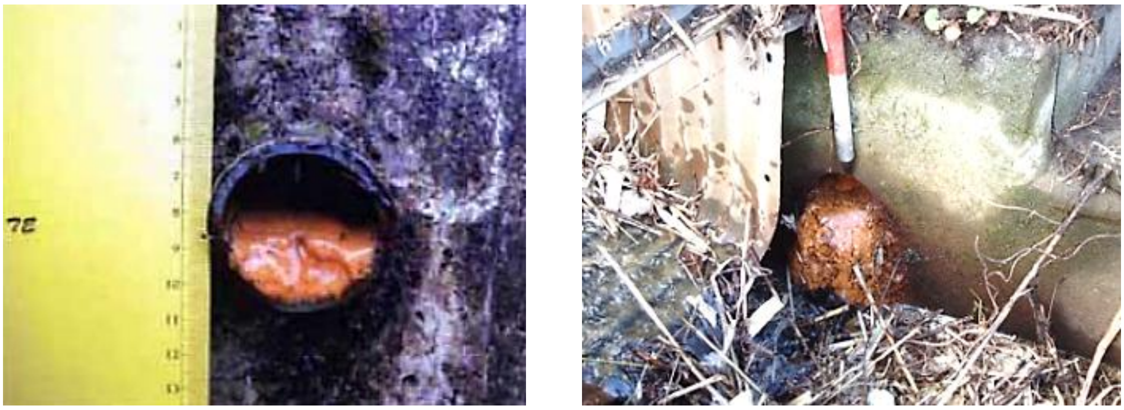
Blockage and burial because of sediment etc.

Overflow due to blockage

②Drain work

- Blockage

Blockage of drainage pipe due to slime, Burial due to sediment accumulation around outlet



Blockage of drainage pipe outlet due to slime

③Surrounding conditions

Impact on channels due to collapse of surrounding slopes and movement of landslide mass etc.

Channel deformation due to movement of landslide mass

Slope collapse under channel

The items that cause a decline in function and their impact on landslides are shown below.

Table 50 Evaluation criteria for deformation level (Channel)

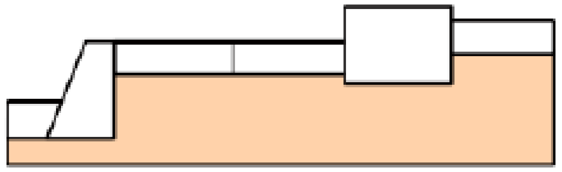
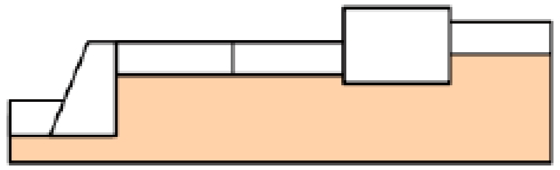
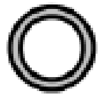
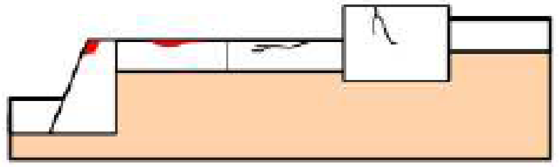
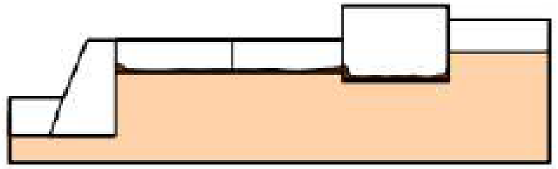
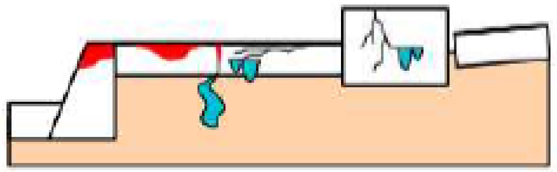
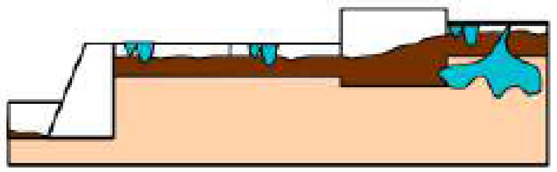
Deformation level		Channel work (channel, catchment basin, drop work), Drain work		
		Corrosion and deterioration, damage and deformation of channel, catchment basin, drop work	Sedimentation in channel, catchment basin, drop work	Blockage of drainage pipe
a	Minor or no damage	No or minor damage 	No sedimentation 	・No blockages ・Small amount of blockage at the oultet of drainage pipe ・Water discharge has been confirmed. 
b	There is damage, but it has not resulted in a decline in function or performance	Some damages, no leaking 	Some sedimentation, no overflow 	・Blockage in the drainage pipe (generally less than 30% of outlet area of drainage pipe) ・Water discharge has been confirmed. 
c	There is a decrease in function or performance	Leaked due to damages 	Overflow due to sedimentation 	・Large amount blockage in the drainage pipe (generally more than 30% of outlet area of drainage pipe) ・It seems that water discharge stopped due to blockage. 
Evaluation points		・Landslide activity and erosion on the sides of channels can cause damage and deformation to channels. ・Progressive corrosion, deterioration, damage, and deformation of channels, catchment basins, and drop works may result in leakage of collected water.	・Progressive sedimentation in channels, catchment basins, and drop works may result in overflow of collected water.	・Blockage of the drainage pipe causes a decrease in drainage capacity and re-infiltrate drained groundwater.
		・Leakage or overflow of collected water can cause groundwater levels to increase, leading to a decrease in landslide stability.		
Points to note for monitoring		・Check for any visible deformation by visual inspection.		
		・Check for corrosion of steel components and deterioration of concrete due to aging. ・Check for damage and deformation of channels, catchment basins, and drop works due to landslide activity, etc.	・Check the accumulation of sediment, plant remains, etc. in channels, catchment basins, and drop works.	・Check for blockages situation in the water outlet.

Table 51 Monitoring Case Study (Corrosion and deterioration in channel work)

Deformation level	Points to note for monitoring	Situation phots
a Minor or no damage	・No or minor damage	
b There is damage, but it has not resulted in decline in function	・Some parts are damaged due to corrosion or deterioration ・No leakage has occurred	
c There is decrease in function	・Leakage has occurred due to corrosion and deterioration	

Table 52　Monitoring Case Study (Breakage and deformation in channel work)

Deformation level	Points to note for monitoring	Situation phots
a Minor or no damage	・No or minor damage	
b There is damage, but it has not resulted in decline in function	・Some parts are damaged and deformed ・No leakage has occurred	
c There is decrease in function	・Leakage has occurred due to damage and deformation	

Table 53　Monitoring Case Study (Blockage in channel work)

Deformation level	Points to note for monitoring	Situation phots
a Minor or no damage	・No or minor sedimentation	
b There is damage, but it has not resulted in decline in function	・Sediment are accumulated in some parts ・No overflow has occurred	
c There is decrease in function	・Overflow has occurred due to sedimentation	

Table 54　Monitoring Case Study (Catchment basin)

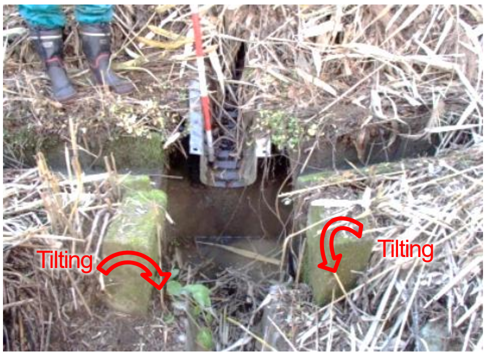
Deformation level	Points to note for monitoring	Situation phots
a Minor or no damage	・No or minor sedimentation	
b There is damage, but it has not resulted in decline in function	・Some parts are damaged and deformed ・No leakage has occurred	
c There is decrease in function	・Leakage has occurred due to damage and deformation	
	・Overflow has occurred due to blockage of catchment basin	

Table 55 Monitoring Case Study (Drian work)

Deformation level	Points to note for monitoring	Situation phots
a Minor or no damage	・No blockages ・Small amount of blockage at the outlet of drainage pipe ・Groundwater drainage has been confirmed.	
b There is damage, but it has not resulted in decline in function	・Blockage in the drainage pipe (generally less than 30% of outlet area of drainage pipe) ・Water drainage has been confirmed.	
c There is decrease in function	・Large amount blockage in the drainage pipe (generally more than 30% of outlet area of drainage pipe) ・It seems that water drainage stopped due to blockage.	

3.3.4 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Table 56 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Soundness level	Deformation condition	Countermeasure
A No action required	No damage	・Continue to monitor
B Observation	In case that although more than one case level b deformation is observed in the channel main body, drop work, catchment basin, or surrounding slope, but there is no relationship between each deformation or progressive and it is judged that there is no functional decrease at present.	・During periodic monitoring, it is monitored the progress of any deformations. ・In some cases, it is considered the frequency and timing of periodic monitoring.
C Required measures	・Deformation level is c. ・There are multiple deformation level b and these deformations are caused by the same factor or these deformation is progressing.	Conduct continuous monitoring, and repair work and emergency measures are considered and implemented.

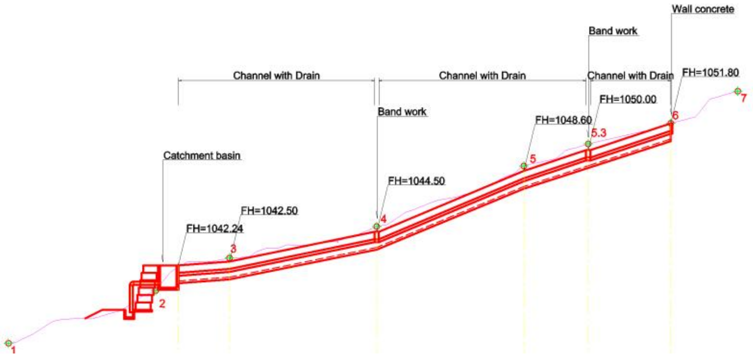
Table 57　Case study of monitoring sheet (Periodic and emergency monitoring)

Site		Campo Ciero	Landslide Block	L-1
Construction year		2002	Structure No.	No.1
Structure specifications	Channel work type	Channel and drain combined work	Report No.	1
	Length	75.0m	Monitoring date	2024/11/11
	Material	Concrete	Organization conducting monitoring	JET
			Name of person conducting monitoring	Hotaka Aoki

Item		Deformation level	Comment
Channel	Breakage	a	No damege
	Deformation	a	No damege
	Corrosion	-	-
	Blockage	a	No blockage
Catchment basin	Breakage	a	No damege
	Deformation	a	No damege
	Corrosion	-	-
	Blockage	b	Accumulation of sediment is comfirmed in the basin. Leakage has not occurred.
Drop work	Breakage	a	No damege
	Deformation	a	No damege
	Corrosion	-	-
	Blockage	a	No blockage
Drain work		a	No damege
Surrounding conditions		a	No deformation

		Comment
Judgement	[✓ A : No action required]	・There are no deformationws in the channel work, drain work and surround.
	B : Observation	
	C : Reruired measures	

Drawing & Photo



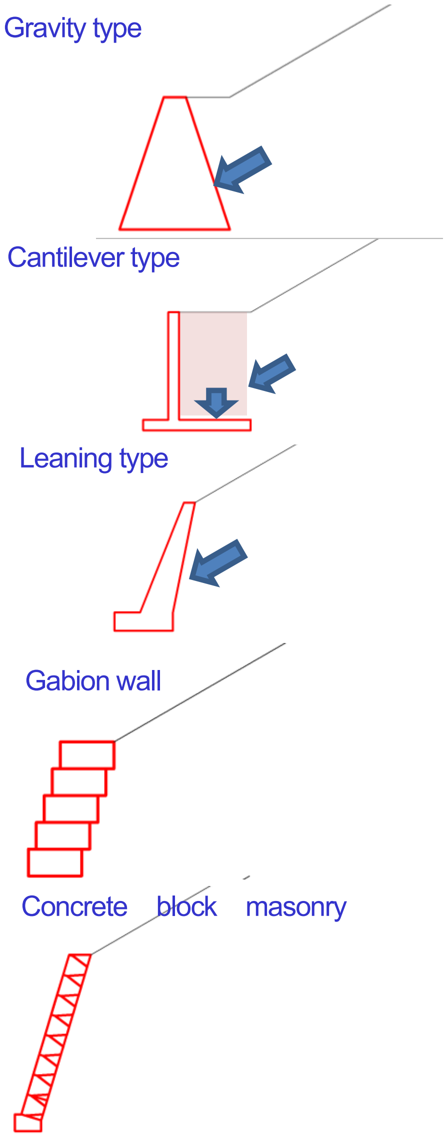
3.4 Retaining wall

3.4.1 Structure of Retaining wall

The retaining wall is an earth retaining structure that is continuously provided in the shape of a wall for the purpose of stabilizing the slope.

Retaining walls are classified according to the main material, shape, mechanical stability mechanism, etc.

Classifications of retaining walls are as follows



Gravity type

A type that resists earth pressure due to the gravity of the retaining wall
Concrete structure is common

Cantilever type

A type that resists earth pressure due to the gravity of the soil upper the retaining wall and the member strength of the cantilever.
Reinforced concrete structure is common

Leaning type

The type that resists earth pressure due to its own weight by leaning the retaining wall against a slope

Gabion wall

Retaining wall made of a basket braided by wire and filled with stones.
It's made in various parts of the world because of its simple structure, easy to construct and easy to obtain material.

Concrete block masonry

It is a retaining wall type made by stacking concrete blocks.
A leaning type retaining wall is common.

Soil retaining structure that constructs a vertical or near-vertical wall surface by laying reinforcements in the embankment.

Figure 21　Classifications of retaining wall

Concrete retaining wall (Gravity type)

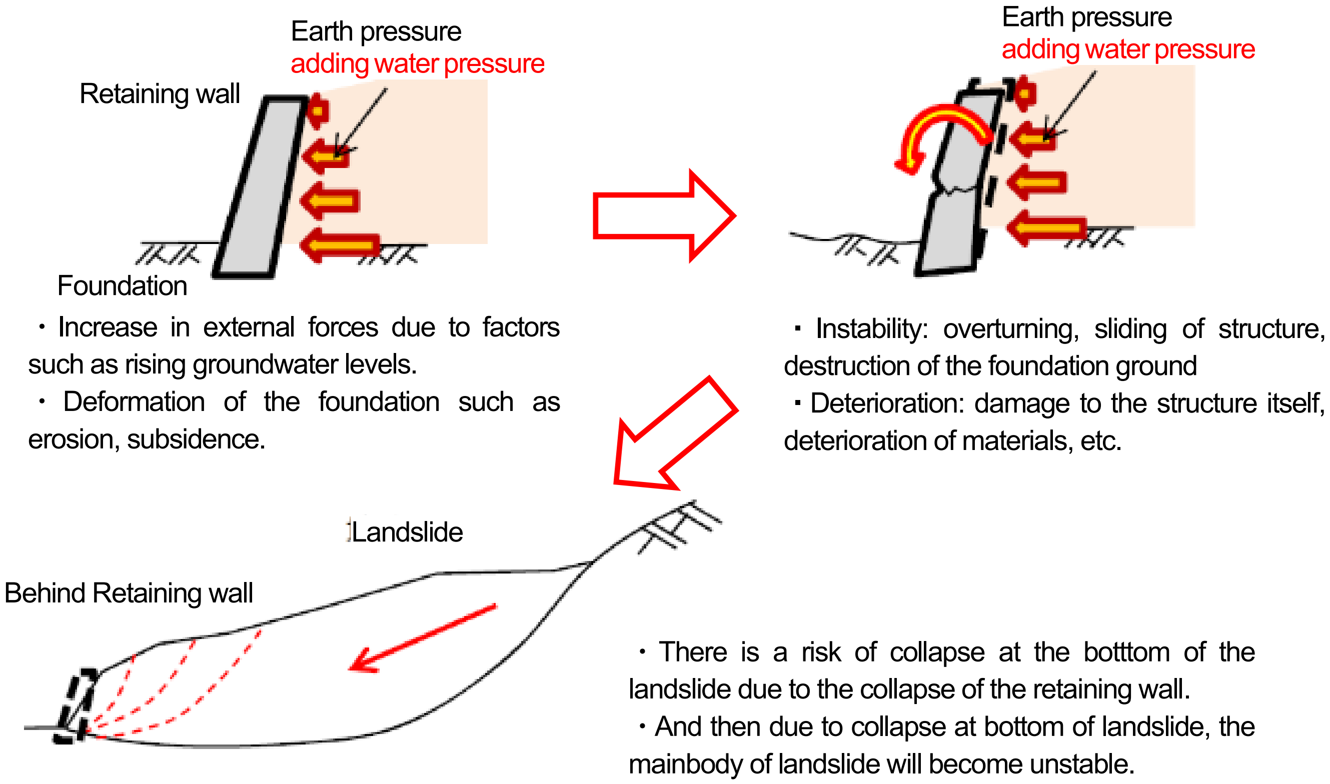
Gabion retaining wall (Leaning type)

Concrete block masonry wall (Leaning type)

Stone wet masonry wall (Gravity type)

3.4.2 Decline in the function of retaining wall and its causes

The items that cause a decline in function and their impact on landslides are shown below.



・Increase in external forces due to factors such as rising groundwater levels.

・Deformation of the foundation such as erosion, subsidence.

・Instability: overturning, sliding of structure, destruction of the foundation ground

・Deterioration: damage to the structure itself, deterioration of materials, etc.

・There is a risk of collapse at the botttom of the landslide due to the collapse of the retaining wall.

・And then due to collapse at bottom of landslide, the mainbody of landslide will become unstable.

Figure 22 Image drawing of cause a decline in function and their impact on landslides

Table 58 Decline in the function of retaining wall and its causes

Effectiveness and functions as a landslide countermeasure method		･By stabilizing the bottom part of the landslide block, the destabilization of the landslide is controled. (The purpose is not to stabilize directly the main body of the landslide, but to stabilize the small collapse at the landslide bottom.)				
Types of functional decline		･Decrease in strength and stability as a structure				
Phenomenon Indicating functional decline	Item	Crack	Spring water	Deformation and breakage	Subsidence	Deformation at the slope behind the retaining wall, etc.
	Content	Cracks occur, due to deterioration or a decrease in the strength of the concrete.	Due to the decreace of drainage functions such as the drainage holes, and drainage layer, water pressure act to the retaining wall.	Due to unexpected soil pressure and various external forces at the time of design, the retaining wall may tilt, shift, deform, or develop cracks. In the case of gabion, corrosion of the frame will progress, then frame will deform and break due to the load.	Because of decline the foundation's bearing capacity, facility is sink.	Damage or deformation of the facility may occur, due to factors such as movement of the slope behind the facility or the suction out of soil behind the facility.
Conditions that may occur due to functional decline		Progress of cracks cause to a decrease in strength of retaining wall and cause to its collapse.	Action of water pressure on the behind of the retaining wall causes the retaining wall to become unstable.	Progress of deformation cause to unstable of retaining wall and cause to its collapse. The deterioration of gabion frame is difficukt to keep boulders in the frame and shape of retaining wall.	Decrease in the bearing capacity of foundation cause retaining wall to become unstable, and there is a risk that retaining wall can collapse.	Deformation of retaining walls cause instability in the surrounding slopes, and the instability of the slopes cause instability in landslide slope.
Impacts on landslides		There is a risk of collapse at the botttom of the landslide due to the collapse of the retaining wall. And then due to collapse at bottom of landslide, the mainbody of landslide will become unstable.				

3.4.3 Evaluation criteria for deformation level (Periodic and emergency monitoring)

Points of focus in monitoring are shown as following

①Mainbody of retainingwall

・Breakage

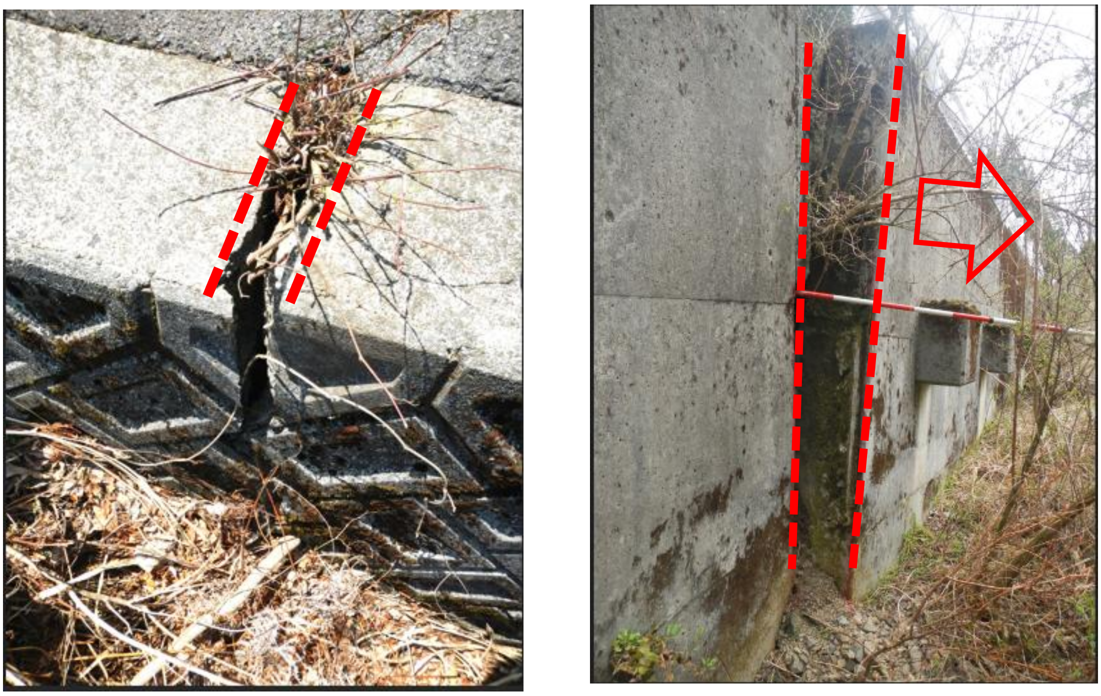
Lost structure, collapse, falling of blocks (boulders in the frame), lost of filling material(boulder in the frame), etc. Situation that function is lost

Collapsed concrete block masonry wall

Collapsed gabion

・Deformation

Subsidence, tilting, shift between joints, deformation, etc.



Retaining wall shift between joints by landslide activitiy

Retaining wall is broken and tilted by landslide activitiy.

- Damage

Cracks, missing parts, rust (corrosion), etc.

Cracks

Rusted gabion frame

- Spring water

There is water seeping out or flowing out from cracks, etc.

In case of gabion, it has a drainage function, so the fact that flowing out water was found is not a problem. (drainage pipe of concrete wall also)

Large amount of spring water

- Gaps at the rear of structures (gaps due to erosion or suction of the ground at the rear, etc.)

  The wall body is not fit with rear ground by suction of rear ground soil, etc.

It's deformed due to erosion of the foundation and suction out of soil behind the retaining wall.

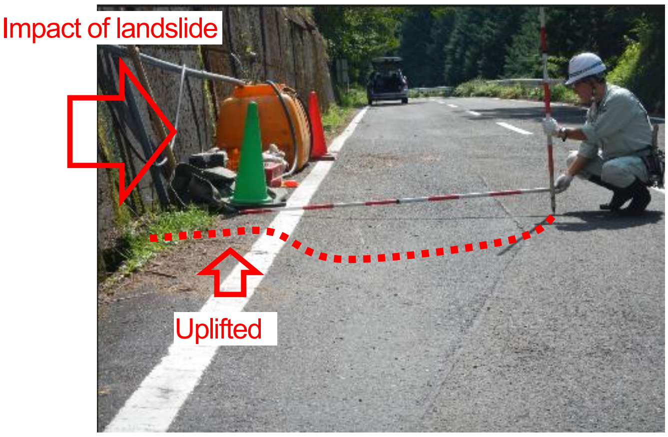
②Foundation ground

- Subsidence, uplift

  The foundation ground is subsided by acting the structure's weight exceeding bering capacity of foundation, or is uplifted due to the impact of landslide, etc.

- Erosion

  The foundation ground is eroded by surface water, etc.



Foundation ground is uplifted

Foundation ground is eroded

③Surrounding conditions

At ,the surround slope of the structure, in case that following phenomena are clearly comfirmed.

Suction of soil, subsidence, erosion, spring water, collapse, deformation, cracks, etc.

Table 59 Monitoring Case Studiy (Conrete retaining wall)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No damage	
b There is damage, but it has not resulted in dec line in func tion	・Some cracks are occured, the cracks are not opened. ・The retaining wall is not tilted.	
c There is decrease infunction	・Cracks are opened, and then retaining wall is tilted. ・It is lost function of retaining wall, has risk of collopose.	

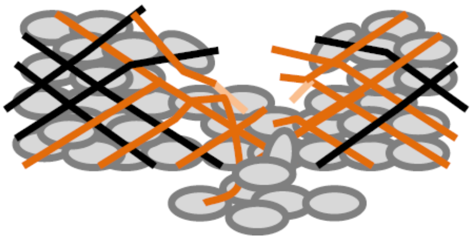
Table 60　Monitoring Case Studiy (Conrete block masonry wall)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No damage	
b There is damage, However, It is not decline in function	・Some cracks are occured, the cracks are not opened. ・Some joint is shifted. ・A part of block is lost. Although, some minor deformations are occured, ・Retaining wall is not tilted. ・It is kept function of retaining wall	 
c There is decrease infunction	・A part of wall is collosed ・Cracks are opened, and then retaining wall is tilted. ・It is lost function of retaining wall, has risk of collopose.	 

Table 61 Monitoring Case Studiy (Gabion wall)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No damage	
b There is damage, However, It is not decline in function	・Some deformations are occured. ・Frame is not broken. ・Filling material is kept in frame. ・It is kept function of retaining wall.	
c There is decrease infunction	・The filling material has been lost due to deformation of wall body or broken frame, etc. ・The stability of the facility has been lost due to significant tilting, etc. ・The wall body is collopsed.	 

Table 62 Monitoring Case Studiy (Gabion frame)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No damage	
b There is damage, However, It is not decline in function	・Corrosion covering the entire frame wire. (the surface of wire is rough all over) ・The corrosion has not caused the frame steel to break, and it has been no lost of the filling material.	
c There is decrease infunction	・Corrosion and other factors have caused deformations, breaking frame wire and lost filling material. ・Due to that, wall is deformated, delined stability.	

3.4.4 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Table 63 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Soundness level	Deformation condition	Countermeasure
A No action required	No damage	・Continue to monitor
B Observation	Level b deformation is observed, but there is no progressive and it is judged that there is no functional decrease at present.	・During periodic monitoring, it is monitored the progress of any deformations. ・In some cases, it is considered the frequency and timing of periodic monitoring.
C Required measures	・Deformation level is c. ・There are multiple deformation level b and these deformations are caused by the same factor or these deformation is progressing.	Repair work and emergency measures are considered and implemented.

Table 64 Case study of monitoring sheet (Periodic and emergency monitoring)

Site		Campo Ciero	Landslide Block	L-1
Construction year		2002	Structure No.	No.1
Structure specifications	Retaining wall type	Gabion	Report No.	1
	Height	3.0m	Monitoring date	2024/11/11
	Length	25.0m	Organization conducting monitoring	JET
			Name of person conducting monitoring	Hotaka Aoki

Item		Deformation	Comment
Wall body	Breakage	a	No damege
	Deformation	a	No damege
	Damage	a	No damege
	Spring water	a	Spring water is comfirmed at the wall bottom and drained through the channel in front of the retaining wall.
Foundation ground		a	No deformation
Surrounding conditions		a	No deformation

		Comment
Judgement	[✓ A : No action required]	･There are no dameges and deformationws at the retaining wall and surround. ･This type of retaining wall (gabion) is highly permeable. ･It drains the groundwater on the slope behind the retaining wall, and contributes to landslide stabilization.
	B : Observation	
	C : Reruired measures	

Drawing & Photo

3.5 Shotcrete

3.5.1 Structure of Shotcrete

Shotcrete work is slope stabilization method that spray mortar or concrete onto slopes using compressed air to coat the slope with mortar or concrete.

It can be used for slope stabilization work of any slope shape, length or height, and is adopted in many case.

The target ground includes weathered bedrock, crushed bedrock, bedrock with developed cracks, and bedrock that is easy to weaken due to rainwater infiltration.

It is also a precondition that no soil pressure acts on the structure.

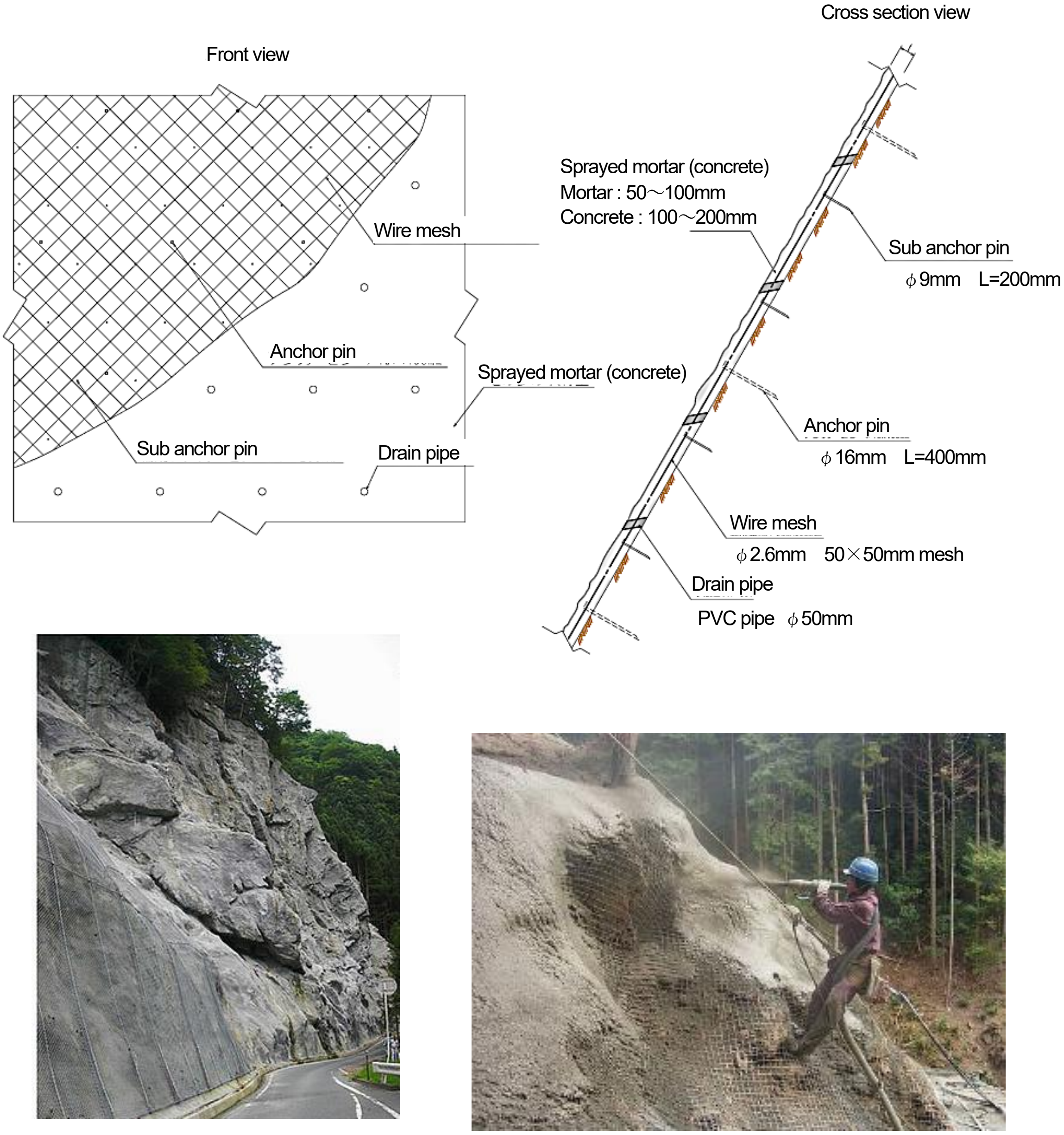


Figure 23　Image drawing and case study photo of shotcrete

3.5.2 Decline in the function of shotcrete and its causes

Table 65 Shotcrete deterioration and damage, and their causes and characteristics

Items		Type of deformations	Deformation characteristics	Causes
Parts	Material			
Spraied mortar & concrete	Mortar Concrete	Damage Deformation	Cracks Joints shifting Peeling Bulging Tilting End shifting Buckling Lifting Sliding Falling Wear Cavities behind shotcrete	Mortar deterioration Decrease in adhesion to the ground Deterioration of the behind ground Slope deformation Soil pressure Drying and swelling Plant root growth Surface water
		Soil runoff behind the shotcrete	Cavities behind shotcrete Spring water	Deterioration of the behind ground Flow water behind shotcrete
		Deterioration Corrosion	Cavities behind shotcrete Peeling Crack Free lime Deterioration of surface Corrosion	Mortar deterioration Decrease in adhesion to the ground Deterioration of the behind ground Drying and swelling Steel materal corrosion Chemical reaction
Drainage pipe	PVCpipe	PVC pipe	Blockage	Suction of soil behind shotcrete Vegetation growth
Surround ground		Damage Deformation	Collapse Crack Spring water Erosion Uplift Subsidence	Slope deformation (landslide etc.) Earthquake Surface water

It is shown case studies of deformation occured in shotcrete as followings.

（1） Peeling

Peeling occurs following proceed.

- Layered structure inside the Shotcrete caused by quality of the construction work is appeared
- Cracks caused by intrusion of plant roots is appeared,
- Rain water penetlate into crack, void and layer,
- Thin layer is weakened, due to repeated wetting and drying .
- Peeling occurs

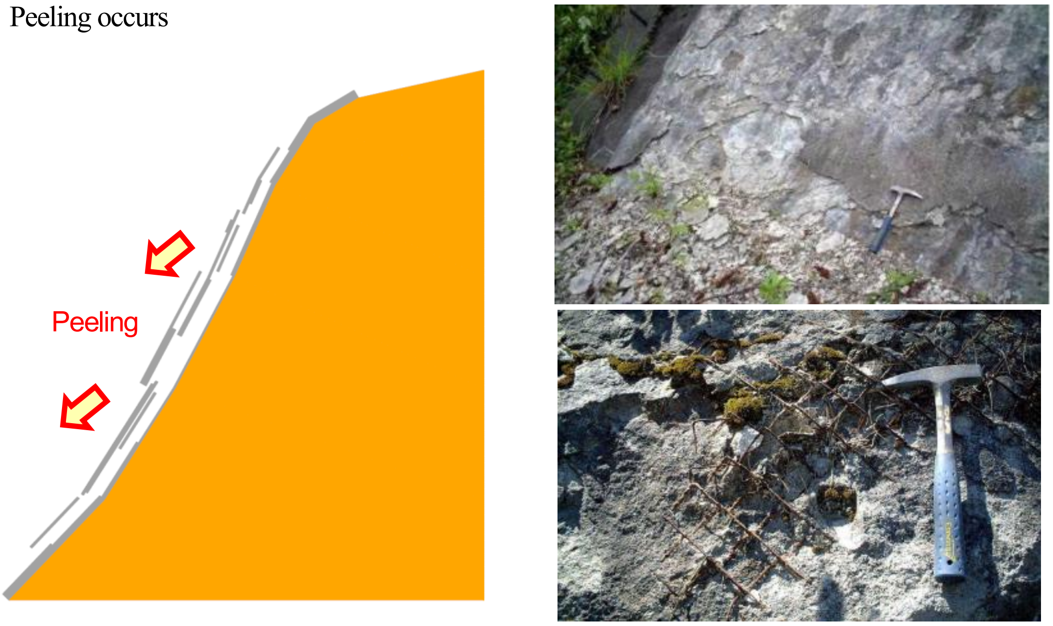


Figure 24　Image drawing and case study photo of peeling

（2） Crack

In general, cracks occur due to the deterioration of shotcrete over time and repeated wet and dry cycles.

The deterioration progresses due to rainwater penetrating these cracks, and this can cause the structure to collapse.

There are also cracks that occur due to the deformation of the ground behind the shotcrete, which will be explained later, so it is important to check the conditions of the ground behind the shotcrete.

Figure 25　Case study photo of crack

(3) Sliding

The shotcrete adheres to the ground and is integrated with the slope due to its adhesion.

In case that bedrock behind the shotcrete weak to weathering, it may be weak and in some cases the adhesion may decrease.

If the adhesion with the shotcrete and slope decreases, the shotcrete itself may not be able to support its own weight and the shotcrete may slide and fall.

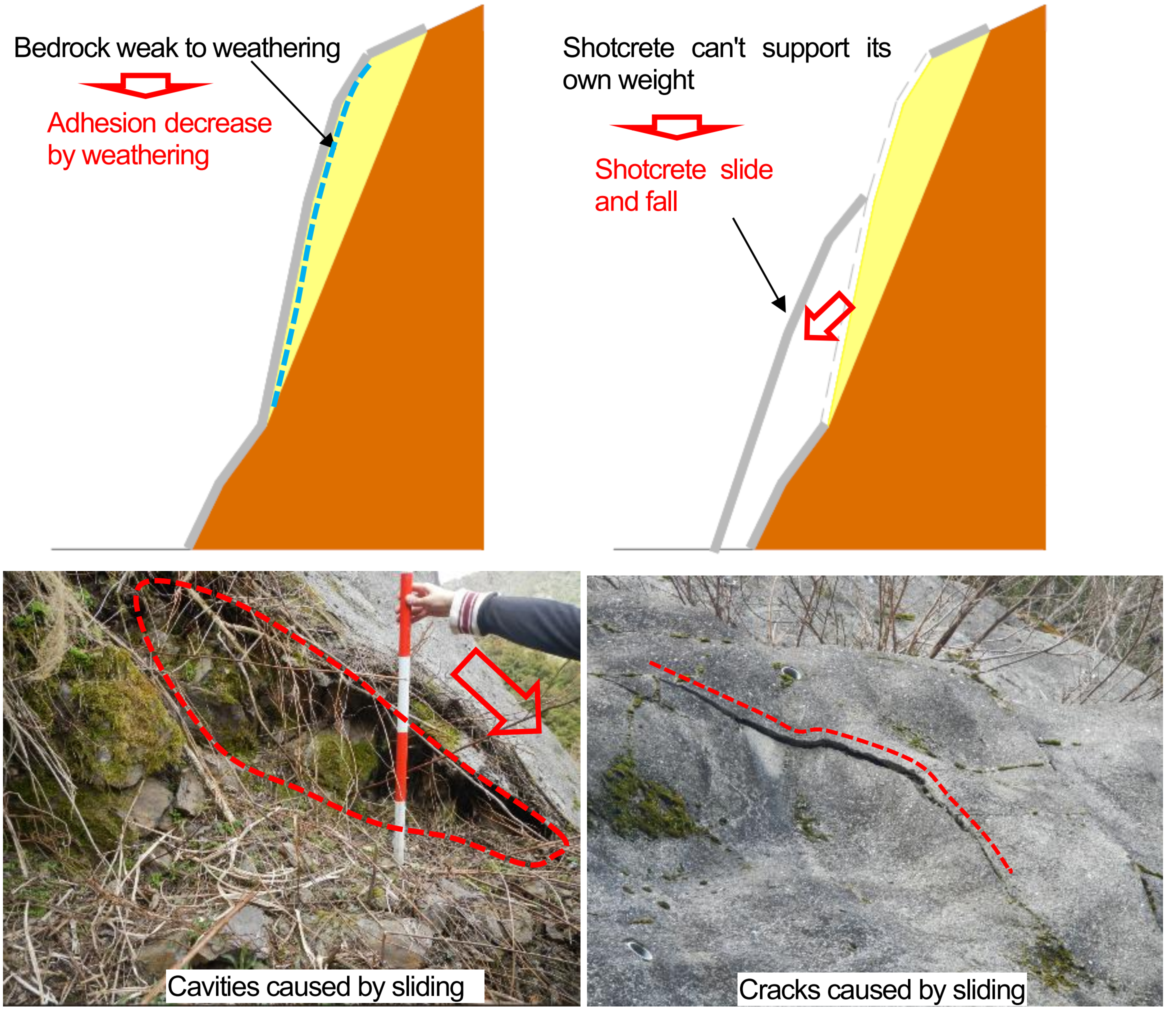


Figure 26 Image drawing and case study photo of sliding

(4) Soil runoff behind the Shotcrete

As the ground behind the shotcrete weathers, it becomes sediment, and due to the effects of seeping water and the repeated cycles of dry and wet, becoming to sediment is progress and sediment moves downward or is sucked out through the drainage holes. This causes a cavity to form behind the shotcrete.

The cavity cause decrease integration with shotcrete and ground, and shotcrete becomes unable to stand on its own. The earth pressure of the displaced soil acts on the shotcrete.

If the weight of the shotcrete and the earth pressure of the earth behind it exceeds the strength of the shotcrete, it will break.

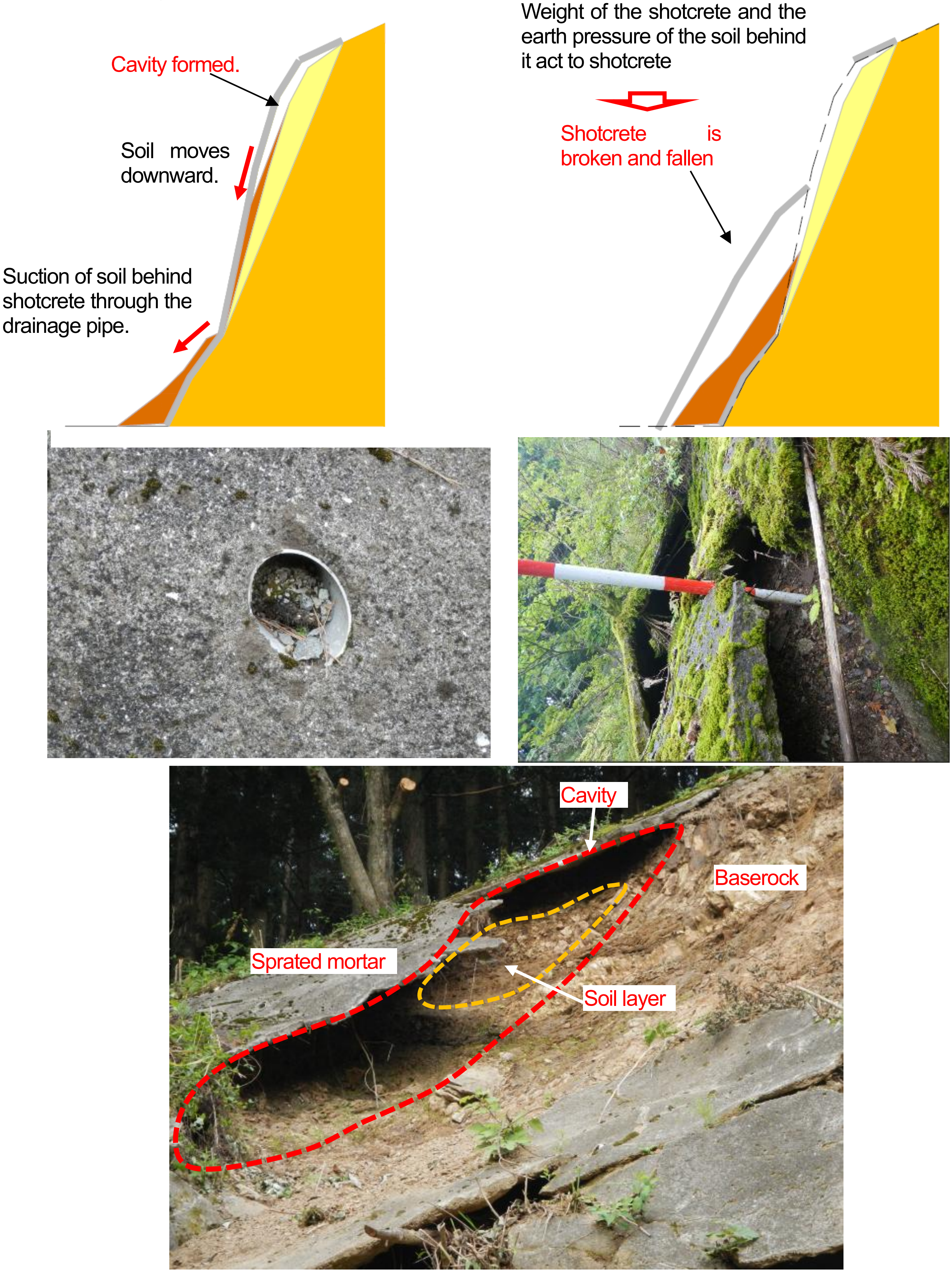


Figure 27 Image drawing and case study photo of soil runoff behind the shotcrete

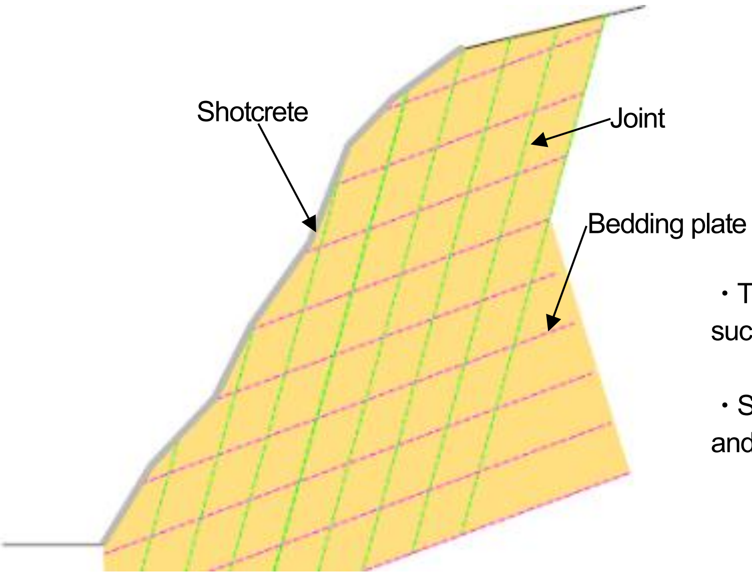
（5）Deformation caused by slope actibity (Tiliting, collapse, buckling etc.)

As the ground weathered, it become more fragile and loose. And then soil pressure begin to act on the shotcrete. The shotcrete can't resist the soil pressure, so deformation occurs in the structure.

The form of the deformation can be various, such as cracks, steps, sliding, buckling, end shifting, joint shifting, and tilting. If these conditions progress, there is a very high risk of collapse.

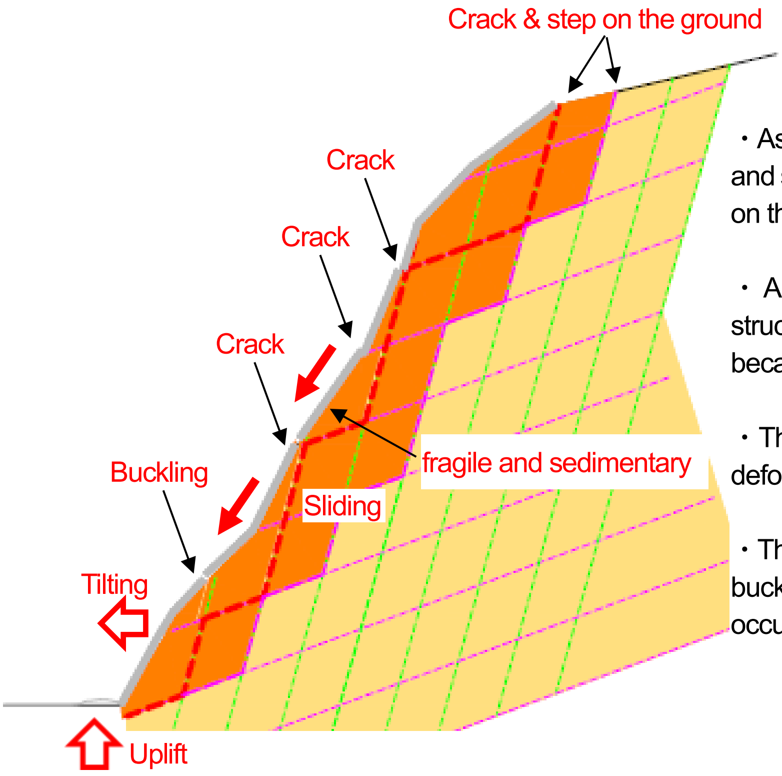
Even if the slope behind shotcrete is a hard bedrock, there are many cases that loosening occurs due to geological structures such as joints and bedding planes, leading to collapse. When this type of displacement occurs, cracks and other deformations are often occured on the surrounding slopes as well.

It is shown deformation caused by slope actibity and procese to collapse occuring as following.



・The slope is developed with geological structures such as joints and bedding planes.

・Shotcrete is installed in order to control erosion and weathering.

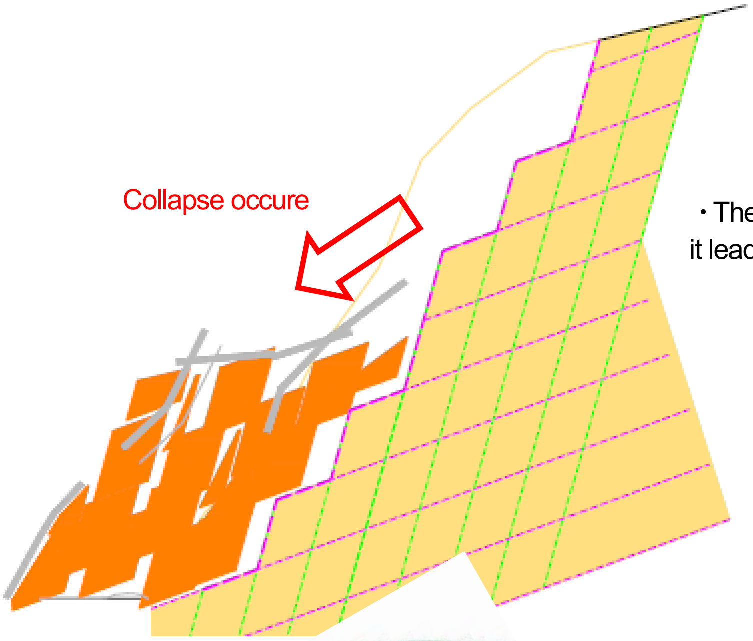


・As the ground weathered, it became more fragile and sedimentary, and the soil pressure began to act on the shotcrete.

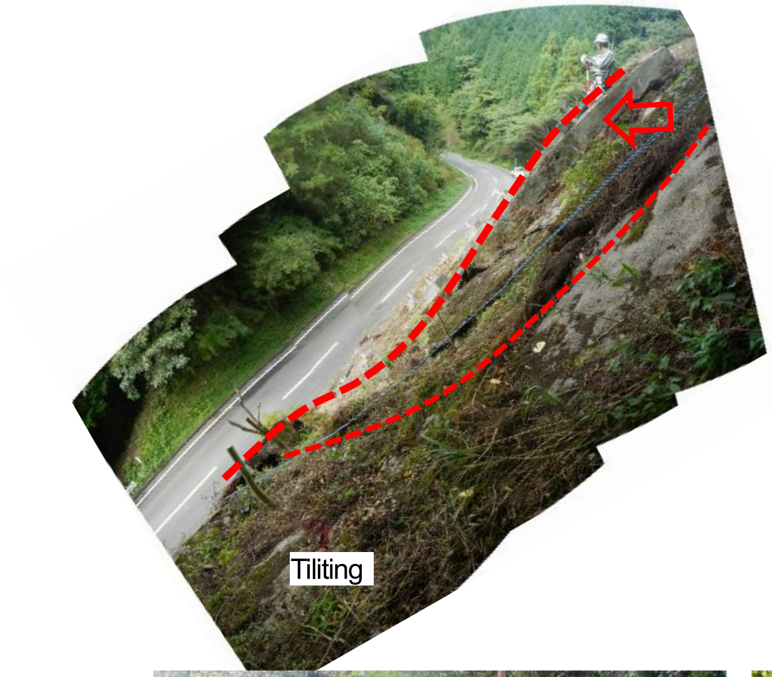
・And bedrocks are separated with geological structures such as joints and bedding planes, became to fragile.

・The shotcrete can't resist the soil pressure, so deformation occurs in the structure.

・The deformation such as cracks, steps, sliding, buckling, end shifting, joint shifting, and tilting occured.



・These deformations are progressed, and then it leads to collapse.



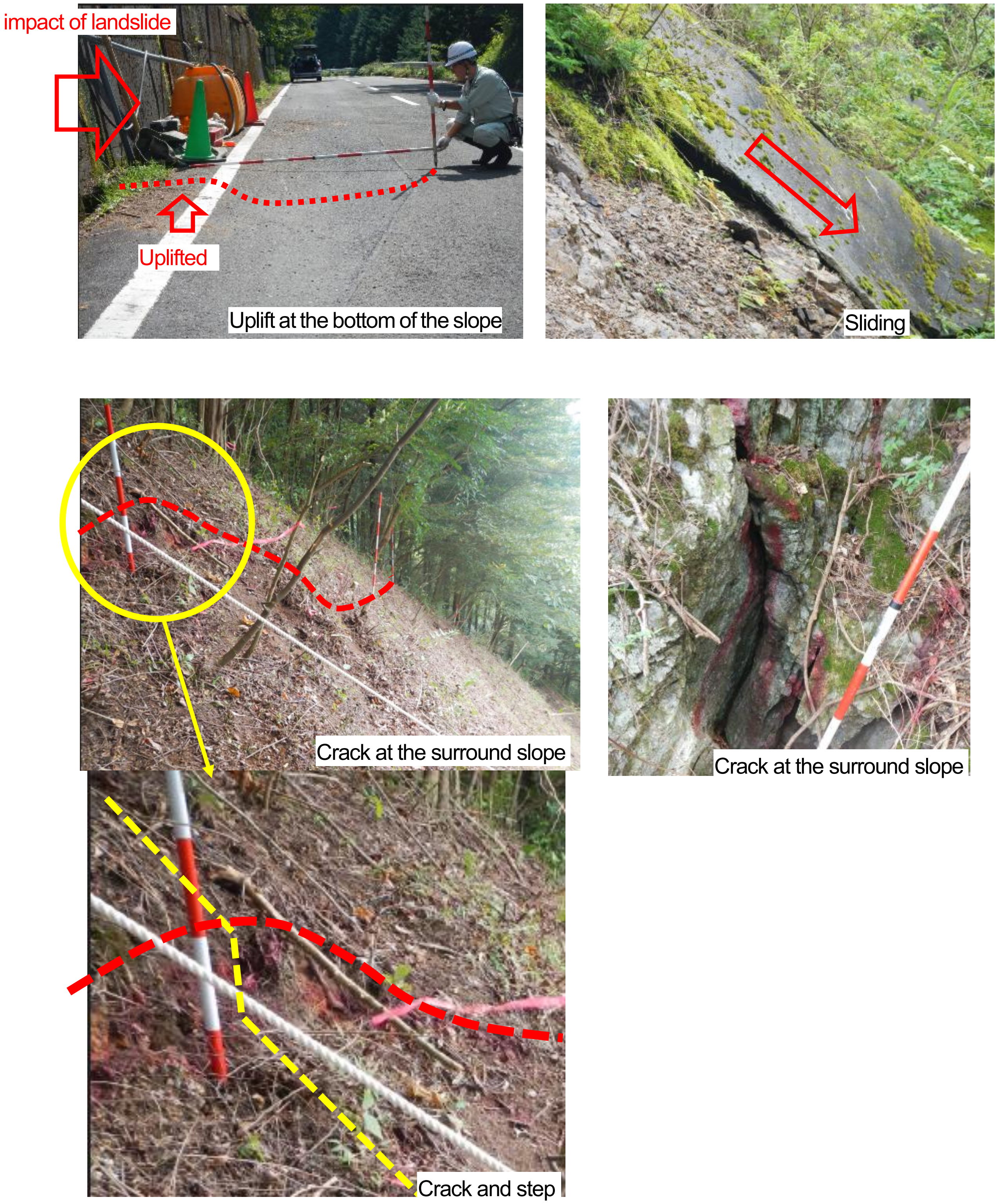


Figure 28 Image drawing and case study photo of facility deformation caused by slope actibity

3.5.3 Evaluation criteria for deformation level (Periodic and emergency monitoring)

Table 66 Evaluation criteria for deformation level (Shotcrete)

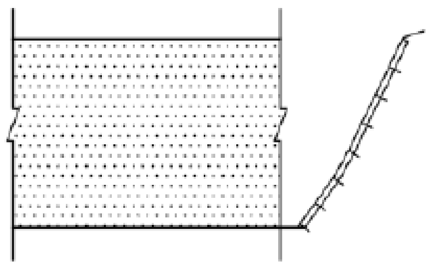
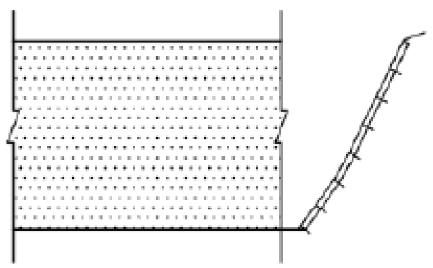
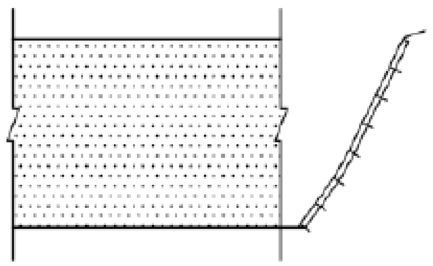
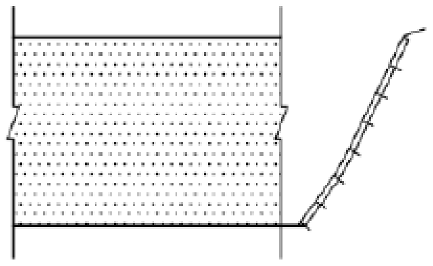
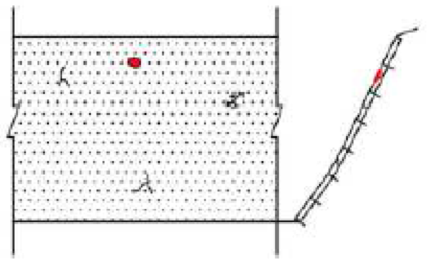
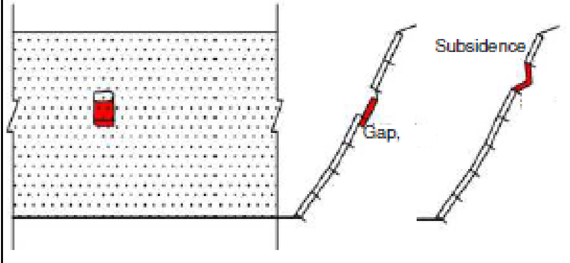
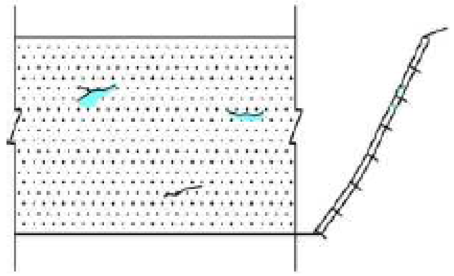
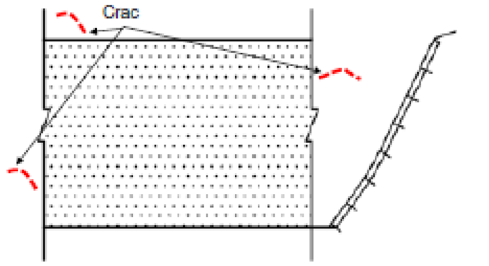
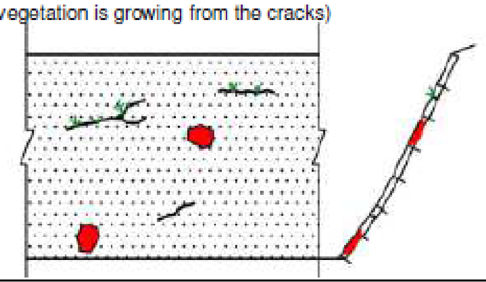
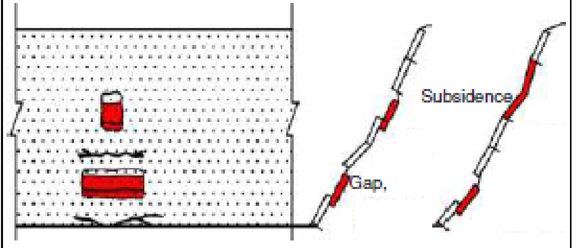
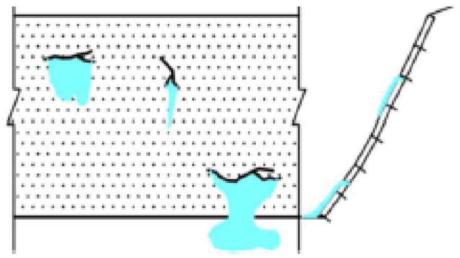
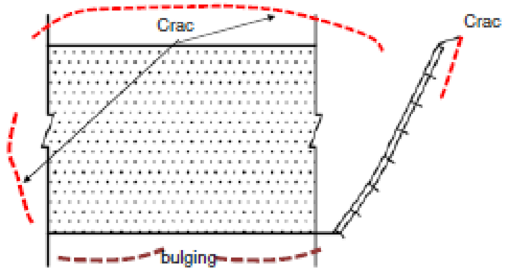
Deformation level		Shotcrete			
		Crack, Peeling, Corrosion,	Joints shifting, Bulging, Tilting, End shifting, Buckling, Lifting, Sliding, Falling, Crack,Subsidence, Cavities behind shotcrete	Spring water	Surround ground
a	Minor or no damage	･No damege ･Minor cracks 	･No damege 	･Constantly spring water or water flowing from drainpipes during rainfall isn't observed. 	･No cracks, subsidence, bulging, or other deformations areobserved on the surrounding slopes. 
b	There is damage, but it has not resulted in a decline in function or performance	･Partial peeling of the surface (thin peeling) ･There are several cracks that is not opened and developed at random (there is no continuous crack) 	･There are localized sliding, shifting, bulging, gaps, cavities and subsidence,etc. 	･Constantly spring water or water flowing from drainpipes during rainfall is observed. 	･Cracks, subsidence, bulging, or other deformations are observed on the surrounding slope locally and these deformations are not continuous or related, and are not 
c	There is a decrease in function or performance	･There are large, thick peels over a wide area. In addition, wire mesh and the ground have been exposed due to the peeling ･ There are open cracks occurring continuously over a wide area. (vegetation is growing from the cracks) 	･There is bulging, gaps, cavities, subsidence and sinking (sliding down) at widely range. ･In addition, these displacements are continuous, and the deformation is progressing. 	･Constantly spring water or water flowing from drainpipes during rainfall is observed at widely range. ･These phenomenon is also observed at crack and other deformation parts. 	･Cracks, subsidence, bulging, or other deformations are observed on the surrounding slope and these deformations are continuous or related, and are progressing. 
Evaluation Points		･If the cracks and peeling progress and holes is formed, the function of the shotcrete have already delined significantly. ･Rainwater flowing in through the cracks will cause further weathering and erosion, weakening the ground. ･It is should be implemented hanmer test to check cracks, peeling, and cavity behind shotcrete progress.	･In many case that the displacement caused by subsidence and cave-ins ocurred, cavities behind shotcrete is formed. The adhesion between the shotcrete and the ground has deteriorated, and the structure's function has declined. ･In areas where the bulging at shotcrete ocurred, earth pressure by soil behind shotcrete is acting to shotcrete. If this situation progresses, it will cause the shotcrete to collapse ･At points where bulging out and subsidence are significant, the situation should be checked by hammer test. In some cases, it is desirable to implement core drilling and check the situation behind the shotcrete.	･If there is a significant amount of spring water, there is a risk to form cavities, due to erosion by flowing water behind the shotcrete. ･If forming cavities progresses, the adhesion between the shotcrete and the ground has deteriorated, and the structure's function has declined. ･For locations where there is significant spring water, it should be implement hammer test.	･If there are significant deformations such as cracks on the surrounding slopes, it is judged that the slope is becoming unstable. ･In this situation, it is difficult to stabilize the slope using Shotcrete alone. ･It is necessary to consider and implement additional countermeasures.
Points to note for monitoring		The deformations shown here are often highly related to the causes of their occurrence. If significant deformations are observed, it is necessary to consider various factors and study their relationship with other deformations and the stability of the slope.			

Table 67　Monitoring Case Studiy (Shotcrete：Deformations of main body)

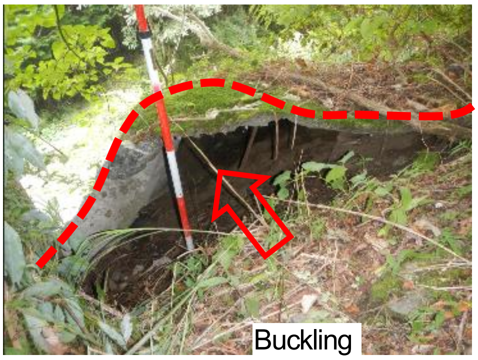
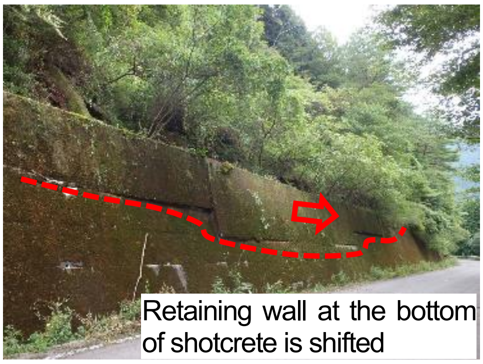
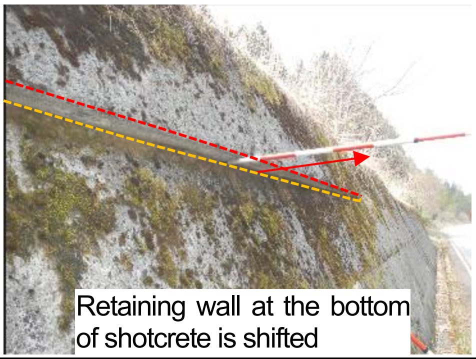
Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No damage	
b There is damage, However, It is not decline in function	・Some cracks are occured. ・Cracks are not opened. ・No spring water at the crack. ・Other deformations are not occured. ・It is kept function of shotcrete.	
c There is decrease infunction	・Deformations such as opened cracks, sliding, buckling, cavity behind shotocrete are occures. ・Shotocrete is not integrated with the ground and already collapsed or moved. ・Shotcrete don't keep function of structure.	  Sliding  Buckling

Table 68　Monitoring Case Studiy (Spring water at the Shotcrete)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No spring water	
b There is damage, However, It is not decline in function	・Some cracks are occured. ・Cracks are not opened. ・Trace of springwater at the crack is confirmed. ・Other deformations are not occured. ・It is kept function of shotcrete.	
c There is decrease infunction	・Big amount spring water is appreared, despite no rainfall. ・In addition, deformations such as opened cracks, sliding, buckling, cavity behind shotocrete etc. are occures.	

Table 69　Monitoring Case Studiy (Surround slope of the Shotcrete)

Deformation level	Points to note formonitoring	Situation phot
a Minor or no damage	・No damage	
b There is damage, However, It is not decline in function	・Some cracks are occured upward slope of shotcrete. ・Cracks are not continuous. ・Deformations are not occurred at shotcrete.. ・It should be observed change of these crack.	
c There is decrease infunction	・Some cracks are occured upward slope of shotcrete. ・These cracks are continuous and encircle shotocrete. ・Retaining wall at the bottom of shotcrete is shifted by slope activity. ・In addition, deformations such as opened cracks, sliding, buckling, cavity behind shotocrete etc. are occures.	  Retaining wall at the bottom of shotcrete is shifted  Retaining wall at the bottom of shotcrete is shifted

3.5.4 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Table 70 Evaluation criteria for soundness level (Periodic and emergency monitoring)

Soundness level	Deformation condition	Countermeasure
A No action required	No damage	・Continue to monitor
B Observation	Level b deformation is observed, but there is no progressive and it is judged that there is no functional decrease at present.	・During periodic monitoring, it is monitored the progress of any deformations. ・In some cases, it is considered the frequency and timing of regular inspections.
C Required measures	・Deformation level is c. ・There are multiple deformation level b and these deformations are caused by the same factor or these deformation is progressing.	Necessary detailed monitoring is conducted, and repair work and emergency measures are considered and implemented.

Table 71 Case study of monitoring sheet (Periodic and emergency monitoring)

○ Case study A : In cases of slope destabilization

Site		Campo Ciero	Landslide Block	L-1
Construction year		2002	Structure No.	No.1
Structure specifications	Thickness of shotcrete	100mm	Report No.	1
	Height	50.0m	Monitoring date	2024/11/11
	Length	40.0m	Organization conducting monitoring	JET
			Name of person conducting monitoring	Hotaka Aoki

Item		Deformation level	Comment
Wall body	Crack	c	Opened cracks with cavity behind shotcrete are confirmed.
	Peeling	c	Peelings are observed in many places
	Shifting	c	At the joint, shotcrete is shifted.
	Bulging	c	At bottom of slope, bulgings of shotocrete are confirmed
	Sliding	c	At edge of slope, sliding of shotocrete are confirmed
	Buckling	c	Significant backling is confirmed below the middle of the shotcrete construction area.
	Other deformations	c	At bottom of the slope, tilting of shotocrete are confirmed
Spring water		c	At bottom of the slope, big amount spring water is appreared, despite no rainfall.
Surrounding conditions		c	At the upper slope of the shotcrete, opened cracks with step are confirmed, they are continue within area of shotcrete. Retaining wall at bottom of the shotcrete is tilted with occuring crack.

		Comment
Judgement	A : No action required	A landslide is occurring over a wide area (50m x 70m), including the shotcrete construction area. As a result, the shotcrete and retaining wall have been damaged. In order to restore the facility, it is necessary to investigate the mechanism of the landslide and then consider countermeasures.
	B : Observation	
	[✓ C : Reruired measures]	

Drawing & Photo

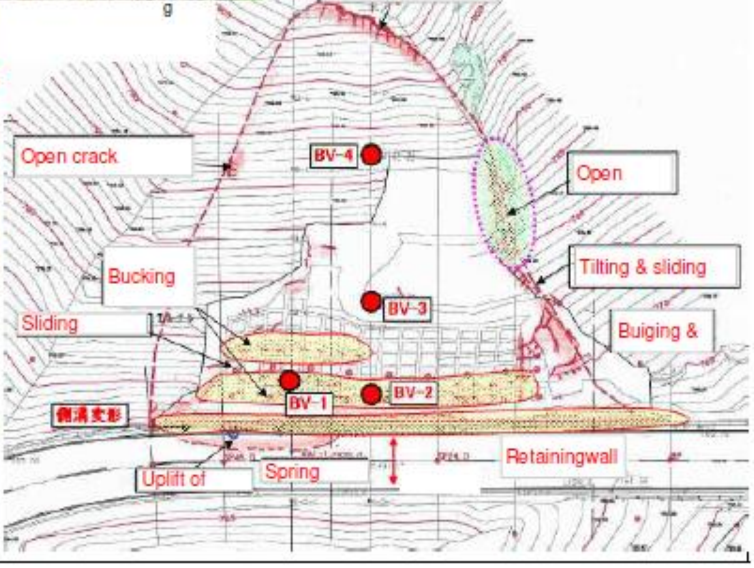


Table 72 Case study of monitoring sheet (Periodic and emergency monitoring)

○ Case study B : In case of structure deformation (slope is not destabilization)

Site		Campo Ciero	Landslide Block	L-2
Construction year		2000	Structure No.	No.2
Structure specifications	Thickness of shotcrete	100mm	Report No.	1
	Height	30.0m	Monitoring date	2024/11/15
	Length	30.0m	Organization conducting monitoring	JET
			Name of person conducting monitoring	Hotaka Aoki

Item		Deformation level	Comment
Wall body	Crack	c	Opened cracks with cavity behind shotcrete are confirmed.
	Peeling	c	Peelings are observed in many places
	Shifting	a	-
	Bulging	a	-
	Sliding	c	At edge of slope, sliding of shotocrete are confirmed
	Buckling	a	-
	Other deformations	a	
Spring water		b	At bottom of the slope, spring water traces are appreared at crack position.
Surrounding conditions		a	

		Comment
Judgement	A : No action required	Because of the ground behind the shotcrete weathering and sediment sucking out, then cavity seems formed at behind shotcrete. And then cracks is occured. At some cracks, there is spring water. It should be confirm range of cavity and deformation by detail monitoring. And depend on the scale of that, repare is required . At the slope surround the shotcrete, there are no deformations such as cracks.
	B : Observation	
	[✓ C : Reruired measures]	

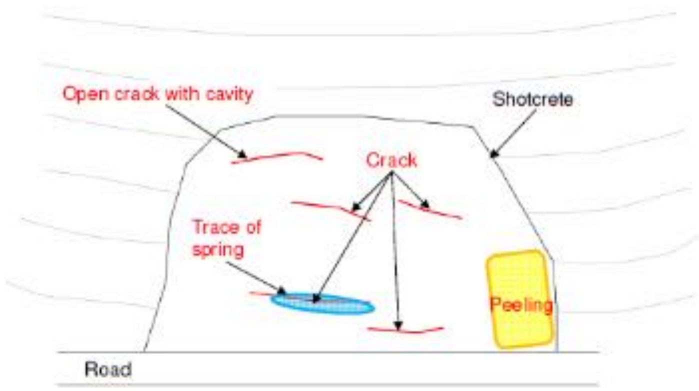
Drawing & Photo


Open crack with cavity


Crack


Peeling


Trace of spring



3.5.5 Detailed monitoring

The reduction in the function of shotcrete is closely related to the geological conditions of the slope in the target area, and the deterioration of the facility itself and the conditions of the slope behind it have a mutual influence on each other.

Shotocrete is a method of covering the surface of a slope with sprayed mortar (concrete) to prevent erosion and weathering of the surface layer

This method itself does not have the strength to resist soil pressure, and only has the function of controlling erosion and weathering by integrating with the ground.

The following factors cause Shotcrete to deteriorate in function.

- Deterioration of the facility itself.
- Decrease in integration with the ground.
- Instability of the slope.

The following items are included in the detailed survey

- Detailed survey of the location and condition of any deformation in the facility.
- Hammer test (to check for facility deterioration and cavity behind shotcrete)
- Core drilling survey.
- Crack monitoring.
- Slope condition survey (geological survey, landslide monitoring, analisys).

（1）Detailed survey of the location and condition of deformation and Hammer test

Check and record all positions of facilities deformated

Check and record the condition of each positions of deformations.

Check for deterioration and cavities behind shotcrete by performing hammer tests

The survey will be more effective if the target slope is divided into small blocks and the survey is carried out in this way

○Check and record all positions of facilities deformated and condition of each positions.

As shown in the diagram below, divide the target facility into small blocks and investigate and record the location, shape and condition of the deformation.

At this time, pay attention to the following points

- ・Clarify the type of deformation. (cracks, buckling, peeling, etc.)
- ・Investigate and record the scale and condition of each deformation.
  (crack width, presence or absence of openings, peeling thickness, blockage of water drainage pipes, etc.)
- ・Take photographs of each deformation and organize them

In addition, the condition of the surrounding slopes should also be investigated.

(Slope cracks, collapses, spring water, etc.)

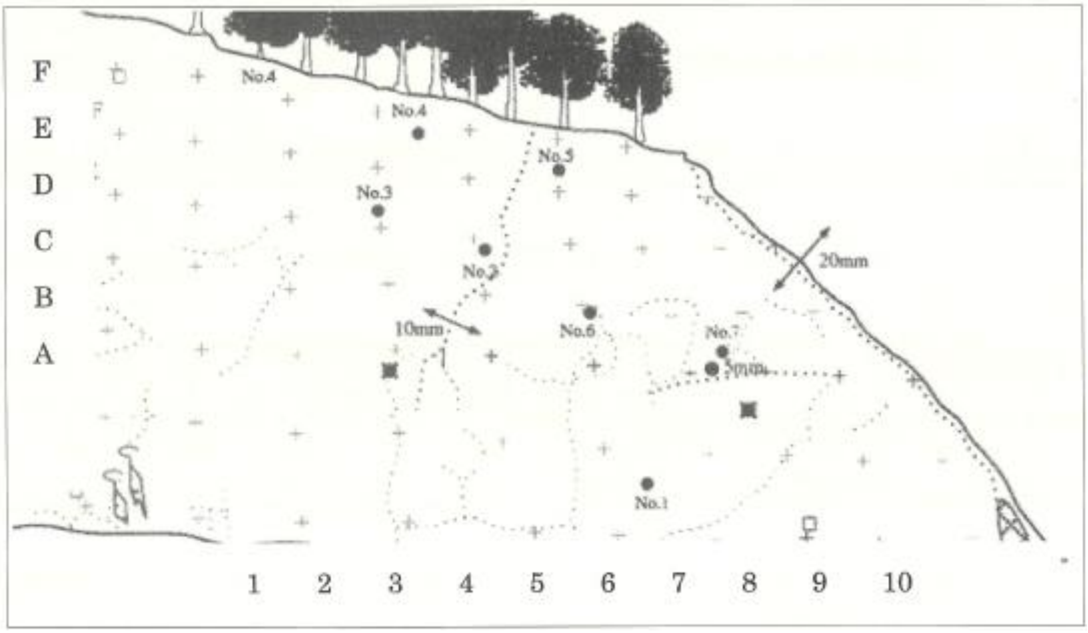


Figure 29　Example of survey summary divided into blocks

○Hanmer test

The hammer test judges the condition of the facility and its rear by hitting the surface of the shotcrete with a hammer and listening to the sounds it makes.

If the sound of the hammering has a clear, high tone, the mortar and concrete have not deteriorated, and the cavity behind the shotcrete has not progressed.

If the sprayed mortar (concrete) has deteriorated or there is a cavity behind shotocrete, it will sound muddy and low. (Refer to P.10)

（2）Core drilling survey

The core drilling survey is drilling the shotcrete, taking core, and directly observing the depth of the cracks and the state of deterioration in the sprayed mortar (concrete), as well as checking for the presence of cavities behind shotcrete.

In addition, the strength of the core is tested to check the state of deterioration and strength.

The items to check are as follows

Table 73　Evaluation items for core drilling survey

Investigation items	Observation items
Sprayed mortar thickness	Check against the design thickness
Cavity	Presence or absence of cavities behind shotcrete
Condition of the ground behind the shotcrete	Check for weathering, cracks, and spring water
Core condition	Check for cracks, discoloration, etc.
Compressive strength	Comparison with design strength (checking for deterioration)
Cabonation thickness	Covering thickness of rebar, corrosion status of rebar

（3）Crack monitoring

This is method that marking or riveting the measurement points where crack occured, observing progress of crack expansion.

In monitoring, it is measured of distance between marking or rivet of crack positions and grasped progress of crack expantion quantitatively.　（See below photo）

If cracks occur on the upper slope of shotcrete, it is also effective to install a profile and measure it them.
(See below photo）

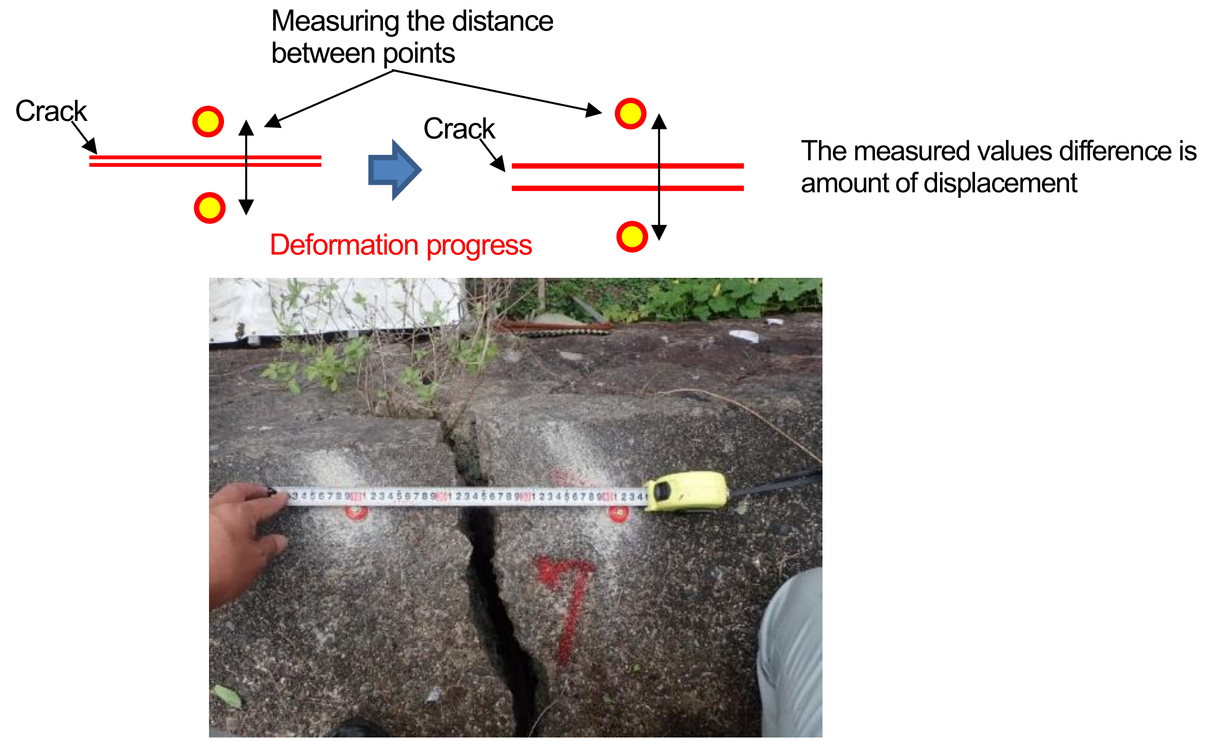


Figure 30　Crack monitoring (Mesuring markings or rivets)

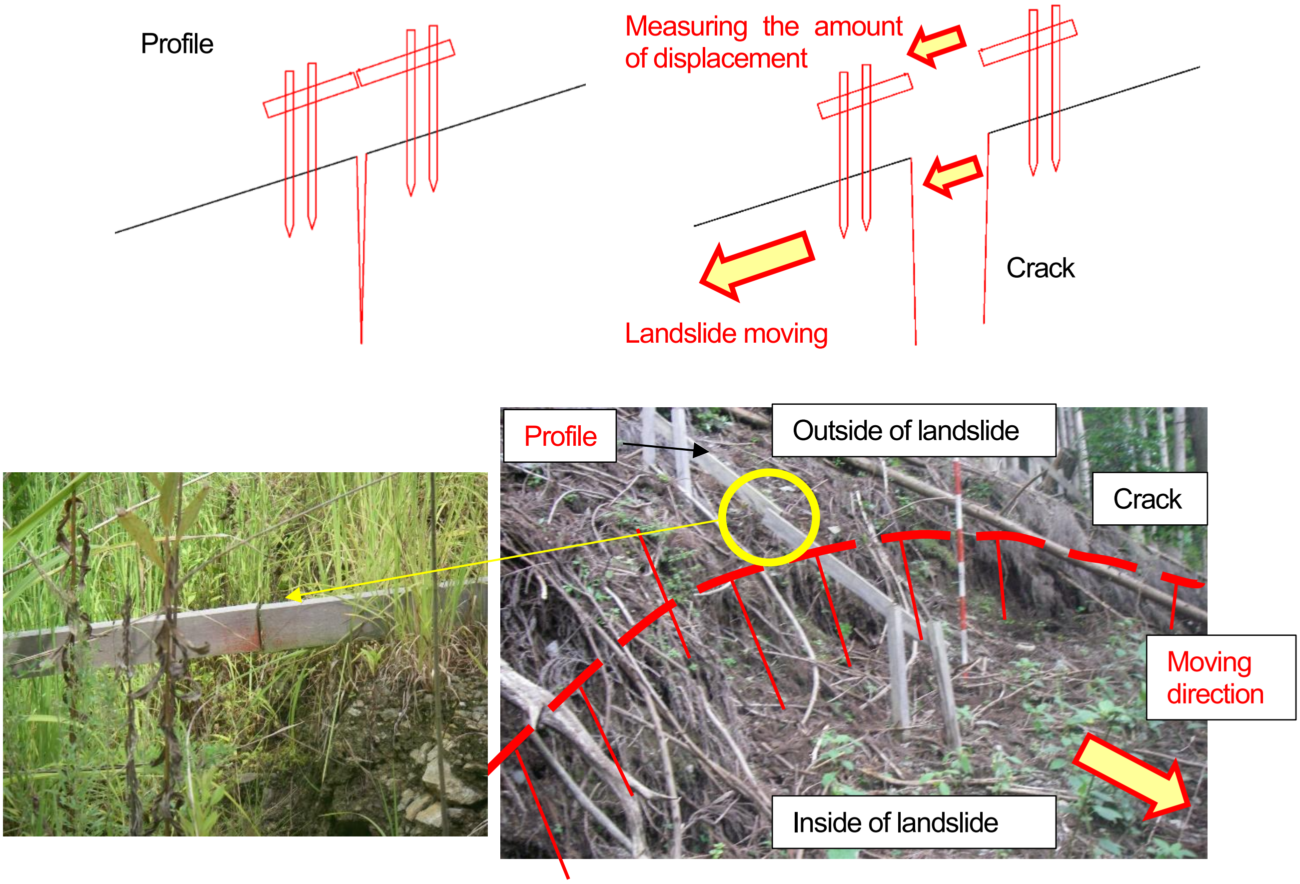


Figure 31　Crack monitoring (Measuring profile)

（4）Slope condition survey (geological survey, landslide monitoring, analisys)

If the target slope is unstable and moving, shotcrete cannot be used to stabilize it.

Therefore, it is necessary to take countermeasures suitable for the slope activity type.

Investigation, analysis and design are required for the implement of countermeasures.

（5）Evaluation of the results of the detailed monitoring

The following are the criteria for evaluating the level of deformation for individual deformations.

Table 74　Evaluation of deformation survey and hammer test. (damage, breakage, deformation)

Deformations level	Evalution of deformations
1	・No damage and deformation ・The hammer test sounds a clear sound. ・Minor crack, peeling occure
2	・There are deformations(demages, peelings or cracks etc) continuouly or within a certain area. ・The opening and gap in the joints can be clearly confirmed. ・Cavities behind of the shotcrete is suspected (based on the results of the hammer test) ・Muddy sound in the hammer test
3	・There is a tilting, bulging, shifting at the end, and opened crack. ・There is a large displacement with a step. ・Cavity is confirmed. ・Muddy sound in the hammer test

Table 75　Evaluation of deformation survey and hammer test. (Corrosion, deterioration)

Deformations level	Evalution of deformations
1	・No or minor deterioration and corrosion ・The hammer test sounds a clear sound.
2	・Free lime, peeling and cracks by deteriorations are confirmed. ・The compressive strength of the sprayed mortar is below the design value. ・Cavities behind of the shotcrete is suspected (based on the results of the hammer test) ・Muddy sound in the hammer test
3	・The sprayed mortar has peeled off, exposing the steel bars and wirenet ・The mortar has lifted and peeled off due to corrosion of the steel bars and wirenet.. ・Cavity is confirmed. ・Muddy sound in the hammer test

It should to be judged based on a single item, but to be considered each item and be made a judgment.

If there is a possibility of cavities forming behind of the shotcrete or if there is concern about deterioration of the interior of the sprayed mortar, core drilling should be carried out.

Table 76 Deformation level by detailed survey of the location and condition of deformation and Hammer test

Item	Deformation level	Comment
Damage Deformation	a	･All areas are Level 1 ･Distribution area of Level 2 areas is less than 10% of the total area.
	b	･Distribution area of Level 2 areas is 10～30% of the total area. ･Level 3 position is more than one, and it's distributed area is less than 10% of the total area.
	c	･Distributed area of Level 3 is more than 10% of the total area. ･Distributed area of Level 2 is more than 30% of the total area. ･There is a risk of it falling cause by floating or peeling off of shotcrete or large displacement with a step.
Corrosion, Deterioration	a	･All areas are Level 1 ･Distribution area of Level 2 areas is less than 10% of the total area.
	b	･Distribution area of Level 2 areas is 10～30% of the total area. ･Level 3 position is more than one, and it's distributed area is less than 10% of the total area.
	c	･Distributed area of Level 3 is more than 10% of the total area. ･Distributed area of Level 2 is more than 30% of the total area. ･Cavity behind shotcrete is developed at concentrated in a specific place with widely area. (Not scattered)

○Case study

The target slope (30 x 50 = 1500 m2) was divided into 5 x 5 = 25 m2 squares, and the deformation in each mesh was investigated

Deformation level 3: 12 meshes = 300 m2, 20% range

Deformation level 2: 6 meshes = 150 m2, 10% range

The deformation level of the facility is judged to be c.

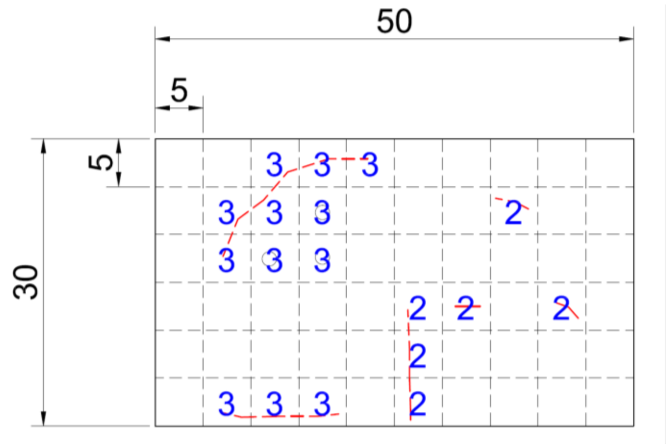


Table 77 Evaluation of detailed survey of the location and condition of deformation (Drainage pipe)

Deformations level	Evalution of deformations
1	・The blockage is slight and the drainage function is maintained.
2	・The blockage is moderate and the drainage function is reduced.
3	・The blockage is significant and the drainage function is reduced or lost.

Table 78 Deformation level by detailed survey of the location and condition of deformation (Drainage pipe)

Item	Deformation level	Comment
Drainage pipe	a	・All areas are Level 1 ・Amount of Level 2 pipes is less than 10% of the total.
	b	・Amount of Level 2 pipes is 10～30% of the total.. ・Level 3 position is more than one, and it's amount is less than 10% of the total.
	c	・Amount of Level 3 pipes is more than 10% of the total. ・Amount of Level 2 pipes is more than 30% of the total.

(6) Overall evaluation

The following are the evaluation criteria for facility soundness base on the deformation level

Table 79 Overall evaluation and measure in monitoring of shotcrete.

Deformation level	Overall evaluation	Measures
A	In the case of Level a for all items (Damage, Deformation, Corrosion, Deterioration, Drainage Pipe)	Continue periodic monitoring
B	In the case of Level b for any item (no items judged as Level c).	<Follow-up observation> Increase the frequency of periodic monitoring. Conduct detailed inspections during periodic monitoring to check for any progression of deformations.
C	In the case of Level c for any item. In case that slope deformation is confirmed and it is difficult to take measures for deformation by only shotcrete, and additional countermeasures are required.	<Take measures> Consider and implement repair work and emergency measures. Additional slope stability countermeasures should be implemented as necessary (based on the slope survey and analysis results).

Table 80　Case study of monitoring sheet (Detailed monitoring)

Site	Campo Cielo	Structure specifications	Thickness of shotcrete	10 cm	Monitoring date	2024/10/10
Construction year	2010		Required strength	180 N/mm2	Organization condunting monitoring	JET
Structure No.	1		Height	30 m	Name of prerson conducting monitoring	Hotaka Aoki
Report No.	1		Length	50 m		

Deformation No.	Position	Deformation	Deformation level	Core drilling			
				Thickness of shotcrete	Thickness of cavety	Ground situation	Compressive strength
1	2-A	Bulding	3				
2	2-D	Crack	3				
3	2-E	Crack	3				
4	3-A	Bulding	3				
5	3-D	Cavity	3	8	5	sediment	130
6	3-E	Crack	3				
7	3-F	Crack	3				
8	4-A	Bulding	3				
9	4-D	Cavity	3	7.5	5	sediment	150
10	4-E	Cavity	3	9	10	sediment	180
11	4-F	Crack	3				
12	5-F	Crack	3				
13	6-A	Gap at joint	2				
14	6-B	Gap at joint	2				
15	6-C	Gap at joint	2				
16	7-C	Crack	2				
17	8-E	Crack	2				
18	9-C	Crack	3				
19	9-D	Cavity	3	8	5	sediment	150
20	9-E	Cavity	3	8	5	sediment	150

Deformation No.	Position	Deformation	Deformation level
1	2-B	Blocage	2
2	3-B	Blocage	2
3	4-B	Blocage	2
4			
5			
6			
7			
8			
9			
10			

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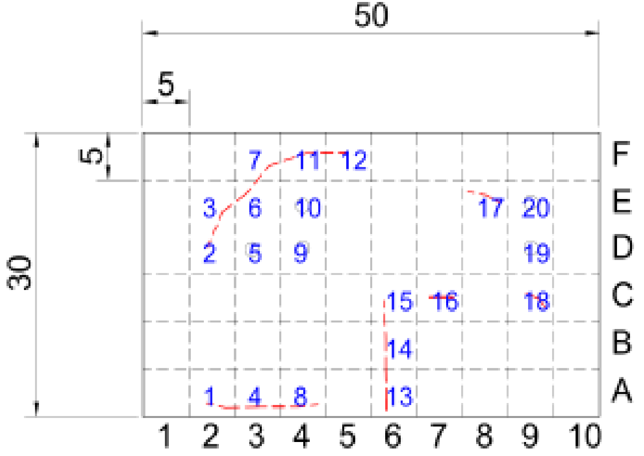


Damage, Deformation				Core drilling		Average	required	
Level 2	5	8.3%	c	Thickness of shotcrete		8.1 cm	10 cm	NG
Level 3	15	25.0%		Compressive strength		152N/mm2	180 N/mm2	NG
Corrosion, Deterioration				Core drilling				
Level 2	0	0.0%	a	Level 2	3	5.0%	a	
Level 3	0	0.0%		Level 3	0	0.0%		
Judgement	A : No action required							
	B : Observation							
	[✓ C : Reruired measures]							

<Comment>

･The cavities behind of the shotcrete and cracks are confirmed at wide range.

･Even in core drilling, cavities behind the shotcrete and the weakening of the slope have been confirmed.

･It is found that the deterioration is progressing because the thickness of the shotcrete is thinner than the thickness at the time of construction (10cm) and the compressive strength do not have the specified strength.

･No cracks or other deformations is confirmed on the slopes around the shotcrete.

･It is considered that the deformations have occurred due to the deterioration of the shotcrete and the decrease in its integration with the slope.

･It is judged that repair is necessary.

Chapter 4. Landslide activity monitoring and facility monitoring.

4.1 Concept

Slope stability can be kept by the health functioning of the installed facilities.

However, the facilities of countermeasure will gradually deteriorate and functions of countermeasure will gradually become reduce.

If a change in the slope condition occurs, it is necessary to determine whether the cause is due to a reduce in the function of the installed countermeasures or unexpected change in the slope conditions, and to investigate and take action to the cause.

Especially in the case of landslide countermeasures, it is important to conduct monitoring of slope condition and facility functions in parallel in order to confirm each condition.

In the previous chapter, it is explained the monitoring method for evaluation the soundness of facilities.

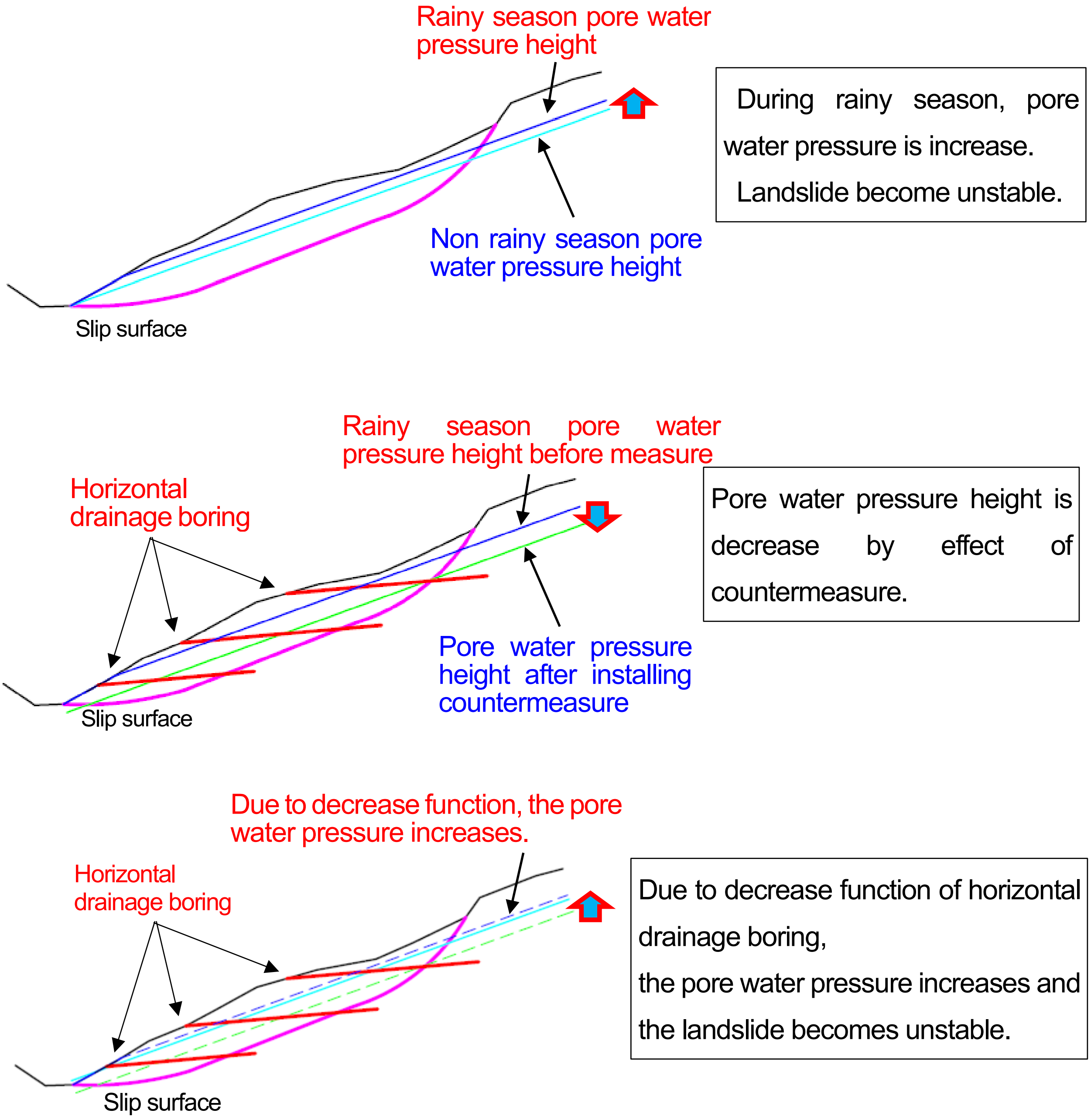
In this chapter, it is focused on landslide countermeasures, in particular, groundwater control work (horizontal drainage boring), and explained the relationship between slope monitoring and facility monitoring and maintenance.

4.2 Landslide activity monitoring results and facility monitoring

The stability of a landslide is affected by the pore water pressure of the groundwater acting on the slip surface. If the pore water pressure increases, the slope becomes unstable, and if it decreases, it becomes stable.

Groundwater control work prevents the pore water pressure from increasing by removing the groundwater that acts on the sliding surface, and stabilizes the landslide.

If the horizontal drainage boring is functioning soundly, it is possible to prevent the pore water pressure increasing and stabilize the landslide. However, if its function decrease, the pore water pressure increases and the landslide becomes unstable.



During rainy season, pore water pressure is increase. Landslide become unstable.

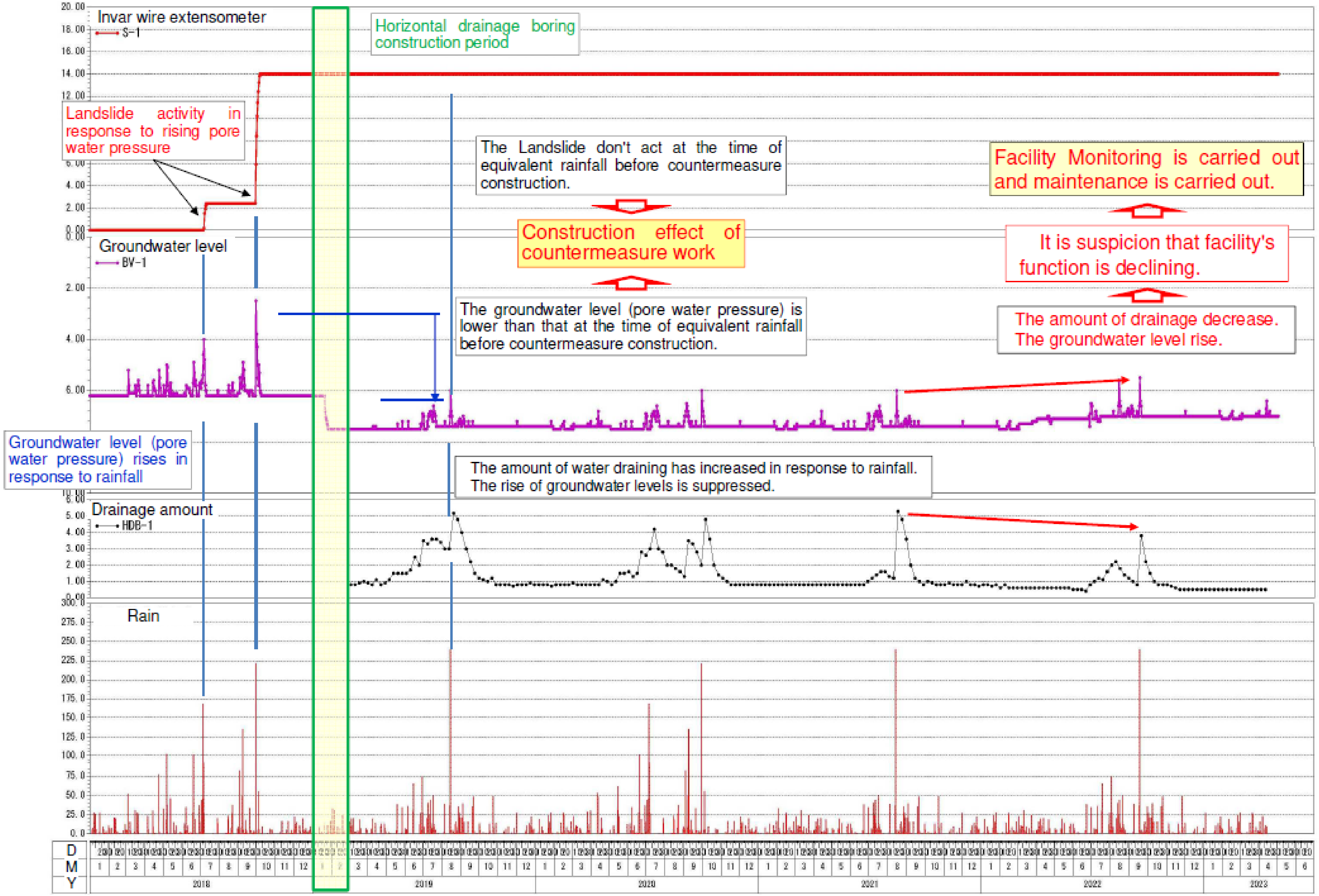
Pore water pressure height is decrease by effect of countermeasure.

Due to decrease function of horizontal drainage boring,
the pore water pressure increases and the landslide becomes unstable.

Figure 32 Image drawing of pore water pressure and landslide activity

In order to understand the soundness of the countermeasure function, it is effective to check the results of the landslide activity monitoring.

The following is a case study that compares the results of the landslide activity monitoring with the results of the facility monitoring.



Horizontal drainage boring construction period

Landslide activity in response to rising pore water pressure

The Landslide don't act at the time of equivalent rainfall before countermeasure construction.

Construction effect of countermeasure work

The groundwater level (pore water pressure) is lower than that at the time of equivalent rainfall before countermeasure construction.

Facility Monitoring is carried out and maintenance is carried out.

It is suspicion that facility's function is declining.

The amount of drainage decrease.
The groundwater level rise.

Groundwater level (pore water pressure) rises in response to rainfall

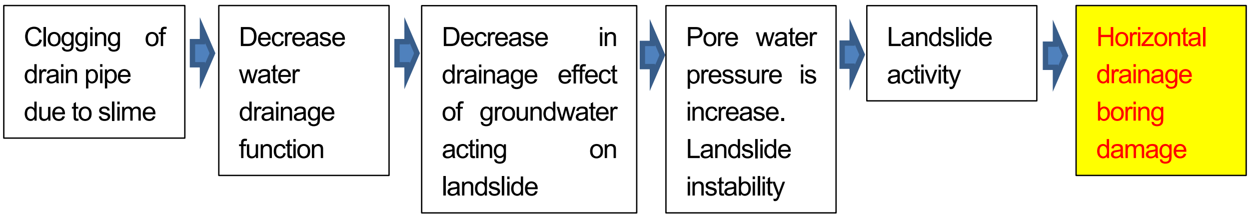
The amount of water draining has increased in response to rainfall.
The rise of groundwater levels is suppressed.

Figure 33 Compare the results of the landslide activity monitoring with the results of the facility monitoring

As shown in the Figure, the following points can be confirmed in the Landslide activity monitoring results

- Before the horizontal drainage boring was constructed, the groundwater level (pore water pressure) increase in response to rainfall, landslide become unstable and slide.
- After the horizontal drainage boring was constructed, groundwater level (pore water pressure) decreased, and even though it is rainfall of the same order as before the countermeasures, the groundwater level (pore water pressure) increase is controlled and landslide activity is also controlled.
- This is effect of countermeasure work.

- Drainage function of horizontal drainage boring will be decrease over time due to factors such as drainage pipe clogging.
- As the result, drainage amount is decrease, groundwater level (pore water pressure) is increase and landslide become unstable.
- If this situation is continued, decrease of horizontal drainage boring's function will progress and landslide become unstable more.
- As the result, it has risk that landslide will slide again and installed countermeasure is broken.



It is important to prevent functional deterioration and to extend service period of the facility by periodic monitoring and maintenance (cleaning inside holes).

Figure 34 Flow from the aging of facilities to the re-sliding of landslides

The relationship between the deterioration of facilities and maintenance is shown on the next page.

The function of facilities deteriorates over time, and finally they are destroyed.

When facilities are destroyed, various problems occur (in this case, landslides re-slide), and there is a risk of landslide damage occurring again and countermeasures being introduced again.

It is effective from the perspective of reducing landslide damage and saving costs to extend the period of use of facilities by implementing periodic monitoring and maintenance.

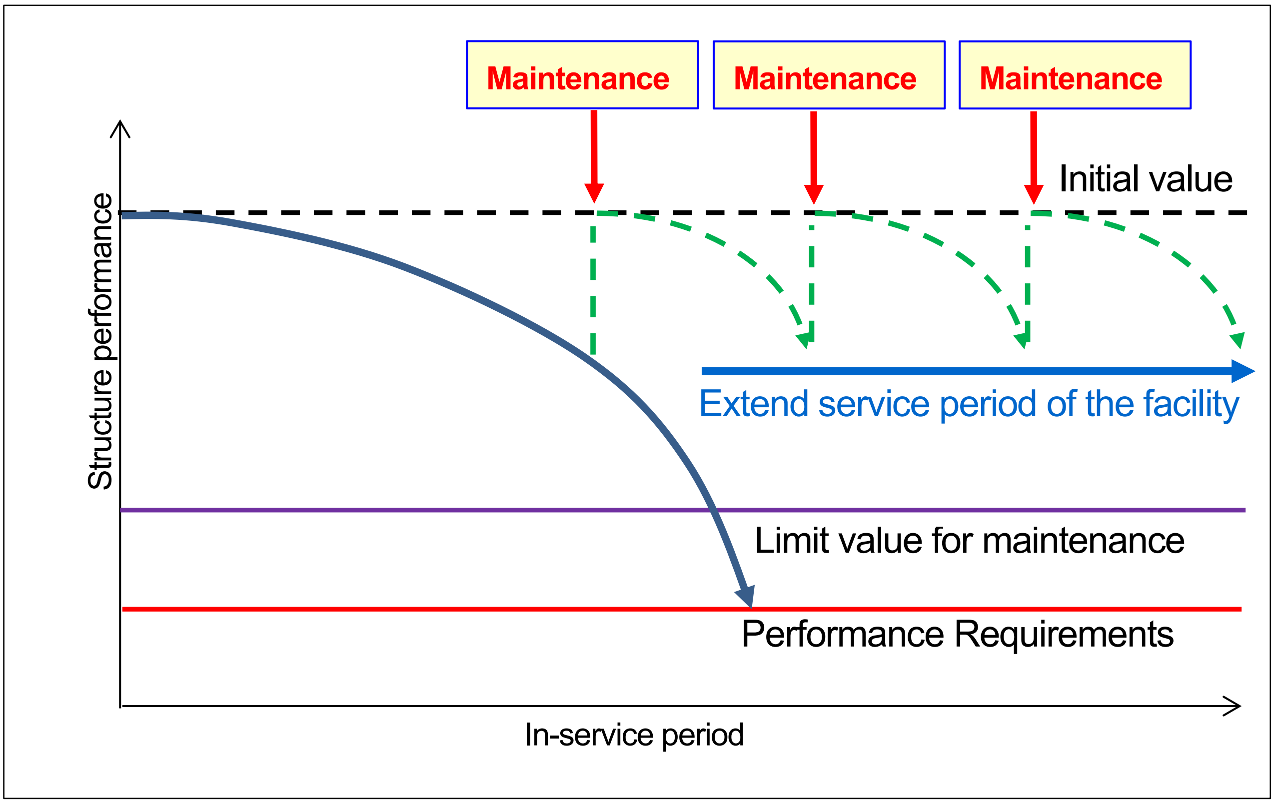


Figure 35 Maintenance and facility lifespan

Chapter 5. Maintenance of facilities

5.1 Horizontal drainage boring

The maintenance items for horizontal drainage boring are as follows

- Removal of blockages in the drainage pipe (cleaning work)
- Repair of ancillary facilities (catchment basin, retaining wall, etc.)
- Reinstallation of facilities

It is explained each method of maintenance as followings.

5.1.1 Removal of blockages in the drainage pipe (cleaning work)

This method is cleaning the drainage pipe with high-pressure water to remove any clogged material using high pressure hose with special nozzle.

It is introduced the cleaning methods used in Japan.

The image figure is shown as following (case of horizontal drainage boring in well).

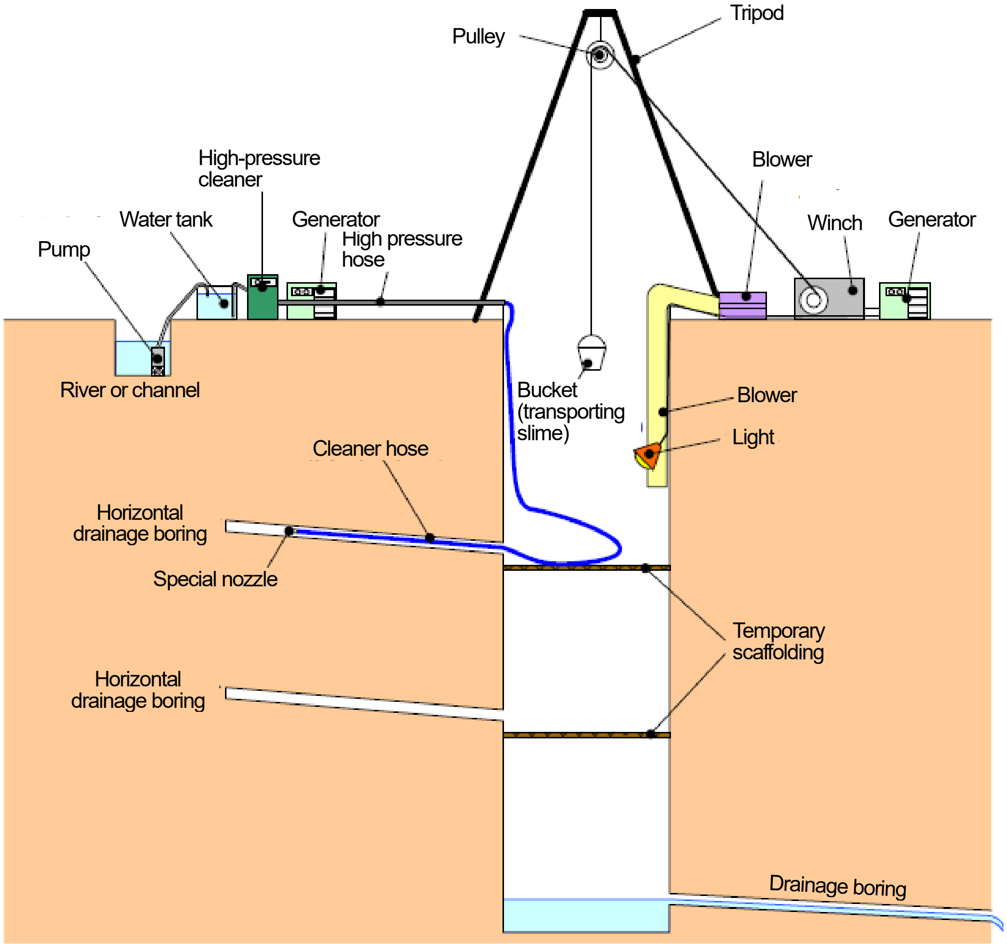


Figure 36 Image figure of cleaning work (case of horizontal drainage boring in well)

The list of machines used is shown below. (Japanese generally case study)

Table 81 List of machines for cleaning work

Item	Specification	Remark
High-pressure cleaner	Discharge pressure 10-30 MPa, Discharge volume 35-80 L/min	Diesel-powered or electric
Generator	Depending on the capacity of the equipment used.	For high-pressure cleaner and other equipments
Pump	Depending on the pumping height of the pump installation location	For supplying cleaning water
Motor winch	Depending on the bucket size	For transporting the slime discharged during cleaning
Brower		For ventilating the well
High pressure hose	Normal pressure 35 MPA	
Cleaning hose	Normal pressure 35 MPA	
Special nozzle	4 type	
Scaffolding material		For working space in well

The workflow of cleaning work is shown as following.

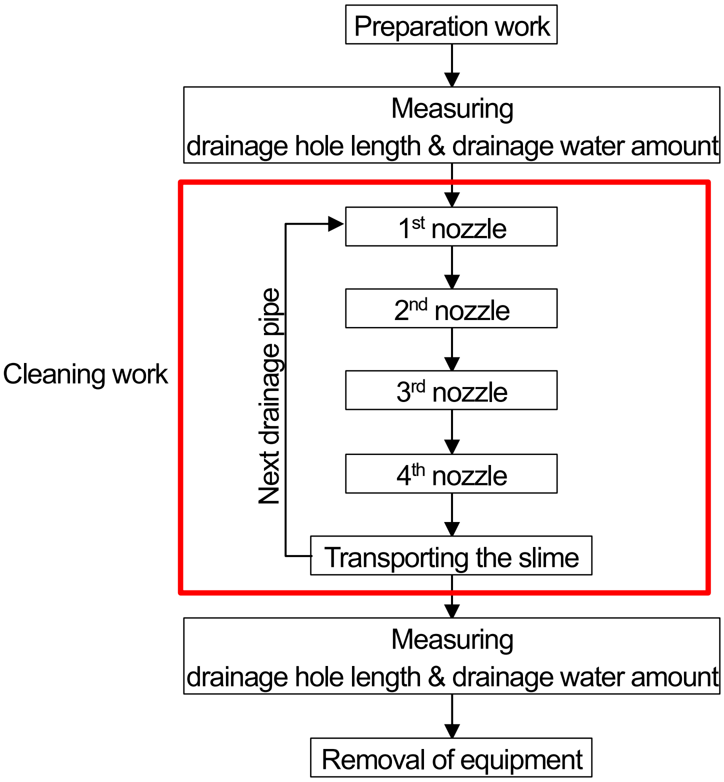


Figure 37 The workflow of cleaning work

The drainage pipe is cleaned using 4 different nozzles attached to a high-pressure hose in 4 stages.

The cleaning process is shown as following.

1st stage	
Discharge pressure	15-30 MPa
Discharge volume	40 L/min
Discharge situation	Cleaning water is sprayed by 1 straght direction jet hole and 10 jet holes 30 degrees to the rear direction.
Cleaning focus	Initial cleaning and understanding the situation inside the pipe
Discharge situation of cleaning water	

2nd stage	
Discharge pressure	10-30 MPa
Discharge volume	70 L/min
Discharge situation	Cleaning water is sprayed by 1 straght direction jet hole and 12 jet holes 45 degrees to the rear direction.
Cleaning focus	Remove and clean the sediment inside the pipe
Discharge situation of cleaning water	

3rd stage	
Discharge pressure	15-20 MPa
Discharge volume	60～80 L/min
Discharge situation	Cleaning water is sprayed by 12 jet holes 45 degrees to the rear direction.
Cleaning focus	Remove and clean the sediment inside of the strainer
Discharge situation of cleaning water	

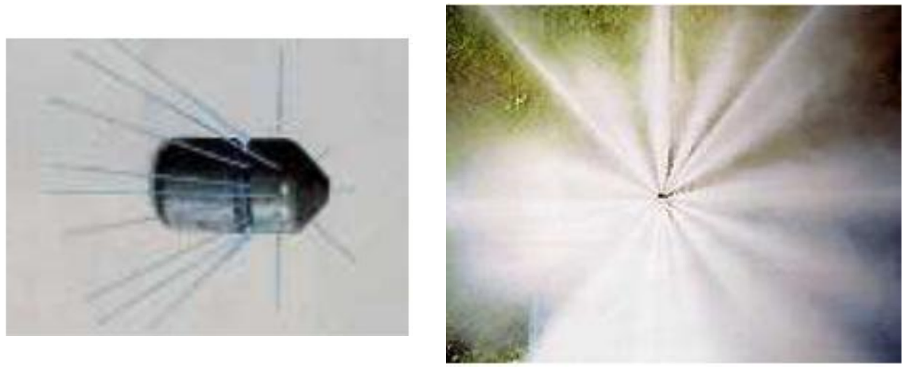
4th stage	
Discharge pressure	10-20 MPa
Discharge volume	60～80 L/min
Discharge situation	Cleaning water is sprayed by 8 right angle direction jet holes and 12 jet holes 45 degrees to the rear direction.
Cleaning focus	Clean by spraying directly into the strainer
Discharge situation of cleaning water	

Figure 38 Cleaning process

Insert the cleaning hose while sending pressurized water through the drainage pipe, and then pull it out when it reaches the back of the drainage pipe (this is one stage of the process).

Replace the nozzle and repeat the cleaning process for each stage until the returned water is clear finaly.

The sediment that is discharged should be caught in a colander and removed.

It is confirmed the effectiveness of the cleaning, the length of the pipe and the amount of drainage water is measured before and after cleaning. (pipe length measuring is used measuring rod. Refer to Capter 3.1.5（1））

The amount of drainage water after cleaning is measured after the effect of the cleaning water has ended off.

Figure 39　Cleaning situation (Case of horizontal drainage boring in well)

After carrying out the cleaning work, it is essential to confirm a decrease in the groundwater level and increase in the drainage water amount by landslide activity monitoring.

5.1.2　　Repair of ancillary facilities (catchment basin, retaining wall, etc.)

If the catchment basin, retaining wall or outlet channel is damaged, the groundwater drained by horizontal drainage boring seep back into the landslide body.

Therefore, repairs need to be carried out according to the type of damage.

Please refer to the following chapters for information on repairing channels and retaining walls.

5.1.3　　Reinstallation of facilities

Horizontal drainage boring should be reinstalled in the following cases.

・If the drainage pipe is broken due to landslide movement.

・If the function (increase in drainage volume, decrease in groundwater level) does not recover even after cleaning. There is a possibility that the groundwater environment on the slope is changing, so additional horizontal drainage boring is required.

5.2 Drainage well

The maintenance and repair of drainage wells can be classified into the following three categories.

- Maintenance and repair of well main body.
- Maintenance and repair of horizontal drainage boring.
- Maintenance and repair of safety facilities.

This section describes the maintenance and repair of the well main body and safety facilities.

For information on the maintenance and repair of the horizontal drainage boring, please refer to the previous section 5.1.

5.2.1 Maintenance and repair of well main body

Steel materials used in drainage wells often occure corrosion by rust, which can reduce the structural function of the drainage well.

In addition, there are cases where vegetation grows in the water collection holes at liner plate and on the reinforcement rings, and the fallen leaves from this vegetation can cause clogging of the drainage pipe at bottom of well.

Corrosion of liner plate　　Corrosion of Vertical Stiffener

Corrosion of bolt　　Vegetation growth

Figure 40　Case study photos of deformation

Maintenance and repair is categorized into the following three categories.

- Repair : replacement of components, painting of steel components, concrete crack seal, cutting down of vegetation, etc.
- Reinforcement : internal reinforcement, addition of components (lateral struts, etc.)
- Renewal: new construction

(1) Repair

This method is only possible if it is safe to work inside the drainage well. If the deterioration of the wall material is so bad and it is difficult to work safety in well, this method cannot be adopted.

Examples of countermeasures are as follows

・Replacement of some components (bolts, nuts, etc.)

If these materials are replaced one by one, it is possible to implement the work without affecting the soil pressure on the wall material.

When the liner plate or reinforcement ring is replaced, there is a risk that the backsoil of the wall push out when the wall material is removed, and that the wall material is destroyed or deformed due to the earth pressure.

If wall material need to be replaced, safety measures is required taking sufficient measures to deal with the earth pressure such as grouting the backyard of the wall and install reinforcement material.

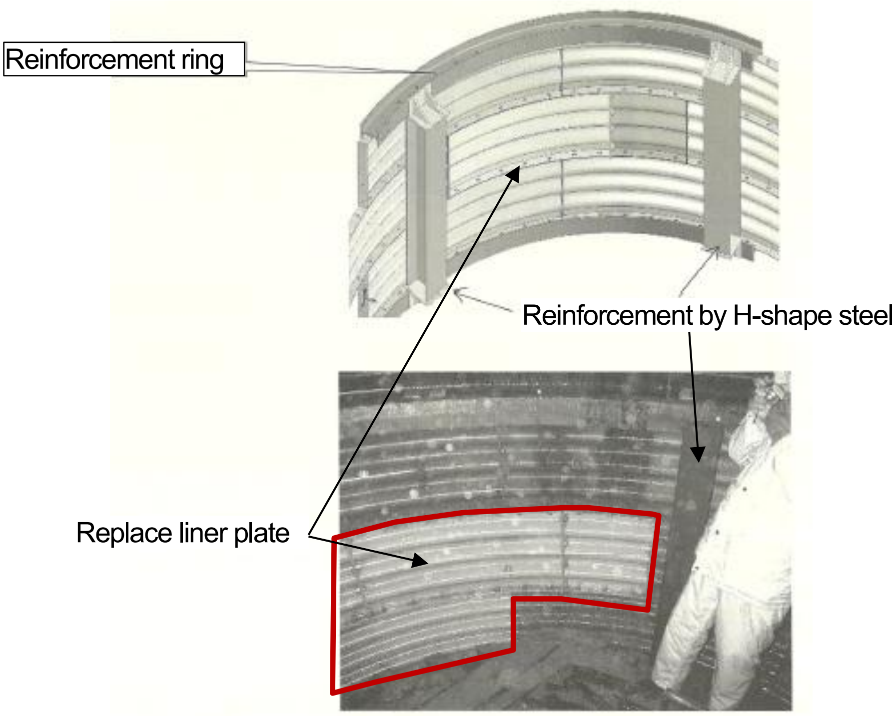


Figure 41　Case study of liner plate replace

・Clearing vegetation

Remove vegetation that grows in the water collection holes at liner plate and on the reinforcement rings

・Crack sealing of the bottom plate concrete and catchment basin

Repair cracks that have occurred in the basin installed in the well bottom plate to prevent water leakage.

・Steel material coating

This is a method that can be implemented when the rust on the wall material is light and there is no decrease in section dimention. There are cases that has been implemented as a measure against acidic soil and water.

After cleaning and scraping (removing rust) the surface of the wall material, apply the coating.

Removal of vegetation and sediment

Creaning surface of wall material

Situation of surface after creaning

Sandblasting (Removal of rust)

Primer coat

Top coat

Figure 42　Case study of coating

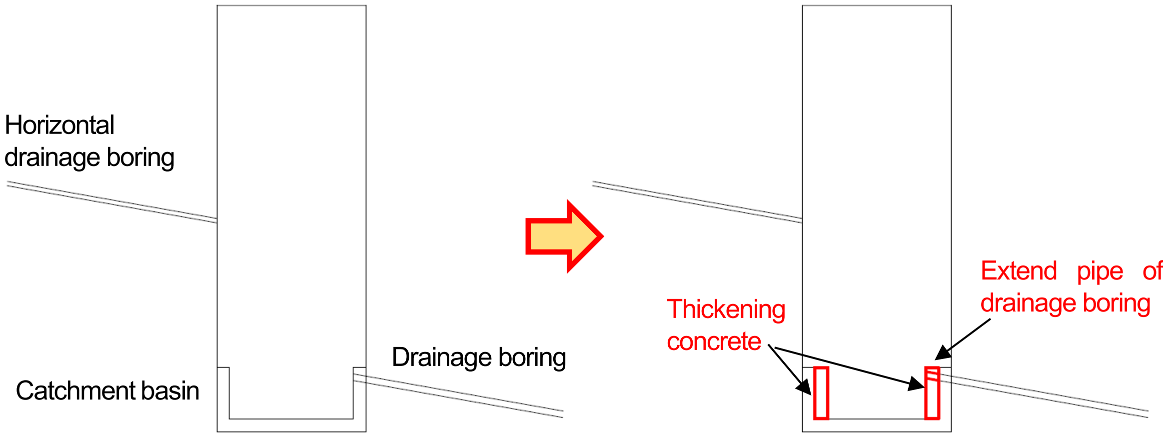
(2) Reinforcement

This method is only possible to implament if it is safe to work inside the drainage well as same as repair.

An example of a reinforcement method is internal reinforcement.

This is method that build a cylindrical structure (such as a liner plate) with a smaller diameter than the existing drainage well into the inside of the exist drainage well.

This method is used when the wall material has deteriorated overall and it is difficult to replace the wall material.



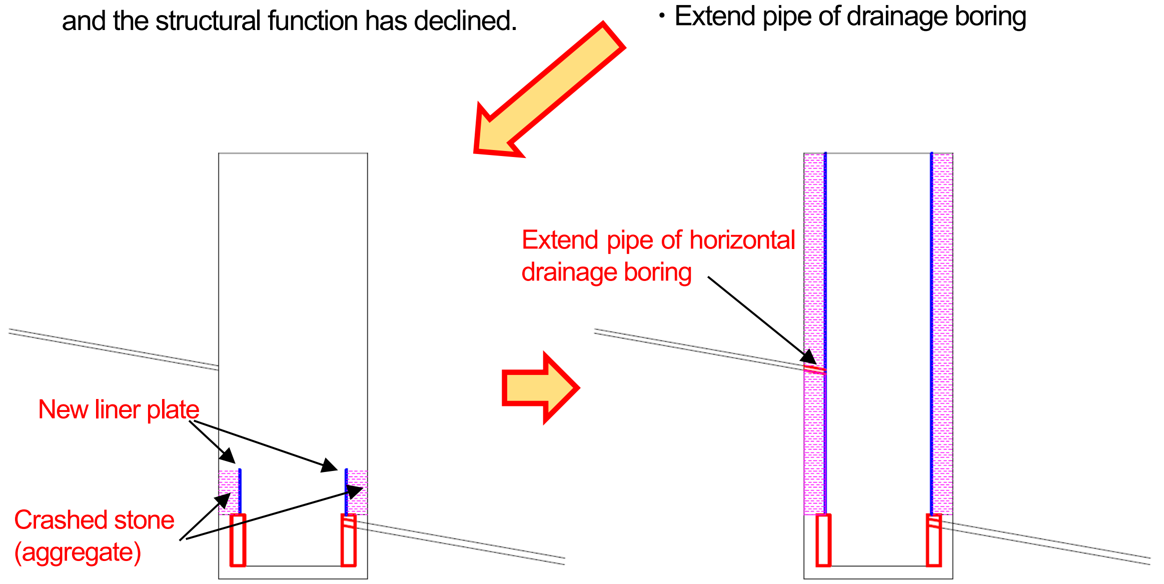
Before reinforcement

The liner plate has deteriorated significantly, and the structural function has declined.

First stage

・Thickening concrete of catchment basin

・Extend pipe of drainage boring



Second stage

・A liner plate with a smaller diameter (standard diameter 2.5m) than the existing one is installed inside the existing well (standard diameter 3.5m)

・Crushed stone is filled in behind the installed liner plate

Third stage

・Up to the surface of the ground, installation of liner plates and filling with crushed stone.

・Extend pipe of horizontal drainage boring into inside of new liner plate

Figure 43　Process of internal reinforcement method

Thickening concrete of catchment basin

Install inner liner plate

Filling crashed stone behind inner liner plate

Extend pipe of horizontal drainage boring

Figure 44 Case study photo of internal reinforcement method

(3) Renewal

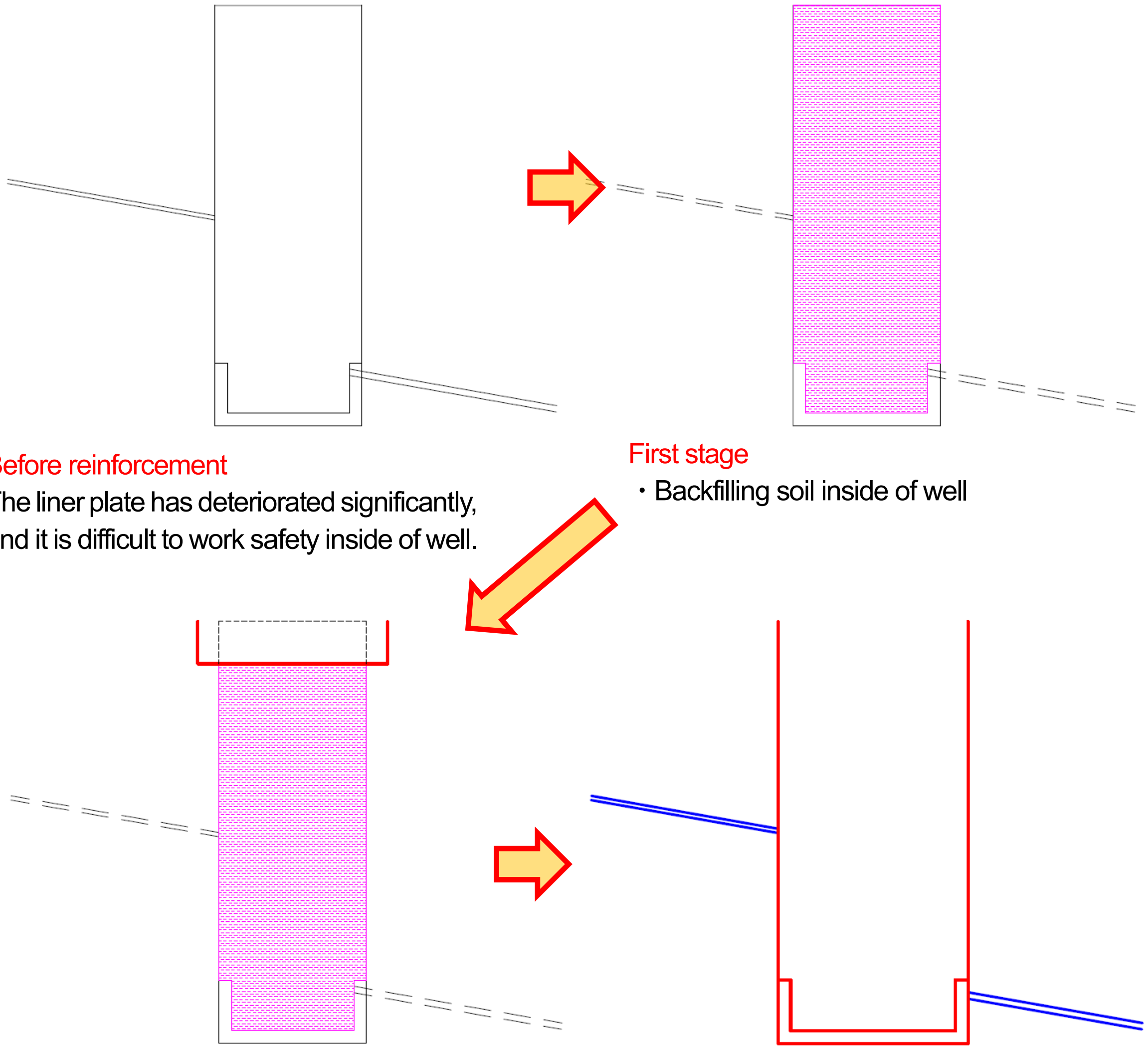
If it is not possible to work safety inside drainage well, it is adopted.

1) Backfilling with crushed stone inside well (in this case, maintenance will not be possible after that)

2) Backfilling with crushed stone inside well + installation a new drainage well at the close position

3) After backfilling inside well once, installation new well at same position. New well diameter is same or bigger than exist well. (In this case that due to construction site restrictions it had to be adopted to construct at the same location.)

In case 2),3), it is required to install horizontal drainage boring and drainage boring again.



Before reinforcement
The liner plate has deteriorated significantly, and it is difficult to work safety inside of well.

First stage
・Backfilling soil inside of well

Second stage
Re-digging and re-installation of new well with bigger diameter than exist well.

Third stage
After install renewal well, Catchment basin, Horizontal drainage boring and drainage boring is re-installed.

Figure 45 Process of renewal of well

5.2.2 Maintenance and repair of safety facilities

Safety facilities are necessary to prevent third-party damage (such as fall into well) , and if any damage, corrosion or deformation is found, it is necessary to take immediate measures.

The following are the items for maintenance of safety facilities.

- Safety fence & locks：repair or replace

This facility is to control access by third parties.

If access to well is possible due to damage, it should be repaired or replaced the damaged parts immediately.

Deformation of safety fence

- Canopy : reinforce or replace.

This facility is installed to prevent people from falling into the well, and if corrosion or deformation occurs, there is a risk of inspectors or third parties falling into the well.

If damege is found, it should be repaired or replaced the damaged parts immediately.

Deformation of canopy

・Ladder in the well : reinforce or replace

This facility is used by inspectors to climb up and down when monitoring the well. If corrosion or deformation occurs, there is a risk of inspectors falling.

If corrosion or deformation is found, reinforcement or replacement is required as soon as possible.

Deterioration due to rust (ladder)

・Subsidence at the ground surface of well

At the behind well wall, suction out of the soil is occures, causing a cavity to form, and then the loosening of the upper part of the cavity, and then it causes subsidence the ground surface.

If left as is, the suction out of the soil and subsidence of the ground surface will progress.

This will cause sediment to deposit in the well, resulting in a decline in function of well, and also cause the subsidence around the well to expand.

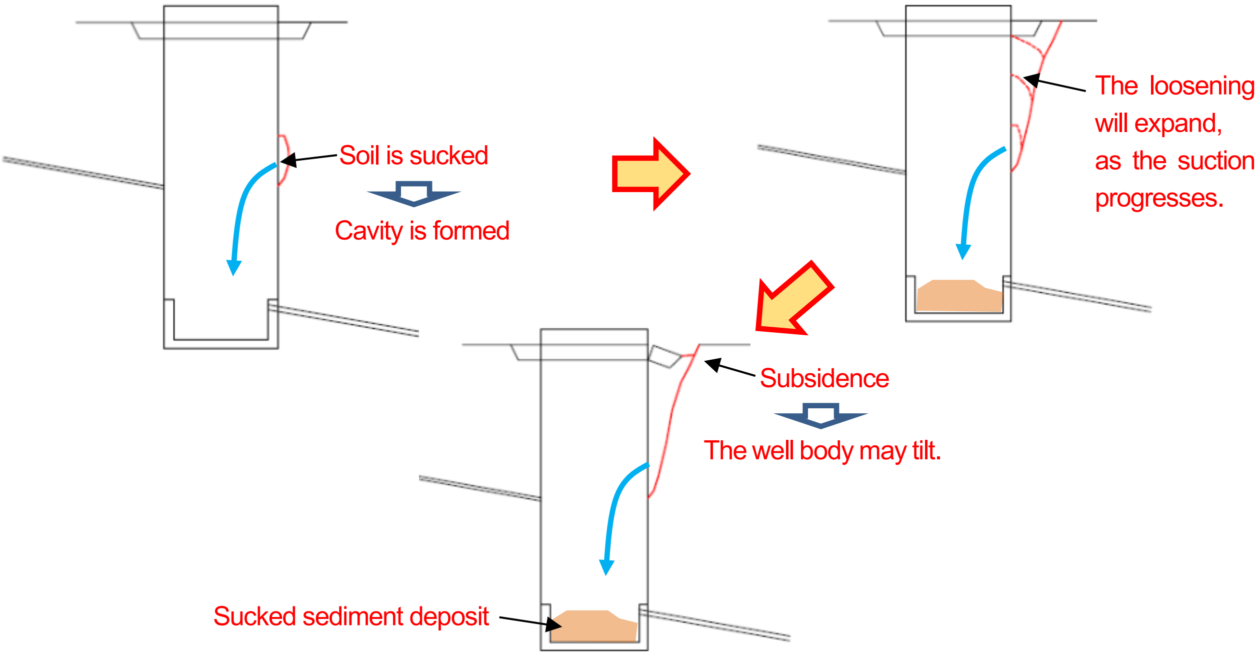


Figure 46　Process of subsidence

Subsidence of surface ground and deformaton of safety fence

The following are examples of repair methods

- Fill the cavity behind the wellwall with mortar
- Fill the surface area with soil
- Remove the sediment from the catchment basin

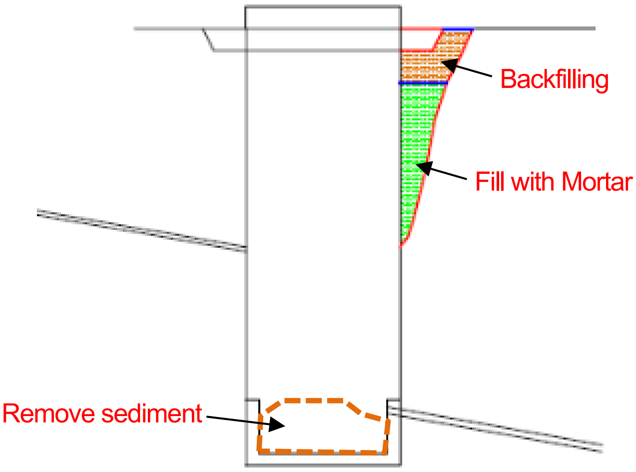


Figure 47 Repair method for subsidence

5.3 Channel

5.3.1 Cause of deformation and policy for maintenance

The following is shown the causes of deterioration and deformation of channels and the policy for maintenance.

○ In cases caused by slope movement

Charactor of deformations	Policy for maintenance
Deformation and damage of channel due to landslide activity. Sinking and rising of channel (Deformation in longitudinal alignment)	After the landslide is stabilized by other countermeasure, channel should be repaired or renewed.

○ In cases caused by external factors

Charactor of deformations	Policy for maintenance
Blockage of channels due to sediment inflow, fallen leaves and branches accumulating in the channels.	Erosion control at channel side. Control of leaf litter and fallen branches in the channel (e.g. by cutting down trees).
Deformation and damage of channel due to scouring of the foundation and collapse of surrounding slopes.	Measures to prevent erosion and repair and renew channel. Measures to prevent the collapse of surrounding slopes and repair and renew channels.

5.3.2 Maintenance method

(1) Maintenance for blockage

1) Removal sediment, fallen leaf & branch and trash

If the blockage of channels by sediment, fallen leaves is left unmaintained, water overflow will occur, causing flowing water infiltration and channel scouring.

It should be remove sediment , fallen leaves & branch, trash in the channel.

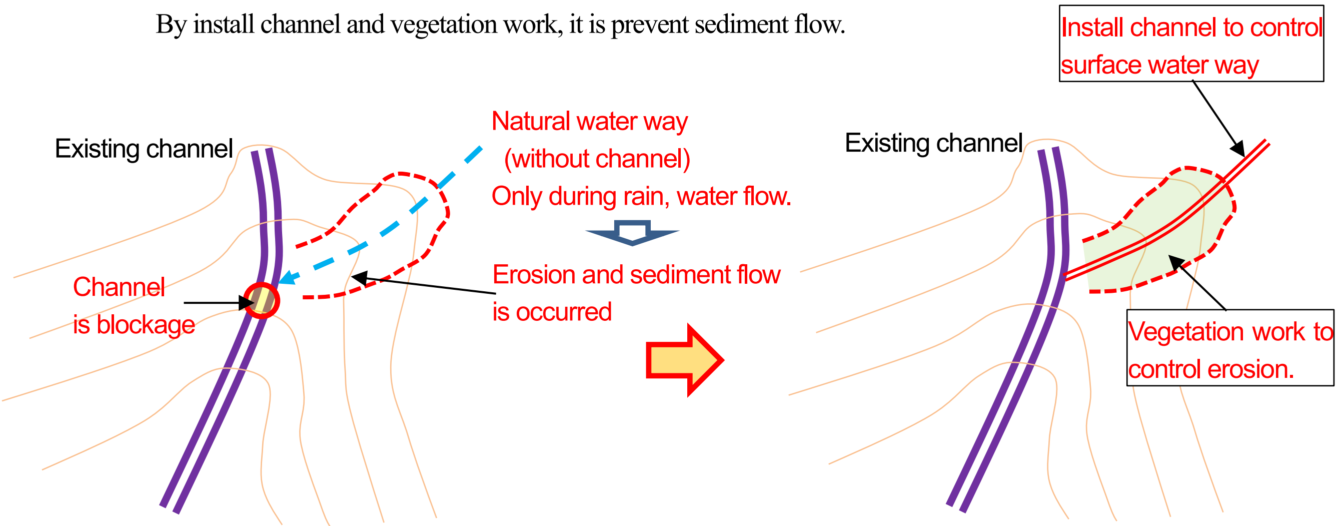
2) Control supply source of sediment and fallen leaves

In case that there are source of sediment inflow at channel side, it should be implement erosion control.

It is shown case study of maintenance.

<Case.1>

By install channel and vegetation work, it is prevent sediment flow.

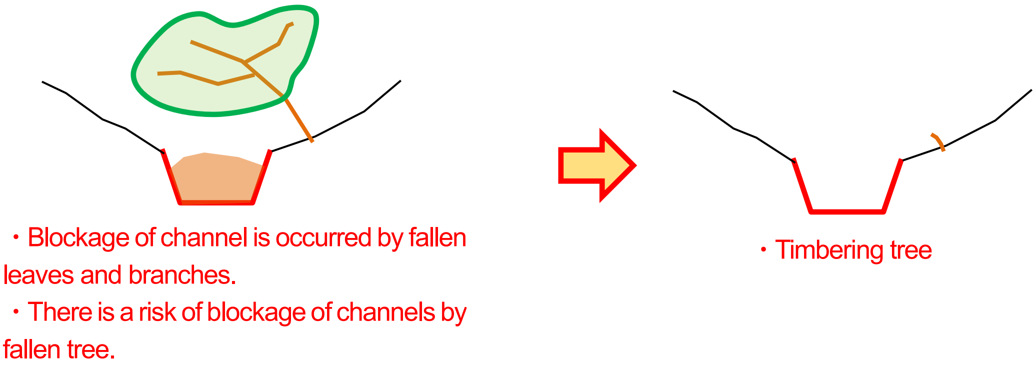


Current situation

Maintenance

<Case.2>

Measures taken by trimming and cutting down trees



Current situation

Maintenance

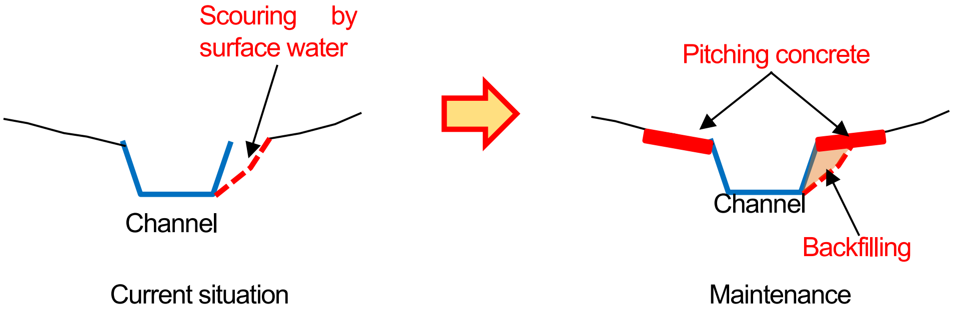
Figure 48 Image drawing of control source of sediment and fallen leaves

(2) Maintenance for scouring

1) Scouring by surface water

<Case.1>

Pitching concrete at channel side. In case that scouring is occurred at channel side, backfilling at scouring position and pitching concrete is implemented.



<Case.2>

Install additional channel

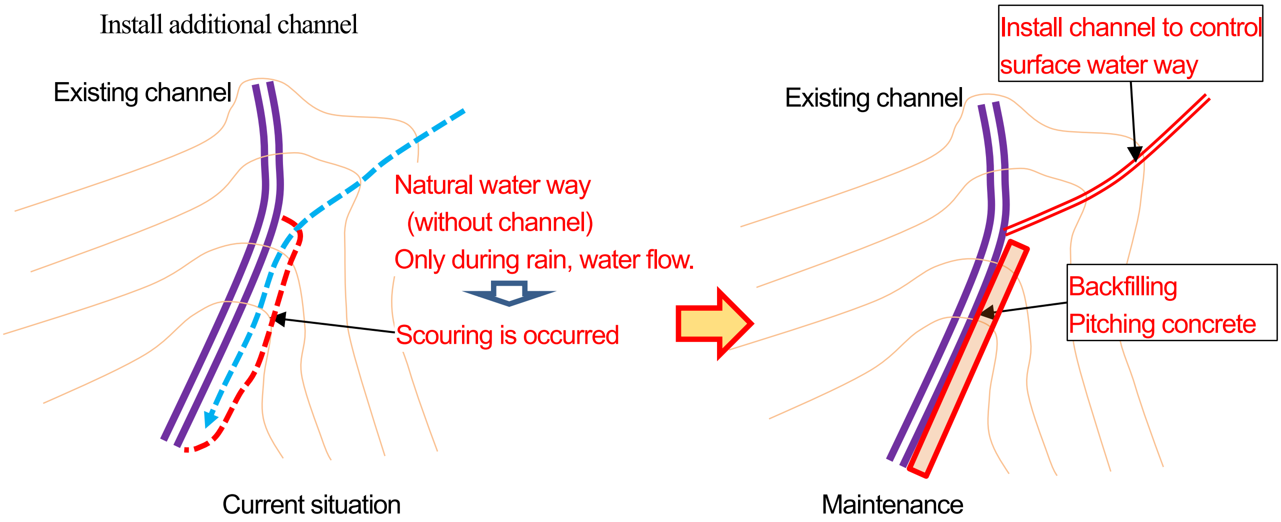


Figure 49 Image drawing of control scouring by surface water

2) Scouring by surface water and shallow groundwater

Changes to the structure of channels. In addition to countermeasures to prevent channel scouring by surface water, install drains to control shallow groundwater.

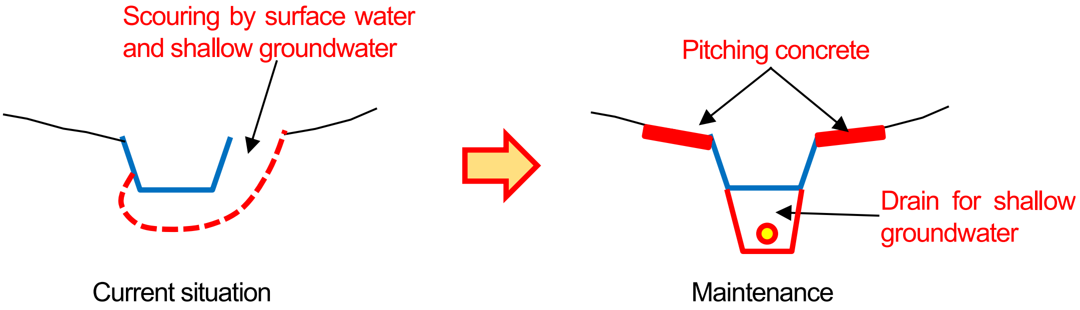


Figure 50 Image drawing of control scouring by surface water and shallow groundwater

(3) Maintenance for deformation or damege (channel, catchment basin, other facilities)

1) Facilities broken by collapse

In case that facilities broken by slope failuer, at once install countermeasure and repair or renew facilities. And in some cases, the alignment is changed. It is shown case study following.

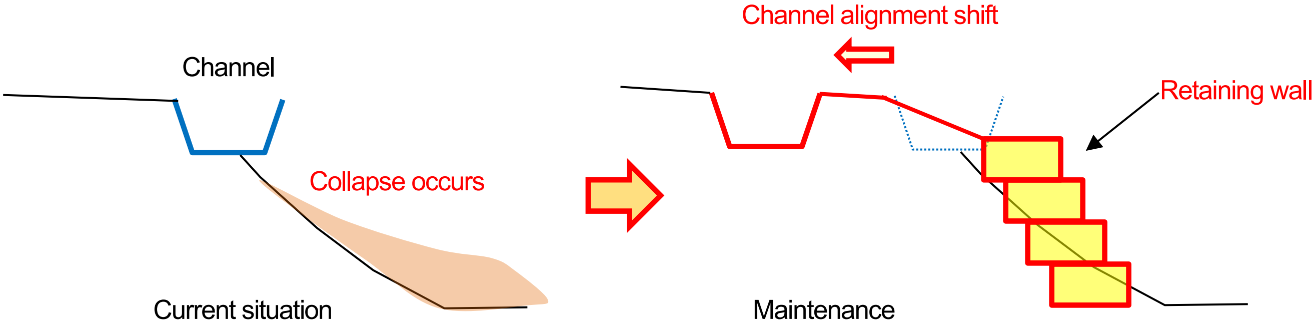


Figure 51 Image drawing of shifting channel alignment

2) Facilities broken or Significant cracks (leakage is a concern)

Basically, it should be taken countermeasure for cause of deformation and facilities should be renewed. (Collapse. Sink. Slide at steep slope etc.)

3) Repair for crack (minor crack)

Minor cracks that do not risk leakage will be treated by crack repair.

However, it is necessary to investigate the cause of the crack, and monitoring is necessary after repair.

If cracks reoccur after repair, it is possible that they are affected by ground subsidence or slope movement, and measures are required to take measure for the cause of the deformation.

Crack repair has already been carried out in Honduras. Here, it introduces the method of crack repair that is generally carried out in Japan. Please refer to it.

By sealing the cracks formed in the concrete, this method is prevented deterioration factors (such as chloride ions, carbon dioxide, and water) from entering the concrete through the cracks.

There are three types of crack repair methods

- Surface coating method
- Crack injection method
- Filling method

The following is a brief overview of each method

○Surface coating method

This method is that improves waterproofing and durability by coating over fine cracks (width of approx 0.2 mm or less). The coating only covers the cracks.

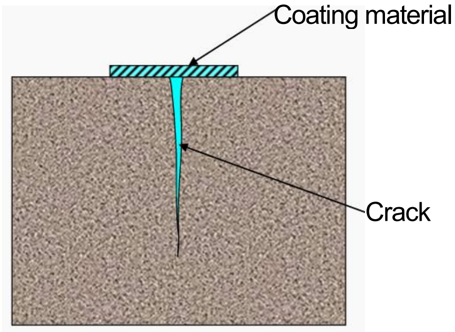


Figure 52 Image drawing of surface coating method

○Crack injection method

This method is that improves waterproofing and durability by injecting resin-(Epoxy resin) or cement-based injection materials into cracks 0.2mm or wider.

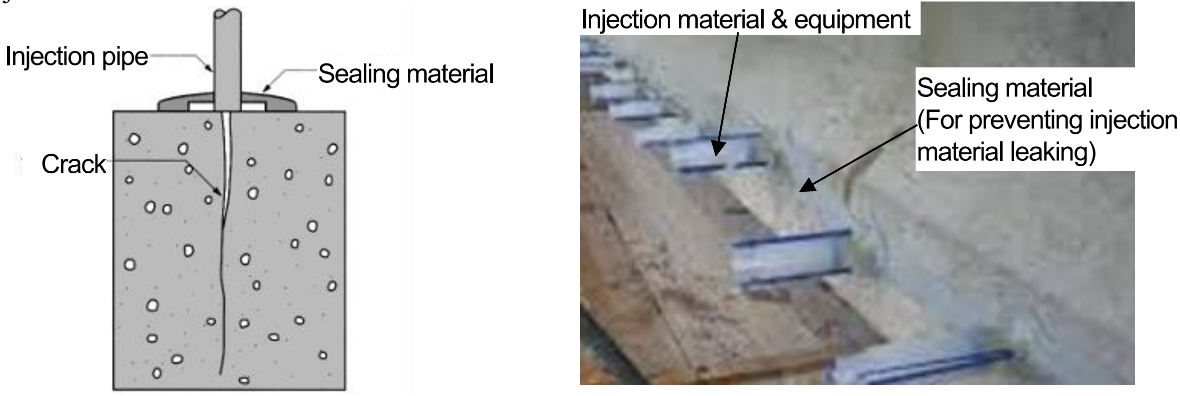


Figure 53 Image drawing of surface coating method

○Filling method

This method is suitable for repairing relatively large cracks 0.5mm or wider. This is method that cut concrete in a U-shape along the crack and filling the cut with repair material.

Filling materials can include elastic sealing materials, flexible epoxy resins, or polymer cement mortars.

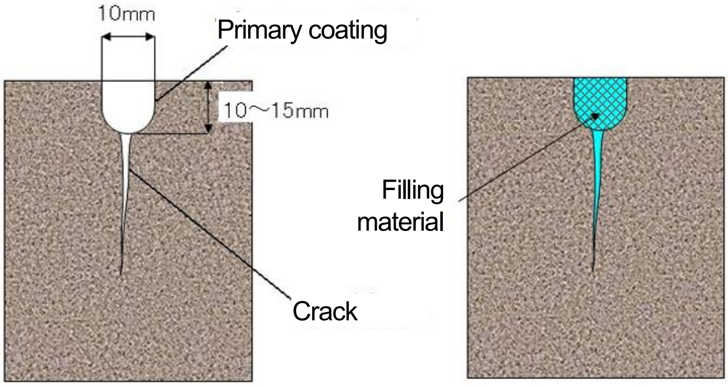


Figure 54 Image drawing of fillling method

5.4 Retaining wall

5.4.1 Cause of deformation and policy for maintenance

The causes of facility deformation are classified into two factors.

- Deformations due to deterioration of facilities
- Deformation due to external factors

It is shown cause of deformation and policy for maintenance following.

○Deformations due to deterioration of facilities

Charactor of deformations	Policy for maintenance
In the case of gabion, corrosion of the frame will progress, then frame will deform and break due to the earth pressure.	Basically, facility is renewed. When study renewal of facility, considering long life of facility, it is better to be adopted plating with a high anti-corrosion effect and thick components that take into account the amount of rust.
Deformations occur, due to deterioration or a decrease in the strength of the concrete.	If crack is minor, it is adopted crack repair. if crack is signcifically, consider to renew or reinforcement wall etc.

When studying method, it should be to consider not only facility condition but surround slope condition.

If it is adopted renewal of facility, it should to be studied slope stability during removal retaining wall.

○Deformation due to external factors

Charactor of deformations	Policy for maintenance
Deformation caused by condition change of the slope behind the retaining wall	Base on the investigation and analysis result of slope, it should be studied the method.
Due to the decreace of drainage functions or change groundwater condition, water pressure act to the retaining wall and deformation occure.	It should be studied to install or repair drainage facilities.
Due to change condition of foundation ground, deformation is occure.	Base on the investigation and analysis result of foundation ground slope, it should be studied the method.

5.4.2 Maintenance method

(1) Maintenance for deteriorated facilities

1）Gabion

The most common cause of deformation in this facility is due to the deterioration of the frame wire.

This member deteriorates due to rust, leading to rupture, the outflow of boulders, and destruction of the structure.

Since it is difficult to replace only the frame wire, it is common to renew the facility.

When study renewal of facility, considering long life of facility, it is better to be adopted plating with a high anti-corrosion effect and thick components that take into account the amount of rust.

2）Concrete retaining wall

Concrete retaining wall (include wet masonry wall) is deformed due to deterioration or decrease in the strength of the concrete. (Crack is occured)

If crack is minor, it is adopted crack repair. if crack is signcificully, consider to renew or reinforcement wall etc.

Regarding crack repair, please refer to previous section. (P.139)

Case study of reinforcement is shown following.

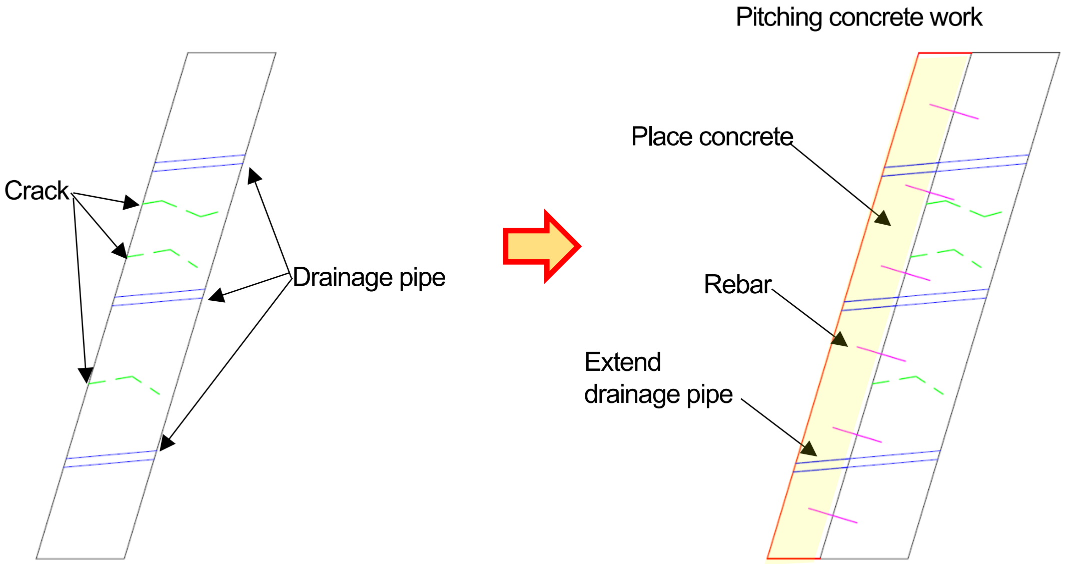


Figure 55 Image drawing of pitching concrete method

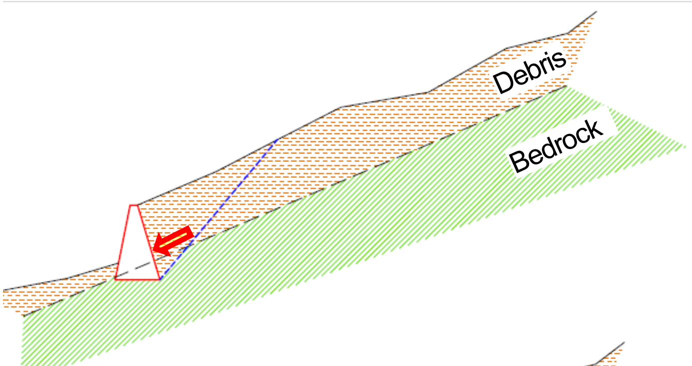
When studying method, it should be to consider not only facility condition but surround slope condition.

If it is adopted renewal of facility, it should to be studied slope stability during removal retaining wall.

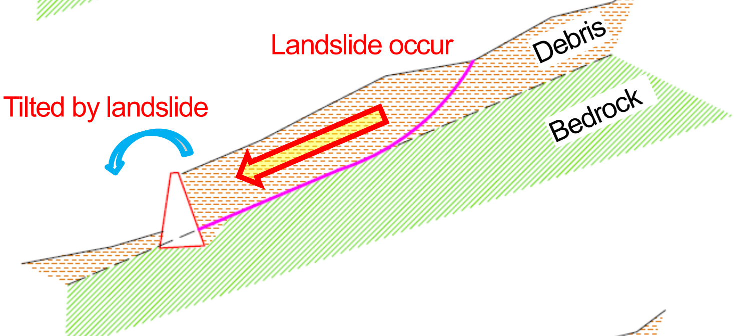
(2) Maintenance for facilities deformed due to external factors

It is shown that is case study of maintenance work of retaining walls deformed due to external factors.

1) Deformation caused by condition change of the slope behind the retaining wall



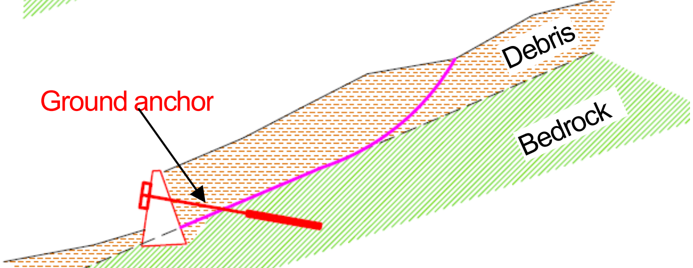
Retaining walls are usually designed with a shape that can resist the soil pressure behind the wall.



Landslide occurred.

The retaining wall is acted greater than expected soil pressure.

The retaining wall is tilted.



Fixing retainingwall by ground anchor.

Figure 56 Case study of Anchor at retaining wall

2) Decreace of drainage functions or change groundwater condition

The drainage pipes installed in the retaining wall are intended to drain the water behind the wall and reduce the water pressure acting on the wall.

In some cases, the drainage pipe may become blocked and drainage may become impossible (in the past, drainage was possible).

There is a risk that the back of the wall may become water-bearing due to the loss to drain, and the water pressure may act on the wall, causing it to deform.

In case that, it should be cleaned drainage pipe.

Figure 57 Clogging situation of drainage pipe.

In some cases, as shown in the photo below, there is a large amount of spring water distributed.

It is not possible to drain the water using only the drainage pipes in the retaining wall, and it is possibility to become water-bearing behind the retaining wall.

In cases like this case, it is also effective to install horizontal drainage boring on the behind slope of the wall to drain the groundwater.

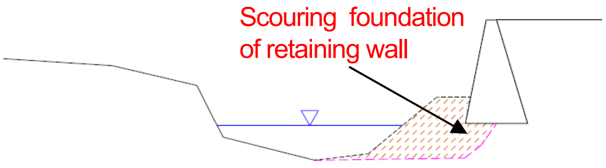
Figure 58 Large amount of spring water

3) Deformation due to change condition of foundation ground

If foundation ground condition of retaining wall is changed, retaining wall may be tilted.

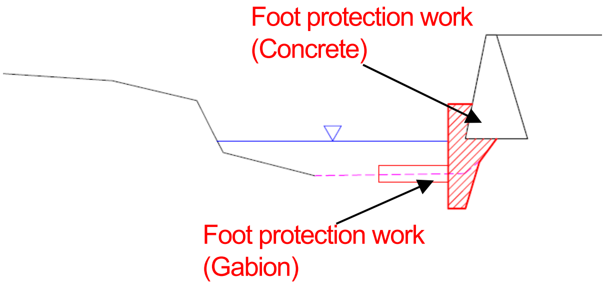
If tilting is progress, stability of retaining wall is loss.

<Case.1> Scouring foundation of retaining wall



The foundation ground of the retaining wall is scoured by river water flow.

Retaining wall lossed foundation makes tilting and unstable structure.

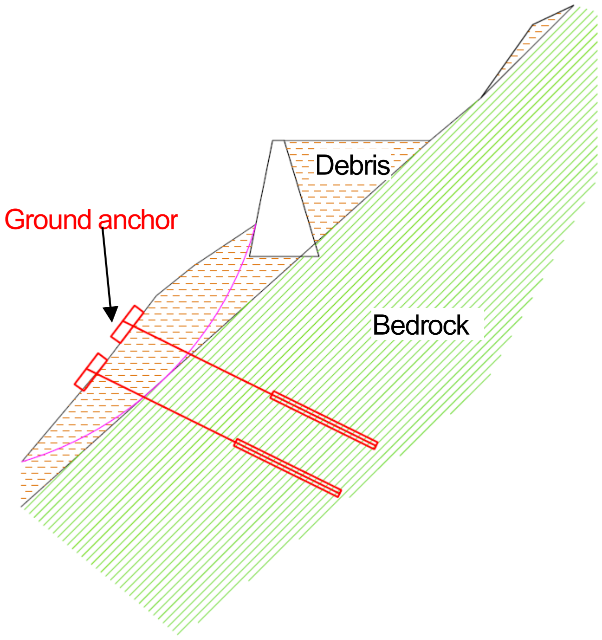


Concrete is placed to foundation of retaining wall. (more1.0m under the riverbed)

In front of foot protection concrete, gabion is installed due to control scour of concrete foundation.

Figure 59 Image drawing of foot protection work

<Case.2> Foundation ground is deformed at the steep slope



The foundation ground of the retaining wall at steep slope become loose.

Progress of loose makes foundation ground shift to downward and then, retaining wall is tilted and become unstable.

It is fixed loosen slope by ground anchor, prevent to become unstable of retaining wall

Figure 60 Image drawing of fixing foundation slope

5.5 Shotcrete

5.5.1 Classified and policy for maintenance

The methods for maintaining of shotcrete are classified into the following categories, taking into account the conditions and causes of deformation.

(1) Maintenance for the deterioration of facilities

- Demolition and reconstruction of existing facilities
- Surface covering work
- Crack repair work
- Cavity filling work

(2) Maintenance considering slope stabilization

- Maintenance combinated reinforcement of slope
- Slope stabilization method

Maintenance method	Policy for maintenance
Demolition and reconstruction.	This is a method that has been commonly adopted. Demolition and reconstruction of existing facility. Issues include safety during demolition, demolition costs, and disposal of large amounts of waste.
Surface covering work	Spraying thin layers of mortar or polymer cement onto the surface existing shotcrete. In case that only surface peeling of shotcrete occured, it is adopted. (it has not be occured decrease of adhesion, cavity, weathering and destabilization of slope)
Crack repair work	Repair the crack on the shotcrete to prevent seeking water and deterioration.
Cavity filling work	Filling Cement milk or mortal into cavity behind shotcrete
Maintenance combination reinforcement of slope	Reinforcement of slope behind the shotcrete and increase the thickness of the shotcrete itself.（include cavity filling work) it is adopted based on the results of the survey of the condition of slope behind shotcrete
Slope stabilization method	In case that facility is deformed by slope destabilization, it is adopted slope stability countermeasure. (Anchor, Horizontal drainage boring, cutting slope etc.)

5.5.2 Maintenance method

(1) Demolition and reconstruction

It is adopted method in case that facility is damaged significantly and difficult to repair.

This is a method that has been commonly adopted.

However, this method has many issues, such as safety measures for the area below the construction site when demolishing the existing mortar, increased demolition costs and construction time due to manual demolition work, and the large amount of industrial waste.

Figure 61 Manual demolition situation

In case that damage is significantly, slope condition is not good (progress of weathering, loose rock or sediment is distributed)

In that case, if same method as existing facility is adopted, it has risk to be damaged again.

Depend on slope condition, it should be study the method.

(2) Surface covering work

Surface covering work is adopted when decrease in adhesion to the bedrock behind the shotcrete and the weathering of the bedrock don't progressed, and only the peeling of the shotcrete surface occurs.

It is method that thin layer (a few millimeters) of mortar or polymer cement is spraied onto the surface of deteriorated shotcrete due to protect the surface. (Polymer cement mortar is a mortar made by mixing cement and fine aggregate with polymer resin. Compared to cement mortar, it has improved adhesive properties, waterproofing, drying shrinkage, chemical resistance, abrasion resistance, and impact resistance.)

If some cracks are occured, it is combinated crack repair work.

(3) Crack repair work

Regarding crack repair, please refer to previous section. (P.139)

(4) Cavity filling work

Cavity filling work is method that is filled mortar or cement milk into the cavities on the back of shotcrete

If cracks occur in the shotcrete and there is a possibility that the filling material will leak out, it should be caulked to prevent leakage.

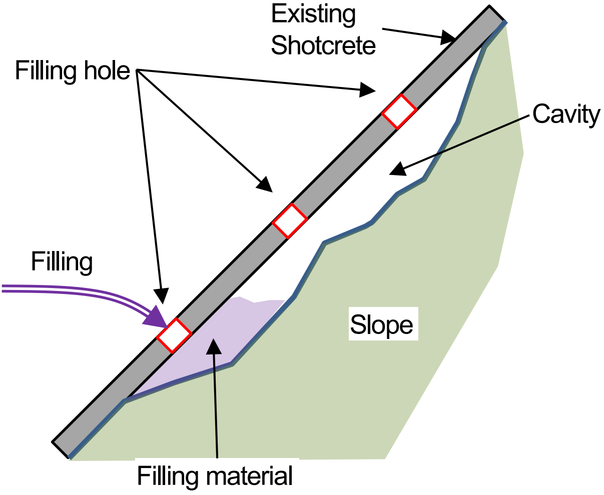


Figure 62　Image drawing of Cavity filling work

(5) Maintenance combination reinforcement of slope.

It is the case that is assumed condition changing of slope behind shotcrete by loosening due to weathering etc. The slope behind shotcrete is reinforced and the deteriorated shotcrete is repaired and reinforced.

Reinforcement of slope behind the shotcrete and increase the thickness of the shotcrete itself. (include cavity fill work)　It is adopted based on the results of the survey of the condition of slope behind shotcrete.

Case studies in Japan are shown in the figure on the right.

- Rockbolt : Used to reinforce loose layer on the behind slope of shotcrete.
- Shotcrete thickening : Used to reinforce existing shotcrete that has deteriorated significantly.
- Drainage pipe : Used to drain surface water from the back of the shotcrete.
- Filling material: Used to fill cavities in the back of the shotcrete.
- Coupling bolt: Used to join existing shotcrete and thickened shotcrete together.

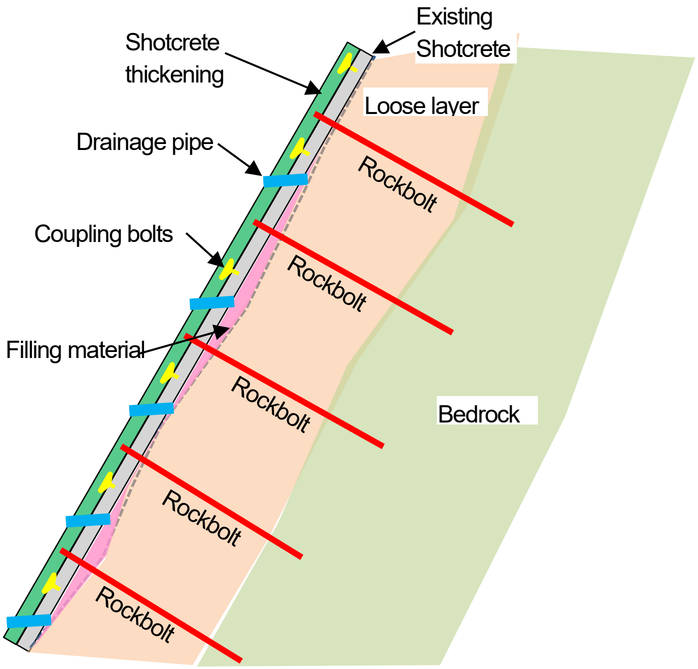


Figure 63　Image drawing of maintenance combination reinforcement of slope

(6) Slope stabilization method

In case that facility is deformed by slope destabilization, it is adopted slope stability countermeasure. (Anchor, Horizontal drainage boring, cutting slope etc.)

First, it should be investigated and analyzed the target slope deformation to understand the deformation mechanism.

Next, it should be studied and designed countermeasures based on the results of the investigation and analysis.

And then, it should be constructed countermeasure.

Case studies in Japan are shown in the following figure.

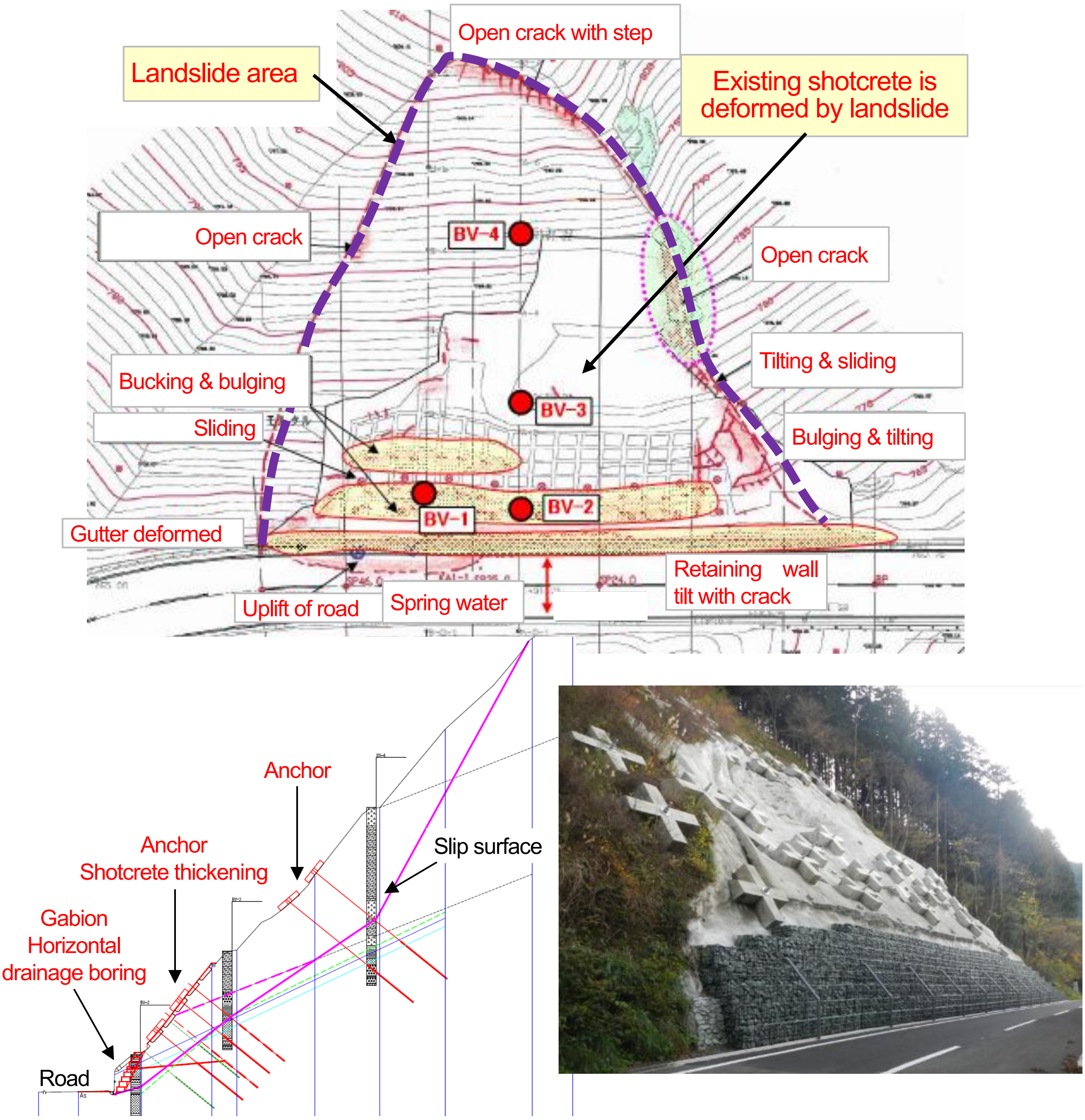


Figure 64 Case study drawing of slope stability countermeasure

Chapter 6. Conclusion

The aging of slope stability countermeasure facilities is an unavoidable problem in future.

In addition, the condition of slopes also changes over time.

If the function of countermeasures deteriorates due to the aging of the facilities and the slope condition changes, the slope may become unstable again and there is a risk of slope disasters occurring again.

Renewal aging facilities requires a huge amount of time and cost, it is difficult to renew all facilities in same time.

In order to ensure the safety of citizens' lives considering the limited budget and time available, it is important to periodically monitor slopes and facilities and carry out periodic repairs based on the results of these monitorings, and to extend the lifespan of facilities.

This manual introduces monitoring and maintenance methods for slope stabilization measures based on case studies of Japan.

We hope that you will use this manual as a reference to establish and implement monitoring and maintenance methods that are suited to the situation in Honduras.

Annex 7

Manual for the Creation of Hazard Map/ Risk Map of Slopes

The Project for Control and Mitigation of Slope Disaster
In the Central District in Republic of Honduras

Manual for the Creation of Hazard Map/ Risk Map of Slopes

July 2023

Alcaldía Municipal de Districo Central

JICA Expert Team

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Preface

This manual is a slope hazard map/risk map creation manual for Output 3 of the "Project for Control and Mitigation of Slope Disasters in the Central District in Republic of Honduras".

From the start of the project, including the period during which we were unable to carry out local activities due to the COVID-19 crisis, we have four years of activity experience from 2019 to 2023. Finally, the counterpart's Output 3 Working Group has the following members (Table 1).

Table 1 Counterpart's Output 3 Working Group members (JET)

No		NAME	C/P
Resultadp 3	1	Silvia Becerra	AMDC-UMGIR
	2	Hugo Daniel Medina Mejia	AMDC-GER
	3	Lorena Maria Lazo Polanco	AMDC-UMGIR
	4	Nidia Luque	AMDC-CODEM
	5	Amircar Pavón	AMDC-CODEM
	6	Roberto Elías Grandos Chahín	AMDC-UMGIR
	7	Dorian Fiallos	AMDC-C&S
	8	Renan Eduardo Rivera García	AMDC-C&S
	9	Mariela Suazo Sibaja	AMDC-UMGIR
	10	Mayuri Sanchez	AMDC-GCC
	11	Ricardo Emesto Aguilar Mira	AMDC-Civil works
	12	José Luis Martinez Reyes	AMDC-UMGIR
	13	Carlos Gustavo Chavez	AMDC-UMGIR
	14	Brandon Anthony Dubon Servilla	AMDC-GER
	15	Liver Fino	AMDC-GER
	16	Laura Marcela Salgado Valladas	UNAH-ENG
	17	Elías Leonardo García Urquía	UNAH-ENG
	18	Maynor Alberto Ruiz	UNAH-IHCIT
	19	Alex Javier Cardona	UNAH-IHCIT
	20	Felix Enrique Rodriquez	UNAH-IHCIT
	21	Lidia Torres Bernahard	UNAH-IHCIT
	22	Jermain Enrique Zeron Izaguirre	COPECO DGP
	23	Jorge Miguel Aguilar Medina	COPECO DGP

[**AMDC**] Silvia Becerra (UMGIR), Hugo Daniel Medina Mejia (GER), Lorena Maria Lazo Polanco (UMGIR), Nidia Luque (CODEM), Amircar Pavón (CODEM), Roberto Elías Grandos Chahín (UMGIR), Dorian Fiallos (C&S), Renan Eduardo Rivera García (C&S), Mariela Suazo Sibaja (UMGIR), Mayuri Sanchez (GCC), Ricardo Emesto Aguilar Mira (Civil works), José Luis Martinez Reyes (UMGIR), Carlos Gustavo Chavez (UMGIR), Brandon Anthony Dubon Servilla (GER), Liver Fino (GER).

[**COPECO**] Jermain Enrique Zeron Izaguirre (DGP), Jorge Miguel Aguilar Medina (DGP)

[**UNAH**] Laura Marcela Salgado Valladas (ENG), Elías Leonardo García Urquía (ENG), Maynor Alberto Ruiz (IHCIT), Alex Javier Cardona (IHCIT), Felix Enrique Rodriquez (IHCIT), Lidia Torres Bernahard (IHCIT).

In addition to them, we would like to add the names and affiliations of the members who have been active so far to reward their efforts. The affiliations in parentheses are those at that time.

[**AMDC**] Sincy Rosa Lozano (UMGIR), Karen Cubas Triminio (GER), Ruben Álvarez Lardizabal (CODEM), Ferid Gabrie (CODEM), Olman Joel Manueles (UMGIR), Oscar Jose Díaz (Civil works).

[**COPECO**] Lenin Díaz (DGP), Heymy Barahona (DGP), Miguel Alejandro López Rivera (DGP).

[**UNAH**] Ana Gabriela Nuñez Palma (ENG), Elisabeth Espinoza (IHCIT), Javier García Reynaud (IHCIT), Nelson Manrique Sevilla (IHCIT).

JICA EXPERT of the OUTPUT 3
HIROTA, Kiyoharu
HASEGAWA, Koichi
ASSISTANTS
Vilma Marina Mejia
Alejandro Jose Flores
PROJECT LEADER
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31 july, 2023

Chapter 1. Introduction

1.1 Purpose and scope of this manual

The purpose of this manual is to allow the elaboration of the slope hazard map and the slope risk map for the slopes of Tegucigalpa. Furthermore, when applying the manual to other regions, the relevant parties, here AMDC, COPECO and UNAH, are considered to create or revise the manual. The scope of Output 3 of the project extends from El Eden to Nueva Santa Rosa in the east and includes El Hatillo, which is involved in Output 4 (Figure 1).

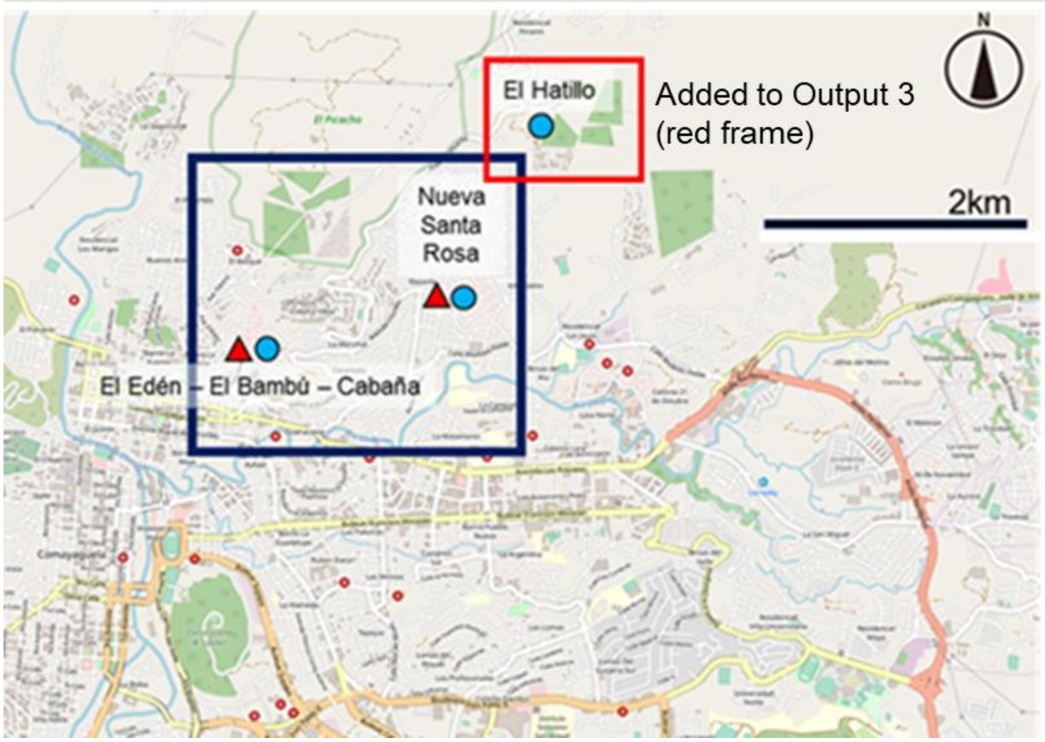
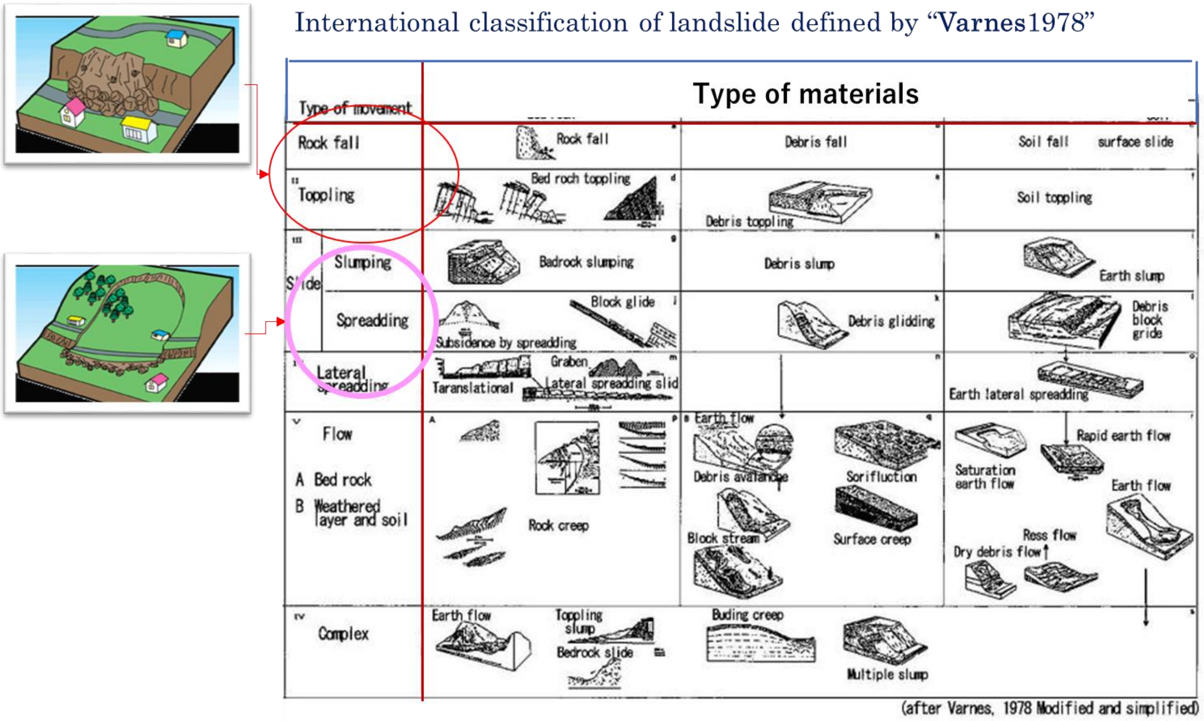


Figure 1 Target area for creating slope hazard maps and risk maps (JET)

The types of slope disasters covered in this manual are “landslide” and “slope failure/rockfall.”(Table 2 and Figure 2).

According to Varnes' classification, these slope disaster types are related in Table 2 (enclosed part).

Table 2 Comparative Table for Landslide classification



International classification of landslide defined by “Varnes1978”

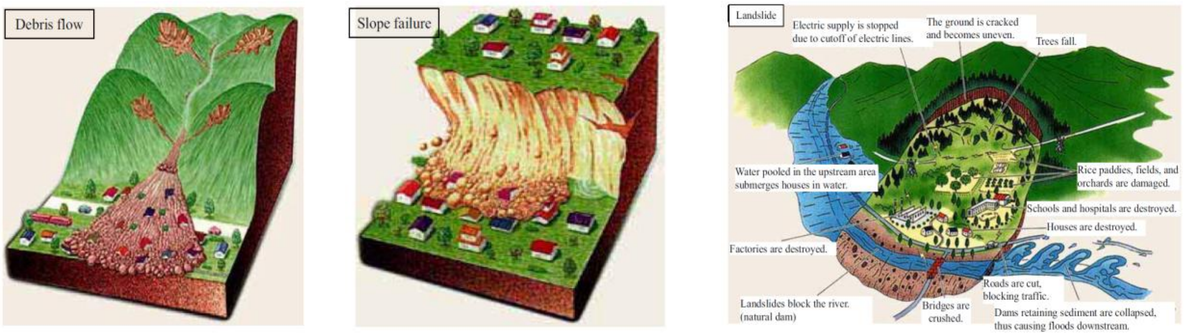
Type of movement	Type of materials		
Rock fall	Rock fall	Debris fall	Soil fall surface slide
Toppling	Bed roch toppling	Debris toppling	Soil toppling
Slide — Slumping	Badrock slumping	Debris slump	Earth slump
Slide — Spreadding	Block glide Subsidence by spreadding	Debris glidding	Debris block gride
Lateral spreadding	Taranslational Graben Lateral spreadding slid		Earth lateral spreadding
Flow A Bed rock B Weathered layer and soil	Rock creep	Earth flow Debris avalanche Sorifluction Block stream Surface creep	Saturation earth flow Rapid earth flow Earth flow Ress flow Dry debris flow
Complex	Earth flow Toppling slump Bedrock slide	Buding creep Multiple slump	

(after Varnes, 1978 Modified and simplified)

Landslides can be compared to "Slide" and "Lateral spreading" in the Varnes movement classification, and hillslides and rockfalls can be compared to "Rockfall" and "Toppling".

For reference, three examples of slope disasters covered by the Sediment- related Disaster Prevention Act in Japan are as follows (Table 3). These are classification methods that take measures into account and are stipulated by the Act. Debris flows are excluded from the survey targets in this project because there are extremely few similar disasters in the Tegucigalpa Basin.

This is regarded as one form of slope failure, as rock falls rarely occur in the study area. In two example, lanndslide and slope failure, the special danger zone on the slope is divided into the red zone, and the danger zone is divided into the yellow zone (Figure 42 in Section 3.3). These categories are used in determining the extent of risk in the map.



Debris flow　Slope failure　Landslide

Figure 2 Three types of slope disaster in the Sediment-related Disaster Prevention Act in Japan. (Public works Research Institute, 2004)

Table 3 Classification of Sediment-related Disaster (Public works Research Institute, 2004)

Debris flow	This is a phenomenon in which soil and rock on the hillside or in the riverbed are carried downward at a dash under the influence of a continuous rain or a torrential rain. Although the flow velocity differs by the scale of debris flow, it sometimes reaches 20-40 km-hr, thereby destroying houses and farmland in an instant.
Slope failure	In this phenomenon, a slope abruptly collapses when the soil that has already been weakened by moisture in the ground loses its self-retainability under the influence of a rain or an earthquake. Because of sudden collapse, many people fail to escape from it if it occurs near a residential area, thus leading to a higher rate of fatalities.
Landslide	This is a phenomenon in which part of or all of the soil on a slope moves downward slowly under the influence of groundwater and gravity. Since a large amount of soil mass usually moves, a serious damage can occur. If a slide has been started, it is extremely difficult to stop it.

1.2 Definition of Hazard Map and Risk Map

The definitions of the hazard map and risk map are as follows:

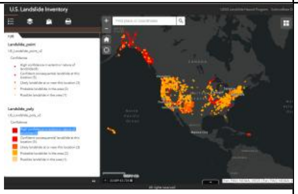
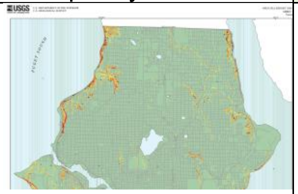
- **Landslide hazard maps**：Landslide hazard maps indicate the possibility of landslides occurring throughout a given area. An ideal landslide hazard map shows not only the chances that a landslide might form at a particular place, but also the chance that it might travel downslope a given distance. -USGS*

  *USGS: United States Geological Survey

- **Landslide risk maps**：Landslide risk maps show landslide potential along with the expected losses to life and property, should a landslide occur. Risk maps combine the probability information from a landslide hazard map with an analysis of all possible consequences (property damage, casualties, and loss of service).–USGS

Table 4 Definitions of several kinds of maps used to depict danger from landslides

(adapted from "What is a landslide hazard map?" by the U.S. Department of the Interior (USGS))

Landslide inventory maps	Landslide susceptibility maps	Landslide hazard maps	Landslide risk maps
Landslide inventory maps show landslide locations and might show the dimensions and geographical extent of each landslide. One clue to the location of future landsliding is the distribution of past movement, so maps that show the location and size of landslides are helpful in predicting the hazard for an area.	Landslide susceptibility maps describe the relative likelihood of future landsliding based solely on the intrinsic properties of a locale or site. Some organizations use the term "landslide potential map" for maps of this kind. Prior failure (from a landslide inventory), rock or soil strength, and steepness of slope are three of the more important site factors that determine susceptibility.	Landslide hazard maps indicate the possibility of landslides occurring throughout a given area. An ideal landslide hazard map shows not only the chances that a landslide might form at a particular place, but also the chance that it might travel downslope a given distance.	Landslide risk maps show landslide potential along with the expected losses to life and property, should a landslide occur. Risk maps combine the probability information from a landslide hazard map with an analysis of all possible consequences (property damage, casualties, and loss of service).
 U.S. Landslide Inventory (arcgis.com)	 of06-1139sh1_test.eps (usgs.gov)	 hazmap2.pdf (usgs.gov)	No example

Chapter 2. Slope survey

2.1 Target slope selection

2.1.1 Landslide

(1) Terminology of Landslide

Confirm the name of each part of the landslide before the field survey (Figure 3).

- **Outer part:** Original ground surface, Crown, Crown cracks, Right flank
- **Related Body:** Main scarp, Minor scarp, Right flank, Head, Foot, Toe, Transverse cracks, Transverse ridges, Surface of rupture, Toe of surface of rupture, Surface of separation.

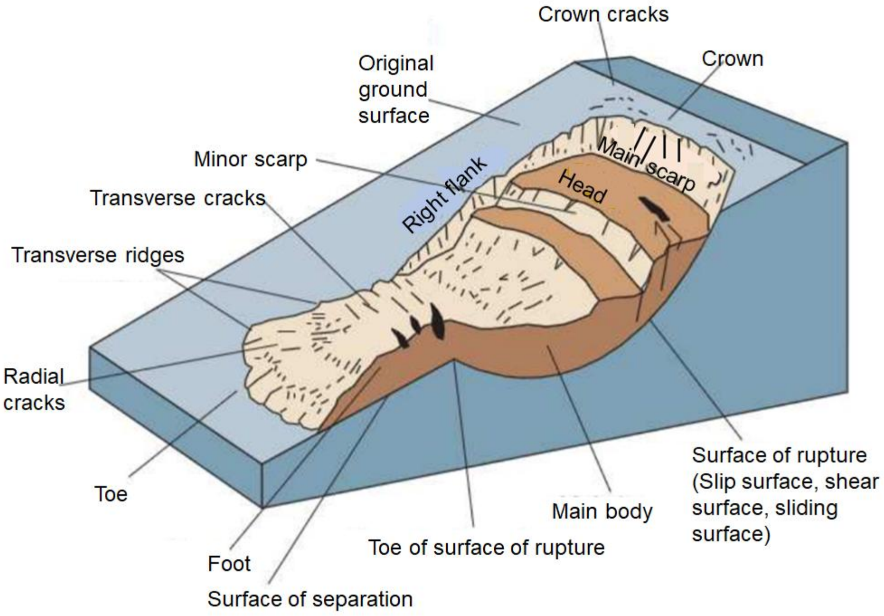


Figure 3 Landslide diagram and their terms (modified USGS)

(2) Photo interpretation

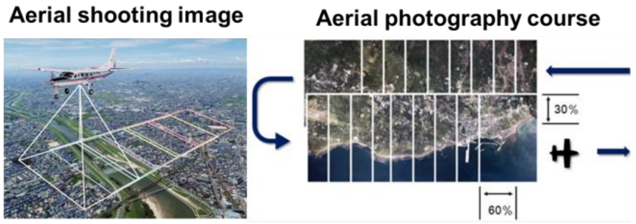
Before site inspection, topographical interpretation shall be carried out using aerial photograph, satellite image or topographical map.

Landslide extraction method by photo interpretation

When selecting a landslide site, the results of interpreting the landslide landform basically using a topographic map and aerial photographs are placed on the map.

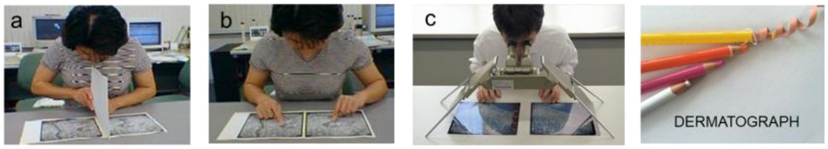
Normally, aerial photographs taken by airplanes are flat, but two adjacent aerial photographs are taken so that 60% of the shooting range overlaps. By"stereoscopic viewing"two adjacent photos, you can see them three-dimensionally as if it could be done looking at a diorama. By juxtaposing two slightly different images, it could be seen a two-dimensional image three-dimensionally. When a human sees an object three-dimensionally, the brain synthesizes slightly different images seen by the right and left eyes to obtain a three-dimensional effect. Stereograms apply this principle to make a flat image appear three-dimensional. In the same way, it could be observed the ground surface three-dimensionally by arranging different left and right photographs side by side for stereoscopic aerial photography.

First, the landslide topography interpreted by stereoscopic vision is drawn on the photograph with a dermatograph, and then expressed on the map.



Photographs will be taken so that adjacent photographs overlap by approximately 60%.

(from Geospatial Information Authority of Japan: https://www.gsi.go.jp/MAPSAKUSEI/25000SAKUSEI/satsuei-satsuei.html)



Aerial photography stereoscopic vision
(a, b: with eyes, c: with a reflective stereoscope)

(a, b: ISABO-Net, https://isabou.net/TheFront/disaster/geology/Hypostatize/zittai.asp
, c: National Institute of Technology, Numazu College, https://user.numazu-ct.ac.jp/~tsato/tsato/graphics/anaglyph/note_stereoscope.html)

Figure 4 Photo interpretation (modified by JET)

When the aerial photograph interpretation is completed, the landslide topography is entered in the survey area and preparations for the field survey are prepared (Figure 5).

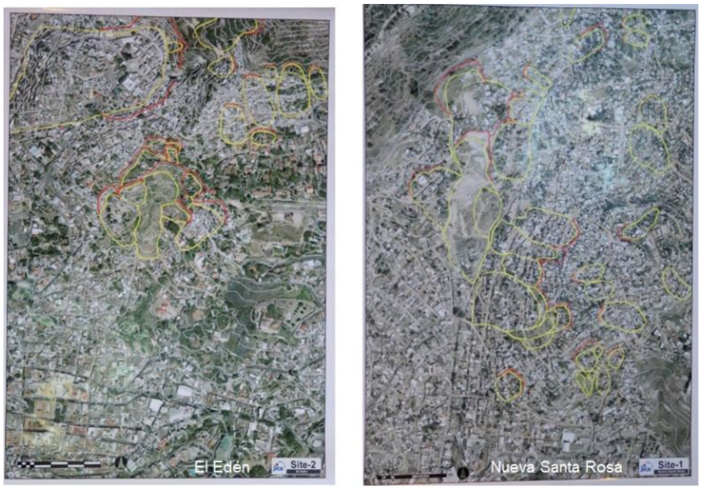


Figure 5 Compile Landslide maps (on aerial photographs, Left: El Edén, Right: Nueva Santa Rosa, JET)

Topographical factor

The topographical factor shall be evaluated by the following two processes. One is photo interpretation, the other is topographic analysis. Before starting the field survey, or in parallel with the field survey, landslide topography is sought through internal work such as aerial photo interpretation and topographic analysis, and a landslide inventory map is created (Figure 6).

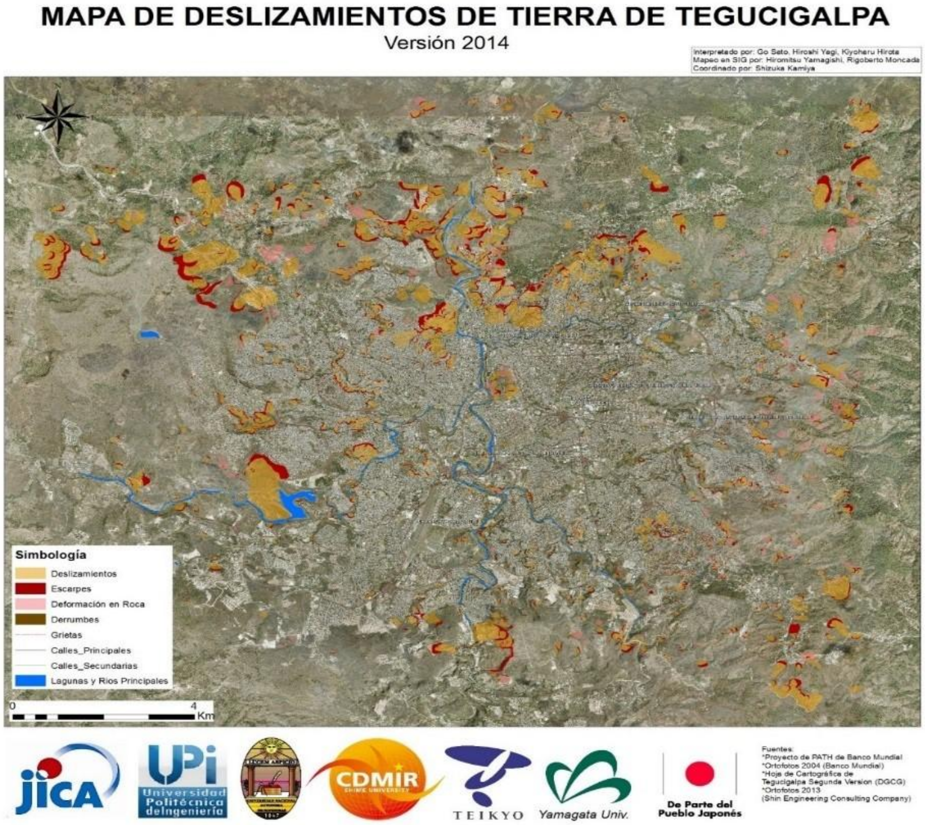


Figure 6 Landslide inventory map in Tegucigalpa (JICA, 2014)

Landslide inventory map of the project (Figure 7) was prepared by using the Figure 6 as the basic material.

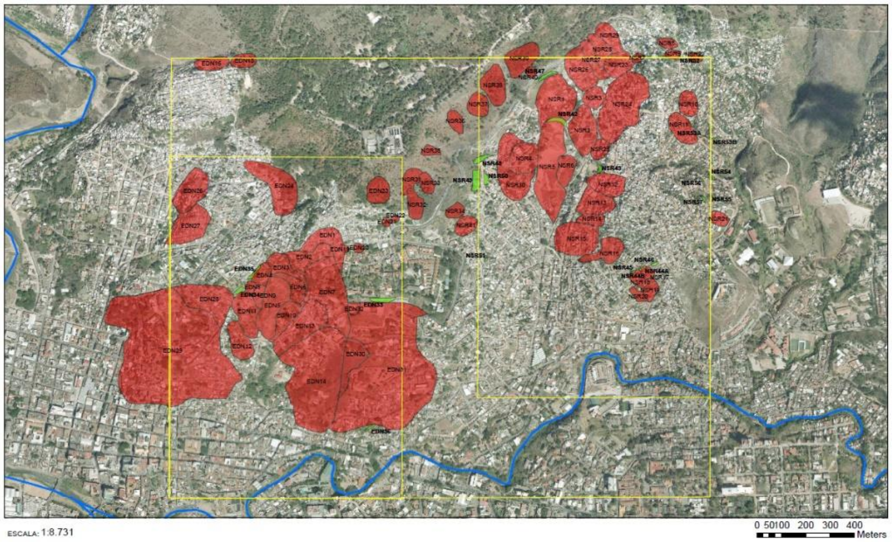


Figure 7 Landslide inventry map of the Project (compiled by JET)

Topographic maps with contour lines are used for topographic analysis. The area surrounded by a square on this map is the area for creating the hazard map and risk map (Figure 8).

Linear topography (lineaments) can be seen in the NE-SW, NNE-SSW, and NE-SE directions. There is a high possibility that these are faults, and there is a possibility that the ground around the straight topography is weakened.

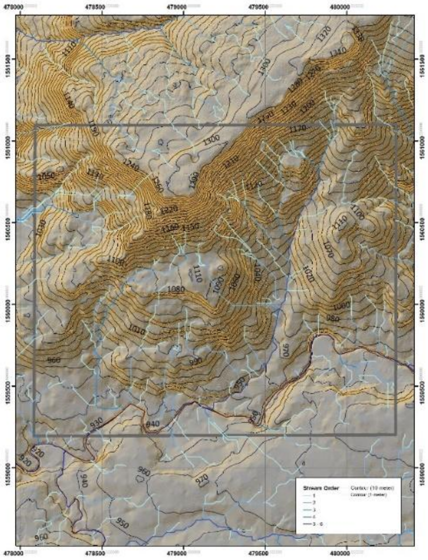


Figure 8 Topographic map with countor line (JET)

In addition, a small mountain can be seen in the central part of the drawing, but a disturbance in elevation is recognized in the southern part, presenting a relatively large landslide topography. A similar topography can be seen on the left side of the drawing.

(3) Site reconnaissance

Surface anomalies shall be evaluated by site reconnaissance.

- The above two methods (photo interpretation and site reconnaissance) shall be evaluated based on the specific landslide features as shown below. Generally, the area which is located next to landslide area shall be potential landslide area.
- Slope surface shows undulation (disarray of contour line on topographical map); steep slope, gentle slope and steep slope again from the top to bottom part of slope. Unevenly sloping ground which are disordered with respect to the general dip and strike of the regional geological structure. Toe part of natural slope shows steep angle or bulging up (Figure 9).

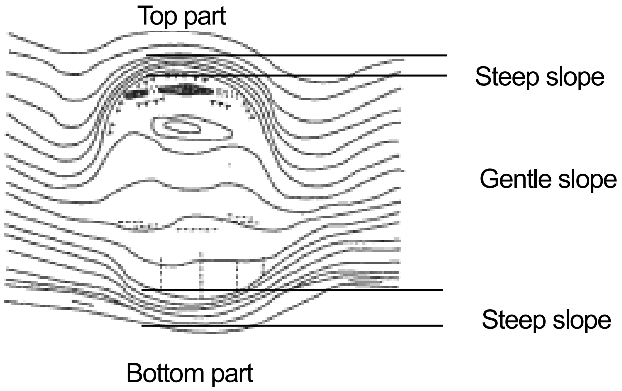


Figure 9 Typical Landslide Topographical Feature (after Fujiwara, 1979, abridgment)

- Top part of the natural slope shows horse-shape or rectangular shape scarp, and middle part of the slope shows flat gentle slope (Figure 10). There may be other terrains such as: Depression zone, cracks and swath of depression zone on the slope or mountain ridge. And Swamp and pond are regularly arranged on the area.

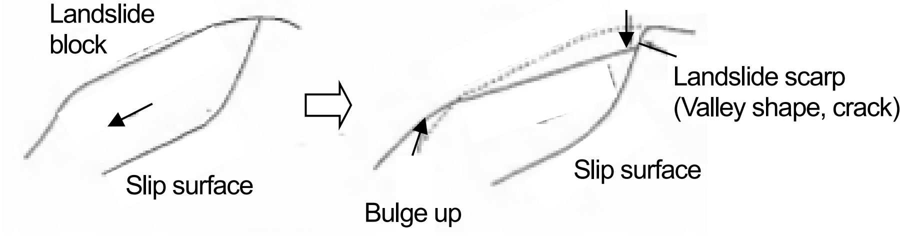


Figure 10 Change of Side ridge of Landslide Block (after Watari and Kohashi, 1987)

- Valley shape or cracks are found on slide ridge of landslide body (Figure 11). A depression often exists near the mountain ridge behind the landslide body.

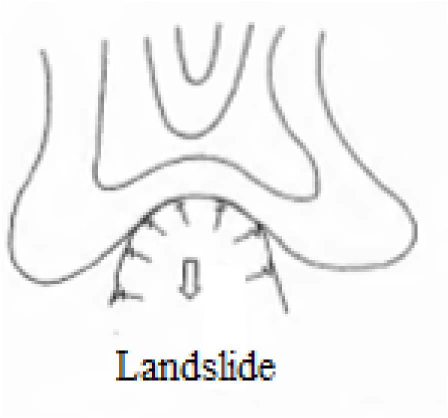


Figure 11 Figure of Mountain Ridge behind Landslide (after Watari and Kohashi, 1987)

- Drainage system on the slope changes direction suddenly, or drainage system is terminated middle part of the slope (Figure 12)

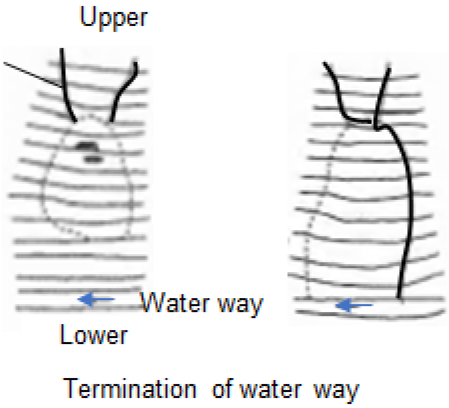
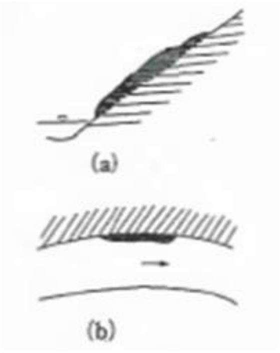


Figure 12 Abnormality of Drainage System (after Watari and Kohashi, 1987)

- River line curves and scouring causes slope instability (Figure 13). Abnormal changing of river line, the part of changing of river width to narrower. Abnormal growing/tilting of trees.



Topographical unstable natural slope (a: section view, b: plan view)

Figure 13 Curve Part of River Line (after Watari and Kohashi, 1987)

１）Geological Condition

Geological Structure

The inspector shall check condition of the target cut/natural slope regarding to the following items to evaluate the predisposing factor of occurrence of landslide.

Fault, Fracture zone:

Fault or fault fracture zones which is considered to affect directly the landslide stability shall be targeted. The fault/fracture zone can be recognized by geological map or outcrops on site. General condition between fault/fault fracture zone and slip surface of landslide is shown on Figure 14. The following relations between fault/fracture zone and occurrence of landslide exist. Part of fault plane make a slip surface, or it impose restrictions on area of landslide. Fault plane or fracture zone becomes channel of groundwater, or since it can become impermeable layer because of fault clay (gouge), the fault controls channel of groundwater. Those conditions can be cause of landslide.

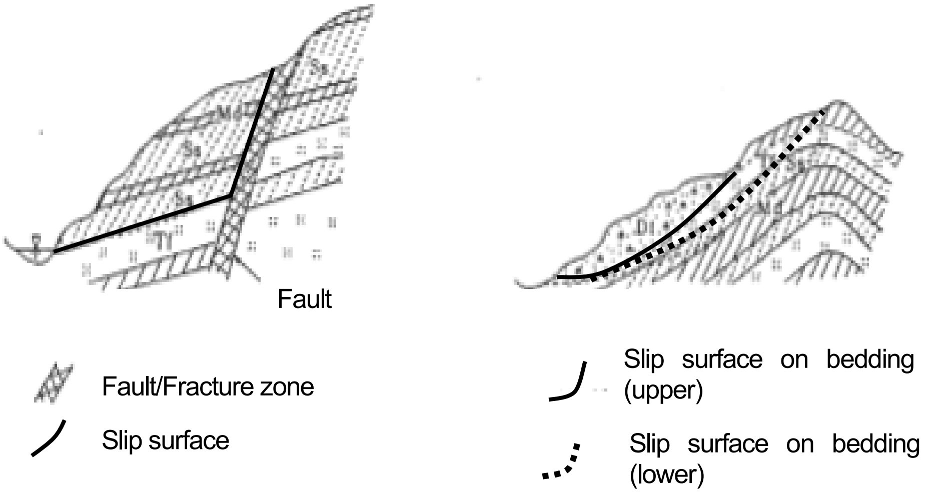


Figure 14 Cases of Dip Slope (after Road Management Techinical Centrer, 2007)

Dip slope:

Dip natural slope is prone to landslide especially of flow type and rock sliding type (Figure 14). There are two (2) cases of dip slope such as case-(a) and case-(b) in Figure 15. Case-(a) is bedding, joint, schistosity etc, that shows steeper angle than slope angle and case-(b) is bedding, joint, schistosity etc. that shows gentler angle than slope angle. Case-(b) is prone to landslide more than case-(a), but case-(a) also shall be taken a note at head part of the slope.

In the case of a non-dip slope (Figure 15), small to medium scale landslides may occasionally occur.

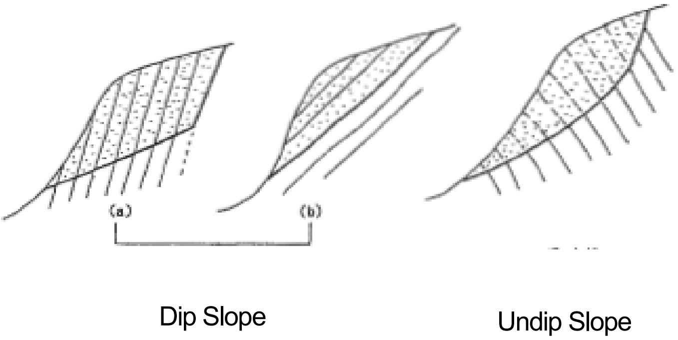


Figure 15 Dip slope and Undip Slope (after Road Management Technical Center, 2007)

Hydrological feature

Groundwater is important factor of trigger of landslide. Groundwater which is inflow or percolated water from upper slope of landslide area or landslide slope can be found around slip surface at toe part of landslide. Spring water is prone to focus on both side of landslide body (Figure 16).

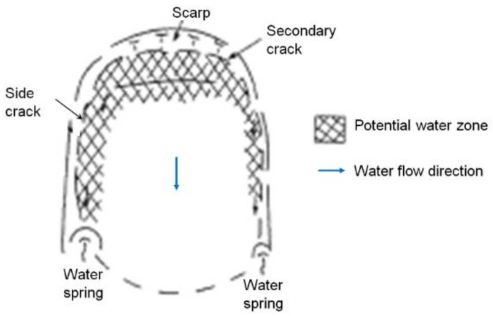


Figure 16 Groundwater flow direction in landslide bocy (after Watari and Kohashi, 1987)

2.1.２ Slope failure/ Rock fall

(1) Types of "Slope Failure/Rockfall" (in cross section)

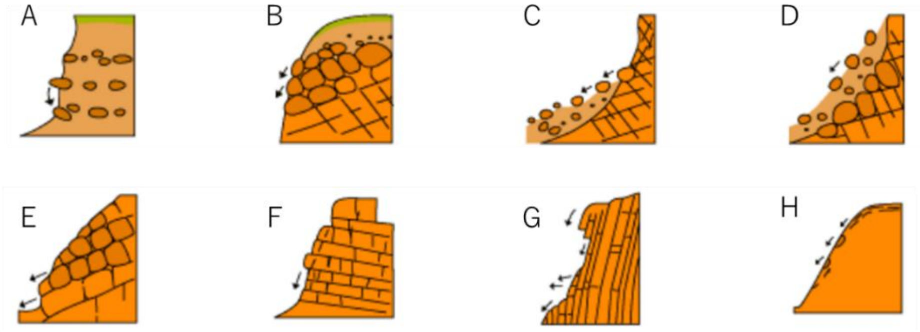


Figure 17 Section profile of Slopes (modified from SABO-Net)

- **A**: Soil slope containing gravel（ex: terrace, pyroclastic)
- **B**: The top is a soil/sand slope (ex: break line of the top of the natural slope, near the shoulder of the cut slope)
- **C**: The foot part is a soil/sand slope (as a talus in the foot part of a natural slope)
- **D**: The topsoil is soil/sand up to a steep eroded rock slope (natural slope in between, etc.)
- **E**: Slope with discontinuity as concordance of slope surface.
- **F**: Slope with discontinuity inclined for mountain.
- **G**: Slope with a discontinuous surface at high angles.
- **H**: Rock slope without discontinuity.

(2) Screening Process

- **Preparation:** Prepare existing landslide inventory maps, topographic maps and aerial photographs. Prepare DEM (Desital Elevation Model) data.

Action：

1) Creation of geologic map, creation of undulation maps, preparation for creation of slope classification maps. Conduct a field survey.
2) Create a slope inclination map. The divisions in Figure 18 are 0≦SI<30m 30≦SI<45, 45≦SI<60, 60≦SI<90 (SI: slope inclination, unit is [°]).
3) Create a relief energy map. The divisions in Figure 19 are 0≦RE<5, 5≦RE<10, 10≦RE<15, 15≦RE<20 (RE: Relief energy, unit is [m]).
4) Create a geologic map. Since the previous geologic maps were created separately from El Edén and Nueva Santa Rosa, a series of geological maps of the project area would be created (Figure 20).
5) Create a diagram that overlaps the relief energy map and the slope incline classification map (Figure 21). Consideration would be made based on the results of the field survey.
6) In the survey area, the slope of Ignimbrite is relatively stable, and it is judged that the impact of falling rocks from the ridge is very small.
7) The area where the Igninbrite distribution range (Figure 21) is excluded from the area of the superimposed figure created in Action 5 and the area for creating the hazard map and risk map of "slope failure/rockfall".

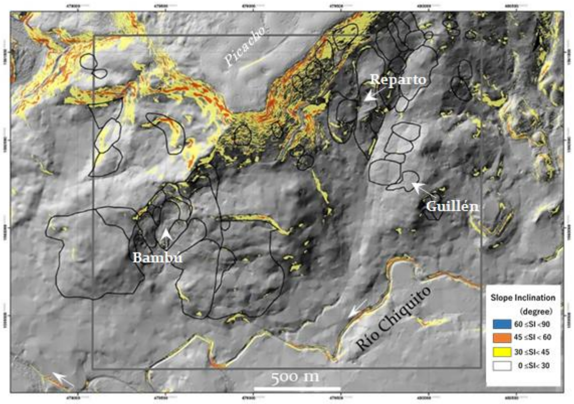


Figure 18 Slope inclination map (JET)

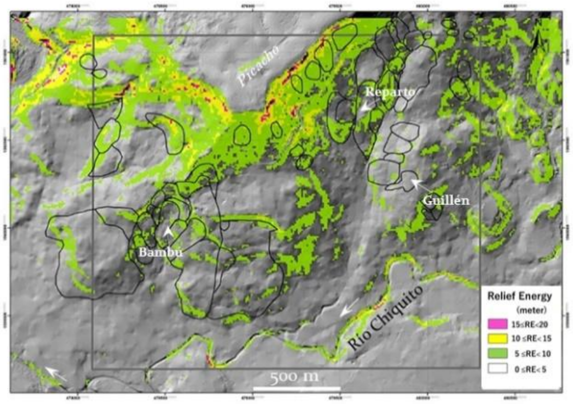


Figure 19 Relief energy map (JET)

Geologic map of the previous project (Figure 20 a) and Geologic map of this project (Figure 20 b) are shown.

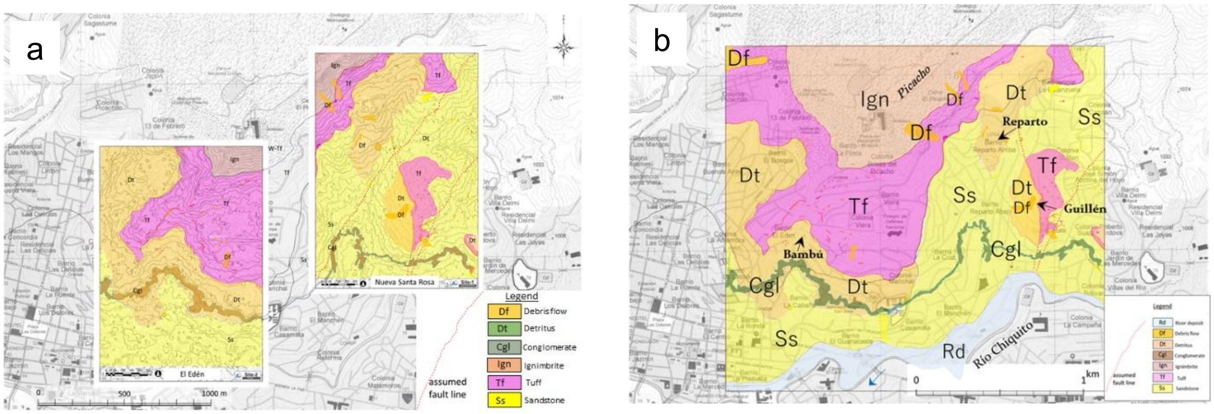


Figure 20 Geologic map (a: El Edén and Nueva Santa Rosa, b: The Project area, JET)

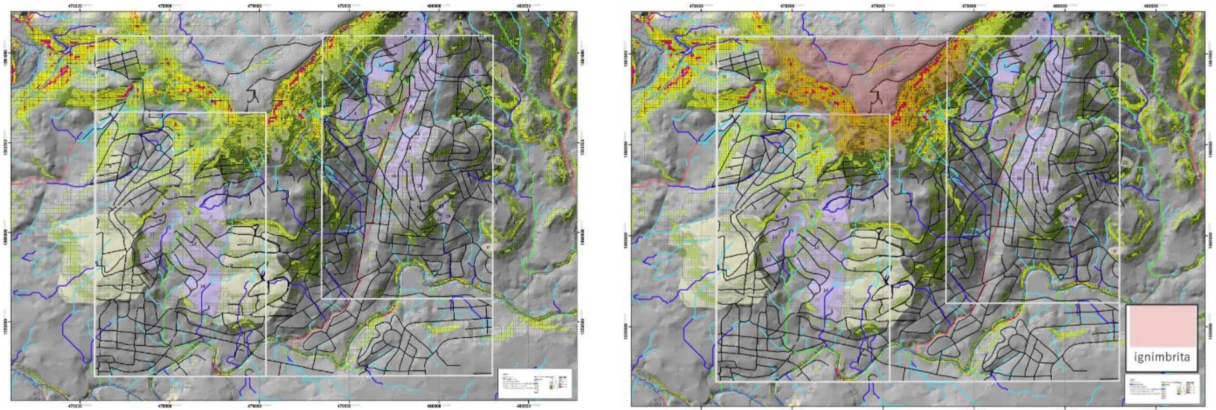


Figure 21 Left: Composite map with Slope inclination (30° more) and Relief energy (5m more). Right: Composite map to select "Slope failure/Rockfall" sites by GIS (relief energy, slope inclination, and geology, JET)

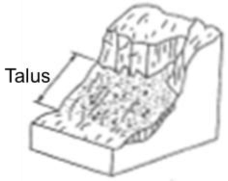
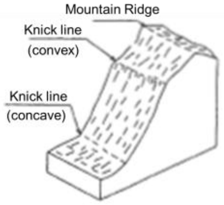
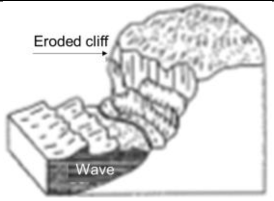
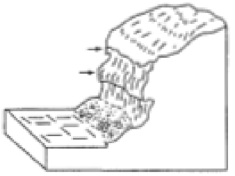
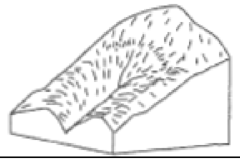
(3) Inspection

a. Topography

Generally specific topographical features which are created as the result of the activity of rockfall/slope failures can be found at slope failure/rockfall prone area. The topographical feature which has those factors of collapse is as follows (Table 5).

Inspector shall check how much the collapsed factor can be matched to the target slope.

Table 5 Topographical Factor (after Road Management Technical Center, 2007)

Talus slope		It is a natural slope which is shown sudden gentle angle at the lower part of the slope. Talus slope is created by sedimentation of fallen debris from upper part of the slope. Talus part, generally consist of gravely soil and is loose condition.
Clear convex break of slope (Knick line)		It is a line connecting the point which is changed suddenly from gentle angle to steep angle of slope in view from top of the natural slope. Generally, occurrence of erosion and collapse is significant in case that the line is shown clearly. In case that there are a number of knick lines, it shall be focused on the clearest line.
Eroded toe of slope		Generally, the part of the slope which faces curved river line is eroded by river flow. Those parts show rock exposure or bare land.
Overhang		Overhang can be found on the undulated rock or soil slope surface. Overhang part shows more than 90 degree of slope angle.
Water catchment slope		Water catchment slope shows a basin-shape valley and the flow down area is narrow. It is notable that debris can flow down from small scale of water catchment slope and mountain stream.

b. Geological Condition

Soil, rock and geological structures which are prone for a collapse to occur shall be evaluated based on the following standard. When it is difficult to observe those factors on the target slope, it can be evaluated from neighbor slope condition or existing data if it is available. In case that the condition of slope is not uniquely; it shall be evaluated based on the most unstable condition on that slope.

b.1 Soil

The inspector shall check whether condition of the most parts of the target cut/natural slope conform to the following soil material, and evaluate as "marked", "a little marked" and "none" according to the actual condition.

- **Soil which is "susceptible to erosion"**: Volcanic ash, highly weathered rock, terrace gravel and sand, sandy soil, etc
- **Soil which has "less strength with water"**: The soil is prone to reduce the strength when it is water bearing. Loam, silty sand, sandy silt, silty cohesive soil, fine grain soil, etc.

b.2 Rock

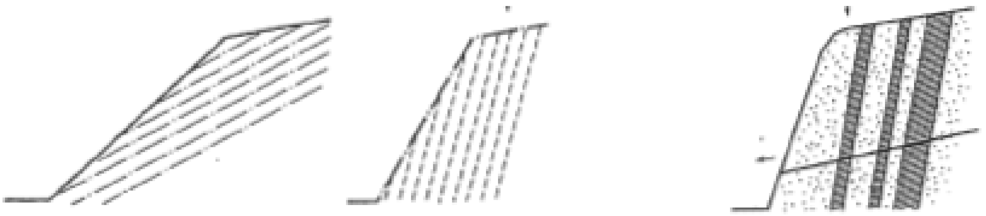
The inspector shall check whether condition of the most parts of the target cut/natural slope conform to the following rock condition, and evaluate as same as b.1 case above.

- **Rock which has "high density of cracks and a weak layer"**: The rock has crack or weak layer (joint, fault, weak bedding plane, schistosity, intrusion plane, etc.) developing within 20cm to 30cm interval, and shows its fragment in the form of plate, column or cubic.
- **Rock which is "susceptible to erosion":** The rock is soft rock. The rock can be broken by hammer easily. The rock slope is prone to small scale surface collapse frequently.
- **Rock which is "fast weathering":** It is expansive rock and rock which is prone to slaking (serpentinite, mudstone, shale, tuffaceous sedimentary rock, weathered schist, etc.). These rocks contain expansive cohesive mineral, and is prone to be fragmented or be muddy condition as part of weathering, even though the rocks look hard.

b.3 Geological Structure

The inspector shall check whether condition of the most parts of the target cut/natural slope conform to the following geological structures condition, and evaluate as same as b.1 case above.

- **Structure which shows "dip slope of bedding plane"**: Check the target slope condition based on the following figures (Figure 22)



(a) Dip slope

(c) Steeper dip slope more than slope angle

(b) Combine many types of dip joints on the slope

Figure 22 Example of Dip Slope (In case of the inspection, (a) and (c) shall be adapted as dip slope, after Road Management Technical Center, 2007).

- **Debris on impermeable bedrock**: Check the target slope condition based on the following figures (Figure 23).

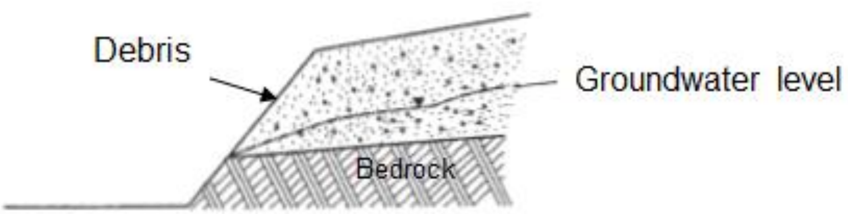


Figure 23 Example of Debris on Impermeable bedrock (after Road Management Technical Center, 2007)

- **Upper part is hard / the toe of slope is weak**: This condition is as the following figure (Figure 24). This geological structure can be known as the Cap rock structure. The inspector checks not only the structure but deformation of soft rock layer at lower part of the slope and vertical cracks of hard rock layer at upper part of the slope also.

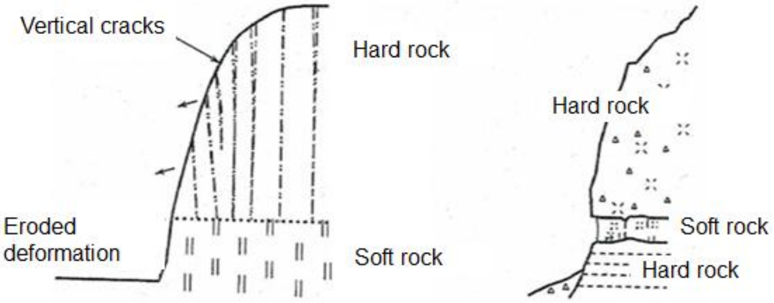


Figure 24 Example of Cap Rock Structure (after Road Management Technical Center, 2007)

c. Surface condition

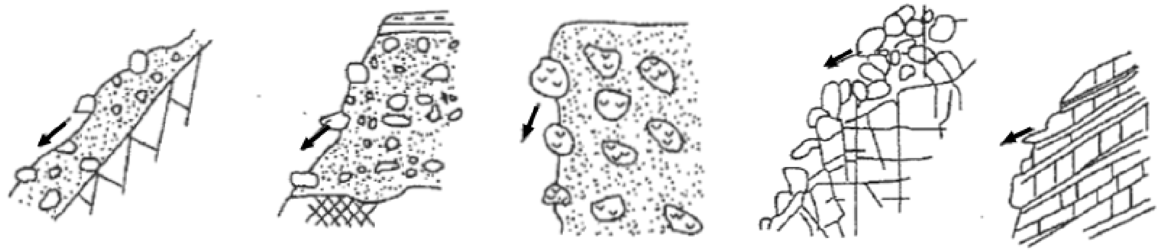
c.1 Topsoil, detached rock and unsteady rock

Since it is an important factor to evaluate stability of cut/natural slope, it requires careful observation and evaluation. Stability of topsoil, detached rock and unsteady rock is evaluated in reference from Table 6.

In case of evaluation of instability, it is evaluated based on recent rock slope failure, unsteady rock, bedrock condition around detached rock, and bearing condition of fallen rocks (Figure 25), as well as soil and vegetation conditions.

Table 6 Criteria of Stability of Topsoil, Detached Rock and Unsteady Rock (after Road Management Technical Center, 2007)

Category of factor	Topsoil	Detached rock and Unsteady rock
Instability	- Thick topsoil layer (more than 50cm) , - Erosion - Trace of movement	A number of the rocks with the following condition are found - 2/3 part of the fallen/ detached rock exposes from ground - Detached completely or estimated to be moved even by a human power
A little unstable	- No eroded and trace of movement even if topsoil layer is thick. - Topsoil layer is thin but it is eroded or has trace of movement	The above condition rocks are found but are not so many. - Grade of exposure of rocks is less than 2/3 - Detached slightly, and it is estimated to be hard to move by human power
Stability	- There is no or thin topsoil layer, and is not trace of movement	- No detached and unsteady rock - Detached/ fallen rocks are under stable condition



(a) Talus deposit (b) Terrace deposit (c) Volcanic pyroclastic rock (d) Fractured rock (Joint) (e) Fractured rock (Schistosity)

Figure 25 Insufficient Bearing Condition of Detached/Fallen Rocks (after Road Management Technical Center, 2007).

c.2 Spring water

Even though number of water spring points and amount of water flow will be changed between after rainfall and before rainfall, it shall be evaluated following three (3) stage approach.

- **Notable spring water**: More than one point of spring water can be found. The spring water has amount of water which can be recognized as water flow or affect the deterioration of soil strength. Artificial water flow from top part of natural slope shall be included.
- **Seepage**: It is the wet condition on cut/natural slope, or spring water which is less amount water volume than the condition of “Notable spring water”.
- **None**

c.3 Surface Condition

It shall be selected from the following three conditions.

- **Bare land with minor vegetation**: The slope consists of rock and gravel or soil mainly and/or the natural slope with grass plant which has weak binding force for covered soil
- **Intermediate (bare, grass, tree)**: Slope surface condition is non-uniform. The slope is covered with mixed condition with bare land, planting part and tree part.
- **Mainly structure/mainly tree**: It is the slope which is covered with artificial structure or trees.

d. Figure

The inspector shall measure a height (H) and a dip (i) of the target slope in reference with the following figures (Figure 26).

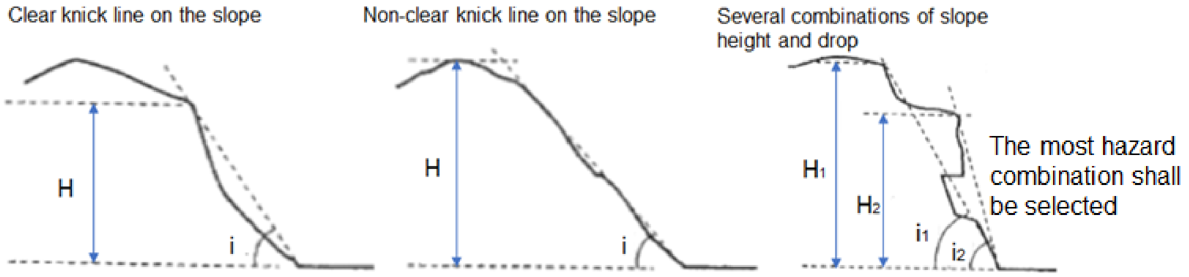


Figure 26 Methodology of Measurement of Slope Height and Dip (after Road Management Technical Center, 2007).

e. Anomaly

Anomalies on cut/natural slope are indication to evaluate a stability of the target slope. Anomalies which are related with slope stability are as follows (Figure 27).

Surface collapse, small fallen rock (more than a few cm diameter), gully, erosion, piping hole (more than a few cm diameter), subsidence (more than 10cm width), heaving (more than 10cm width), bending of tree root, fallen tree, crack, open cracks, anomaly on existing countermeasure.

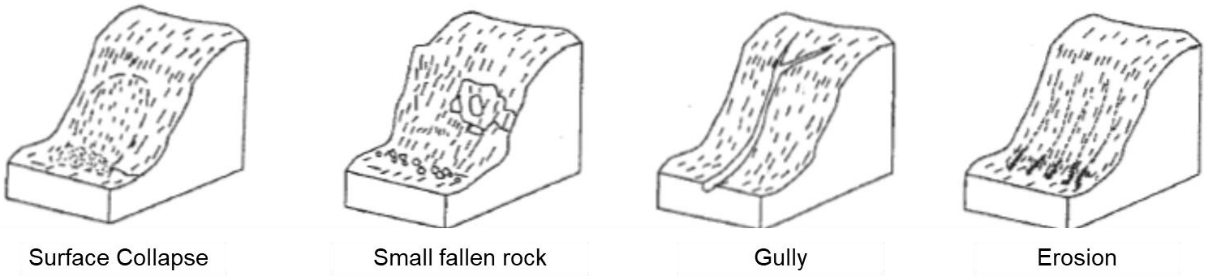


Figure 27 Anomalies on the slope (after Road Management Technical Center, 2007).

2.2 Basic information required

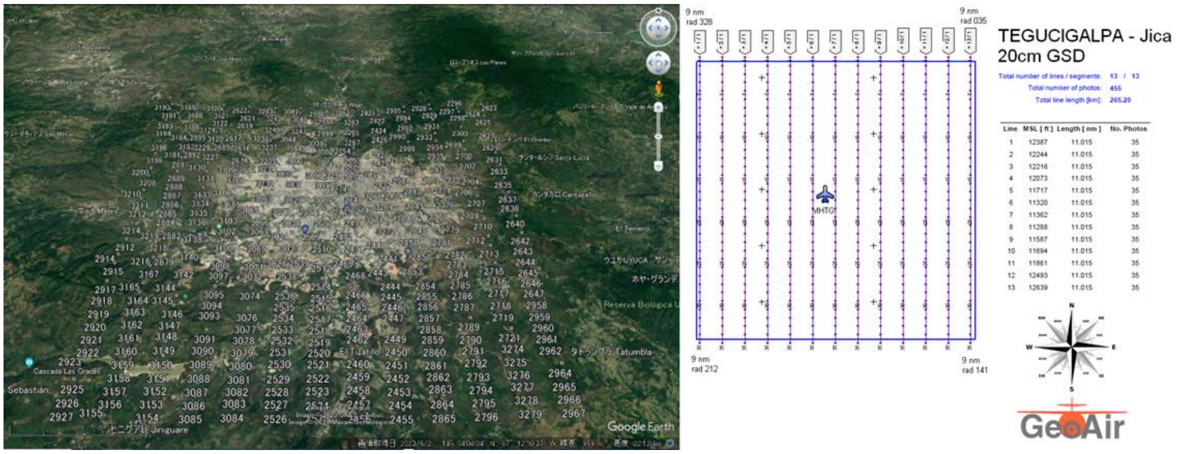
2.2.１ Information related to the internal causes of slope disasters (topography and geology)

(1) Topography

Aerial photography

Aerial photographs of Tegucigalpa were taken in the following years, but they are poorly preserved and provide insufficient information about changes in topography over time (Figure 28). On the other hand, there are 455 aerial photographs taken in 2013 by the JICA project "Hazard geology focusing on the landslides in Tegucigalpa" (Figure 29). In 2013, based on this photo, aerial photo interpretation was performed and a landslide distribution map was created. It is an effective material for interpreting topography in Tegucigalpa city.

Figure 28 Aerial photographs archived at IGN (Instituto Geografico Nacional)



Line	MSL [ft]	Length [nm]	No. Photos
1	12387	11.015	35
2	12244	11.015	35
3	12216	11.015	35
4	12073	11.015	35
5	11717	11.015	35
6	11320	11.015	35
7	11362	11.015	35
8	11288	11.015	35
9	11587	11.015	35
10	11694	11.015	35
11	11861	11.015	35
12	12493	11.015	35
13	12639	11.015	35

Figure 29 Aerial photography route map (Left: Location on Tegucigalpa Google image, Right: Route map, taken by JICA 2013)

The smallest scale topographic map is the 1:1,200 urban topographic map (4 sheets) published by Tegucigalpa. Figure 30 specifically reflects the scope of this project.Figure 56 overlays the contours computed by ArcMap on a map of the city covering this area.

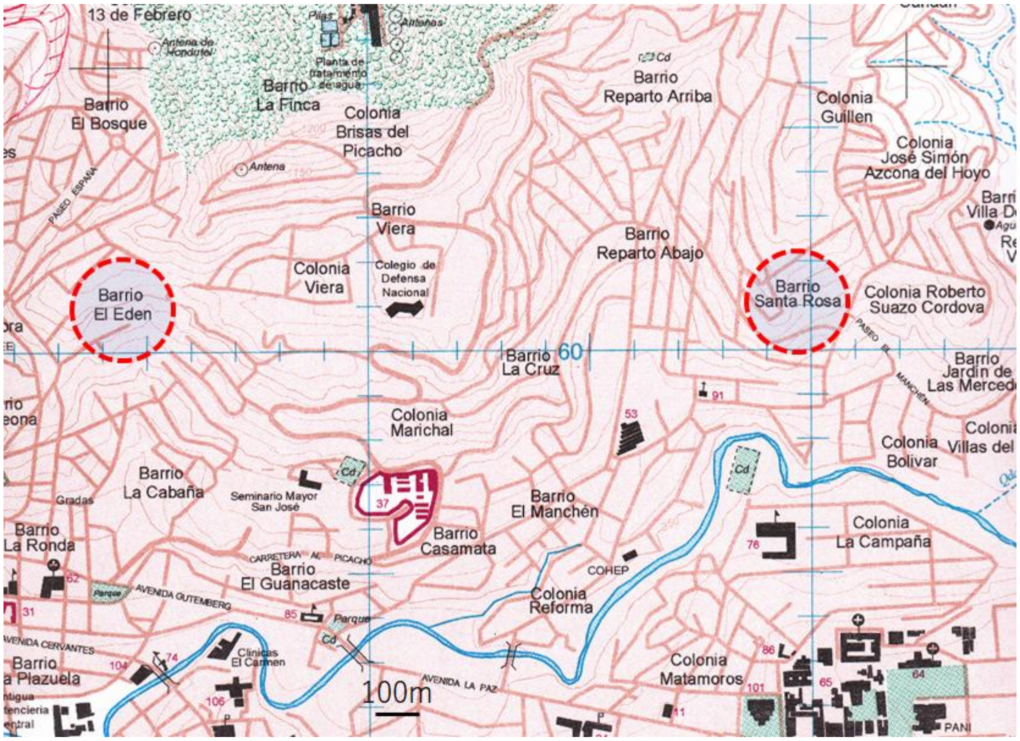


Figure 30 Urban Map of Tegucigalpa (added a part of one of 4sheets, from TEGUCIGALPA, HONDURAS 1:12,000 E952 EDITION 2-NIMA, Hoja 2)

(2) Geology

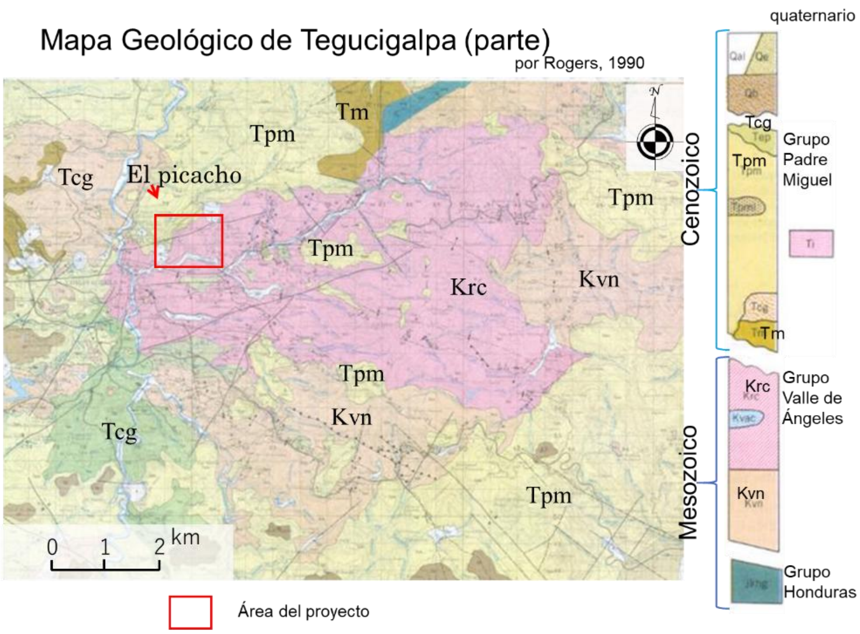
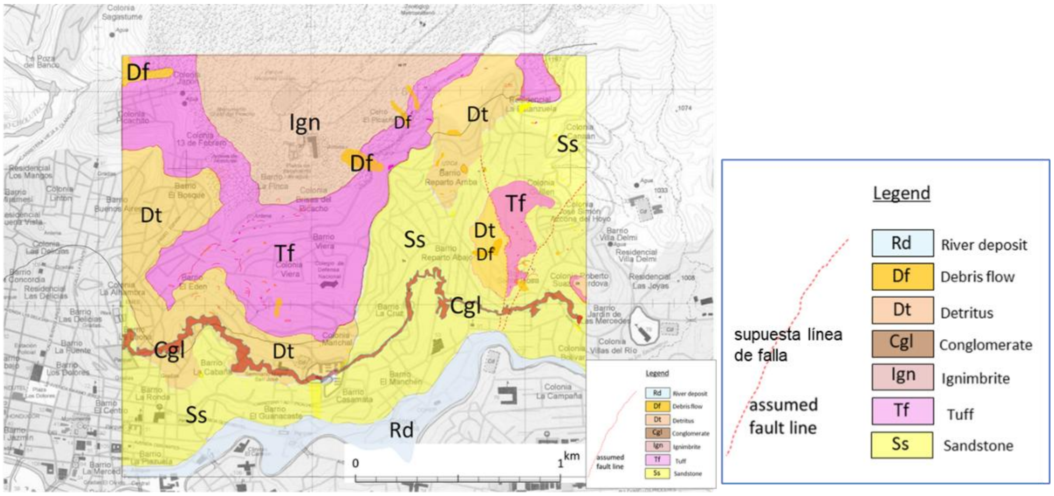


Figure 31 Map of Tegucigalpa (part) (modified from Rogers et al., 1990)

Focusing on the geology of Tegucigalpa, rhyolitic tuff and pumice tuff are found on top of the sandstone and ignimbrite that forms the hill called El Picacho, along the northern margins of the basin. The sandstone of the Valle de Ángeles Group is characterized by a fine-grained reddish sandstone, in which the strata present facies that partially transform into siltstones.



Mapa geológico del área estudiada en la parte norte de Tegucigalpa, Honduras
Mapa base: TEGUCIGALPA, HONDURAS 1: 12,000 E952 EDICIÓN 2-NIMA

Figure 32 Geologic map in the project area

2.2.２ Information related to external causes of slope disasters (hydrology)

(1) Precipitation

Get precipitation data during a disaster.

Collect precipitation data related to landslide disasters and use it to issue future warnings and advisories.

Here are track and precipitation data for Hurricane Mitch, which devastarted Honduras in 1998 (Figure 33).

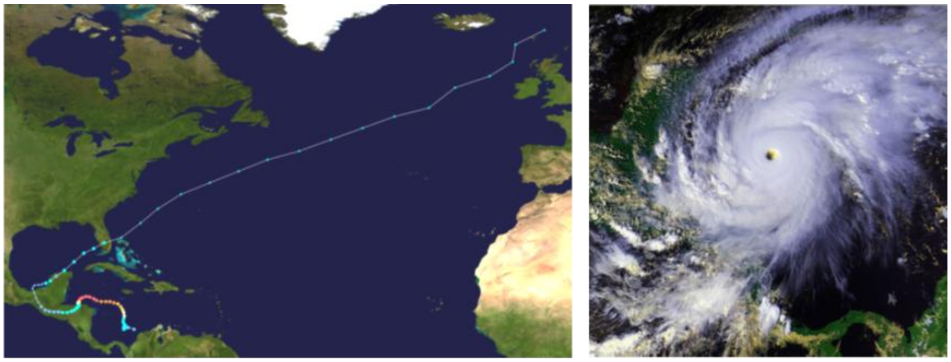


Figure 33 Path of Hurricane Mitch and satellite image of the hurricane (after WIKIPEDIA)

(2) Rainfall data and meteorological observatories in the Tegucigalpa Basin

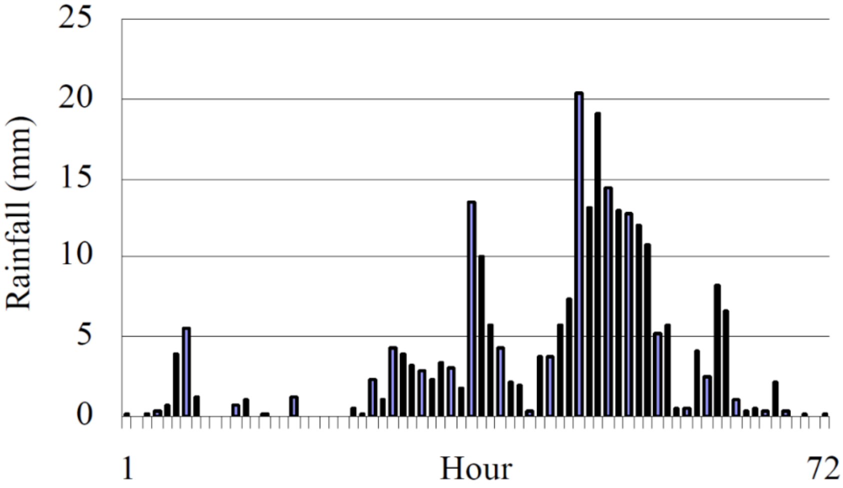


Figure 34 Rainfall data in Toncontín area during the Hurricaine Mitch (JICA, 2002)

Table 7 Condition and damages caused by the Hurricaine Mitch (JET)

Date	Time	Condition and Damage
October 30	22:45	Los Laureles dam spillway exceeded
October 30	23:00	Pescado lagoon collapsed
October 30	22:00-24:00	Violent erosion and landslide occurred on the El País bridge
October 30-31	23:00-6:00	Outflow at the peak of La Concepción dam
October 30	24:00	Río Chiquito reaches its maximum level
October 30-31	24:00-1:00	Landslides occurred in many places
October 31	1:00	Flow to the Chile Bridge reached its peak
October 31	Morning	Landslide occurred in Berrinche

Source: ”Recognition of responses on the Hurricane MItch in Honduras in 1998” by USGS

Based on the precipitation data (Table 8), when Hurricane Mitch hit, the precipitation for the previous half year reached 1,000mm. When considering rainfall and slope disasters, knowing the amount of continuous rainfall for 72 hours that affects slope disasters and the cumulative rainfall amount going back half a year may be used to identify vulnerable slopes. Precipitation data should be saved together with disaster history.

Table 8 Observed precipitation at the Toncontín airport when Hurricane Mitch struck (UNITE: mm)

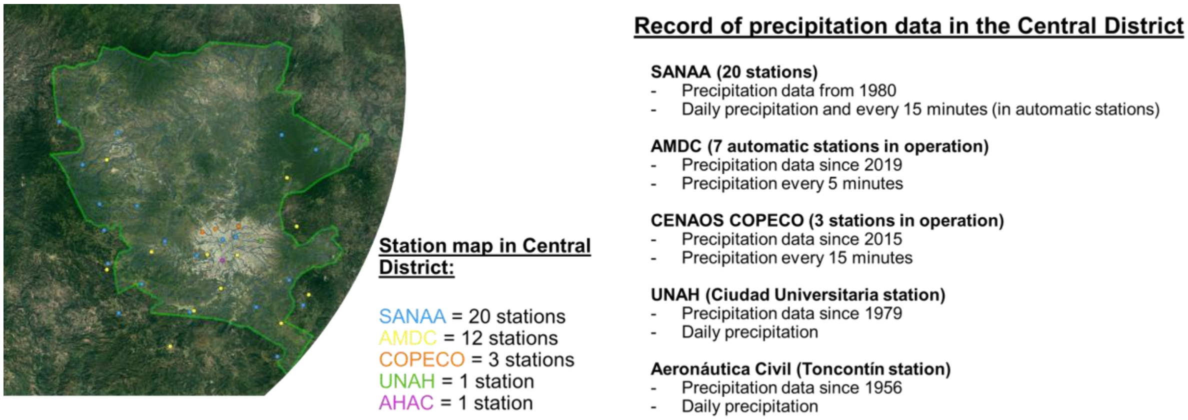
DATE	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL	AUG	SEPT.	OCT.	NOV.	DEC.	SUMA TOTAL	AVERAGE
1	0.8	0.0	0.0	0.0	4.4	30.6	9.0	0.3	0.0	1.8	2.0	0.0	48.9	4.1
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.2	2.3	2.4	0.0	31.9	2.7
3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.3	0.0	11.7	1.0
4	0.0	0.0	0.0	0.0	0.0	9.6	0.0	0.0	1.6	0.0	1.5	0.0	12.7	1.1
5	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	16.6	8.6	0.0	0.0	27.6	2.3
6	0.0	0.0	0.0	0.0	0.0	0.0	21.0	3.8	14.6	0.2	0.2	0.0	39.8	3.3
7	0.0	0.0	0.0	0.0	0.0	0.0	9.9	13.4	0.1	8.9	0.0	0.1	32.4	2.7
8	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.7	9.9	0.0	0.0	11.0	0.9
9	0.0	0.0	0.0	0.0	0.0	1.5	38.0	0.0	0.0	0.6	1.2	0.1	41.4	3.5
10	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.7	0.1	0.0	1.0	0.1
11	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	10.1	1.2	0.0	12.9	1.1
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	0.0	7.5	0.6
13	0.0	0.0	0.0	0.0	0.0	0.0	6.4	1.1	4.0	25.4	0.0	0.1	37.0	3.1
14	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	15.7	17.4	0.0	0.0	38.0	3.2
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	16.7	0.0	0.0	19.0	1.6
16	0.0	0.0	0.0	0.0	0.0	39.8	0.0	0.2	5.4	18.2	0.1	0.0	63.7	5.3
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.3	3.6	4.9	0.0	10.5	0.9
18	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.7	7.0	0.0	8.0	0.7
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	10.3	5.1	0.9	0.0	18.7	1.6
20	0.0	0.0	4.9	0.0	0.0	4.5	0.0	26.1	0.1	0.1	2.9	1.4	40.0	3.3
21	0.0	0.0	0.8	0.5	0.0	3.5	0.0	0.3	0.0	0.5	2.9	0.0	8.5	0.7
22	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	21.9	0.5	0.0	23.6	2.0
23	0.0	0.0	0.0	0.0	2.9	4.8	0.7	0.0	40.5	17.8	0.3	0.1	67.1	5.6
24	0.0	0.0	0.0	0.0	28.4	18.5	5.7	16.1	7.4	7.5	0.1	0.0	83.7	7.0
25	0.0	0.0	0.0	0.0	0.0	6.3	8.8	34.2	6.6	2.0	0.0	0.0	57.9	4.8
26	0.0	0.0	0.0	0.0	0.0	0.0	2.5	9.2	7.4	8.9	0.6	0.0	28.6	2.4
27	0.0	0.0	0.0	0.0	0.0	0.0	14.7	0.0	1.8	17.2	0.0	0.0	33.7	2.8
28	0.0	0.0	0.0	4.0	29.3	0.0	0.0	31.1	0.4	13.7	0.0	0.0	78.5	6.5
29	0.0		0.0	0.0	45.9	0.0	1.3	7.6	0.0	33.4	0.1	0.0	88.3	8.0
30	0.0		15.5	4.7	31.7	2.6	0.0	4.8	0.0	129.3	0.0	0.0	188.6	17.1
31	0.0		0.0		6.6		0.0	0.0		89.7		0.0	96.3	13.8

Mitch

985.3mm

SUMA TOTAL	1.2	0.0	21.2	10.8	149.2	122.2	126.9	152.3	163.0	490.7	29.2	1.8	1268.5	113.5
AVERAGE	0.0	0.0	0.7	0.4	4.8	4.1	4.1	4.9	5.4	15.8	1.0	0.1	40.9	3.7

The rainfall observatories in Tegucigalpa are as Figure 35.



Station map in Central District:

SANAA = 20 stations
AMDC = 12 stations
COPECO = 3 stations
UNAH = 1 station
AHAC = 1 station

Record of precipitation data in the Central District

SANAA (20 stations)
- Precipitation data from 1980
- Daily precipitation and every 15 minutes (in automatic stations)

AMDC (7 automatic stations in operation)
- Precipitation data since 2019
- Precipitation every 5 minutes

CENAOS COPECO (3 stations in operation)
- Precipitation data since 2015
- Precipitation every 15 minutes

UNAH (Ciudad Universitaria station)
- Precipitation data since 1979
- Daily precipitation

Aeronáutica Civil (Toncontín station)
- Precipitation data since 1956
- Daily precipitation

Figure 35 Rainfall observatories and specifications in the catchment area affecting Tegucigalpa (from Roberto Granados data)

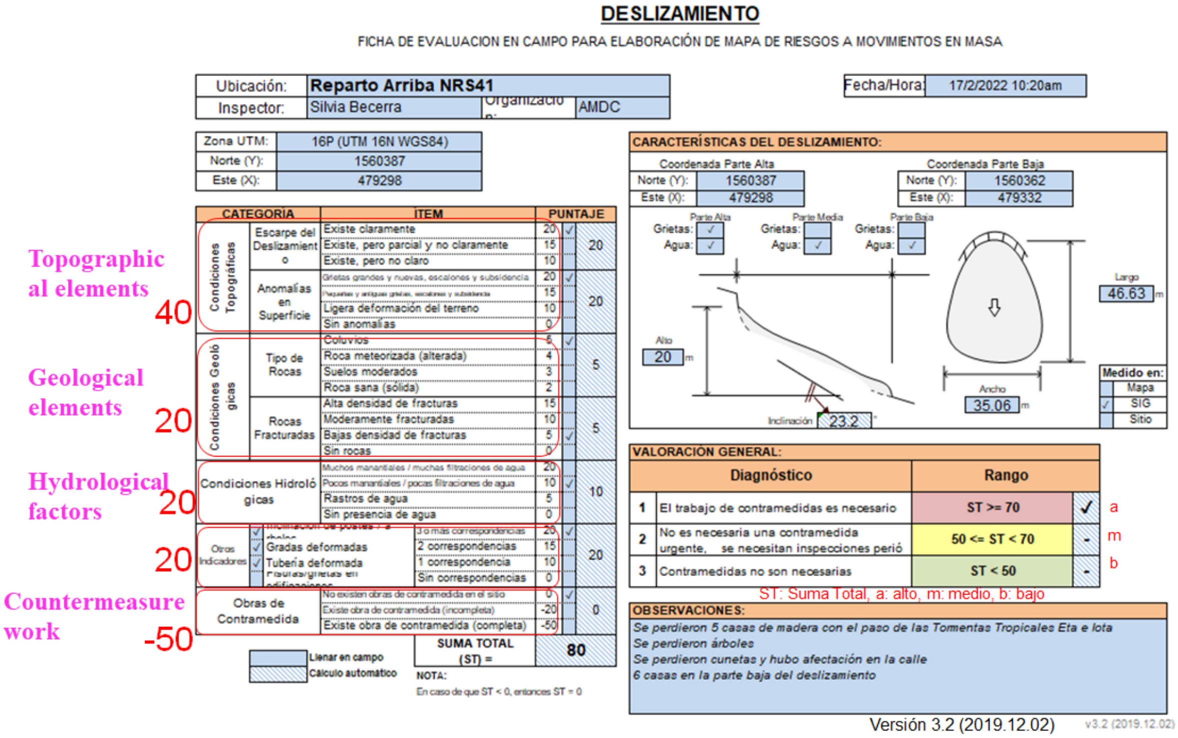
2.3 In situ assessment of slope vulnerability

2.3. 1 Creating survey sheets

There are two types of survey sheets, one for Landslides and another for slope failure/rockfall. All of them have common items, and create a sheet by the following procedure.

However, it is necessary to re-evaluate the evaluation items based on the points assigned to the survey items in the check sheet as an evaluation sheet after completing the entire survey (or even if it is in the middle procedure). This is because even a stable slope may be classified as a high hazard classification, and even a low hazard classification may be recognized as an unstable slope in a field survey.

1) **Decide what to investigate**: As major items of the two types of survey sheets, “topographical elements”, “geological elements”, and “elements affected by hydrology” are established. “Elements affected by hydrology” are elements involved in topographical deformation caused by surface water and groundwater, but they are related to precipitation, so they are referred to as “topographical elements”. In terms of “social factors”, they are focused mainly on the site situation, such as land modification, and evaluate the soundness of artifacts, the locations of alterations, the presence or absence of countermeasures, and the effects.
2) **Allotted Points**: The total number of points allotted for the elements listed in the survey sheet shall be 100 points.
3) The points for the “**Landslide”** survey sheet are as follows: (Figure 36). “Geological elements” **- 20** points, “Topographical elements” **- 40** points, “Hydrological factors” **- 20** points, Deformation **- 20** points, expected “Countermeasure work” effect **- 50** minus points.



DESLIZAMIENTO

FICHA DE EVALUACION EN CAMPO PARA ELABORACIÓN DE MAPA DE RIESGOS A MOVIMIENTOS EN MASA

Ubicación:	**Reparto Arriba NRS41**		
Inspector:	Silvia Becerra	Organización:	AMDC

Fecha/Hora: 17/2/2022 10:20am

Zona UTM:	16P (UTM 16N WGS84)
Norte (Y):	1560387
Este (X):	479298

CATEGORÍA		ÍTEM	PUNTAJE		
Condiciones Topográficas	Escarpe del Deslizamiento	Existe claramente	20	✓	20
		Existe, pero parcial y no claramente	15		
		Existe, pero no claro	10		
	Anomalías en Superficie	Grietas grandes y nuevas, escalones y subsidencia	20	✓	20
		Pequeñas y antiguas grietas, escalones y subsidencia	15		
		Ligera deformación del terreno	10		
		Sin anomalías	0		
Condiciones Geológicas	Tipo de Rocas	Coluvios	5	✓	5
		Roca meteorizada (alterada)	4		
		Suelos moderados	3		
		Roca sana (sólida)	2		
	Rocas Fracturadas	Alta densidad de fracturas	15		5
		Moderamente fracturadas	10		
		Bajas densidad de fracturas	5	✓	
		Sin rocas	0		
Condiciones Hidrológicas		Muchos manantiales / muchas filtraciones de agua	20		10
		Pocos manantiales / pocas filtraciones de agua	10	✓	
		Rastros de agua	5		
		Sin presencia de agua	0		
Otros Indicadores	✓ Inclinación de postes / árboles	3 o más correspondencias	20	✓	20
	✓ Gradas deformadas	2 correspondencias	15		
	✓ Tubería deformada	1 correspondencia	10		
	Fisuras/grietas en edificaciones	Sin correspondencias	0		
Obras de Contramedida		No existen obras de contramedida en el sitio	0	✓	0
		Existe obra de contramedida (incompleta)	-20		
		Existe obra de contramedida (completa)	-50		
		SUMA TOTAL (ST) =			80

Topographical elements 40

Geological elements 20

Hydrological factors 20

20

Countermeasure work -50

▭ Llenar en campo

▨ Cálculo automático

NOTA:
En caso de que ST < 0, entonces ST = 0

CARACTERÍSTICAS DEL DESLIZAMIENTO:

Coordenada Parte Alta		Coordenada Parte Baja	
Norte (Y):	1560387	Norte (Y):	1560362
Este (X):	479298	Este (X):	479332

	Parte Alta	Parte Media	Parte Baja
Grietas:	✓	☐	☐
Agua:	✓	✓	✓

Alto 20 m

Inclinación 23.2 °

Ancho 35.06 m

Largo 46.63 m

Medido en:	
☐	Mapa
✓	SIG
☐	Sitio

VALORACIÓN GENERAL:

	Diagnóstico	Rango		
1	El trabajo de contramedidas es necesario	ST >= 70	✓	a
2	No es necesaria una contramedida urgente, se necesitan inspecciones perió	50 <= ST < 70	-	m
3	Contramedidas no son necesarias	ST < 50	-	b

ST: Suma Total, a: alto, m: medio, b: bajo

OBSERVACIONES:

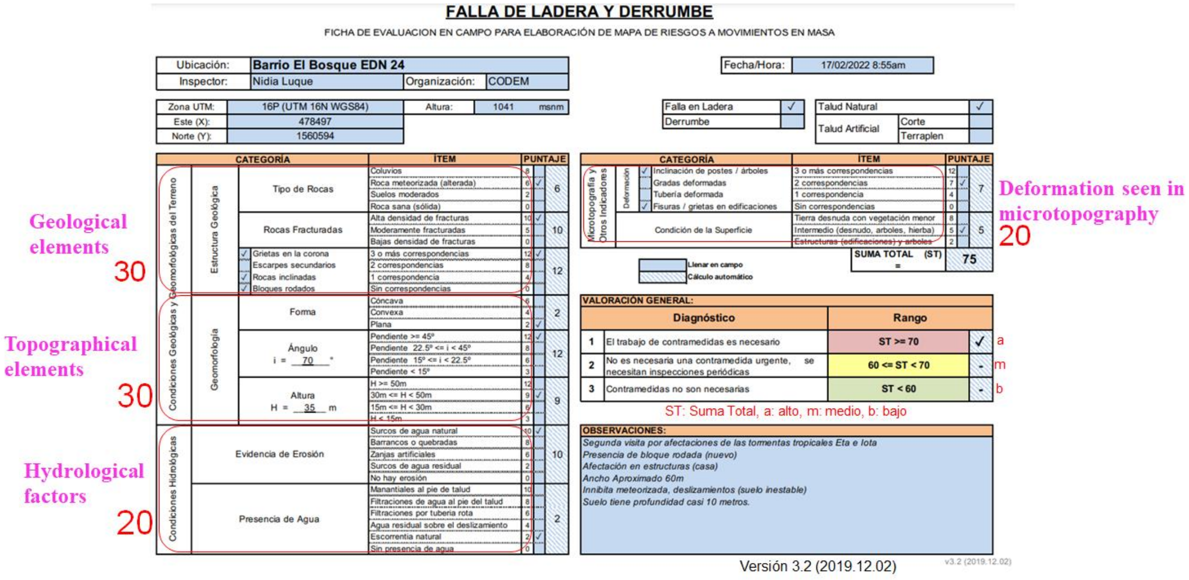
Se perdieron 5 casas de madera con el paso de las Tormentas Tropicales Eta e Iota
Se perdieron árboles
Se perdieron cunetas y hubo afectación en la calle
6 casas en la parte baja del deslizamiento

Versión 3.2 (2019.12.02) v3.2 (2019.12.02)

Figure 36 Survey sheet showing the division of points at "Landslide" (added to field survey example, JET)

4) The points for the "**Slope failure/Rockfall"** survey sheet are (Figure 37): "Geological elements" - **30** points, "Topographical elements" - **30** points, "Hydrological factors" - **20** points, "Deformation seen in microtopography" - **20** points.

As for "Slope failure/Rockfall", there is no decrease due to the effect of countermeasures such as the survey sheet for "Landslide". It is a matter of scale to deal with, and it is because there is no idea to treat countermeasures such as control work to slow down long-term deformation like landslide phenomenon.



FALLA DE LADERA Y DERRUMBE

FICHA DE EVALUACION EN CAMPO PARA ELABORACIÓN DE MAPA DE RIESGOS A MOVIMIENTOS EN MASA

Ubicación:	Barrio El Bosque EDN 24		
Inspector:	Nidia Luque	Organización:	CODEM

Fecha/Hora: 17/02/2022 8:55am

Zona UTM:	16P (UTM 16N WGS84)	Altura:	1041 msnm
Este (X):	478497		
Norte (Y):	1560594		

Falla en Ladera	✓
Derrumbe	

Talud Natural		✓
Talud Artificial	Corte	
	Terraplen	

CATEGORÍA			ÍTEM	PUNTAJE		
Condiciones Geológicas y Geomorfológicas del Terreno	Estructura Geológica	Tipo de Rocas	Coluvios	8		6
			Roca meteorizada (alterada)	6	✓	
			Suelos moderados	2		
			Roca sana (sólida)	0		
		Rocas Fracturadas	Alta densidad de fracturas	10	✓	10
			Moderamente fracturadas	5		
			Bajas densidad de fracturas	0		
		✓ Grietas en la corona	3 o más correspondencias	12	✓	12
		Escarpes secundarios	2 correspondencias	8		
		✓ Rocas inclinadas	1 correspondencia	4		
		✓ Bloques rodados	Sin correspondencias	0		
	Geomorfología	Forma	Cóncava	6		2
			Convexa	4		
			Plana	2	✓	
		Ángulo i = 70 °	Pendiente >= 45º	12	✓	12
			Pendiente 22.5º <= i < 45º	8		
			Pendiente 15º <= i < 22.5º	6		
			Pendiente < 15º	3		
		Altura H = 35 m	H >= 50m	12		9
			30m <= H < 50m	9	✓	
			15m <= H < 30m	6		
			H < 15m	3		
Condiciones Hidrológicas	Evidencia de Erosión		Surcos de agua natural	10	✓	10
			Barrancos o quebradas	8		
			Zanjas artificiales	6		
			Surcos de agua residual	2		
			No hay erosión	0		
	Presencia de Agua		Manantiales al pie de talud	10		2
			Filtraciones de agua al pie del talud	8		
			Filtraciones por tuberia rota	6		
			Agua residual sobre el deslizamiento	4		
			Escorrentia natural	2	✓	
			Sin presencia de agua	0		

CATEGORÍA			ÍTEM	PUNTAJE		
Microtopografía y Otros Indicadores	Deformación	✓ Inclinación de postes / árboles	3 o más correspondencias	12		7
		Gradas deformadas	2 correspondencias	7	✓	
		Tubería deformada	1 correspondencia	4		
		✓ Fisuras / grietas en edificaciones	Sin correspondencias	0		
	Condición de la Superficie		Tierra desnuda con vegetación menor	8		5
			Intermedio (desnudo, arboles, hierba)	5	✓	
			Estructuras (edificaciones) y arboles	2		
			SUMA TOTAL (ST) =			75

🟦	Llenar en campo
▨	Cálculo automático

VALORACIÓN GENERAL:

	Diagnóstico	Rango	
1	El trabajo de contramedidas es necesario	ST >= 70	✓
2	No es necesaria una contramedida urgente, se necesitan inspecciones periódicas	60 <= ST < 70	-
3	Contramedidas no son necesarias	ST < 60	-

ST: Suma Total, a: alto, m: medio, b: bajo

OBSERVACIONES:

Segunda visita por afectaciones de las tormentas tropicales Eta e Iota
Presencia de bloque rodada (nuevo)
Afectación en estructuras (casa)
Ancho Aproximado 60m
Innibita meteorizada, deslizamientos (suelo inestable)
Suelo tiene profundidad casi 10 metros.

Versión 3.2 (2019.12.02)

v3.2 (2019.12.02)

Figure 37 Survey sheet showing the division of points at "Slope failure/ Rockfall" (added to field survey example, JET)

5) **Remarks column of the survey sheet**: new deformations of microtopography affected by rainfall, minor artificial alterations, deformations caused by earthquakes, etc. are described in the remarks column.
6) The date of the survey, the surveyor, and the location of the survey (GPS data, etc.) should be written on the **survey sheet**, and any new deformations should be photographed.

Overall Judgment: exapple of Slope failure/ Rockfall

The risk of Slope failure/Rockfall is judged from the above-mentioned causes, the countermeasures and the history. Inspection engineers decide future response for the potential Slope failure/ Rockfall as follows:

1) The countermeasure work is necessary.
2) Though the urgent countermeasure is not necessary, regular inspections are needed.
3) The countermeasure work is not necessary.

Some of the terms used in the field survey sheet are common in the evaluation tables for "landslide" and "Slope failure/Rockfall", so the term "Slope failure/Rockfall" is given here.

The slope evaluation table needs to be suitable for the land, so when creating the survey sheet, the selection of elements that match the target slope/site is confirmed through field surveys. Including general geological and topographical conditions, it is necessary to examine the geological conditions that are suitable for the research site.

ROCKS TYPE

Colluvia, Weathered Rock, Moderate Soils, Solid Rock

FRACTURED ROCKS

High fracture density, moderately fractured, Low fracture density

CORRESPONDENCES

Crown Cracks, Secondary Scarps, Inclined Rocks, Rolled Boulders

FORM

Concave, Convex, Flat

EVIDENCE OF EROSION

Flows of natural water, Gullys, Artificial ditches, Flows of residual water

WATER PRESENCE

Watersprings at the foot of the slope, water seepage at the foot of the slope, Seepage from broken pipes, Residual water on the landslide

SURFACE CONDITIONS

Bare land with minor vegetation, Intermediate (bare, trees, grass), Structures (buildings) and trees

2.3.２ Data compilation and re-evaluation

(1) Evaluation for slopes

Evaluation is performed using the check sheet as follows:

1) Conduct a field survey using the check sheet for all target slopes.
2) Examine the adequacy of hazard classification.
3) Site resurvey for sites at the boundaries of the classification (high, medium, and low hazard classification boundaries).
4) After confirmation, if there is any re-correction, proceed to hazard map creation according to the evaluation after re-evaluation.

(2) Arrangement after field survey and consideration of validity of classification evaluation

Set three categories: high hazard (Category 1), medium hazard (Category 2), and low hazard (Category 3) as follows (Figure 36 and Figure 37, ver.3.2 survey has the evaluation category values) :

1) Find the average and median of the aggregated values
2) If two values are similar, use the average value as a reference for the boundary classification value between Category 2 and 3.

3) If the values are different, confirm the properties of the slope corresponding to the median value and the average value on site and adopt an appropriate value.
4) If the appropriate value is selected, place the value on the borderline between medium hazard (Category 2) and low hazard (Category 3).
5) Evaluate the limits of high danger (Category 1) and medium danger (Category 2) after evaluating the properties of the slope in each range of 10 points. In this case, slopes that are clearly collapsing or prone to collapse are high hazard (Category 1).
6) Each classification value is not always the same for "Landslide" and "Slope failure/Rockfall".

(3) Implementation

The total score evaluation categories for "Landslides" in the survey results using the check sheet are Category 1: ST ≥ 70, Category 2: 50 ≤ ST < 70, Category 3: ST < 50. Data from El Edén (n=23, mean 57, median 50) and data from Nueva Santa Rosa (n=38, mean 50, median 50) show that the mean is slightly higher in El Edén. (57), but the median values are both 50, which is on the border between Category 2 and Category 3, which is a reasonable category considering the stability of the local situation.

On the other hand, the total score evaluation categories for "Slope failure/Rockfall" are Category 1: ST≧70, Category 2: 60≦ST<70, Category 3: ST<60. Based on the data from El Edén (n=11, mean 59, median 59) and from Nueva Santa Rosa (n=23, mean 59, median 59), both the mean and median are 59. This is the boundary between Category 2 and Category 3, and is a reasonable category considering the stability of the local situation.

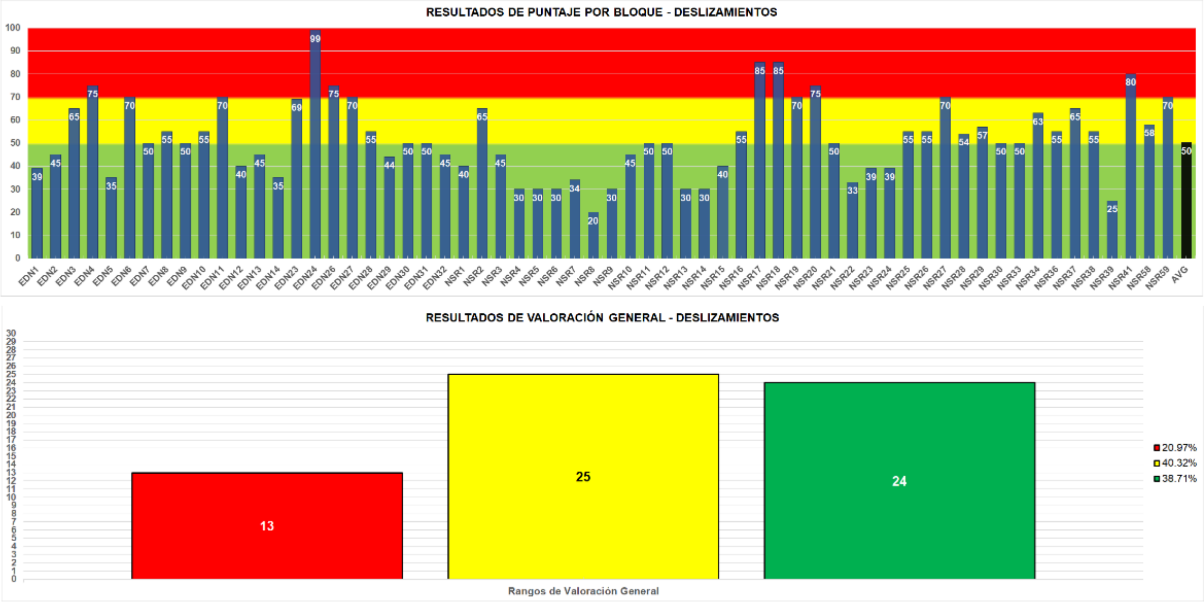


Figure 38 "Landslides" Rank Classification (From the left, El Edén and Nueva Santa Rosa are collectively displayed, n=62, JET)

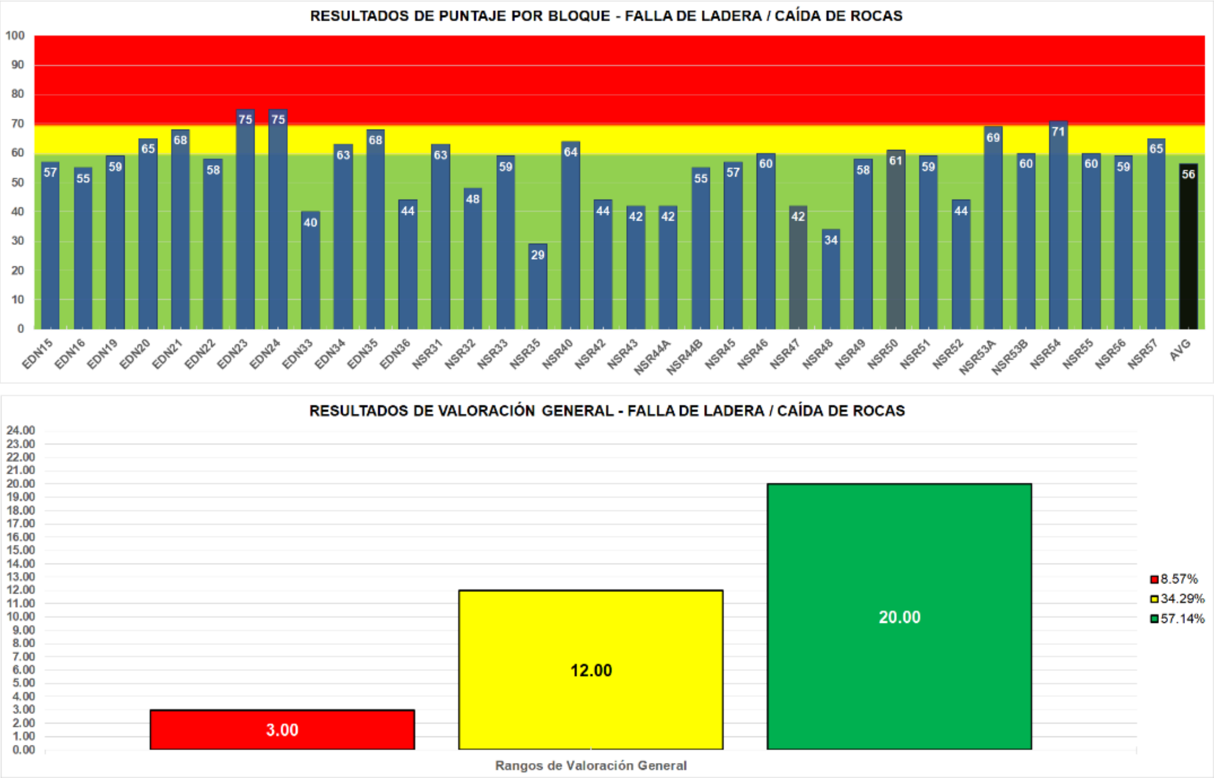


Figure 39 “Slope Failure/Rockfall” Rank Classification (from the left, El Edén and Nueva Santa Rosa, n=35, JET)

Chapter 3. Slope related hazard and risk assessment

3.1 Slope evaluation procedure appearance

The flow from hazard map creation to risk map creation is as follows (Figure 40).

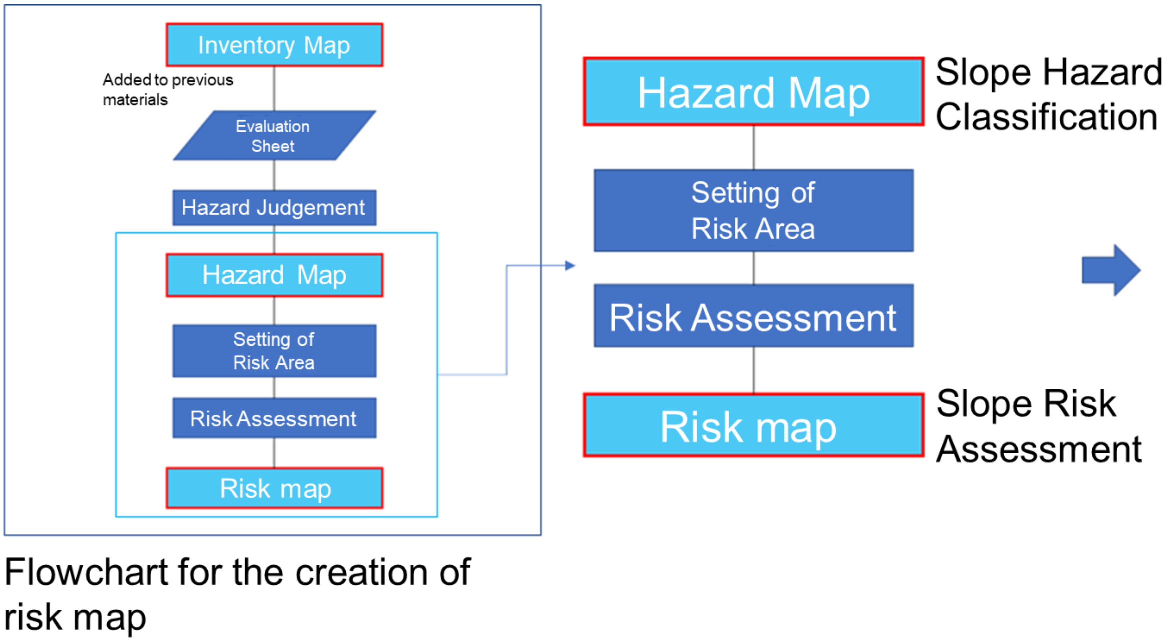


Figure 40 Diagrama de flujo para crear un mapa de riesgos (JET)

3.2 Slope hazard assessment

(1) Confirmation of evaluation by on-site survey after classification of hazards in survey sheet

Using the evaluation points for each slope obtained using the survey table, the slopes on the boundaries of the evaluation categories are extracted. After that, a field survey will be conducted to confirm the relevant slopes and examine the validity of the hazard assessment categories.

Before going to the site, the score range is summarized in 10-point increments and shown on a graph, and the sites on the division boundaries are extracted. There are 10 divisions in 10-point increments: 1 to 10, 11 to 20, 21 to 30, 31 to 40, 41 to 50, 51 to 60, 61 to 70, 71 to 80, 81 to 90, 91 to 100 (Figure 41).

(2) Target slopes are slopes/sites in the hazard boundary division:

1) Landslide:

Sites with 70 points: EDN6, EDN11, EDN27, NSR19, NSR27 (5 sites)

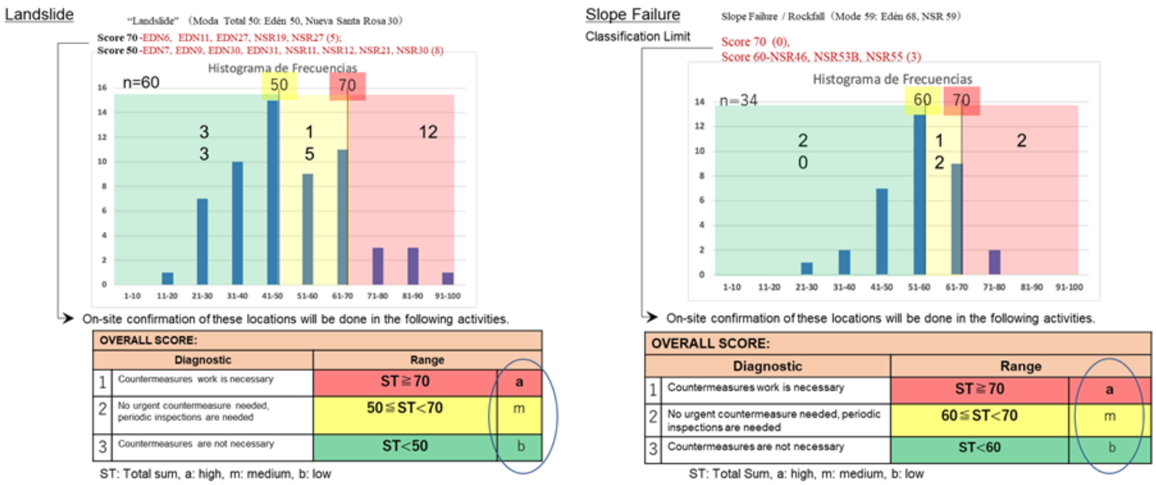
Sites with 50 points: EDN7, EDN9, EDN30, EDN31, NSR11, NSR13, NSR21, NSR30 (9 sites).

2) Slope failure/ Rockfall

Sites with 70 points: None

Sites with 60 points: NSR46, NSR55B, NSR55 (3 sites)

As a result of the field survey of the site in the boundary numerical value, it is the same as the previous survey division designated area.



On-site confirmation of these locations will be done in the following activities.

OVERALL SCORE:			
Diagnostic		Range	
1	Countermeasures work is necessary	ST≧70	a
2	No urgent countermeasure needed, periodic inspections are needed	50≦ST<70	m
3	Countermeasures are not necessary	ST<50	b

ST: Total sum, a: high, m: medium, b: low

On-site confirmation of these locations will be done in the following activities.

OVERALL SCORE:			
Diagnostic		Range	
1	Countermeasures work is necessary	ST≧70	a
2	No urgent countermeasure needed, periodic inspections are needed	60≦ST<70	m
3	Countermeasures are not necessary	ST<60	b

ST: Total Sum, a: high, m: medium, b: low

Figure 41 Rating chart and list (left: for Landslide, right: for Slope failure/ Rock fall, JET)

3.3 Slope risk assessment

3.3.1 Setting risk area

Set the risk area for creating a risk map by referring to Sediment-related disaster special warning areas (red zone) and Sediment-related disaster warning areas (yellow zone) in the “Sediment-related Disaster Prevention Act” of Japan (Figure 42).

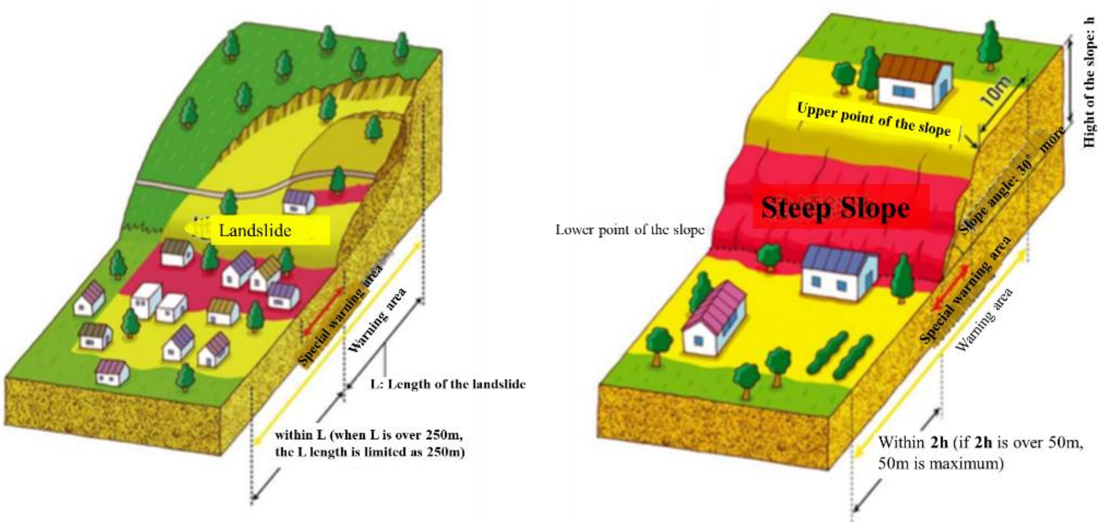


Figure 42 Types of slope disasters (Landslides, Slope failure/ Rockfall, modified by JET)

Next, as a step before creating a risk map, determine the range that the hazard range (polygon) will affect.

- **Area:** Use polygons for hazard assessment.

  The area A where a polygon and the polygon itself have been moved is B + C (Figure 43).

  The distance is taken in the direction of the slip and the length of the same distance as the length of the slip polygon (L) is added.

  However, if L(L') ≤ 250 m and L is greater than 250 m, then L' is 250 m.

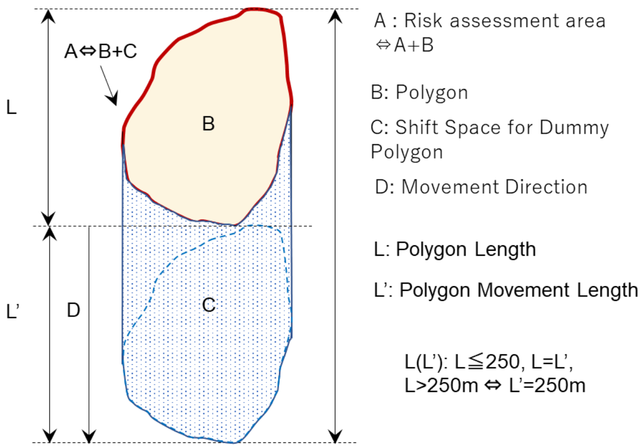


Figure 43 Slope risk Target area (Landslide, JET)

- **Area:** Use polygons for hazard assessment.

  The target slope is shown in a cross section (Figure 44, right). Move 10m up from the top of the "Slope Failure/Rockfall" polygon in the hazard category, and move down from the bottom to twice the height of the slope (A) (2A). The area is the same. However, the maximum area of influence of 2A is 50 m.

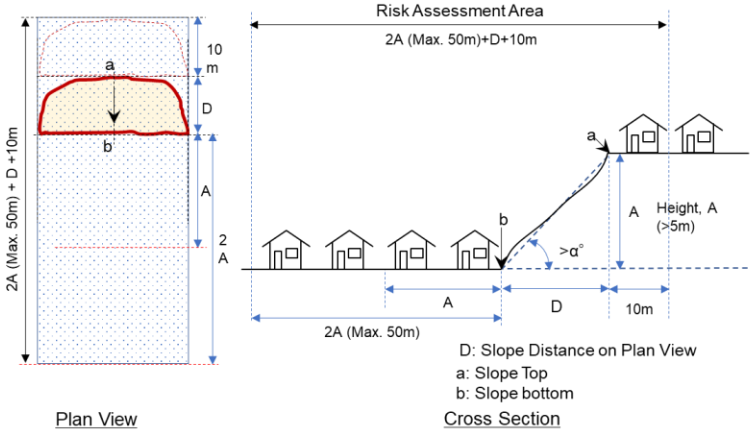


Figure 44 Slope risk Target area (Slope failure/ Rockfall, JET)

3.3.２ Risk matrix diagram and evaluation

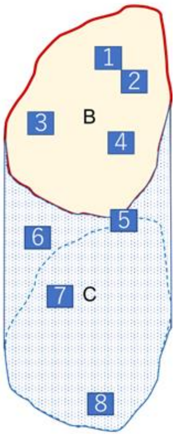
A risk map for slopes is created after performing a risk assessment. When surveying houses within the risk area on site, use the risk affected map created tentatively on the desk (Figure 45, Table 9).

Figure 45 Risk assumption and building survey in the risk zone (JET)

Table 9 Example of the Building survey list (JET)

Buildings						
Nº	Atribute			Current Use		
	Public	Private (residential)	Not Clear	Daily (houses/ work)	Temporary (rituals, events)	Not clear/ abandoned
1	1				1	
2		1		1		
3		1		1		
4		1			1	
5	1				1	
6	1			1		
7		1			1	
8			1			
total	3	4	1			

Numbering



In the risk assessment matrix diagram (Figure 46), the vertical axis is the number of buildings (Table 10) and the horizontal axis is the hazard category (Table 11).

Table 10 Estimated damage classification table (JET)

Degree of damage: according to number of houses

Level	Elements to evaluate		
	Qualitative expression		Number of houses
3	Sector	Many	100～
2	Neighborhood	Medium	10～99
1	Scattered	Few	1～9

Table 11 Comparison between Hazard classification of survey sheet and classification of Risk matrix diagram

(Hazard classification and level classification use opposite numbers, JET)

Hazard level: follow the hazard assessment category according to the investigation sheets.

Level	Qualitative expression		Landslide Scoring		Slope failure/ Rock fall Scoring	
III	high	h	1	ST≧70	1	ST≧70
II	medium	m	2	50≦ST<70	2	60≦ST<70
I	low	l	3	ST<50	3	ST<60

ST: suma total (total amount)

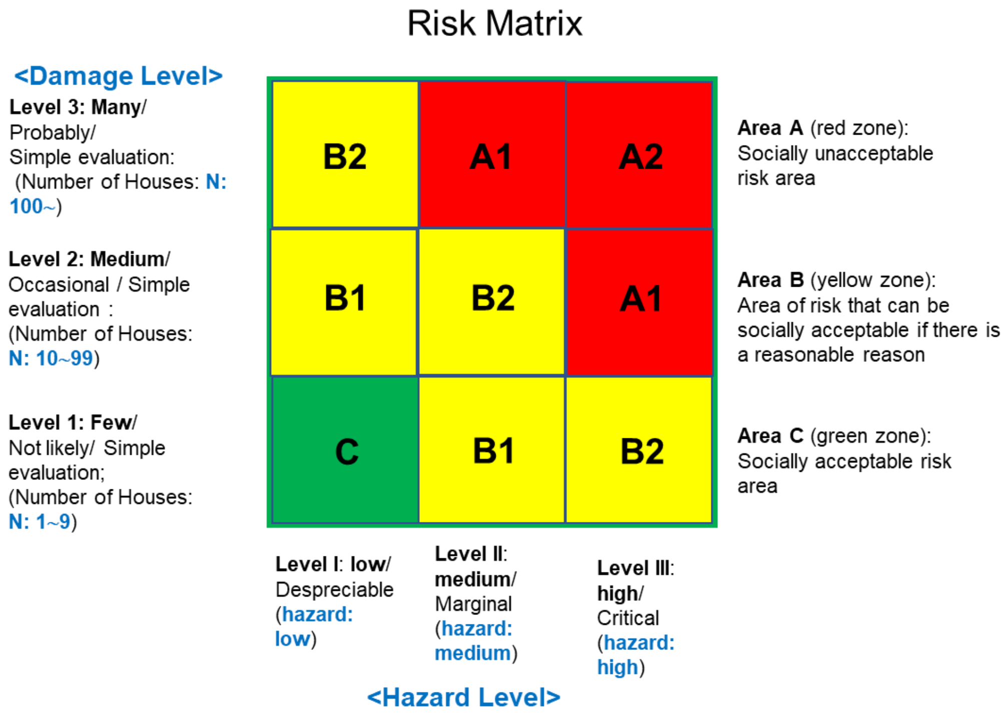


Figure 46 Risk assessment matrix diagram (JET)

[Note]

1) It is basic to put "Frequency of occurrence" on the vertical axis of the matrix.
2) "Precipitation" is thought as "Frequency of occurrence", but there is no precipitation data related to Disasters in Tegucigalpa.
3) For this reason, the vertical axis has been selected as "Degree of damage" in the number of houses
4) Even if "Slope Fault/Rockfall" is less than 5m high, it is level 3 if it has collapsed.
5) Level 3 if there are main roads in the area of influence.

Chapter 4. GIS-based Hazard and Risk mapping and support

4.1 Spatial Analysis for slope failure / rockfall survey and geological map

4.1.1 Concept of Screening

GIS can operate any kind of maps, but if the map is not georeferenced, it should be georeferenced. In this project, geological map is one of the basic map information for screening a hazardous Slope failure/Rockfall area or site. Digital Elevation Models (DEM, DTM) also provide some important features of topography. Slope is most famous topographic feature generated from DEM. Relief energy can show a grid cells including steep slopes. The following figure shows a concept of screening for finding field survey sites of Slope failure/Rockfall.

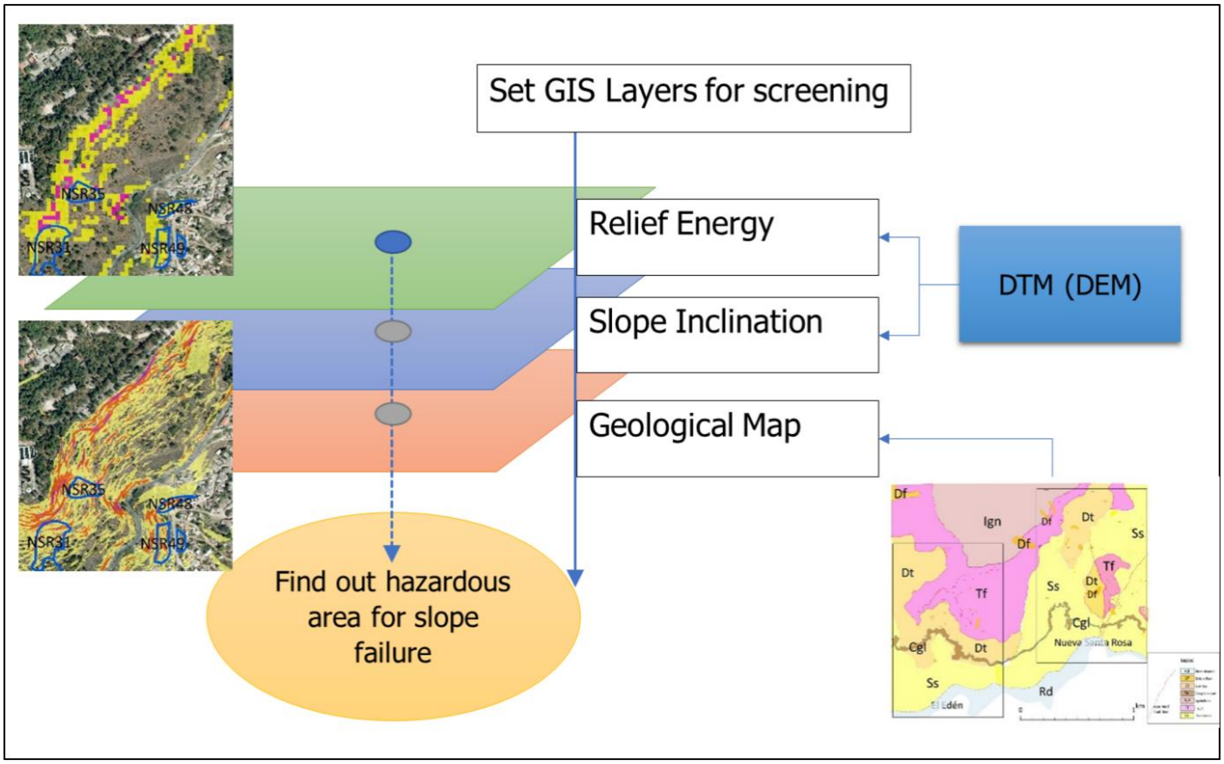


Figure 47 Concept of Screening for Slope failure / rockfall (JET)

4.1.2 Preparation of Geological Map for Screening

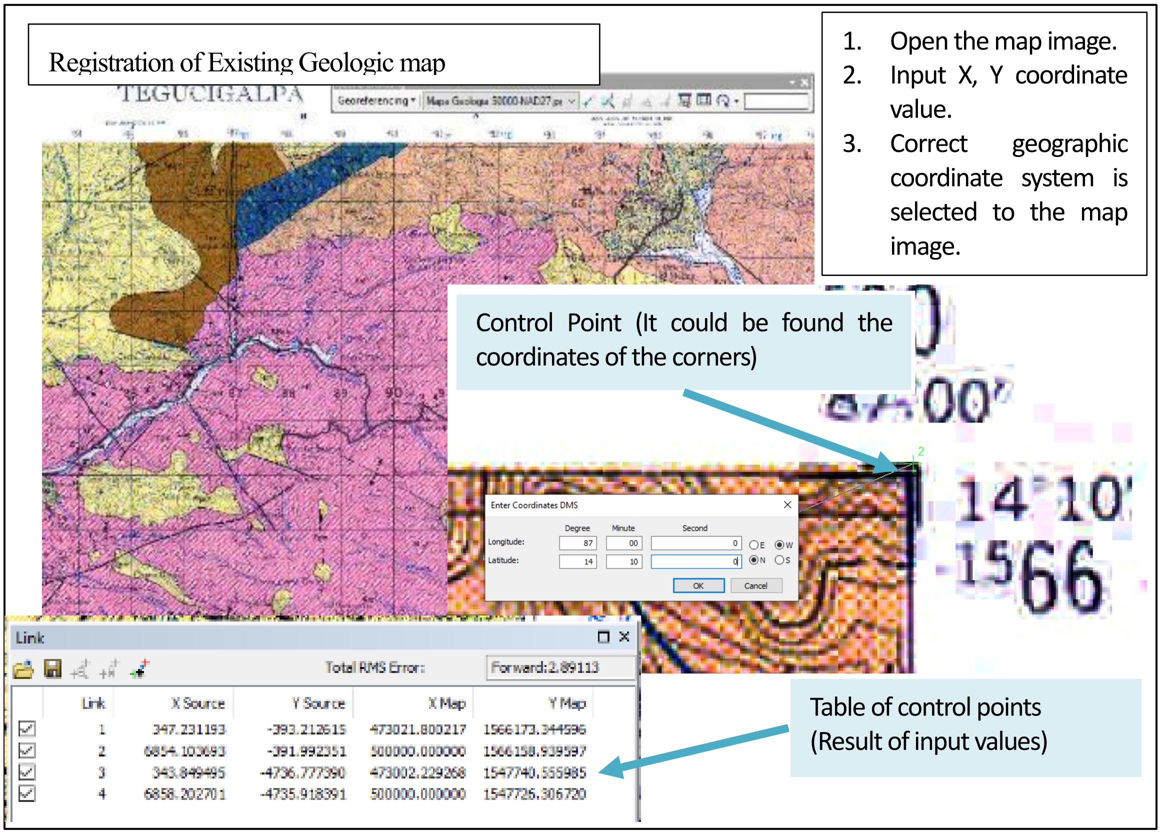
(1) Georeference Existing Geological Map in Honduras

If it needs to refer to hard copies of old geologic maps or scanned images of them, it is necessary to georeference the maps correctly using the GIS traditional coordinate system. The following explanation procedure and figure shows an example to georeference the old geological map in Tegucigalpa.

Explanation

- One of the most useful tools, since there is a lot of information generated in the NAD27 coordinate system which is one of the popular Datum in north and central US continent, is Georeferencing maps.

- In the course the georeferencing of an old geological map was practiced with the use of the Georeferencing tool. To perform georeferencing, control points must be defined and assigned with the georeferencing tool.
- Most important part in georeferencing tool is how to handle in the case of overlaying layers with different Datum. Please imagine that vector layers are based on WGS84 in the map window, but the georeferenced geological map is based on NAD27. GIS usually has parameters for "geographic transformation" to convert NAD27 to WGS84. In ArcGIS, it is defined as "NAD_1983 To_WGS_1984". It is important work to reduce such gap of geographic errors by parameter settings, not edit or shift geographic data itself.



Registration of Existing Geologic map

1. Open the map image.
2. Input X, Y coordinate value.
3. Correct geographic coordinate system is selected to the map image.

Control Point (It could be found the coordinates of the corners)

Enter Coordinates DMS

	Degree	Minute	Second		
Longitude:	87	00	0	○ E	● W
Latitude:	14	10	0	● N	○ S

Link

Total RMS Error: Forward:2.89113

	Link	X Source	Y Source	X Map	Y Map
☑	1	347.231193	-393.212615	473021.800217	1566173.344596
☑	2	6854.103693	-391.992351	500000.000000	1566158.939597
☑	3	343.849495	-4736.777390	473002.229268	1547740.555985
☑	4	6858.202701	-4735.918391	500000.000000	1547726.306720

Table of control points (Result of input values)

Figure 48 Georeferrencing procedure in Arc Map (JET)

(2) Overlay of the previous JICA project Geological Map on the Existing Geological Map

After georeferencing work, the next step is to superimpose the old geologic maps with the latest project-based geologic maps (eg materials of previous JICA project). The following figure show an example of overlay of two geologica maps. It may be noticed that there is a difference in scale.The bottom (existing geologic map) is 1:50,000, on the other hand, the upper one is detailed.

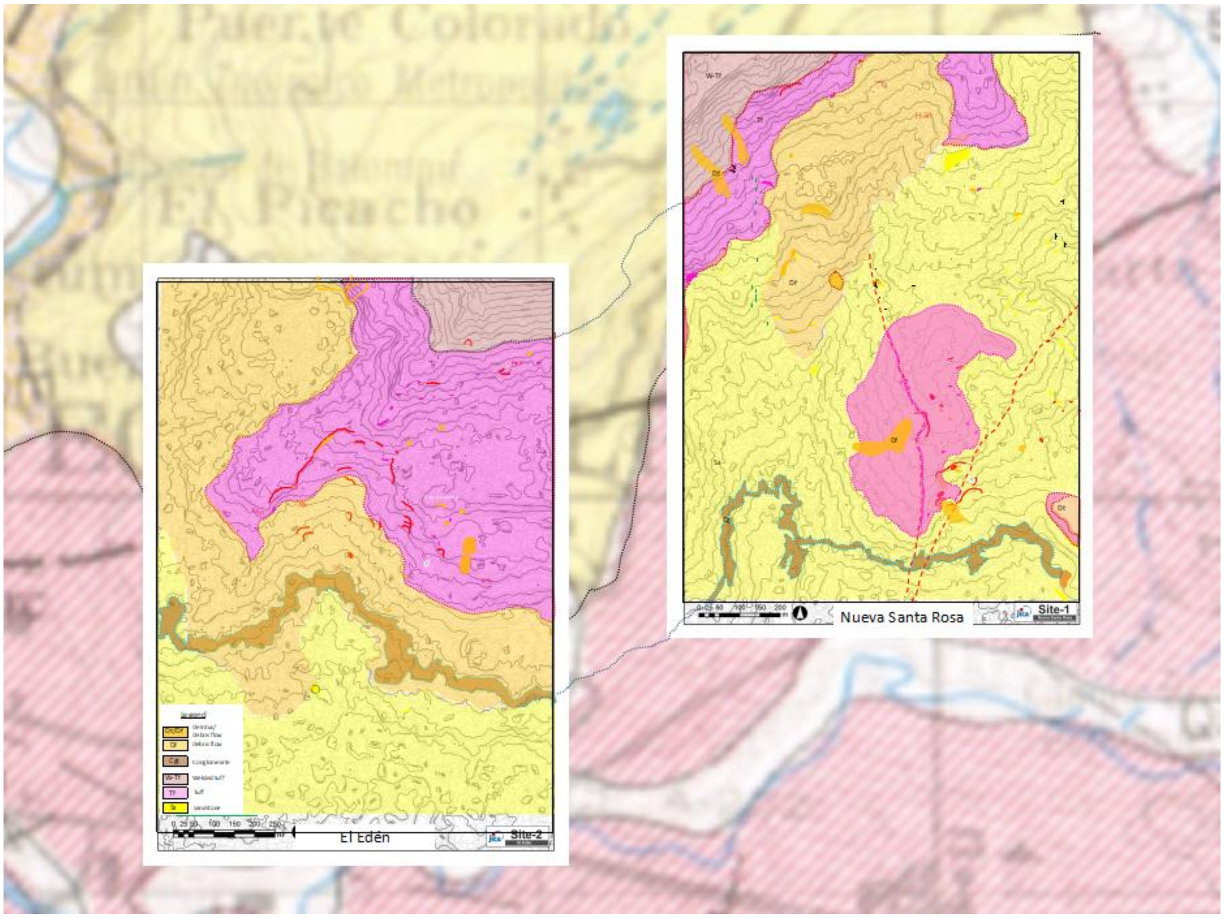


Figure 49 Image of georeferrencing two types of geological map (existing 1:50,000 scale one and detailed one)

(3) Compiling and Digitizing the Detailed Geological Map using GIS

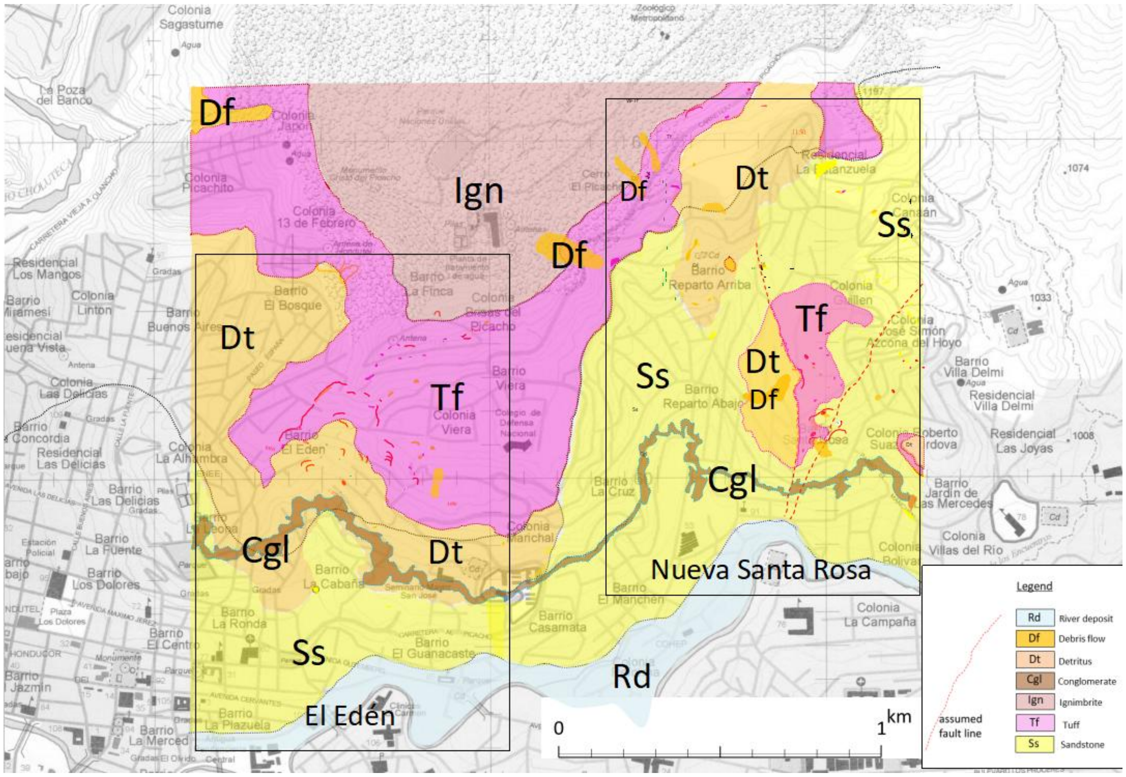
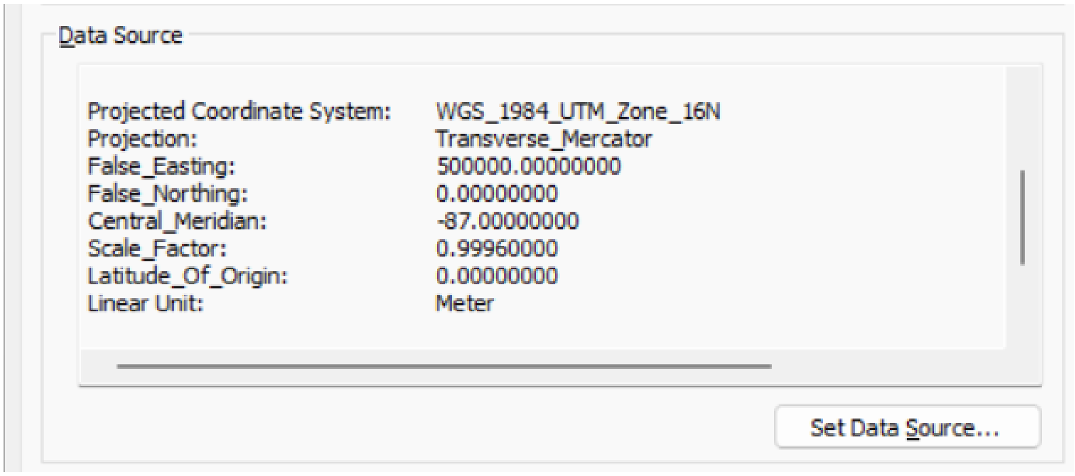


Figure 50 Compiling work based on the existing geologic map (JET)

(4) Latest Coordinate system in Honduras

In recent years, the geographic coordinate system of Honduras is to use UTM Zone 16 North. Therefore, when digitizing in GIS, start the geographic coordinate system.



Projected Coordinate System: WGS_1984_UTM_Zone_16N
Projection: Transverse_Mercator
False_Easting: 500000.00000000
False_Northing: 0.00000000
Central_Meridian: -87.00000000
Scale_Factor: 0.99960000
Latitude_Of_Origin: 0.00000000
Linear Unit: Meter

Figure 51 Example of Coordinate System in Arc Map (JET)

4.1.３ Preparation of Topographic Maps for Screening

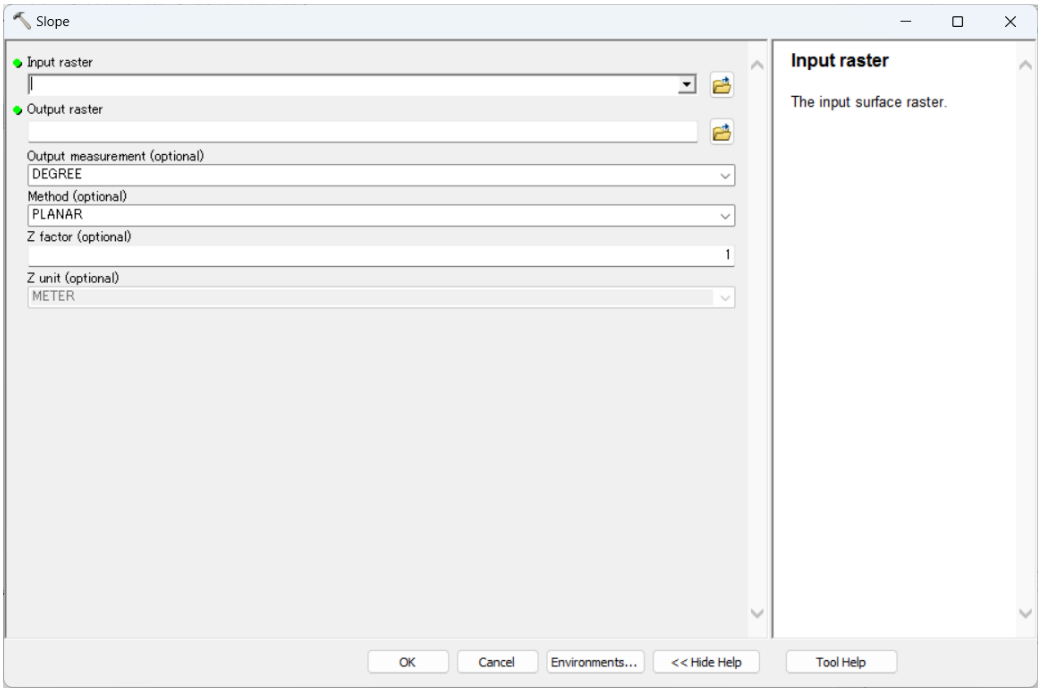
Before a geological expert conducts a slope survey on-site, GIS identifies areas where there are likely to be dangerous spots. This process is called screening. The following maps are basically used for such screening work.

(1) Slope Inclination Map

It is a very basic information of topography. It is usual to purchase a raster data of elevation, called DEM. In this project 1-meter grid cell data was purchased. The following shows actual procedure in ArcMap.

Explanation of how to calculate

1) Launch ArcMap.
2) Load DEM.
3) Execute ArcMap – ArcToolbox - Spatial Analyst Tools – Surface – Slope.
4) The following Dialogbox is displayed. Select the data and output filename, and then press “OK”.



Slope

Input raster

Output raster

Output measurement (optional): DEGREE

Method (optional): PLANAR

Z factor (optional): 1

Z unit (optional): METER

Input raster

The input surface raster.

Figure 52 Dialogbox of Slope calculation by Arc Map (JET)

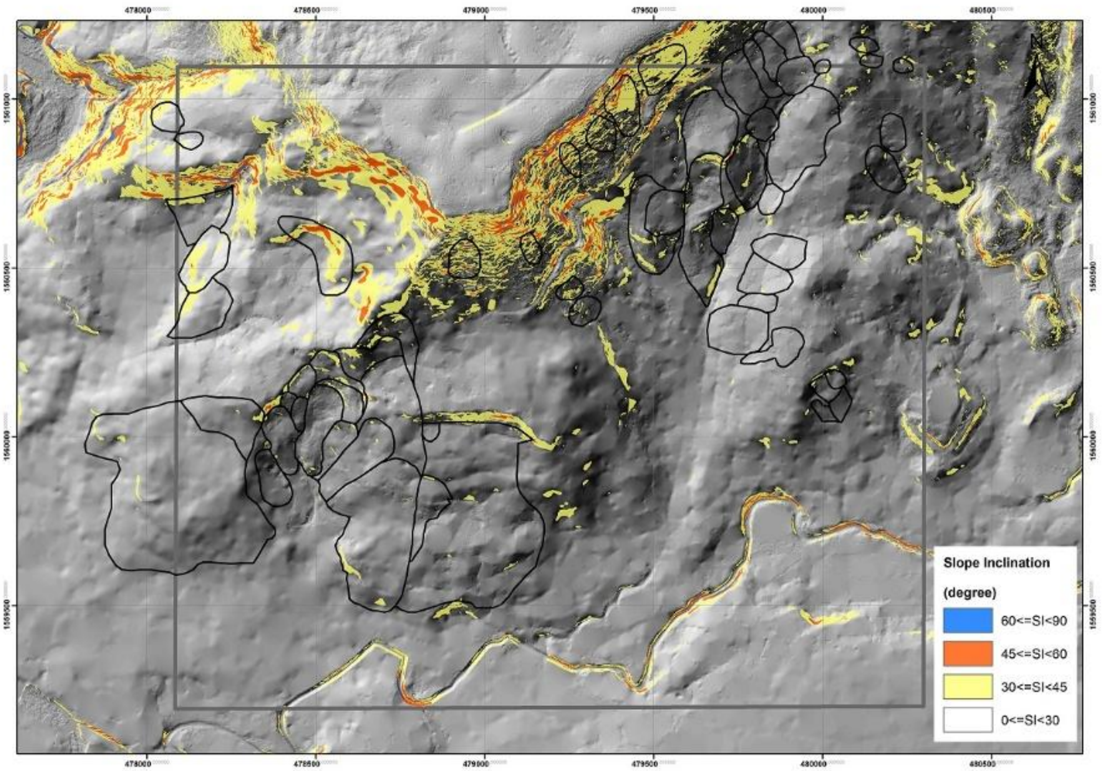


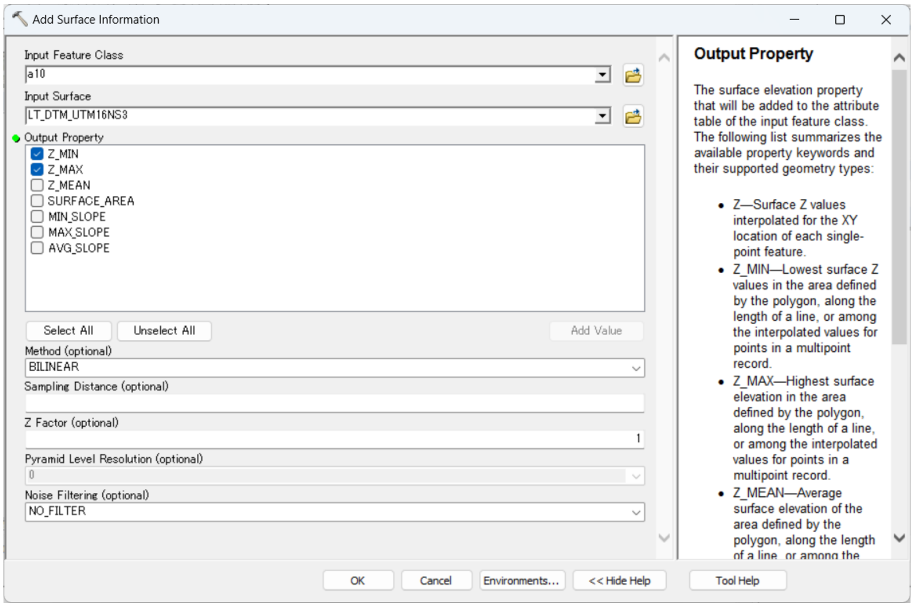
Figure 53 Slope Inclination Map calculated by Arc Map (JET)

(2) Relief Energy Map

Relief Energy means the result of calculating the difference in elevation on a certain grid cell map. This map show a trend of topographic feature. To calculate relief energy, 10-meter grid cell polygon layer is prepared.

Explanation of how to calculate

1) Launch ArcMap.
2) Create 10-meter square polygon.
3) Load DEM.
4) Calculate Z_Max and Z_Min as maximum and minimum elevation in each square polygon using Add Surface Information of 3D Analyst Tools - Functional Surface as following.
5) In the attribute table of 10-meter square polygons, absolute value of (Z_Max – Z_Min) is Relief Energy.



Input Feature Class
a10

Input Surface
LT_DTM_UTM16NS3

Output Property
☑ Z_MIN
☑ Z_MAX
☐ Z_MEAN
☐ SURFACE_AREA
☐ MIN_SLOPE
☐ MAX_SLOPE
☐ AVG_SLOPE

Method (optional)
BILINEAR

Sampling Distance (optional)

Z Factor (optional)
1

Pyramid Level Resolution (optional)
0

Noise Filtering (optional)
NO_FILTER

Output Property

The surface elevation property that will be added to the attribute table of the input feature class. The following list summarizes the available property keywords and their supported geometry types:

- Z—Surface Z values interpolated for the XY location of each single-point feature.
- Z_MIN—Lowest surface Z values in the area defined by the polygon, along the length of a line, or among the interpolated values for points in a multipoint record.
- Z_MAX—Highest surface elevation in the area defined by the polygon, along the length of a line, or among the interpolated values for points in a multipoint record.
- Z_MEAN—Average surface elevation of the area defined by the polygon, along the length of a line, or among the

Figure 54 Dialogbox of getting elevation maximum and minimum value by Arc Map (JET)

(3) Topographic Contour Map

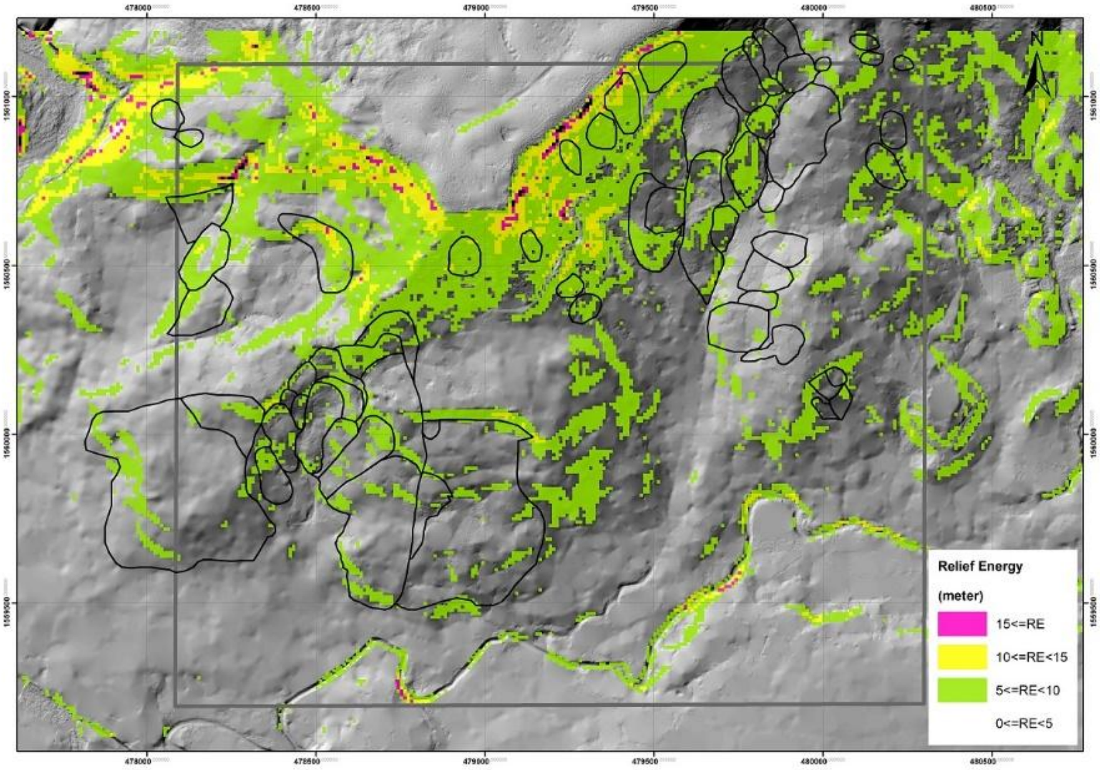


Figure 55 Relief Energy Map calculated by Arc Map (JET)

Contour lines are created from DEM. This is one of the basic calculation of topography using DEM. Arc Map has a tool to create contour line layer from DEM.

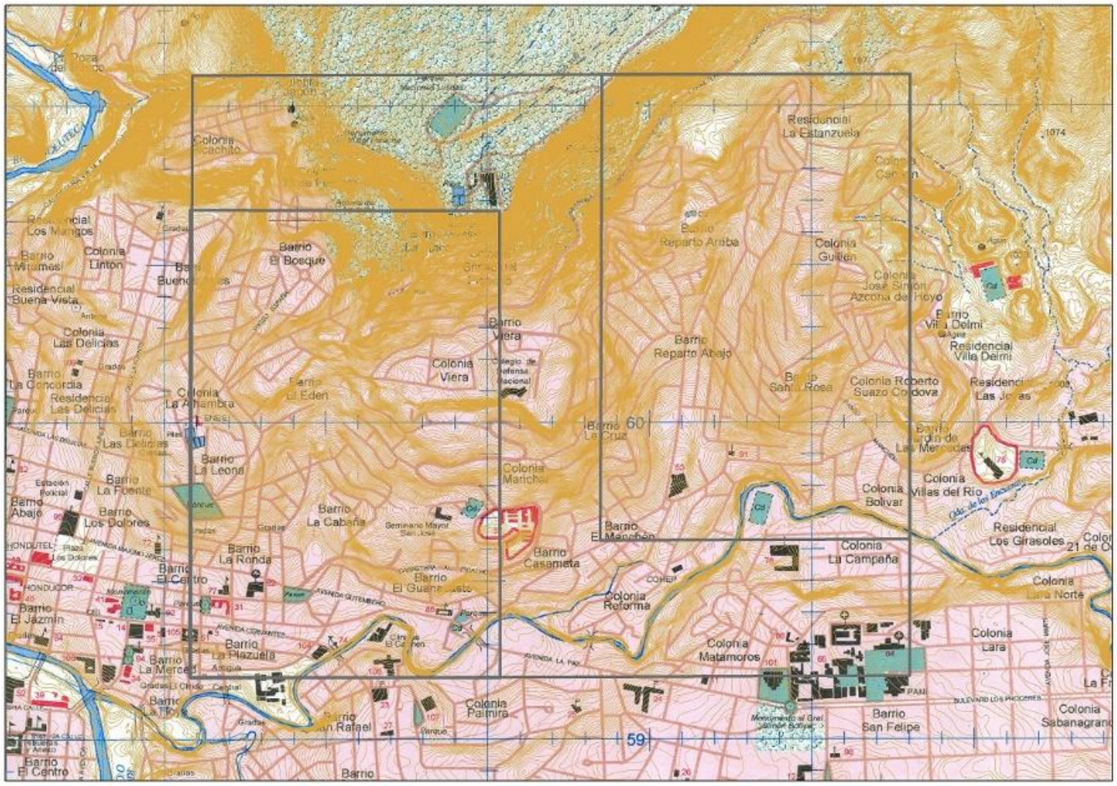
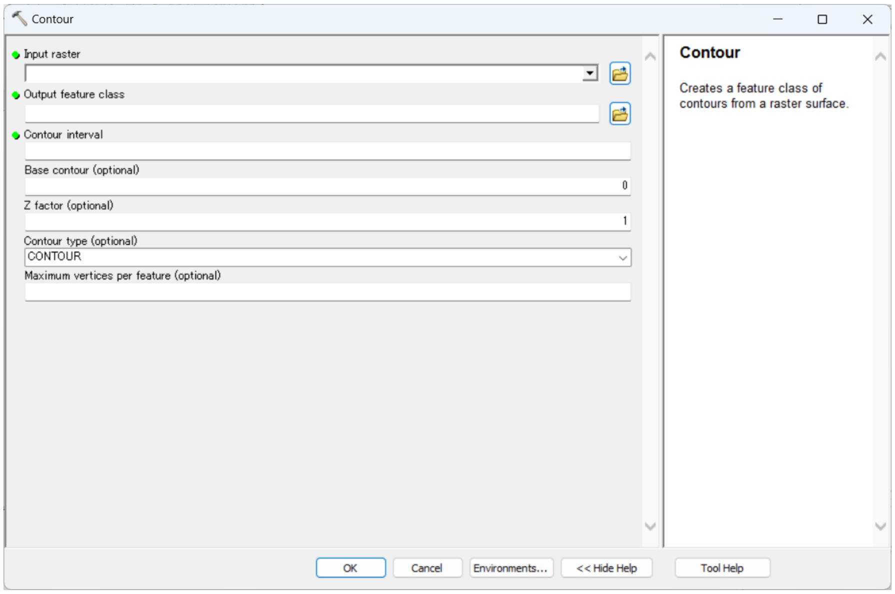


Figure 56 Contour Map calculated by Arc Map (JET)

Explanation of how to calculate:

1) Launch ArcMap.
2) Load DEM.
3) Execute Arc Toolbox – 3D Analyst Tools – Raster Surface – Contour. (see the following dialogbox)
4) At the dialogbox, set up Raster DEM, output file name, contour interval and push OK.



Input raster

Output feature class

Contour interval

Base contour (optional) 0

Z factor (optional) 1

Contour type (optional) CONTOUR

Maximum vertices per feature (optional)

Contour

Creates a feature class of contours from a raster surface.

Figure 57 Dialogbox of Contour in ArcMap (JET)

4.2 GIS-based Digitizing Influence Area of Hazard for Risk assessment

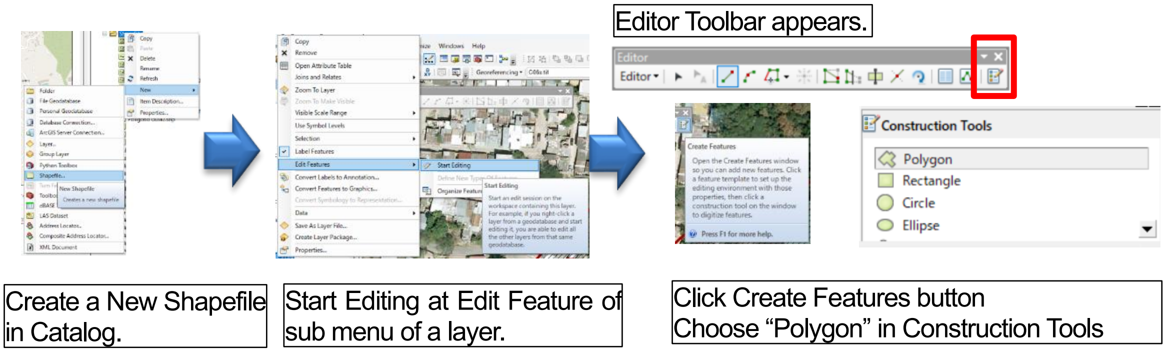
4.2. 1 Topographic Hazardous area of Landslide and Slope Failure / rockfall

The original hazard map of landslide and slope failure / rockfall is, in principle, carried out by geological experts. As specific technical methods are described in detail in Chapter 2, it is prefarable to refer to the geological explanation for better understanding. This section describes GIS actual procedure of "Editing new feature" and shows the outputs of these works by GIS.

Actual work in ArcMap is digitizing. After field survey, shape of hazardous area is drawn on a map by refering contour map, detailed geological map, etc. Next, editing a layer in ArcMap starts by right click at the layer name. Procedure of ArcMap is as following,

1) Launch ArcMap.
2) Prepare a new shape file layer using Catalog of ArcMap.
3) Click "Start Edit" by right click sub menu at the layer name.
4) Find the "Editor" toolbar. Then Click "Create Features" button to start editing polygon features.
5) Select the layer name at the Create Features Dialogbox. And select Polygon in the Construction Tools.

Refer to the following figure for actual editing work in ArcMap.



Editor Toolbar appears.

Create a New Shapefile in Catalog.

Start Editing at Edit Feature of sub menu of a layer.

Click Create Features button
Choose "Polygon" in Construction Tools

Figure 58 Procedure of Editing a new Polygon shapefile in ArcMap (JET)

After digitizing, in the attribute table of the polygon layers hazard rank which is surveyed on site and summarized in Excel sheet is input. Refer Chapter 3 for details of field survey, record the result as scores and finally ranking. The following figures shows the thematic maps with hazard rank, High, Medium and Low.

(1) Landslide

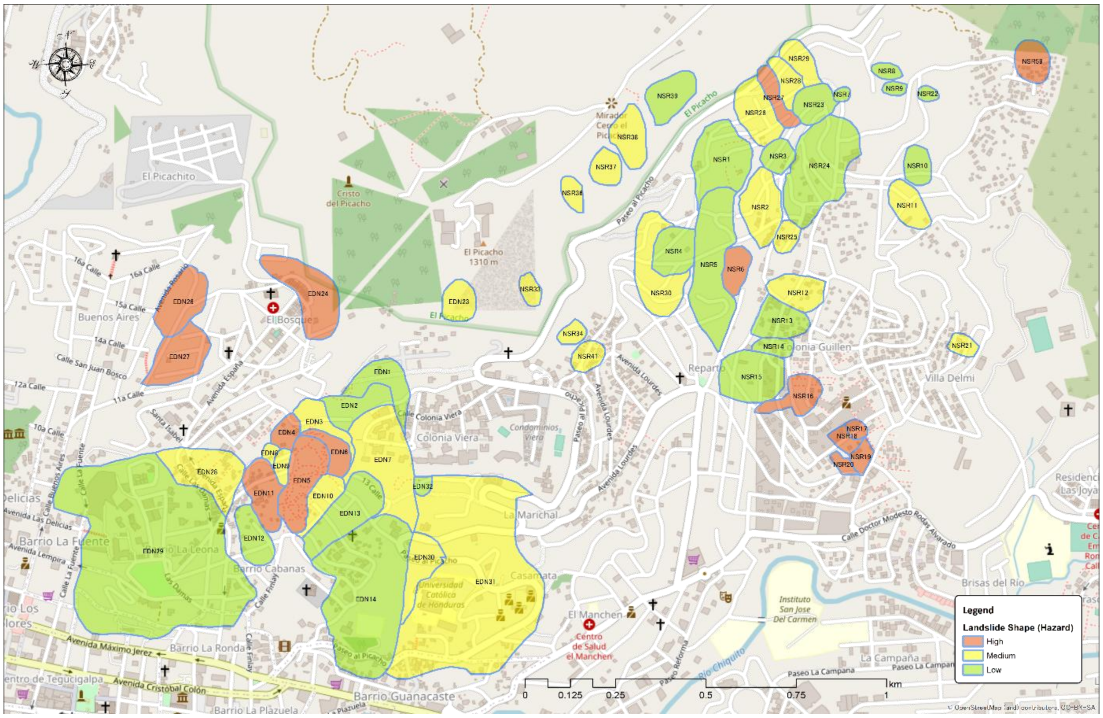


Figure 59 Landslide shape Hazard Map (JET)

(2) Slope Failure / Rockfall

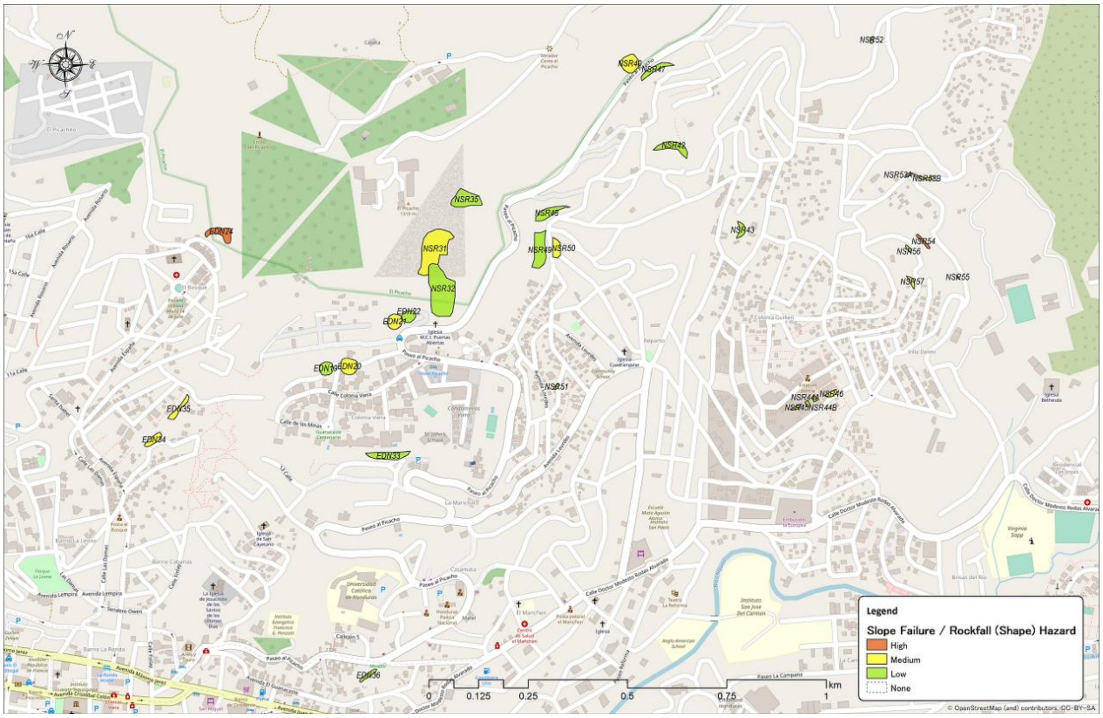


Figure 60 Slope Failure / Rockfall shape Hazard Map (JET)

4.2.２ Digitizing Influence Area

Basic idea to expand influence area from original hazardous shape polygons of landslide and slope failure / rockfall comes from the Japanese method “Sediment-related Disaster Prevention Act”. Please refer Chapter 3 for the basic method.

After identifying original hazardous shape polygons in GIS, influence area to the polygons are detected according to the Japanese basic method. The following explanation describes an actual procedure of digitizing influence area to landslide in ArcMap.

1) Launch ArcMap.
2) Prepare new shape file layers for “arrow direction line”, “dummy polygon” and “landslide influence area” using Calaog of ArcMap.
3) Add a contour line layer in ArcMap.
4) Click “Start Edit” by right click sub menu at the layer “arrow direction line”.
5) Draw a line on a target polygon with the length of 2xL, where L means the length of the landslide. The arrow direction lines extend downward in a direction generally perpendicular to the contour.
6) Make sure that the length of 2L does not exceed 250 meters. (That is, the maximum value of 2L is 250 meters.)
7) Save Edit and Stop Edit at the Edit toolbar.
8) Start Edit at “dummy polygon” layer.
9) Copy and paste the target polygon of landslide into “dummy polygon”.
10) Shift the target dummy polygon according to the direction arrow line.
11) Save Edit and Stop Edit at the Edit toolbar.
12) Then start tracing the perimeter of the target influence area.
13) Start Edit at the “landslide influence area”.
14) You find the “Editor” toolbar. Then Click “Create Features” button to start editing polygon features.
15) Select the layer name at the Create Features Dialogbox. And select Polygon in the Construction Tools.
16) Digitize the polygon by tracing the perimeter of the whole area including original landslide polygon and dummy polygon.
17) Save Edit and Stop Edit at the Edit toolbar.

The following tigure also shows the output of digitizing influence area of landslide.

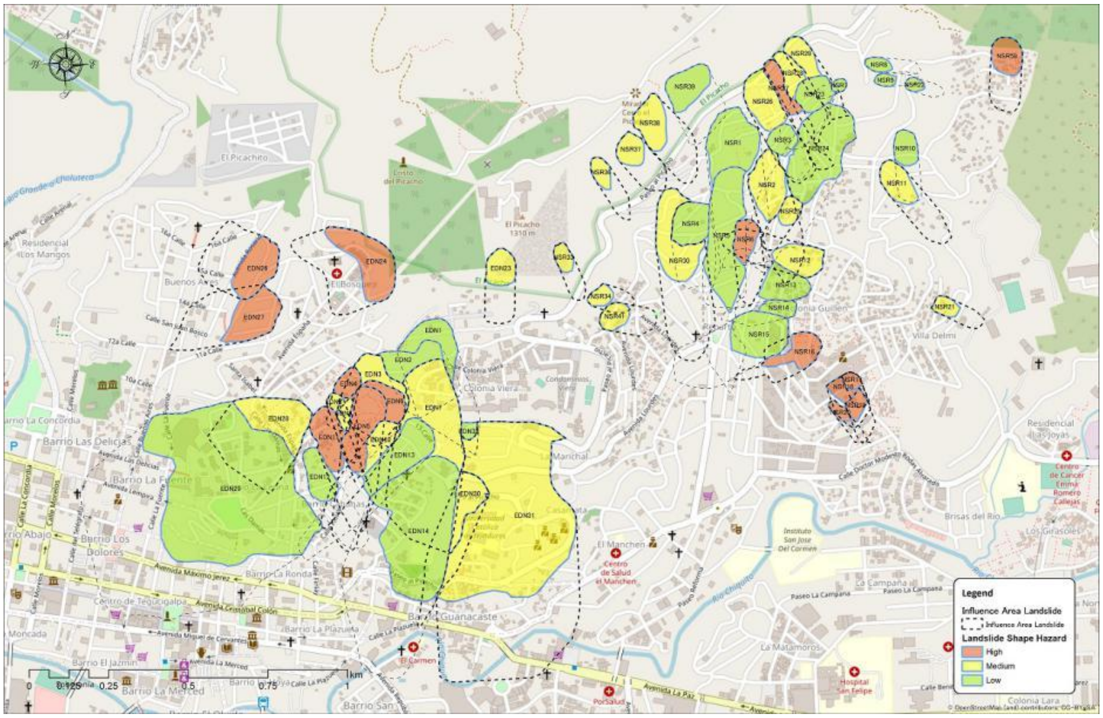


Figure 61 Landslide Influence Area Map (JET)

In the same way, influence area for slope failure / rockfall polygons can also be digitized in ArcMap. Difference is to use “10 meters buffer” layer as perimeter of top of the target polygon. The following figure shows a case study to detect the influence area to the target slope failure / rockfall polygon. Make sure that the length of 2L does not exceed 50 meters. (That is, the maximum value of 2L is 50 meters.)

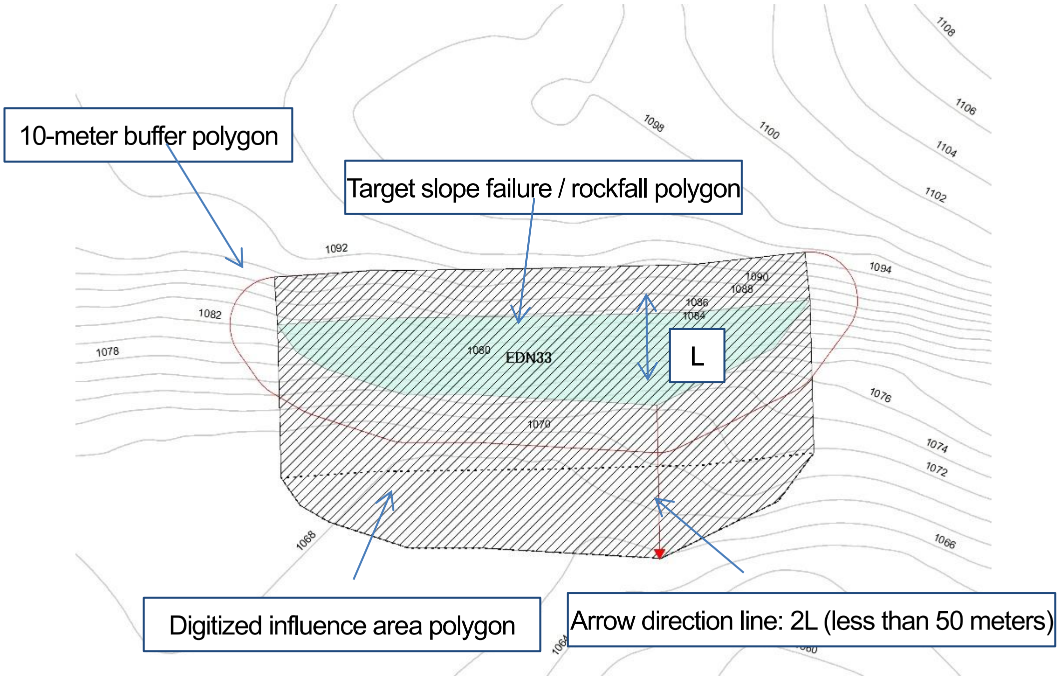


Figure 62 Case study of digitizing the Influence Area to the target slope failure / rockfall polygon (JET)

The following figure shows the output of digitizing influence area of slope failure / rockfall.

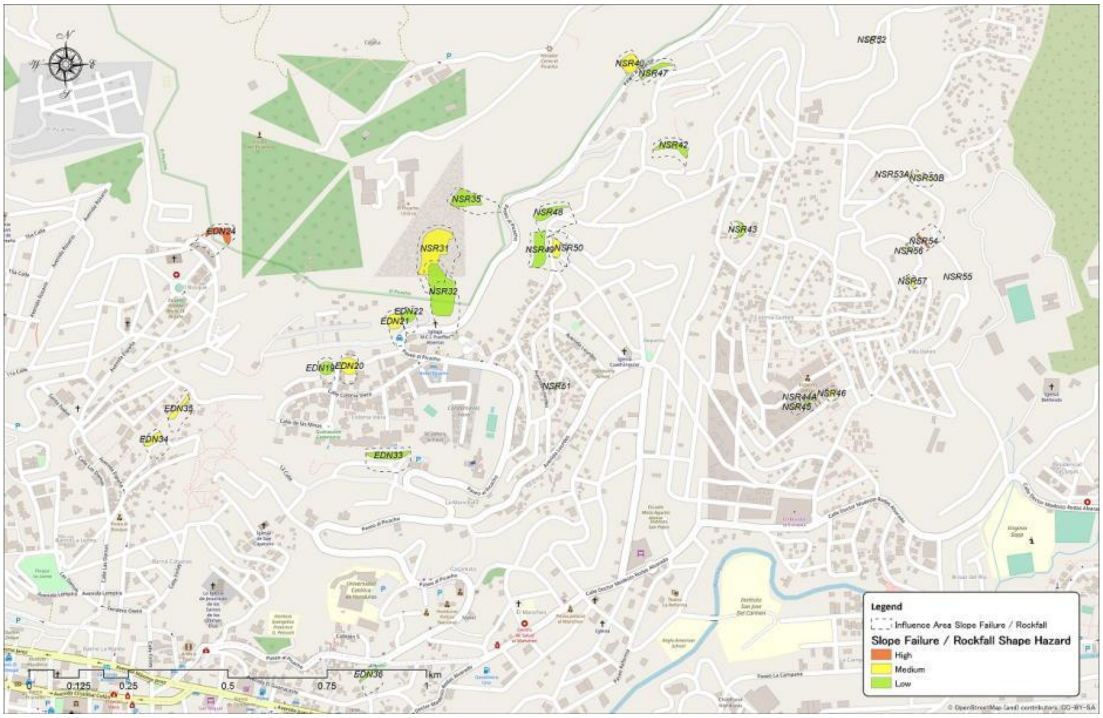


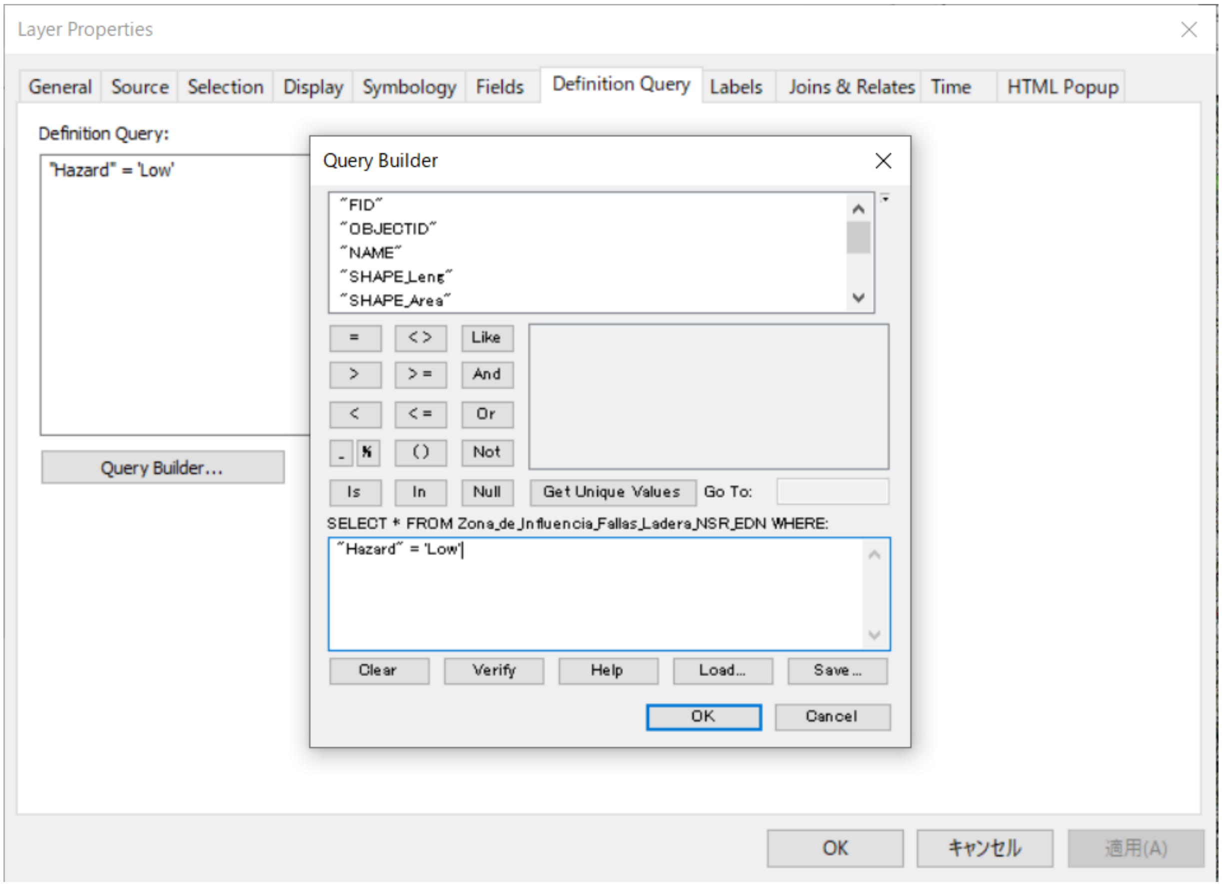
Figure 63 Slope failure / Rockfall Influence Area Map (JET)

4.3 GIS Mapping of Hazard and Risk Evaluation

4.3.1 Concept of Overlaying Layers

A hazard map for landslides and slope failures/rockfalls is completed by assigning hazard ranks to the attribute table of area of influence polygons. Regarding risk evaluation method, see Chapter 3. Using the Risk Matrix, risk rank is evaluated and input to each polygon.

Note that High, Medium, and Low are extracted by SQL search and each is made into a separate layer. And by overlaying those layers in order from the top, the layer with the higher hazard rank can be stacked on top. The following figure shows an example of SQL in ArcMap to create layers of each hazard level.



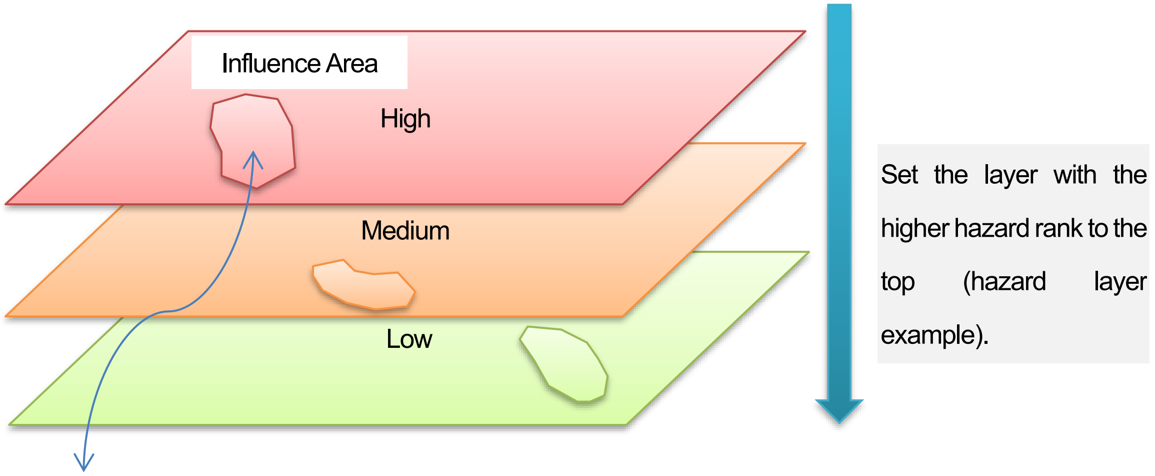
Definition Query:

```
"Hazard" = 'Low'
```

SELECT * FROM Zona_de_Influencia_Fallas_Ladera_NSR_EDN WHERE:

```
"Hazard" = 'Low'
```

Figure 64 Definition Query of Layer Properties to a Hazard Layer in ArcMap (JET)



Set the layer with the higher hazard rank to the top (hazard layer example).

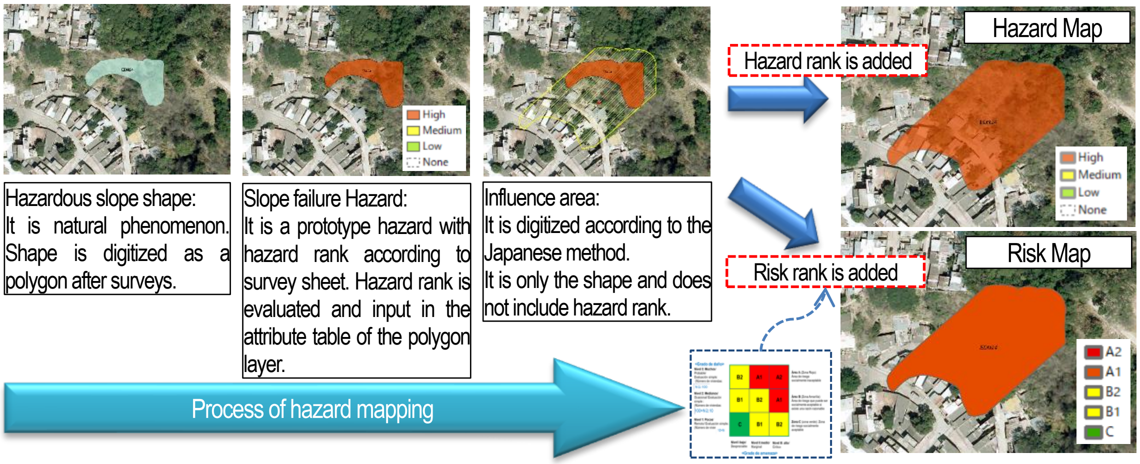
Attribute Table

Name	Hazard	Risk
NSR77	High	A1
EDN88	Medium	B2
EDN99	Low	C

Figure 65 Setting the order of overlaying the ranked hazard/risk layers (JET)

4.3. 2 Hazard and Risk Maps

The following figure shows the Hazard and Risk Maps of Landslide and Slope Failure / Rockfall. Concept of hazard and risk to the polygons are shown in the following figure.



Hazardous slope shape:
It is natural phenomenon. Shape is digitized as a polygon after surveys.

Slope failure Hazard:
It is a prototype hazard with hazard rank according to survey sheet. Hazard rank is evaluated and input in the attribute table of the polygon layer.

Influence area:
It is digitized according to the Japanese method.
It is only the shape and does not include hazard rank.

Figure 66 Concept of Hazard / Risk to the hazardous polygons (JET)

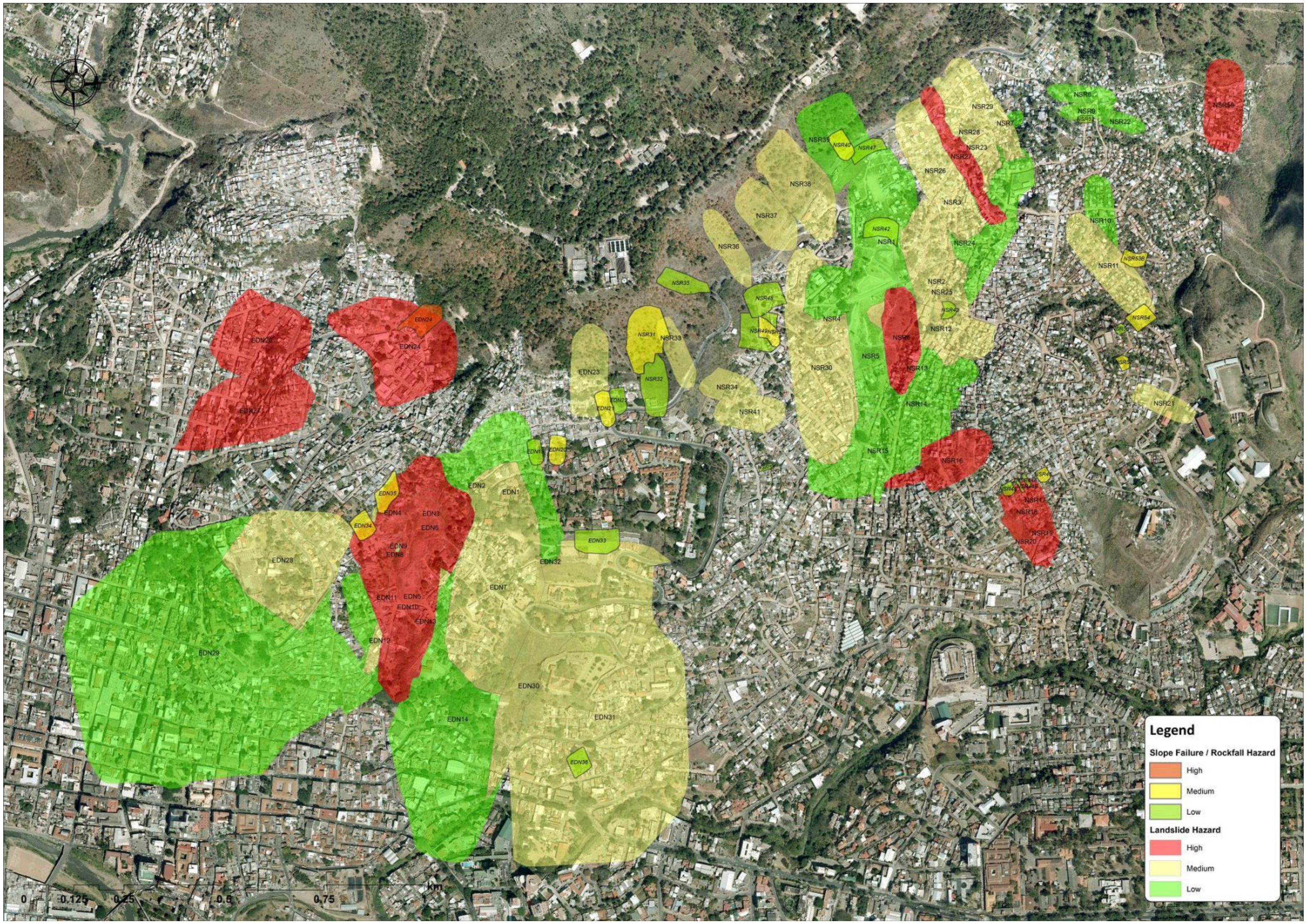


Figure 67 Hazard Map of Landslide and Slope Failure / Rockfall (JET)

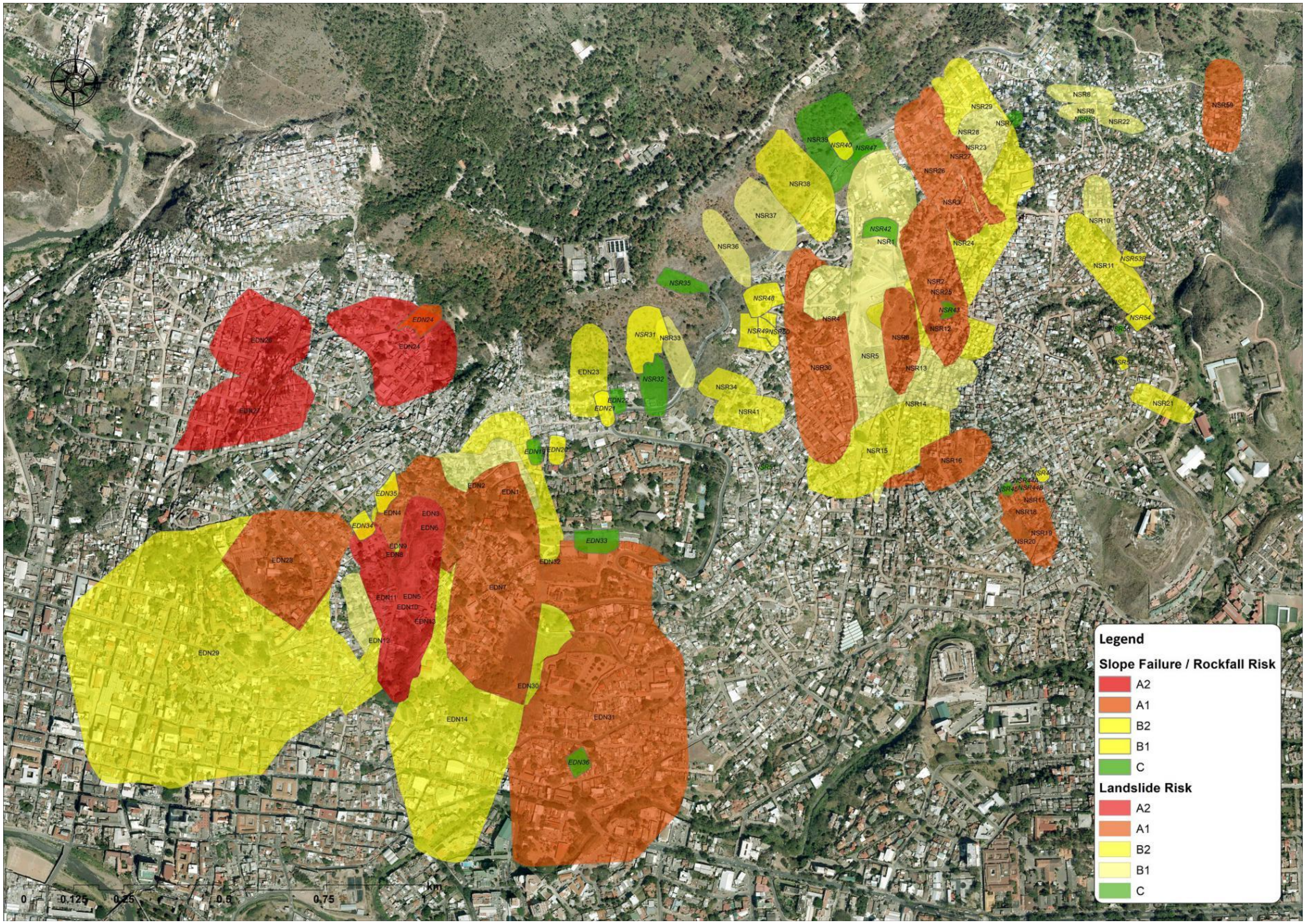


Figure 68 Risk Map of Landslide and Slope Failure / Rockfall (JET)

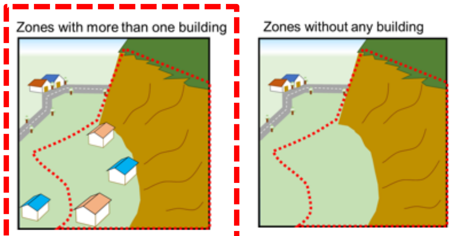
4.4 Land use Regulation Map for Output 4

4.4. 1 Procedure

As Output 4 prepared a classification of zones according to the land use regulation category, hazard rank defined by Output 3 is applied to the classification of zones. The following figure shows the two types of regulation category. **Note that each zone division corresponds to a hazard rank, not a risk rank.**

- Zones with more than one building: Zone A to C corresponds to **Hazard rank** High, Medium and Low.
- Zones without any buildings: Zone D corresponds to **Hazard rank** High or Medium, Zone E is Low.

Case study Map is presented in the next figure for "Zones with more than one building".



Hazard rank	Regulation category	Regulation category
High Hazard	ZONE A	ZONE D
Middle Hazard	ZONE B	
Low Hazard	ZONE C	ZONE E

In the Pilot Area including El Hatillo only has cases of "Zones with more than one building".

Figure 69 Slope failure / Rockfall Influence Area Map (JET)

4.4. 2 Land use Regulation Map

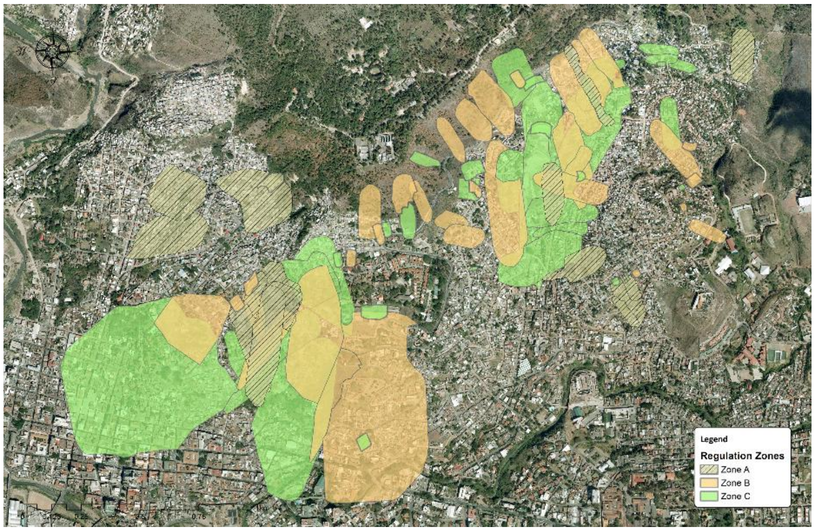


Figure 70 Case Study of Landuse Regulation Map (JET)

Chapter 5. Data Update and Maintenance

5.1 Data Upload and Management in SIMET

5.1.1 What is SIMET?

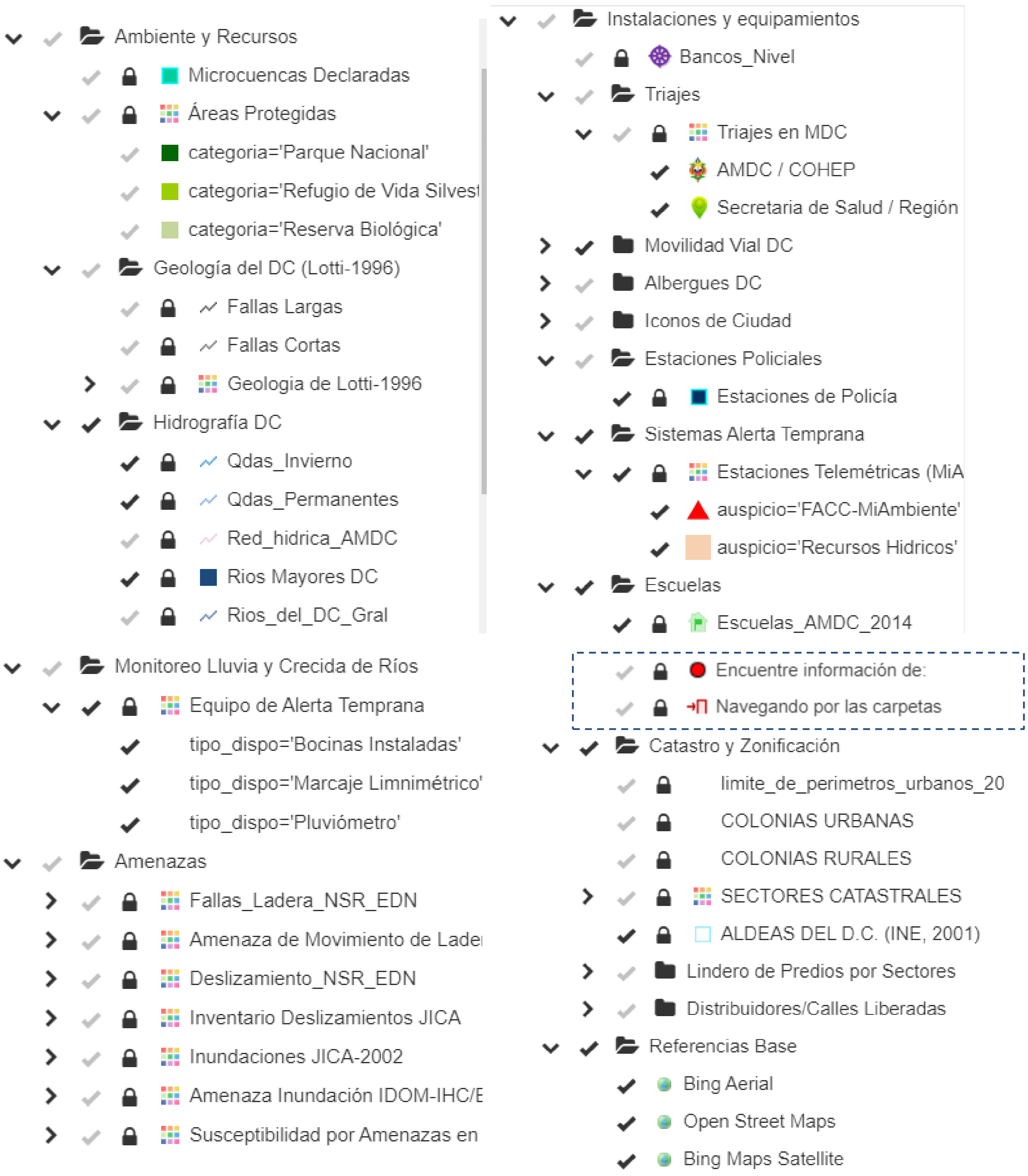
SIMET is the AMDC's web GIS service for the people. The layers includes hazardous area of landslide, slope failure and flood. You can see the following list of existing layers.

- **SIMET**: Sistema de Informacion Municipal sobre Estudios Territoriales

SIMET is a system that integrates the theme of risk management, climate change and land use planning, which involves a series of tools based on geographic information systems, software and hardware, which together provide information to the population, decision makers, academy, and civil organizations so that it is used in a timely manner for the development of its functions. The system is made up of 3 modules: Information Management, Territorial Management and Monitoring and Evaluation.

SIMET structure goes beyond a program and/or computer applications; this includes: hardware equipment, programs, applications, web portal, models, geographic information systems, databases, specialized human resources, policies and procedures.

SIMET is also prepared to be used for AMDC DOT / GER staff to judge whether a construction site is inside hazardous area or not.



- Ambiente y Recursos
  - Microcuencas Declaradas
  - Áreas Protegidas
    - categoria='Parque Nacional'
    - categoria='Refugio de Vida Silvest
    - categoria='Reserva Biológica'
  - Geología del DC (Lotti-1996)
    - Fallas Largas
    - Fallas Cortas
    - Geologia de Lotti-1996
  - Hidrografía DC
    - Qdas_Invierno
    - Qdas_Permanentes
    - Red_hidrica_AMDC
    - Rios Mayores DC
    - Rios_del_DC_Gral
- Monitoreo Lluvia y Crecida de Ríos
  - Equipo de Alerta Temprana
    - tipo_dispo='Bocinas Instaladas'
    - tipo_dispo='Marcaje Limnimétrico'
    - tipo_dispo='Pluviómetro'
- Amenazas
  - Fallas_Ladera_NSR_EDN
  - Amenaza de Movimiento de Lade
  - Deslizamiento_NSR_EDN
  - Inventario Deslizamientos JICA
  - Inundaciones JICA-2002
  - Amenaza Inundación IDOM-IHC/E
  - Susceptibilidad por Amenazas en
- Instalaciones y equipamientos
  - Bancos_Nivel
  - Triajes
    - Triajes en MDC
      - AMDC / COHEP
      - Secretaria de Salud / Región
  - Movilidad Vial DC
  - Albergues DC
  - Iconos de Ciudad
  - Estaciones Policiales
    - Estaciones de Policía
  - Sistemas Alerta Temprana
    - Estaciones Telemétricas (MiA
      - auspicio='FACC-MiAmbiente'
      - auspicio='Recursos Hidricos'
  - Escuelas
    - Escuelas_AMDC_2014

Encuentre información de:
Navegando por las carpetas

- Catastro y Zonificación
  - limite_de_perimetros_urbanos_20
  - COLONIAS URBANAS
  - COLONIAS RURALES
  - SECTORES CATASTRALES
  - ALDEAS DEL D.C. (INE, 2001)
  - Lindero de Predios por Sectores
  - Distribuidores/Calles Liberadas
- Referencias Base
  - Bing Aerial
  - Open Street Maps
  - Bing Maps Satellite

Figure 71 Existing GIS Layers in SIMET (Part 1, JET)

Table 12 Existing GIS Layers in SIMET (Part 2, JET)

NAME OF DATA -YEAR (ENGLISH)	DESCRIPTION
UNIDADES GEOGRAFICAS ADMINISTRATIVAS.	
Límites de barrios y colonias – 2018 (Neighborhood boundaries – 2018)	Polygons with boundaries of neighborhoods and colonies, name of neighborhoods and colonies, City, Sector.
Límites de predios- 2018 (Property boundaries – 2018)	Official data - political-administrative division at urban level.
Límites Municipal -2001 (Municipal Boundaries -2001)	Official data - political-administrative division at the municipal level.
Límites de Aldeas-2001 (Village Boundary-2001)	Official data - political-administrative division at the municipal level.
Límites de perímetros urbanos – 2010 (Urban perimeter boundaries – 2010)	Official data - political-administrative division at urban level.
Límites de sectores- 2010 (Sector boundaries – 2010)	Official data - political-administrative division at urban level.
Límites de barrios y colonias – 2010 (Neighborhood boundaries – 2010)	Official data - political-administrative division at urban level.
Límites de predios- 2010 (Property boundaries – 2010)	Official data - political-administrative division at urban level.
Urbanizaciones en construcción -suelos vacantes- 2016 (Housing developments under construction - vacant land- 2016)	Official data - political-administrative division at urban level.
ORTHOPHOTOGRAPHY -TOPOGRAPHY.	
Imágenes satelitales 1993, 2003, 2014 - – IDOM IH Cantabria. (Satellite images 1993, 2003, 2014 - - IDOM IH Cantabria)	Official data - topographical information.
Orthophotos 2014 - JICA. (Orthophotos 2014 - JICA.)	Official data - topographic information.
Hojas cartográficas – IGN – Honduras. 1982 (Cartographic sheets - IGN - Honduras. 1982)	Official data - topographic information.
Curvas de nivel – elevación 2010 (Contour lines - elevation 2010)	Official data - topographic information.
Red Hídrica – 2010 (Water Network – 2010)	Official data - topographic information.
PHYSIOGRAPHY AND NATURAL RESOURCES	
Áreas Protegidas – ICF 2010 (Protected Areas - ICF 2010)	Official data - Physiography and Natural Resources.
Formaciones vegetales y uso del suelo – 1993 (Plant formations and land use – 1993)	Official data - Physiography and Natural Resources.
Formaciones vegetales y uso del suelo – 2003 (Plant formations and land use – 2003)	Official data - Physiography and Natural Resources.
Formaciones vegetales y uso del suelo – 2014 (Plant formations and land use – 2014)	Official data - Physiography and Natural Resources.
Unidades morfológicas – 2014 (Morphological units – 2014)	Official data - Physiography and Natural Resources.
Subcuencas declaradas ICF/SANAA 2010 (Sub-basins declared ICF/SANAA 2010)	Official data - Physiography and Natural Resources.
Formaciones geológicas – 1987 (Geological formations – 1987)	Official data - Physiography and Natural Resources.
Fallas geológicas – 1987 (Geological faults – 1987)	Official data - Physiography and Natural Resources.
Grietas - geología – 1987 (Cracks - geology – 1987)	Official data - Physiography and Natural Resources.
Localización de embalses ICF/SANAA 2010	Official data - Physiography and

NAME OF DATA -YEAR (ENGLISH)	DESCRIPTION
(Location of reservoirs ICF/SANAA 2010)	Natural Resources.
Microcuencas declaradas 2018 (Micro-basins declared 2018)	Layer managed through the Environmental Management Unit of the AMDC.
Áreas protegidas del Distrito Central 2018 (Central District Protected Areas 2018)	Layer managed through the Environmental Management Unit of the AMDC.
CLIMATE	
Pluviómetro 2017 (Rain gauge 2017)	Official information used by CODEM
Bocinas Instaladas 2017 (Horns Installed 2017)	Official information used by CODEM
Marcaje Limnimétrico 2017 (Limnimetric Marking 2017)	Official information used by CODEM
SOCIAL ASPECTS	
CODEL 2017 (CODEL 2017)	Information on the existence of Local Emergency Committees in neighborhoods and barrios of the CD.
Juntas Administradoras de Agua del DC 2017 (DC Water Boards 2017)	Information on the existence of water boards in neighborhoods and neighborhoods of the DC.
Patronatos 2017 (Patronage 2017)	Information on the existence of boards of trustees in neighborhoods and barrios of the CD.
Albergues 2017 (Lodges 2017)	Official information used by CODEM
Información del observatorio violencia 2017 (Information from the violence observatory 2017)	Information provided by the Directorate of Community Management and Human Development of the Violence Observatory.
Intervención territorial total -2014 (Total territorial intervention -2014)	Official data - Social aspects - municipal level.
Intervención territorial urbana -2014 (Urban territorial intervention -2014)	Official data - Social aspects - municipal level.
Intervención territorial predial urbana -2014 (Urban real estate territorial intervention -2014)	Official data - Social aspects - municipal level.
Sin Intervención territorial predial urbana -2014 (No territorial intervention urban real estate -2014)	Official data - Social aspects - municipal level.
Patrimonio cultural (Cultural heritage)	
Instalaciones referenciales Publicas y Privadas -2014 (Public and Private Reference Facilities -2014)	Official data - Social aspects - municipal level.
ECONOMIC ASPECTS	
Concesiones mineras – 2014 (Mining concessions – 2014)	Official data - Economic aspects - municipal level
VULNERABILITY AND RISKS	
Amenaza a deslizamientos -2015 (Landslide Hazard -2015)	Official data - Vulnerability and Risks - municipal level.
Amenaza a inundación – 2002 (Flood hazard - 2002)	Information obtained from the JICA master plan 2002.
Mapa multiamenazas 2011(Multi-hazard map 2011)	High and medium landslide hazard information, high, medium and low landslide susceptibility.
Amenazas DC (Geologia y Pendientes) -2014 (DC Hazards (Geology and Slopes) -2014)	High and medium landslide hazard information, high, medium and low landslide susceptibility.
Amenaza a inundaciones -2015 (Flood Hazard -2015)	Official data - Vulnerability and Risks - municipal level.

NAME OF DATA -YEAR (ENGLISH)	DESCRIPTION
Amenaza a deslizamientos -2015 (Landslide Hazard -2015)	Official data - Vulnerability and Risks - municipal level.
Susceptibilidad a deslizamientos -2015 (Susceptibility to landslides -2015)	Official data - Vulnerability and Risks - municipal level.
Exposición urbana frente a susceptibilidad a deslizamientos -2015 (Urban exposure to landslide susceptibility -2015)	Official data - Vulnerability and Risks - municipal level.
Riesgo urbano – edificaciones que colapsan frente a inundaciones – Tr 10 años (Urban risk - buildings collapsing in the event of flooding - Tr 10 years)	Official data - Vulnerability and Risks - municipal level.
Riesgo urbano – edificaciones que colapsan frente a inundaciones – Tr 20 años (Urban risk - buildings collapsing in the face of floods - Tr 20 years)	Official data - Vulnerability and Risks - municipal level.
Riesgo urbano – edificaciones que colapsan frente a inundaciones – Tr 50 años (Urban risk - buildings collapsing in the face of floods - Tr 50 years)	Official data - Vulnerability and Risks - municipal level.
Riesgo urbano – edificaciones que colapsan frente a inundaciones – Tr 100 años Urban risk - buildings collapsing in the face of floods - Tr 100 years	Official data - Vulnerability and Risks - municipal level.
Riesgo urbano – edificaciones que colapsan frente a inundaciones – Tr 500 años Urban risk - buildings collapsing in the face of floods - Tr 500 years	Official data - Vulnerability and Risks - municipal level.
LAND USE PLANNING.	
Copia de ZONIFICACION DEL DISTRITO CENTRAL-2018 (Copy of ZONIFICATION OF THE CENTRAL DISTRICT-2018)	Zoning information of neighborhoods and districts of the Central District.
Escenario óptimo de intervención social y económico- 2015 (Optimal scenario of social and economic intervention- 2015)	Official data - land use planning.
Escenario óptimo – zonas de intervención social y económico- 2015 (Optimal scenario - social and economic intervention zones – 2015)	Official data - land use planning.
Escenario óptimo zonas de intervención ambiental y riesgos- 2015 (Optimal scenario environmental intervention zones and risks- 2015)	Official data - land use planning.
Escenario óptimo – propuesta de zonificación - 2015 (Optimal scenario - zoning proposal – 2015)	Official data - land use planning.
Escenario tendencial zonas de intervención ambiental y riesgos- 2015 (Trend scenario environmental intervention zones and risks- 2015)	Official data - land use planning.
Escenario tendencial – propuesta de zonificación - 2015 (Trend scenario - zoning proposal – 2015)	Official data - land use planning.
Escenario tendencial – propuesta de zonificación periurbana – 2015 (Trend scenario - proposed peri-urban zoning – 2015)	Official data - land use planning.
Propuesta de viabilidad – 2015 (Feasibility proposal – 2015)	Official data - land use planning.
Propuesta de mejoramiento de drenaje – 2015 (Drainage improvement proposal – 2015)	Official data - land use planning.
Propuesta de densificación vertical – 2015 (Vertical densification proposal – 2015)	Official data - land use planning.
Zonas de producción hídrica.- 2014 (Water production zones – 2014)	Official data - land use planning.
Ubicación de Semáforos 2018 (Traffic Light Locations 2018)	Official data provided by management
Estaciones de taxis 2018 (Taxi stands 2018)	Official data provided by management
Iconos Comayagüela 2019 (Comayagüela Icons 2019)	Official data from the Tourism Management
Iconos Tegucigalpa 2019 (Tegucigalpa Icons 2019)	Official data from the Tourism Management

NAME OF DATA -YEAR (ENGLISH)	DESCRIPTION
Distribuidores/Calles liberadas 2018 (Distributors/Streets released 2018)	Official data from the Construction Control Department

There is currently a development on the amdc.giscloud.com portal that contains the official information of the AMDC that has been worked with COMUDE since 2017. The last official information was dated in November 2021 and since then it has not been updated again. Parallel to this development, another application of the AMDC has been set up through a GEONODE installed on the servers that have been purchased for the development of SIMET thanks to the GOAL/USAID and GIZ Resilient Neighborhood program. Within this development, the last official COMUDE database, which was that of November 2021, has been integrated and there are other applications that are integrated such as the hazard of landslides, hazard of floods, monitoring of precipitation and river levels, and forecast of flooding, as well as hydrological and hydraulic modeling platforms, a bulletin platform on hydrometeorological conditions, and a real-time monitoring platform for rain conditions.

The following figures show the entrance screens to the two developments that are within the AMDC for the management of geographic information, SIMET (mapas.simet.amdc.hn/mapstore, amdc.giscloud.com).

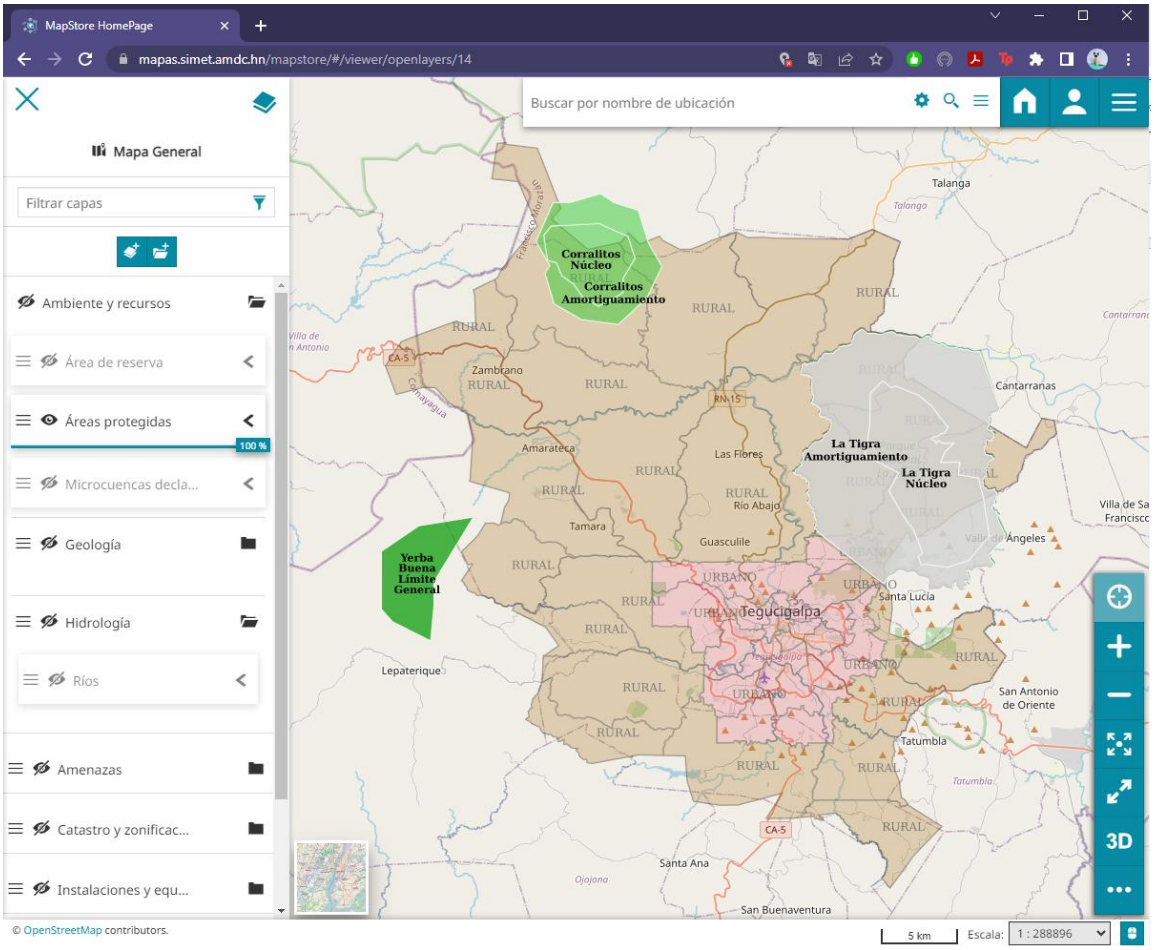
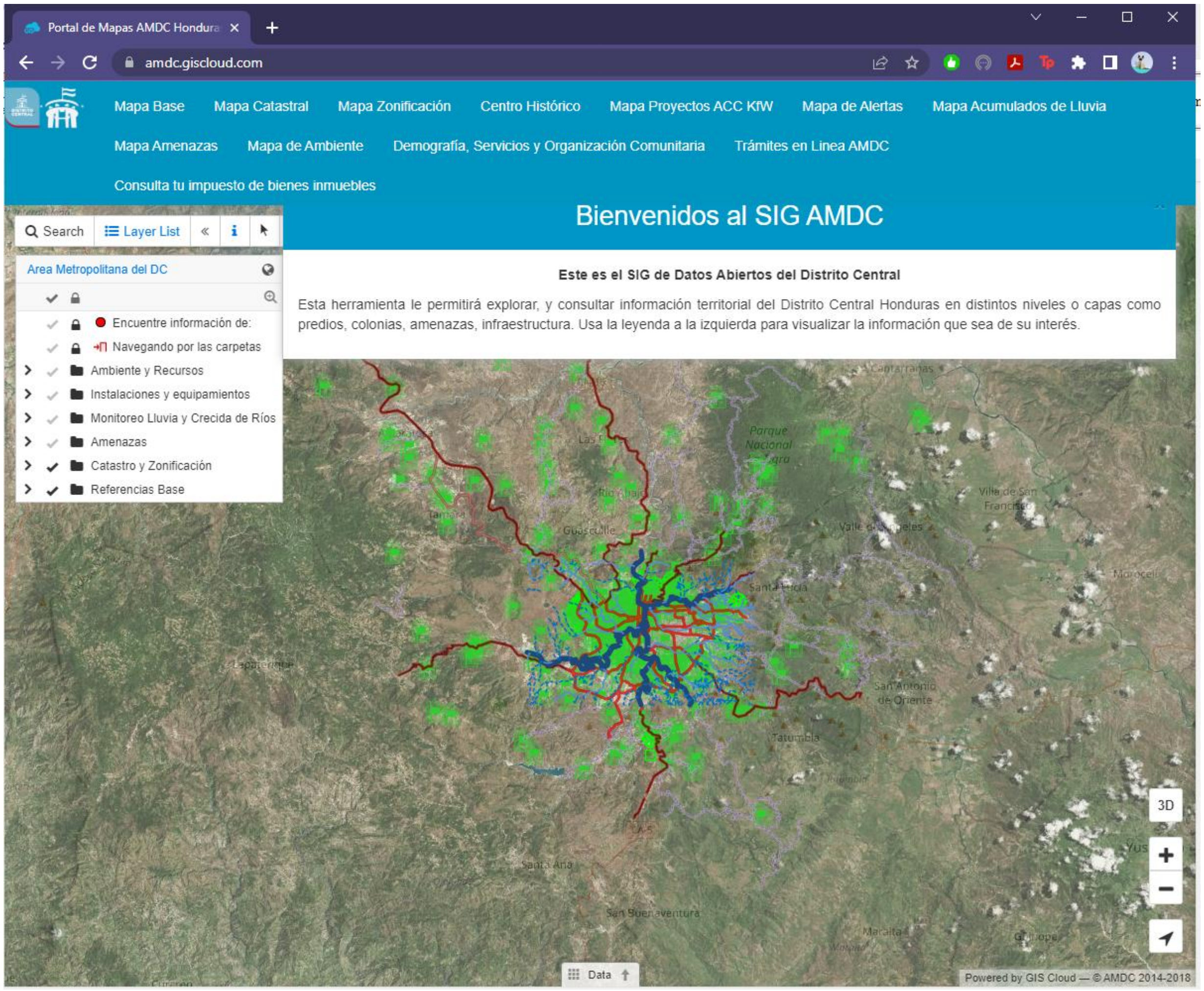


Figure 72 SIMET screenshot in mapas.simet.amdc.hn/mapstore/#(AMDC)

(https://mapas.simet.amdc.hn/mapstore/#/viewer/openlayers/14)



Bienvenidos al SIG AMDC

Este es el SIG de Datos Abiertos del Distrito Central

Esta herramienta le permitirá explorar, y consultar información territorial del Distrito Central Honduras en distintos niveles o capas como predios, colonias, amenazas, infraestructura. Usa la leyenda a la izquierda para visualizar la información que sea de su interés.

Figure 73 SIMET screenshot in amdc.giscloud.com (https://amdc.giscloud.com/)

5.1.2 Management System in AMDC

(1) Procedure to update SIMET data

Landslide and Slope failure / rockfall data may be updated basically once a year. Procedure is as following, JET complete a layer and submit it to UMGIR. After UMGIR receive the data, submision of letter to COMUDE committee start. After UMGIR receive approve from COMUDE, actual GIS data upload to SIMET is conducted by the Administrator of UMGIR IT Section. The procedure usually takes one to three months for updating existing data.

First, the information that is entered as a risk update is submitted by UMGIR to COMUDE for analysis by its Permanent Technical Committee (CTP-COMUDE), after being analyzed by the CTP, it is submitted to the COMUDE plenary meeting so that be officialized. After becoming official, the risk information representative (UMGIR) uploads it using their credentials to any of the two platforms, either in GISCLOUD or GEONODE.

***The AMDC is looking for the GISCLOUD information to be migrated to GEONODE (SIMET)

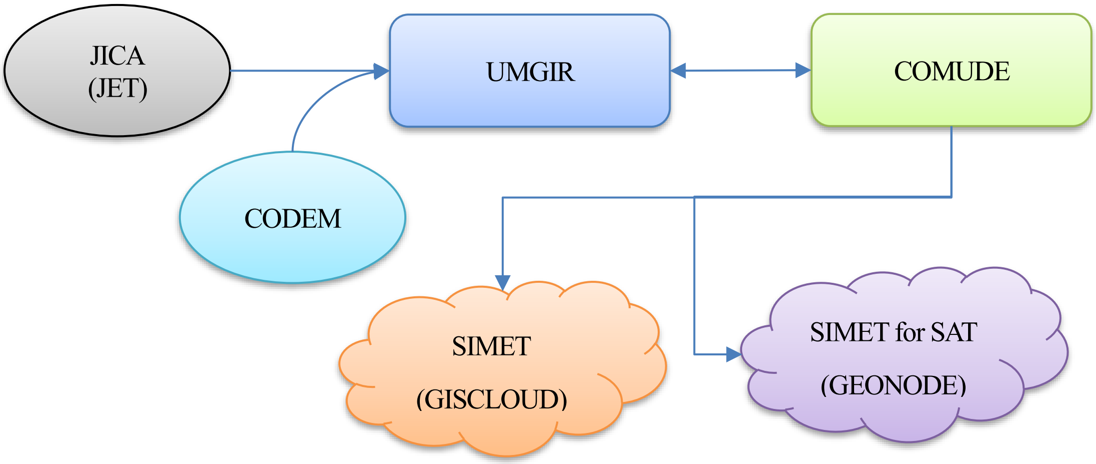


Figure 74 Procedure of update data in SIMET (JET)

(2) Section name in charge of updating SIMET data

- **Managing office of SIMET in AMDC:** IT Section, UMGIR
- **Person in charge:** (Chief) Adminitrator of SIMET (UMGIR, IT section), (Assistant) Staff for Information and Systems Management

At this time, the two AMDC Units that have credentials for full access to SIMET are UMGIR and the Information and Systems Management (GIS). In the coming months, efforts will be made to empower other AMDC units so that they can be the creators of their own maps.

Remarks:

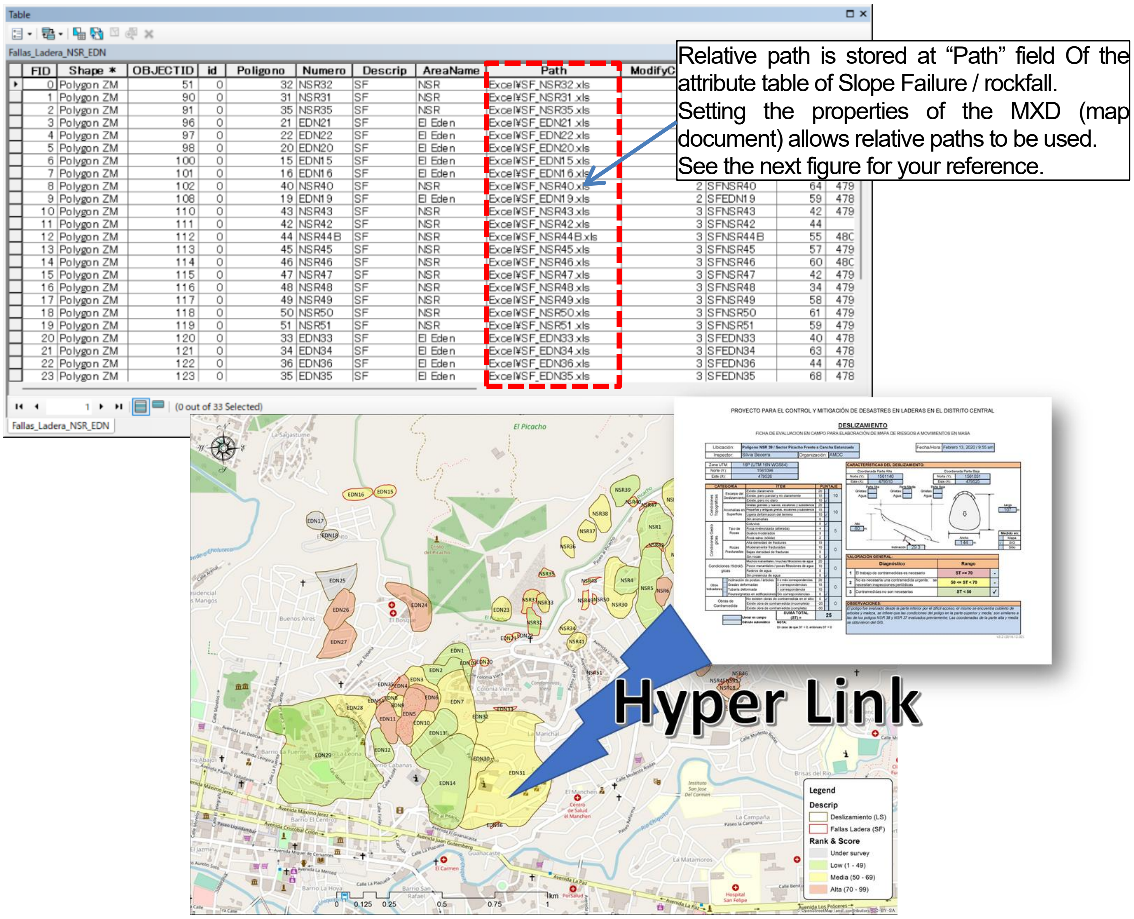
- **SIMET**: Sistema de Información Municipal sobre Estudios Territoriales (Municipal Information System on Territorial Studies)
- **SAT**: Sistema de Alerta Temprana (Early Warning System)

5.2 GIS-based Data Management

5.2. 1 Hyperlink tool in ArcMap

In Ouput 3 activity of the project, many survey sheets are stored after field activity. One Excel file was prepared to each survey site. Sometimes, it is difficult to search one excel file in a project folder.

ArcMap has a useful tool “Hyperlink” to link such survey related data sheet to GIS features. Preparation for this tool is to store path of the data file in the attribute fable. For example, the following figure shows a part of the attribute table of landslide hazard polygon layer. It is one good idea to use Hyperlink tool for management of survey data sheet in ArcMap.



Table

Fallas_Ladera_NSR_EDN

FID	Shape *	OBJECTID	id	Poligono	Numero	Descrip	AreaName	Path	ModifyC			
0	Polygon ZM	51	0	32	NSR32	SF	NSR	Excel¥SF_NSR32.xls				
1	Polygon ZM	90	0	31	NSR31	SF	NSR	Excel¥SF_NSR31.xls				
2	Polygon ZM	91	0	35	NSR35	SF	NSR	Excel¥SF_NSR35.xls				
3	Polygon ZM	96	0	21	EDN21	SF	El Eden	Excel¥SF_EDN21.xls				
4	Polygon ZM	97	0	22	EDN22	SF	El Eden	Excel¥SF_EDN22.xls				
5	Polygon ZM	98	0	20	EDN20	SF	El Eden	Excel¥SF_EDN20.xls				
6	Polygon ZM	100	0	15	EDN15	SF	El Eden	Excel¥SF_EDN15.xls				
7	Polygon ZM	101	0	16	EDN16	SF	El Eden	Excel¥SF_EDN16.xls				
8	Polygon ZM	102	0	40	NSR40	SF	NSR	Excel¥SF_NSR40.xls	2	SFNSR40	64	479
9	Polygon ZM	108	0	19	EDN19	SF	El Eden	Excel¥SF_EDN19.xls	2	SFEDN19	59	478
10	Polygon ZM	110	0	43	NSR43	SF	NSR	Excel¥SF_NSR43.xls	3	SFNSR43	42	479
11	Polygon ZM	111	0	42	NSR42	SF	NSR	Excel¥SF_NSR42.xls	3	SFNSR42	44	
12	Polygon ZM	112	0	44	NSR44B	SF	NSR	Excel¥SF_NSR44B.xls	3	SFNSR44B	55	48C
13	Polygon ZM	113	0	45	NSR45	SF	NSR	Excel¥SF_NSR45.xls	3	SFNSR45	57	479
14	Polygon ZM	114	0	46	NSR46	SF	NSR	Excel¥SF_NSR46.xls	3	SFNSR46	60	48C
15	Polygon ZM	115	0	47	NSR47	SF	NSR	Excel¥SF_NSR47.xls	3	SFNSR47	42	479
16	Polygon ZM	116	0	48	NSR48	SF	NSR	Excel¥SF_NSR48.xls	3	SFNSR48	34	479
17	Polygon ZM	117	0	49	NSR49	SF	NSR	Excel¥SF_NSR49.xls	3	SFNSR49	58	479
18	Polygon ZM	118	0	50	NSR50	SF	NSR	Excel¥SF_NSR50.xls	3	SFNSR50	61	479
19	Polygon ZM	119	0	51	NSR51	SF	NSR	Excel¥SF_NSR51.xls	3	SFNSR51	59	479
20	Polygon ZM	120	0	33	EDN33	SF	El Eden	Excel¥SF_EDN33.xls	3	SFEDN33	40	478
21	Polygon ZM	121	0	34	EDN34	SF	El Eden	Excel¥SF_EDN34.xls	3	SFEDN34	63	478
22	Polygon ZM	122	0	36	EDN36	SF	El Eden	Excel¥SF_EDN36.xls	3	SFEDN36	44	478
23	Polygon ZM	123	0	35	EDN35	SF	El Eden	Excel¥SF_EDN35.xls	3	SFEDN35	68	478

(0 out of 33 Selected)

Relative path is stored at “Path” field Of the attribute table of Slope Failure / rockfall. Setting the properties of the MXD (map document) allows relative paths to be used. See the next figure for your reference.

Figure 75 Image of Hyper Link tool and actual attribute table (JET)

Procedure to set up Hyperlink is as following,

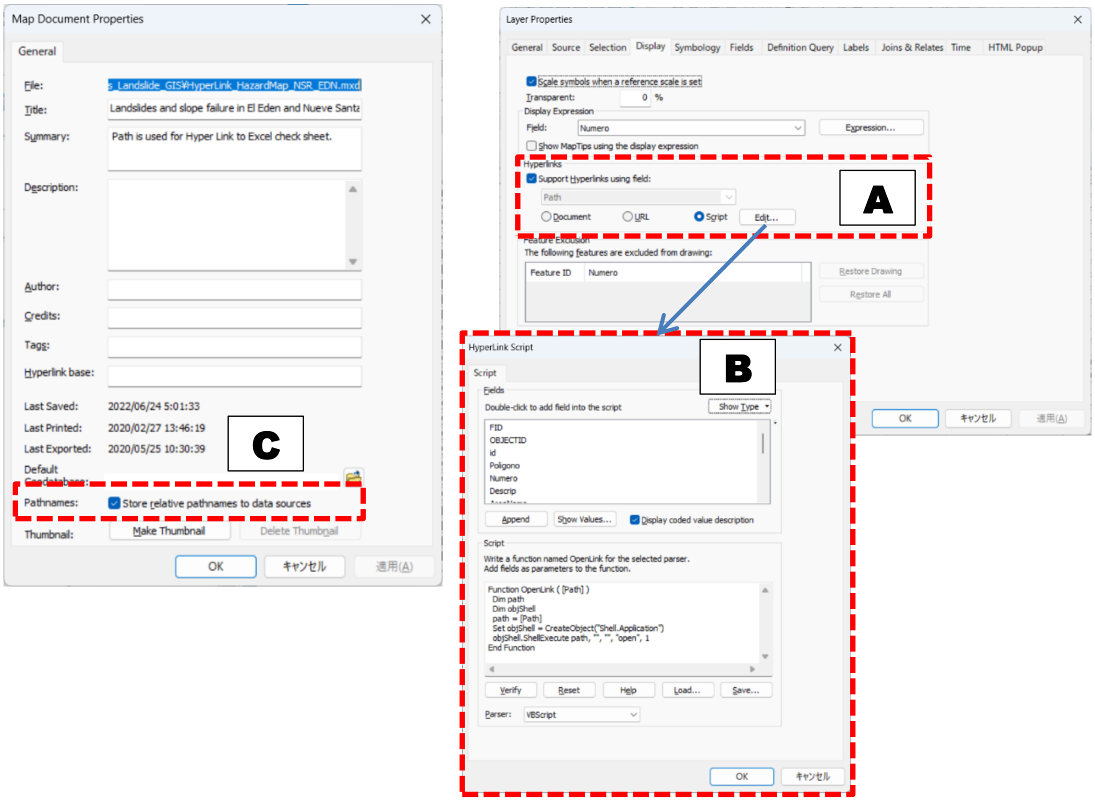
1) Launch ArcMap
2) Add a vector layer to set up Hyperlink.
3) Input path of the data file in the attribute table. (In the previous figure, the field name is “Path”.)
4) Right click of the target layer, and then open Layer Properties. Then click the Display tab.

5) The Hyperlink setting in the middle of the dialogbox is found. (See A in the following figure)

6) Check on “Support Hyperlinks using field;”, and then choose Path for the target field.

7) Click Edit button and make sure the HyperLink Script (See B the following figure).

8) Before saving MXD file, make sure Map Document Property and check on Pathnames: “Store relative pathnames to data sources” if you want to use relative path system. (See C in the figure)



File: s_Landslide_GIS¥HyperLink_HazardMap_NSR_EDN.mxd
Title: Landslides and slope failure in El Eden and Nueve Santa
Summary: Path is used for Hyper Link to Excel check sheet.
Description:
Author:
Credits:
Tags:
Hyperlink base:
Last Saved: 2022/06/24 5:01:33
Last Printed: 2020/02/27 13:46:19
Last Exported: 2020/05/25 10:30:39
Default Geodatabase:
Pathnames: ☑ Store relative pathnames to data sources
Thumbnail:

☑ Scale symbols when a reference scale is set
Transparent: 0 %
Display Expression
Field: Numero
☐ Show MapTips using the display expression
Hyperlinks
☑ Support Hyperlinks using field:
Path
○ Document ○ URL ● Script
Feature Exclusion
The following features are excluded from drawing:

Feature ID	Numero

Fields
Double-click to add field into the script
FID
OBJECTID
id
Poligono
Numero
Descrip
☑ Display coded value description

Script
Write a function named OpenLink for the selected parser.
Add fields as parameters to the function.

```
Function OpenLink ( [Path] )
  Dim path
  Dim objShell
  path = [Path]
  Set objShell = CreateObject("Shell.Application")
  objShell.ShellExecute path, "", "", "open", 1
End Function
```

Parser: VBScript

Figure 76 Important settings for Hyper Link tool (JET)

5.2. 2 How to manage old and new data

Let UNGIR decide how to manage the old and new data. There is a method of archiving and preserving old data.

5.3 Disaster history storage

5.3.1 Media Damage History

Articles in newspapers, magazines, etc. indicate the source, and in some cases permission may be required (Figure 77 and Figure 78).

14 La Tribuna Miércoles 7 de junio, 2023

SOS Capitalino

ANUNCIA ALCALDÍA

Mantienen en monitoreo permanente y mitigación zona cero de la Guillén

Ante las últimas tormentas, un equipo municipal instaló plástico en el suelo para evitar filtración de agua y deslizamientos.

Personal de la alcaldía capitalina colocó plástico sobre el suelo para evitar más deslizamientos en la colonia Guillén.

El agua que se acumuló tras las lluvias, en un punto de la Guillén, fue succionada con bombas especiales.

DATOS

Las autoridades de la Alcaldía Municipal del Distrito Central (AMDC) recomiendan a la población capitalina que, ante una situación de riesgo, llame a cualquier hora y día a la línea de teléfono 100 para ser asistida por el personal de la municipalidad.

SUCCIONAN AGUA

Los desechos y piedras arrastrados por las últimas tormentas fueron recogidos con retroexcavadoras.

El plástico fue extendido en varios sectores de la zona cero de la colonia Guillén, previniendo así la saturación con agua.

Figure 77 Guillén disaster (La Tribuna, June 7, 2023)

36 METRO

37 AGENDA CIUDADANA DE HOY

NUEVO MAPA DE RIESGO SE PRESENTA EN 2014

Identifican 1,000 zonas de riesgo en el Distrito Central

Expertos de JICA realizan estudio para medir la vulnerabilidad real de las ciudades gemelas. Copeco estima que el 85 por ciento de fallas son geológicas y el 15 por ciento, hidrológicas

BENEFICIOS DEL NUEVO MAPA

UBICACIÓN

TERRITORIO

FORMACIÓN

EDUCACIÓN

LA CIFRA

85 POR CIENTO de los deslizamientos en la capital son producto de fallas geológicas. El 15% restante son por causas hidrológicas.

LOS PROTAGONISTAS

Go Sato

Kiyoharu Hirota

Rigoberto Moncada

Gonzalo Funes

Yanira Flores

Lupita Figueroa

CIUDAD DEL ÁNGEL

Permisos se dejaron de emitir en 2012

SOLICITUD

Figure 78 La Colonia Izaguirre (EL HERALDO, November 12, 2013)

5.3.２ Observational data

If observation data including monitoring data is updated on SIMET, indicate the location, date and time, and observation period.

5.3.３ Field survey data

The results of the field survey should be completed as much as possible. If field personnelwrite articles during the survey, make sure that the date and location are known (ex. GPS data).

Reference:

Fujiwara A. (1979): Analysis and Prevent-Plan of Landslides, Rikoh Publish Co., Tokyo. (in *Japanese*)

JICA (2002) The study on flood control and landslide prevention in Tegucigalpa metropolitan area of the republic of Honduras (official document). Final Report in English version.

JICA (2012): Final Report, The Project for Developig Countermeasures against Landslides in the Abay River Gorge.

Ministry of Land, Infrastructure and Transport Infrastructure Development Institute-Japan (2004): Guidelines for Construction Technology Transport: Development of warning and Evacuation System Against Sediment Disasters in Developing Countries.

Road Management Technical Center (2007): Guideline for inspection on road slope disaster in Japan (in *Japanese*).

Rodgers, R. D. and O'Conner, E. A. (1990): Geologic map of the Tegucigalpa quadrangle, Honduras (scale 1: 50,000), Instituto Geográfico Nacional.

Tefera M., Chernet T. and Haro W. (1996): Geological map of Ethiopia 1:2,000,000, Second edition, Geological Survey of Ethiopia.

Varnes D.J. (1978): Slope movement 43. types and processes, in Schuster, R.L., and Krizek, R.J., eds., Landslides—Analysis and control: Transportation Research Board Special Report 176, National Research Council, Washington, D.C., p. 11–23.

Watari M. and Kohashi S. (1987): Prediction and countermeasures for landslides and slope failures, Sankaido Publish Co., Tokyo. (in *Japanese*).

Appendix

Appendix 1 Examples of Assessment Sheet Format (Landslides, Slope Failure/Rockfall)

PROYECTO PARA EL CONTROL Y MITIGACIÓN DE DESASTRES EN LADERAS EN EL DISTRITO CENTRAL

DESLIZAMIENTO

FICHA DE EVALUACION EN CAMPO PARA ELABORACIÓN DE MAPA DE RIESGOS A MOVIMIENTOS EN MASA

Ubicación:			
Inspector:		Organización:	

Fecha/Hora:

Zona UTM:	
Latitud:	
Longitud:	

CATEGORÍA		ÍTEM	PUNTAJE	
Condiciones Topográficas	Escarpe de Deslizamiento	Existe claramente	20	
		Existe, pero parcial y no claramente	15	
		Existe, pero no claro	10	
	Anomalías en Superficie	Grietas grandes y nuevas, escalones y subsidencia	20	
		Pequeñas y antiguas grietas, escalones y subsidencia	15	
		Ligera deformación del terreno	10	
		Sin anomalías	0	
Condiciones Geológicas	Tipo de Rocas	Coluvios	5	
		Roca meteorizada (alterada)	4	
		Suelos moderados	3	
		Roca sana (sólida)	2	
	Rocas Fracturadas	Alta densidad de fracturas	15	
		Moderamente fracturadas	10	
		Bajas densidad de fracturas	5	
		Sin rocas	0	
Condiciones Hidrológicas		Muchos manantiales / muchas filtraciones de agua	20	
		Pocos manantiales / pocas filtraciones de agua	10	
		Rastros de agua	5	
		Sin presencia de agua	0	
Otros Indicadores	* ☐ Inclinación postes / árboles	3 o más correspondencias	20	
	☐ Gradas deformadas	2 correspondencias	15	
	☐ Tubería deformada	1 correspondencia	10	
	☐ Fisuras/grietas en edificaciones	Sin correspondencias	0	
Obras de Contramedida		No existen obras de contramedida en el sitio	0	
		Existe obra de contramedida (incompleta)	-20	
		Existe obra de contramedida (completa)	-50	
		SUMA TOTAL (ST) =		

* marcar las opciones que apliquen

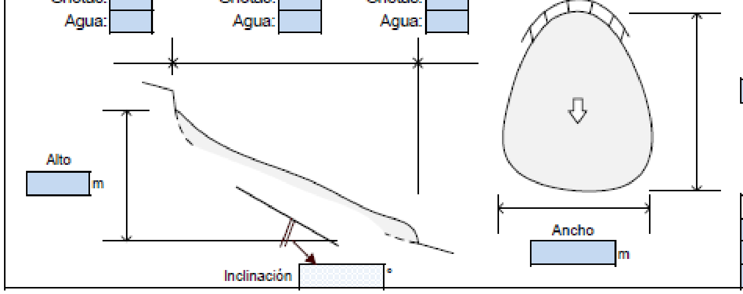
▭	**Llenar en campo**
▨	**Cálculo automático**

NOTA:
En caso de que ST < 0, entonces ST = 0

CARACTERÍSTICAS DEL DESLIZAMIENTO:

Coordenada Parte Alta		Coordenada Parte Baja	
Latitud:		Latitud:	
Longitud:		Longitud:	

	Parte Alta	Parte Media	Parte Baja
Grietas:			
Agua:			



Medido en:	
	Mapa
	SIG
	Sitio

VALORACIÓN GENERAL:

	Diagnóstico	Rango	
1	El trabajo de contramedidas es necesario	ST >= 70	-
2	No es necesaria una contramedida urgente, se necesitan inspecciones periodicas	50 <= ST < 70	-
3	Contramedidas no son necesarias	ST < 50	-

OBSERVACIONES:

v3.1 (2019.11.28)

PROYECTO PARA EL CONTROL Y MITIGACIÓN DE DESASTRES EN LADERAS EN EL DISTRITO CENTRAL

FALLA DE LADERA Y DERRUMBE

FICHA DE EVALUACION EN CAMPO PARA ELABORACIÓN DE MAPA DE RIESGOS A MOVIMIENTOS EN MASA

Ubicación:			
Inspector:		Organización:	

Fecha/Hora:

Zona UTM:		Altura:	msnm
Latitud:			
Longitud:			

Falla en Ladera	
Derrumbe	

Talud Natural		
Talud Artificial	Corte	
	Terraplen	

CATEGORÍA			ÍTEM	PUNTAJE		
Condiciones Geológicas y Geomorfológicas del Terreno	Estructura Geológica	Tipo de Rocas	Coluvios	8		
			Roca meteorizada (alterada)	6		
			Suelos moderados	2		
			Roca sana (sólida)	0		
		Rocas Fracturadas	Alta densidad de fracturas	10		
			Moderamente fracturadas	5		
			Bajas densidad de fracturas	0		
		* ☐ Grietas en la corona ☐ Escarpes secundarios ☐ Rocas inclinadas ☐ Bloques rodados	3 o más correspondencias	12		
			2 correspondencias	8		
			1 correspondencia	4		
			Sin correspondencias	0		
	Geomorfología	Forma	Cóncava	6		
			Convexa	4		
			Plana	2		
		Ángulo i = _____°	Pendiente > 45º	12		
			Pendiente 22.5º <= i < 45º	8		
			Pendiente 15º <= i < 22.5º	6		
			Pendiente < 15º	3		
		Altura H = _____ m	H >= 50m	12		
			30m <= H < 50m	9		
			15m <= H < 30m	6		
			H < 15m	3		
Condiciones Hidrológicas	Evidencia de Erosión		Surcos de agua natural	10		
			Barrancos o quebradas	8		
			Zanjas artificiales	6		
			Surcos de agua residual	2		
			No hay erosión	0		
	Presencia de Agua		Manantiales al pie de talud	10		
			Filtraciones de agua al pie del talud	8		
			Filtraciones por tuberia rota	6		
			Agua residual sobre el deslizamiento	4		
			Escorrentia natural	2		
			Sin presencia de agua	0		

CATEGORÍA			ÍTEM	PUNTAJE		
Microtopografía y Otros Indicadores	Deformación	* ☐ Inclinación postes / árboles ☐ Gradas deformadas ☐ Tubería deformada ☐ Fisuras / grietas en edificaciones	3 o más correspondencias	12		
			2 correspondencias	7		
			1 correspondencia	4		
			Sin correspondencias	0		
	Condición de la Superficie		Tierra desnuda con vegetación menor	8		
			Intermedio (desnudo, arboles, hierba)	5		
			Estructuras (edificaciones) y arboles	2		
			SUMA TOTAL (ST) =			

* marcar las opciones que apliquen

🟦 **Llenar en campo**

▨ **Cálculo automático**

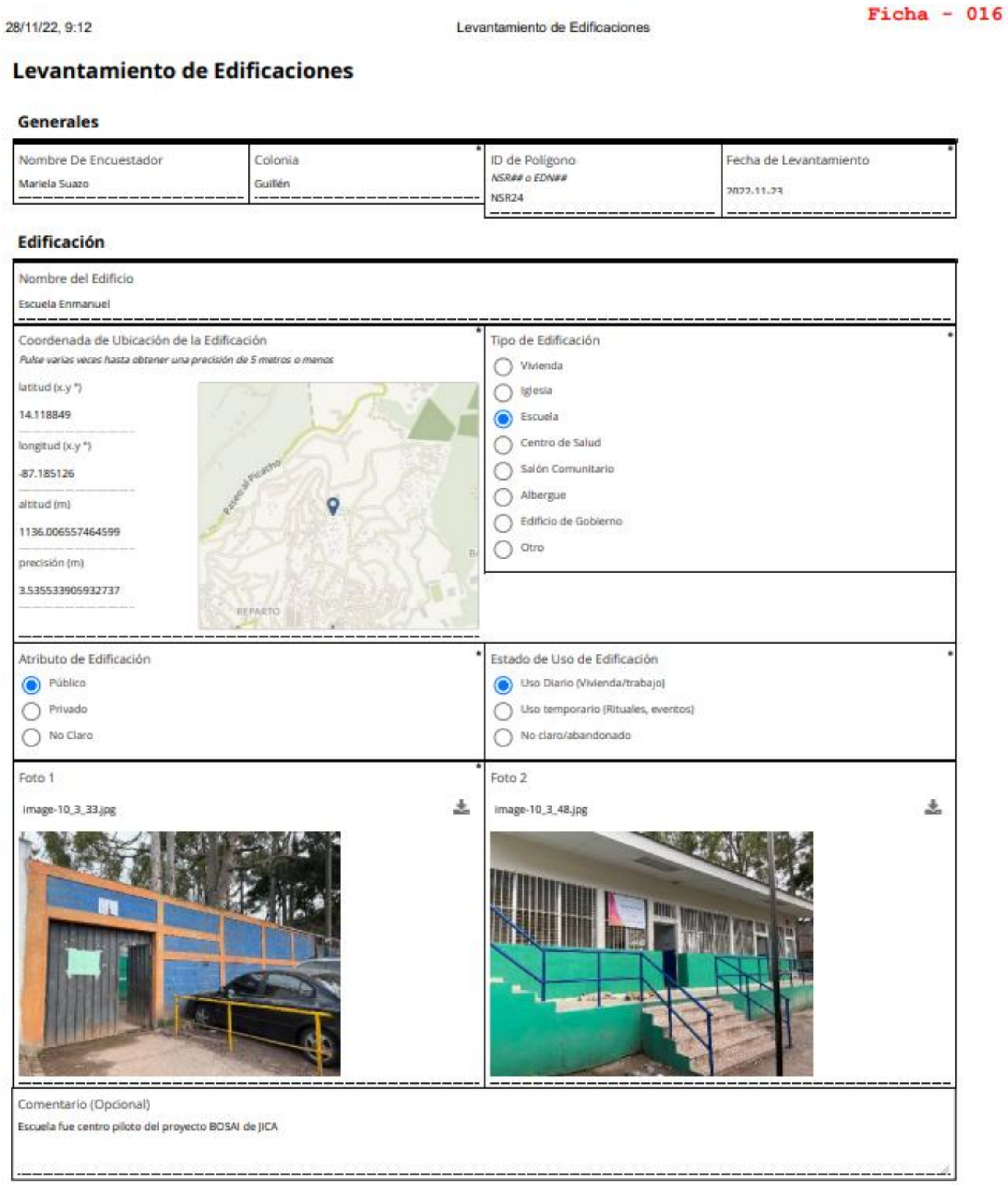
VALORACIÓN GENERAL:			
	Diagnóstico	**Rango**	
1	El trabajo de contramedidas es necesario	**ST >= 70**	-
2	No es necesaria una contramedida urgente, se necesitan inspecciones periodicas	**60 <= ST < 70**	-
3	Contramedidas no son necesarias	**ST < 60**	-

OBSERVACIONES:

v3.1 (2019.11.28)

Appendix 2. Example of Data Record of Field Survey Results (Building Survey)

If the risk assessment examines buildings (public facilities) in and around the risk polygon, consider the following example.



Ficha - 016

28/11/22, 9:12 Levantamiento de Edificaciones

Levantamiento de Edificaciones

Generales

Nombre De Encuestador: Mariela Suazo

Colonia: Guillén

ID de Polígono (*NSR## o EDN##*): NSR24

Fecha de Levantamiento: 2022-11-23

Edificación

Nombre del Edificio: Escuela Enmanuel

Coordenada de Ubicación de la Edificación

Pulse varias veces hasta obtener una precisión de 5 metros o menos

latitud (x.y °): 14.118849

longitud (x.y °): -87.185126

altitud (m): 1136.006557464599

precisión (m): 3.535533905932737

Tipo de Edificación
- ○ Vivienda
- ○ Iglesia
- ● Escuela
- ○ Centro de Salud
- ○ Salón Comunitario
- ○ Albergue
- ○ Edificio de Gobierno
- ○ Otro

Atributo de Edificación
- ● Público
- ○ Privado
- ○ No Claro

Estado de Uso de Edificación
- ● Uso Diario (Vivienda/trabajo)
- ○ Uso temporario (Rituales, eventos)
- ○ No claro/abandonado

Foto 1: image-10_3_33.jpg

Foto 2: image-10_3_48.jpg

Comentario (Opcional): Escuela fue centro piloto del proyecto BOSAI de JICA

Building Investigation Sheet (NSR 24)

Buildings list by survey (NSR 24)

No	**Atributo**			**Estado de Uso**		
	Publico	Privado (Residencia)	No Claro	Diarias (Viviendo / Trabajo)	Temporal (Rituales, Eventos)	No Claro (Abandonado)
1	Iglesia Bautista				Iglesia	
2	Iglesia Bautista				Iglesia	
3	Esc. Enmanuel			Escuela		
4						
5						
6						
7						
Total	**3**	**0**	**0**	**1**	**2**	**0**

Appendix 3 Example of how to organize the selection of survey sheet elements

When selecting the elements and facros of the survey sheet, it is helpful to understand the site by following the steps below to prepare materials.

This is for the elements of the presentation, but the same is true for the way of making a material (see below fifure).

- Name
- Title of Presentation
- Location of the Site (UTM Coordinates Zone 16 N): East, North, and Elevation
- Photographs
- Considerations of the Observed Phenomenon and Conclusions
- Comment (by Experts)

Proyecto para el Control y Mitigación de Desastres en Laderas
del Distrito Central en la República de Honduras
Resultado 3

Nombre: ______________________________

Título de Presentación: ____________________

Ubicación del Sitio (Coordenadas UTM Zona 16 N)

Este: ______________________
Norte: _____________________
Elevación: __________________

Fotografías

Consideraciones del Fenómeno Observado y Conclusiones

El miembro del Resultado 3 deberá describir el fenómeno observado y explicar las razones por las cuales considera es importante para el análisis de amenaza para un deslizamiento o falla de ladera / caída de rocas. También deberá escribir una breve conclusión sobre el mismo.

Comentario (Prof. Hirota)

El Prof. Hirota realizará un breve comentario sobre el fenómeno seleccionado.

Here is a good example of slope observation results.

Slope evaluated by WG investigator (partially edited)

Slope failure/Rockfall survey sheet by investigator (red boxe is observation element items)

Summary of points raised by presenter and comments from JET

Annex 8

Manual for Land use regulation for slope disaster

Japan International Cooperation Agency

Project for Control and Mitigation of Slope Disaster
in the Central District in Republic of Honduras

Manual for
Land use regulation for slope disaster

July, 2023

Alcaldía Municipal del Districo Central

JICA Expert Team

Abbreviation

Abberviation	Official name in English
AMDC	Municipality of the Central District
CODEL	Local Emergency Committee
CODEM	Municipal Emergency Committee
DAyF	Department for Finance and Administration
DGCDH	Department for Community Management and Human Development
GCC	Construction Control Management
IDEM	Institute for Municipal Development
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
UGA	Environmental Management Unit
UMGIR	Municipal Unit for Integral Risk Management
UMPEG	Municipal Unit for Management Planning and Evaluation
WG	Working Group

Contents

Chapter 1. Introduction, Background to Regulation.

1.1 Purpose of the Manual and Its Goal.

Purpose

Under the framework of the Project for Control and Mitigation of Slope Disasters in the Central District in Republic of Honduras(hereinafter referred as "the Project"), the Japanese International Cooperation Agency (hereinafter referred as "JICA"), has collaborated with the Municipality of the Central District (hereinafter referred as "AMDC"), in strengthening the capacity to regulate land use planning in areas at risk of Slope disasters in the Municipality, over which it is required to exercise strict control in the execution of various works and/or or activities that could be allowed on such zones, in order to reduce the risk of slope disasters.

Under the project activity, JICA Expert Team (hereinafter referred as "JET") and AMDC has created a draft of the "REGULATION FOR THE TERRITORIAL PLANNING FOR HAZARD ZONES FOR SLOPE DISASTERS" (hereinafter referred as "the Regulation for slope disaster") which has been submitted to the Municipal Corporate.

As part of the correct interpretation and implementation of the Regulation for slope disaster, the manual is prepared so that the members of the AMDC and residents in regulated areas correctly understand the regulation. The detailed explanations on each Article of the Regulation for slope disaster are also summarized in the ANNEX 1.

This manual was prepared by the Counterpart members belonging to the Working Team on Output 4 (hereinafter referred as "WG4") and JET. It summarizes the AMDC's actions to be conducted in order to apply the Regulation for slope disaster smoothly. It includes also the process diagram to issue work license for the construction activity to be conducted in the regulated zones and clarifies the responsible department of each activity.

During the preparation of the Regulation for slope disaster, workshops, meetings, as well as technical transfer seminars were held in order for the WG4 to understand the procedures for the approval of the Regulation for slope disaster in AMDC, formats and explanatory materials to be prepared, types of slope disasters, hazard evaluation, types of land use that can be implemented in each regulated zone and structural restriction.

Within this manual, the protocol for disseminating the Regulation for slope disaster, the flow of application and formats for work license, and the possible questions and answers of AMDC staff and the taxpayer face regarding the implementation of the manual are explained.

Objective

This manual facilitates AMDC's implementation and understanding of the Regulation for slope disaster, when construction, amplification, remodeling or any type of land use in slope disaster areas is carried out.

1.2 Reason why the land use regulation is necessary

One of the keys to land use planning and risk management is to regulate land uses in the specific areas appropriately. If land use distribution or structure of buildings are not regulated, that would cause the urban growth that can increase risk exposure and violate the quality of citizens life.

In the Central District, it is said that at least 1 in 3 of the population live in conditions of risk for slope disasters. Despite the efforts of the central and local government, it has not been possible to reduce exposure to risk. A significant part of the budgets and investment plans are oriented towards climate action and risk reduction for natural disasters, however, they are insufficient to reverse the municipality's vulnerability indices. Meanwhile, it takes an enormous amount of time and budget to implement countermeasure works to all the zones where slope disasters occur. Therefore, in addition to the countermeasure works, a regulation to limit the new development activities and to require existing residents to relocate from such zones as a non-structural measure.

The Regulation for slope disaster, of which the WG4 prepared its draft, provides a wider range of opportunities to regulate construction works carried out in the zones facing the risk for slope disasters. On the other hand, it clarifies the scope of what can be built and a series of actions in slope disaster areas where settlement is not possible.

1.3 Examples of Slope Disasters from Past Events in DC

1.3. 1 El Berrinche landslide

The El Berrinche landslide in Tegucigalpa was the largest of the landslides caused by Hurricane Mitch in Honduras in 1998. It destroyed a portion of the city centre known as Colonia Soto and dammed the Choluteca River, creating a sewage lagoon upstream of the dam formed by the landslide. This complex landslide had a volume of approximately 6 million cubic metres. Due to the slow initial movement of the landslide during the hurricane-induced rains, it was possible to evacuate residents living in the landslide block before the landslide began to move rapidly and culminated in the damming of the river.

In the figure, several letters can be seen where "T", denotes the toe of the landslide, "L", denotes the lagoon dammed by the toe of the landslide. "DT" denotes the very deformed tip of the landslide, which is where the centre of the Colonia Soto was located, "SB" denotes the upper block of the subsidence.

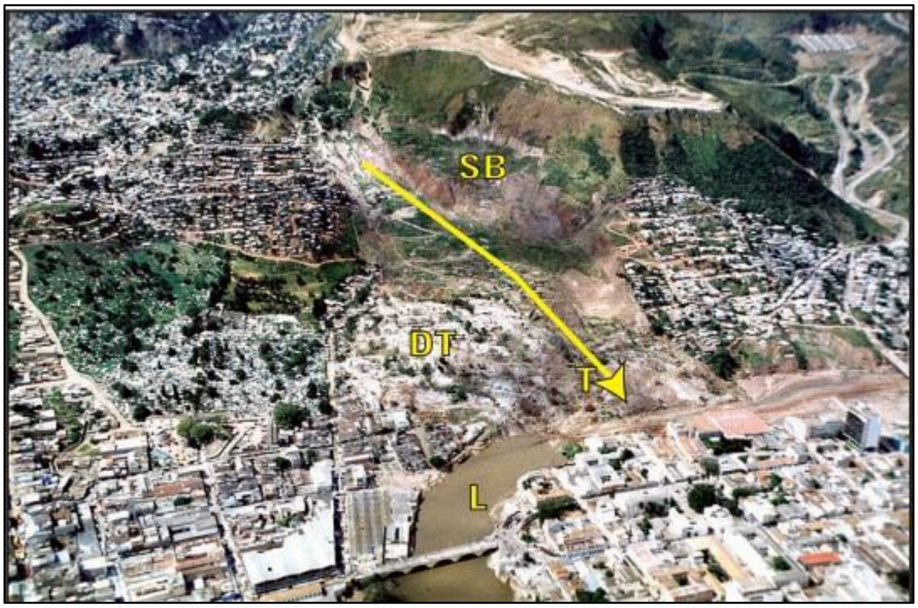


Figure 1 *Aerial view of the El Berrinche landslide where the arrow indicates the direction of displacement (AMDC)*

The El Berrinche landslide has remained stable, except for the localised subsidence at the lower end of the landslide tip, where the excavation of the channel has resulted in steeper slopes.

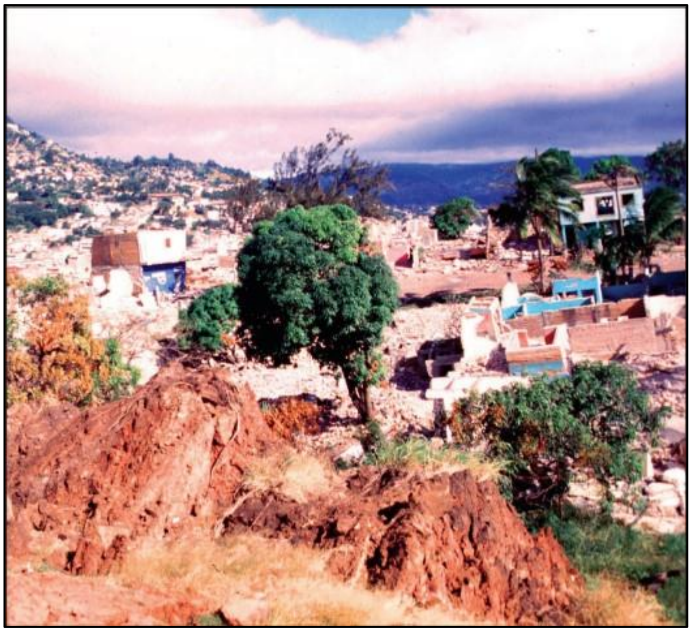


Figure 2 View of the badly deformed toe area of the El Berrinche landslide (AMDC)

1.3. 2 El Reparto Landslide

This landslide occurred in the mid-morning of 31 October 1998 and lasted for several hours. The final movement of the landslide caused the formation of a debris flow, which formed from the excessively steep toe of the landslide and demolished the houses. Since the initial movement of the landslide was slow, it was possible to evacuate all the inhabitants of these houses.

In July 2000, several observation points were set up on the landslide block. At these observation points, regular monitoring activities were made to detect any further movement. This activity was carried out as there are houses that are still occupied and located next to the landslide and slope below it.

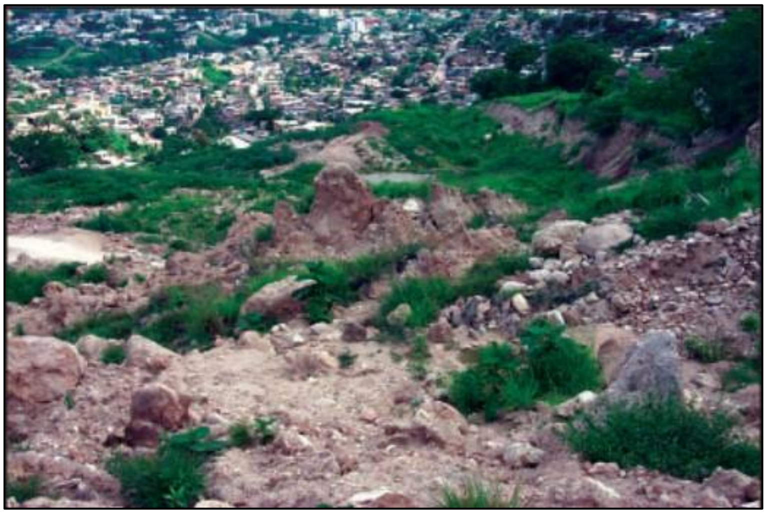


Figure 3 El Reparto landslide (AMDC)

1.3.3 Other slope disasters occured in the past years

Other deep-seated landslides also caused damage to inhabitants and property in the Municipality of Tegucigalpa. Two landslide caused by the undercutting of the riverbanks destroyed houses in Barrio Mira-Mesi, along the Rio Choluteca and in Nueva Esperanza, along the Rio Guacerique. The landslide in Barrio Mira-Mesi originated as a relatively small landslide. The landslide destroyed or damaged several houses due to sliding and subsidence caused by the erosive undercutting of the river on the embankment. The front crack of this landslide remained unstable even during the dry seasons of 1999 and 2000.

Figure 4 Landslide in the Mira Mesi neighbourhood, adjacent to the Choluteca River (AMDC)

The Nueva Esperanza landslide, caused by the Guacerique River undermining and eroding the slope, which reached its peak during the passage of Hurricane Mitch, destroyed more than 20 houses perched on top of the steep slopes of the river bank.

Figure 5 Landslide along the Guacerique River (AMDC)

Chapter 2. Technical basis for the Regulation for slope disaster

2.1 Type of slope disaster

The type of slope disaster that the Regulation for slope disaster focuses on as the target is landslide and slope failure. So, hereafter, the term “slope disaster” means landslide and slope failure in this manual. Detailed definition is explained in the Manual for the Creation of Hazard Map/ Risk Map of Slopes (Output 3).

Landslide:

A landslide is a phenomenon in which a gentle slope slides down over a wide area. This phenomenon takes place slowly, taking some time. When a landslide occurs, the damage is enormous over a wide area, including houses, agricultural fields and roads.

It should be mentioned that landslides are characterised by their tendency to occur repeatedly on the same slope.

Figure 6 Image of landslide
(NPO Sediment Disaster Prevention Publicity Center)

Slope failure:

The collapse of a steep slope is called a "slope failure". The main cause is rainwater that seeps down the slope in enormous proportions. This type of failure is characterised as sudden with rapid movement without prior indication, usually as a result of damage, structural weakness or lack of support.

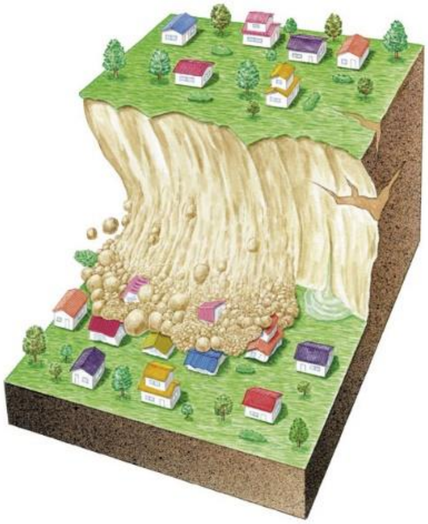


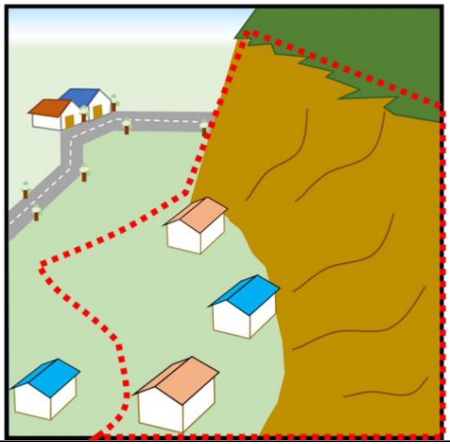
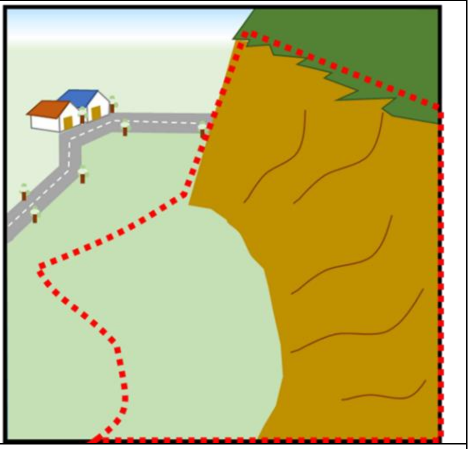
Figure 7 Image of slope failure
(NPO Sediment Disaster Prevention Publicity Center)

2.2 Regulated Zones

2.2.１ Type of zones where the Regulation for slope disaster is applied

In order to mitigate the damages to existing residents in the zones where buildings already exist, and to prevent future damages for future residents and buildings in the non-urbanized zones, the zones where the Regulation would be applied were divided into 2 categories: urbanized zones (Inhabited zones with more than one building) and non-urbanized zones (Vacant zones without any building).

Table 1 Type of regulated zones (JET)

		
Land type	Urbanized zones: Zones with more than one building	Non-urbanized zones: Zones without any building
Concept of regulation	Regulation to limit construction works and to share information in order to reduce the possible damage in case of slope disaster.	Regulation to limit new construction works in order to prevent the possible damage in the future events.
Category	Category A, B, C	Category D, E

2.2.２ Activities to be regulated by the Regulation for slope disaster

The type of development activities to be regulated is defined as “new construction”, “amplification” and “remodeling”. The Regulation for slope disaster defines each term as shown below based on the Regulations on zoning, works, and land uses in the Central District (hereinafter referred as “GCC Regulation”):

- ✓ **New construction:** Work to be built without using parts or elements of any pre-existing construction on the property.
- ✓ **Amplification:** It is defined as the set of works to be carried out on an existing structure, building or installation, increasing its surface area and/or volume.
- ✓ **Remodeling:** Interior or exterior modification of an existing building to adapt to new conditions of use without the addition of structural elements, retaining the substantial aspects or the facades of the original building, provided that it does not extend the useful or complementary areas of a building.

In the urbanized zones, it is decided to regulate new construction of buildings as well as amplifications and remodeling of existing buildings in order to reduce the future population at risk from slope disasters. With the aim of preventing the future damage by slope disasters, new construction activity is also prohibited in non-urbanized zones.

2.3 Methodology to designate the regulation category and regulated zones.

2.3. 1 Regulation Category

The Regulation for slope disaster defines 5 (five) categories of the zones where construction activities are restricted, three of which are for the urbanized zones and two of which are for non-urbanized.

The regulation category corresponds to the hazard level of the slope in the zone. Zone evaluated by the Hazard evaluation sheet[1] and classified as high, middle or low hazard, are regarded as "regulated zone".

- ✓ **Category A (Inhabited zone of high hazard for slope disaster):** Urbanized zones evaluated as high hazard,
- ✓ **Category B (Inhabited zone of middle hazard for slope disaster):** Urbanized zones evaluated as middle hazard,
- ✓ **Category C (Inhabited zone of low hazard for slope disaster):** Urbanized zones evaluated as low hazard,
- ✓ **Category D (Vacant zone of high and middle hazard for slope disaster):** Non-urbanized zones classified as high or middle hazard, and
- ✓ **Category E (Vacant zone of low hazard for slope disaster):** Non-urbanized zones classified as low hazard

The regulation contents to be applied in each zone are explained later.

In order to select the appropriate regulation category to be applied in zones with hazard for slope disaster zone, the hazard level will be used.

2.3. 2 Hazard evaluation

For the zones where the slope disasters could occur, the evaluation of the slope condition shall be carried out through field visits. Each zones to be damaged in case of slope disasters is evaluated as High hazard, Middle hazard or Low hazard. The detailed methodology on hazard evaluation is explained in the Manual for the Creation of Hazard Map/ Risk Map of Slopes.

The following shows the responses required for each hazard level.

- ✓ **Hazard level 1 (High hazard):** Currently the sings of slope disasters occur and the countermeasure works is required. Efforts are needed to promote the reduction of population suffering from slope disasters.

---

[1] Detailed methodology are explained in the Manual for the Creation of Hazard Map/ Risk Map of Slopes which is prepared by the Working Group on Output 3 of the Project.

✓ **Hazard level 2 (Middle hazard):** No countermeasure works are required at the moment. However it is probable to be transferred to Level 1 due to heavy rain or other factor. The efforts such as limitation of population growth in the zone are necessary.

✓ **Hazard level 3 (Low hazard):** No countermeasure works are needed and construction activities are allowed. But, non-structural measures such as regulating land use or providing information on slope disasters are necessary since the hazard exists in the zones of this category.

Table 2 Relation between hazard level and regulation category (JET)

Hazard level of Output 3		Regulation category of Output 4	
Level	Explanation	Urbanized zones	Non-urbanized zones
1. High	Countermeasure works must be implemented.	Inhabited zone of high hazard (Zone A)	Vacant zone of high and middle hazard (Zone D)
2. Middle	Countermeasure works are not needed urgently but monitoring of the site is necessary.	Inhabited zone of middle hazard (Zone B)	
3. Low	No countermeasure works are necessary.	Inhabited zone of low hazard (Zone C)	Vacant zone of high and low hazard (Zone E)

For regulations in urbanized zones, the three categories are defined such as inhabited zone of high hazard (Zone A), inhabited zone of middle hazard (Zone B), and inhabited zone of low hazard (Zone C) according to the 3 hazard level categories.

For regulations in non-urbanized zones, 2 categories are set up. The zones classified as hazard level 1 or hazard level 2 are designated as vacant zone of high and middle hazard (Zone D). The zones classified as hazard level 3 as vacant zone of low hazard (Zone E).

2.3. 3 Enter to the private and public land for evaluation

The Regulation for slope disaster is applied according the hazard level. In case that residents in the slope disaster zones refuse the evaluation, the evaluation can not be implemented, which means the regulation is not able to be applied. In order to avoid such situation, the Regulation for slope disaster includes an article that mentions the right to enter to the slope disaster zones for the purpose of the hazard evaluation.

When AMDC enters to public and private properties for the purpose of the hazard evaluation, the owner of properties and current residents shall be informed of activities to be conducted by AMDC in advance. The land owner and current residents may not refuse AMDC to enter without specific reason.

In order to ensure the appropriateness of the regulation-related activities, AMDC may enter the subject land and inspect the condition of the land or construction in question when it is necessary to conduct the activities under the the following purpose.

- ✓ To conduct a hazard evaluation for the purpose of determining regulation categories to be applied in the subject zone
- ✓ To conduct another hazard evaluation because the regulation categories in the subject zone need to be changed due to changes in the environment surrounding the slope caused by natural phenomena or man-made activities, etc.
- ✓ To confirm whether technical standards (building type, number of stories, etc.) defined by the Regulation for slope disaster are properly respected.

In addition, persons who enter the lands occupied by others for the purpose of hazard evaluation shall carry identification and show it upon request of the person concerned.

The owner of property and current residents are able to refuse AMDC's entering to their lands for the hazard evaluation in case of the following situation:

- ✓ AMDC's evaluation team comes without any explanation to owner of property or current residents in advance.
- ✓ Person who obviously has nothing to do with the evaluation accompanies with AMDC's evaluation team.
- ✓ Person from AMDC's evaluation team does not show their ID or identification that prove they are in charge of the evaluation.
- ✓ AMDC's evaluation team comes to the evaluation at times that infringe on the private lives of current residents (for example before sunrise and after sunset).

2.4 Regulation map

Once the hazard level of slope disaster is defined, AMDC shall immediately announce the regulated zones defined according to the hazard evaluation. In order for the residents to easily understand and respect the regulation, AMDC establishes and distributes a regulation map that shows range of regulated zones and regulation category.

2.4.1 Step to make regulation map

It is made through the Application such as ArcGIS. Basic flow to make the regulation map is as shown below:

- ✓ **STEP 1:** Implementing the hazard evaluation and defining hazard level
- ✓ **STEP 2:** Defining whether the evaluated zone corresponds to urbanized zone or non-urbanized zone
- ✓ **STEP 3:** Defining the regulation category based on the hazard level and type of zones the Regulation for slope disaster is applied

The details on operation of GIS related application is explained in the Manual for the Creation of Hazard Map/ Risk Map of Slopes. It is important to note that the risk evaluation is conducted at the affected zones but its result does not have any relation with regulation map. As the regulation category is decided only based on the hazard level.

Table 3 Steps to make regulation map (JET)

STEPs	Explanation
STEP 1: Implementing the hazard evaluation and defining hazard level	
	- The hazard evaluation is carried out at the slope disaster zones by using the evaluation sheet. - The evaluation result is used to decide the regulation category.

STEP 2: Defining whether the evaluated zone corresponds to urbanized zone or non-urbanized zone	 - On the ArcGIS application, the number of existing buildings are calculated. If there is more than 1 house in the evaluated zone, the zone is classified as Zones A, B, or C. If not, Zones D, or E.
STEP 3: Defining the regulation category based on the hazard level and type of zones the Regulation for slope disaster is applied	 - Regulation category is decided based on the hazard level and existence of house in the zone.
N.B.: Sample images are not correspond to the actual hazard level nor regulation category.	

As the hazard map and risk map are produced for each disaster type, the regulation map also should be prepared for each type of disaster. AMDC prepares 2 map for one place. Following table shows an example.

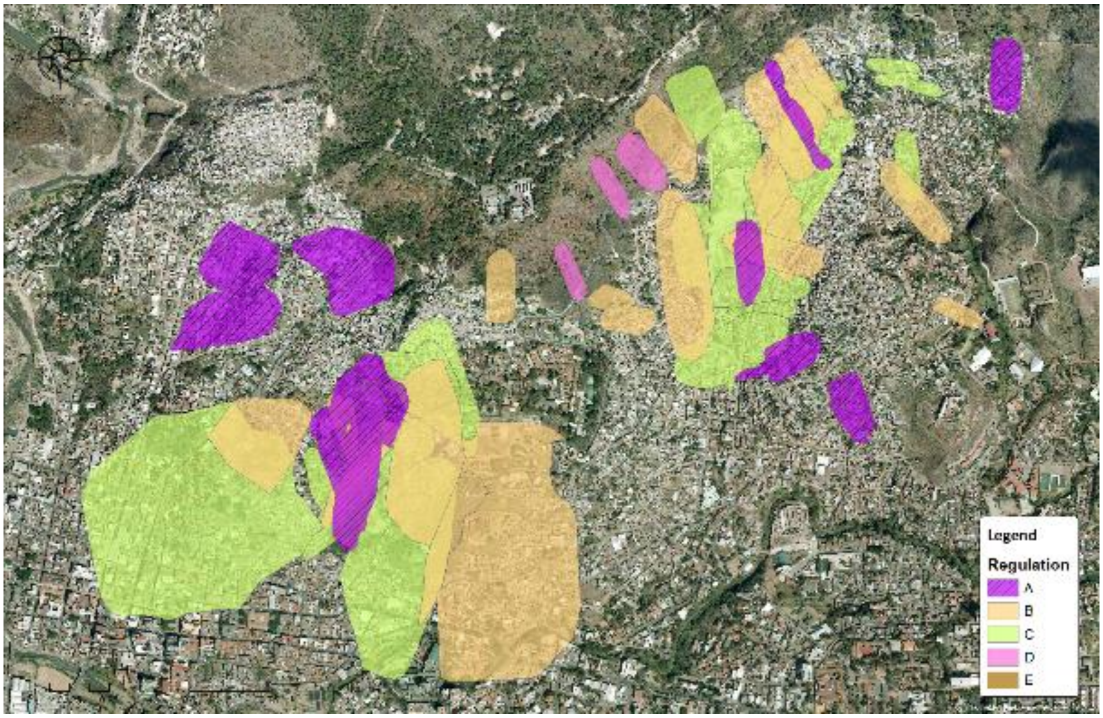


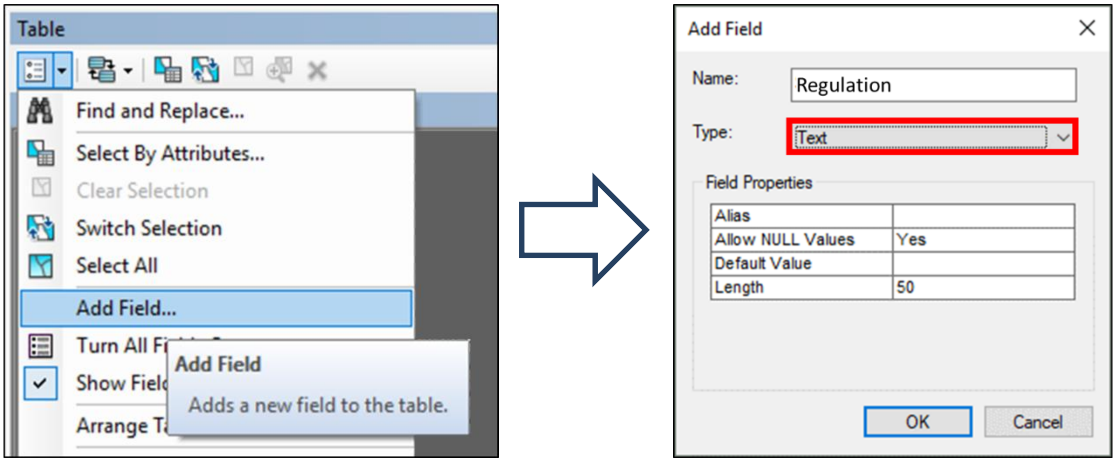
Figure 8 Regulation map for Landslide prepared on GIS application (JET)

Figure 9 Slope failure/rockfall prepared on GIS application (JET)

2.4. 2 Demonstration on ArcGIS

Attribute table

A “Field” that represent the regulation category should be made in the attribute table of the regulation map. The attribute information to be entered to the field is one of the regulation category such as A, B, C, D or E. The type of attribute information to be entered shall be TEXT.



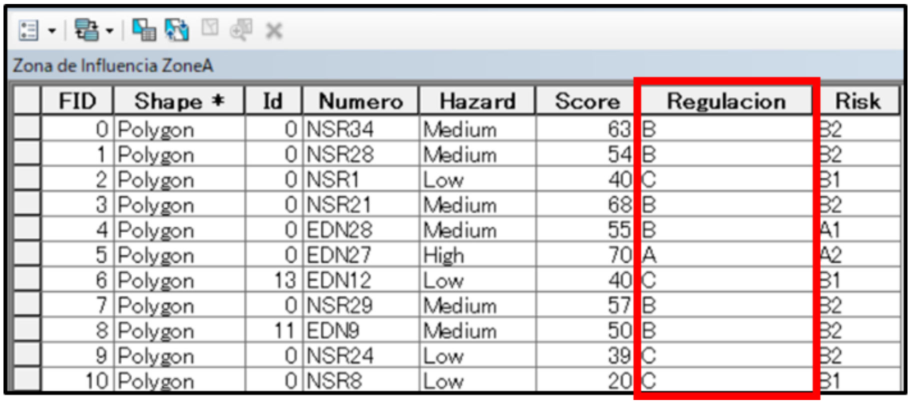
Name: Regulation

Type: Text

Field Properties

Alias	
Allow NULL Values	Yes
Default Value	
Length	50

Figure 10 Creation of the new field for regulation category (JET)



Zona de Influencia ZoneA

FID	Shape *	Id	Numero	Hazard	Score	Regulacion	Risk
0	Polygon	0	NSR34	Medium	63	B	B2
1	Polygon	0	NSR28	Medium	54	B	B2
2	Polygon	0	NSR1	Low	40	C	B1
3	Polygon	0	NSR21	Medium	68	B	B2
4	Polygon	0	EDN28	Medium	55	B	A1
5	Polygon	0	EDN27	High	70	A	A2
6	Polygon	13	EDN12	Low	40	C	B1
7	Polygon	0	NSR29	Medium	57	B	B2
8	Polygon	11	EDN9	Medium	50	B	B2
9	Polygon	0	NSR24	Low	39	C	B2
10	Polygon	0	NSR8	Low	20	C	B1

Figure 11 New field for regulation category (JET)

Color of the regulated zone on the regulation map

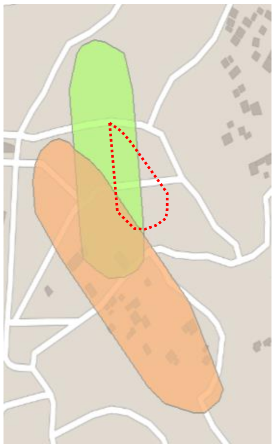
The colors which have never been used in the past maps will be used for the Regulation map to describe the regulated zones, so that people in the Central District will easily understand the regulation category. Following table shows the color coding in RGB for each regulated zone.

Table 4 Colors to be used in the regulation map (RGB) (JET)

ZONE A: Purple(197, 0, 255)	ZONE D: Pink (255, 115, 223)
ZONE B: Orange (255, 211, 127)	
ZONE C: Light green (209, 255, 155)	ZONE E: Brown (168, 112, 0)

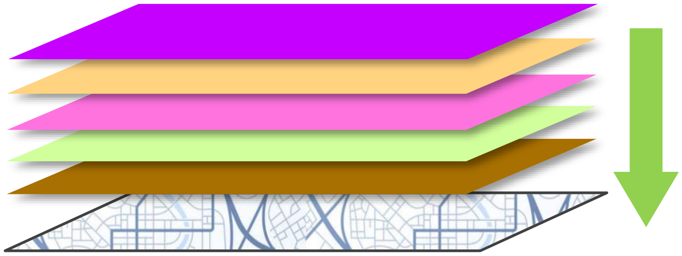
When two or more overlapping polygons of affected zones exist, the regulation category with the higher hazard level shall be applied to the land in question. Following figure shows the case study that the regulation category for zones B and C are overlapping.

For this reason, when AMDC prepares the regulation map with GIS application, the layers of the regulation map are superimposed on each other so that zones with a higher hazard of slope disasters are more clearly indicated on the regulation map.



The regulation category for zone B shall be applied in the sub-zone highlighted in red.

Figure 12 Case study that zones B and C are overlapping (JET)



In order to represent the layers with the highest hazard level from the top, the layers are represented from top to bottom as Zones A, B, D, C and E.

Figure 13 Example of overlapping layers on regulation map (JET)

AMDC prepares the regulation map with OpenStreetMap© as base map and the one with aerial photograph. Each maps should be distinguished by following purpose:

- ✓ **OpenStreetMap©:** Map for socialization activity and distribution to the residents
- ✓ **Aerial photo:** AMDC's internal use to count the number of houses in the regulated zone

2.4. 3 Regulation map for socialization

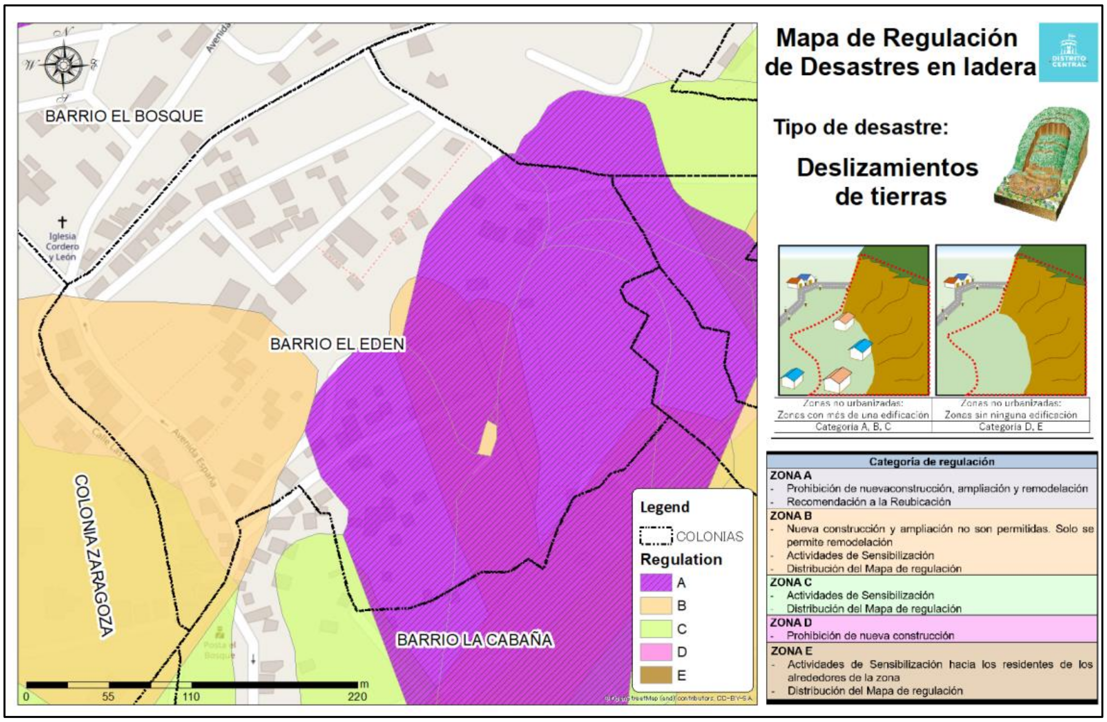
AMDC is responsibility to conduct the socialization activities on slope disasters. In order for the residents to understand the Regulation for slope disaster properly, the regulation map should be distributed to residents that might be damages in case of slope disasters or be posted around the regulated zones.

Since the residents are not experts on the slope disasters, the regulation map shall describe the information that helps them to understand the meaning of the map such as following:

- ✓ AMDC's logo and title of the regulation map
- ✓ Type of slope disaster
- ✓ Regulated zones with legends
- ✓ Regulation contents to be applied in each category

The regulation maps should be drawn to a scale that helps residents to identify their houses, evacuation routes, etc. It is also advisable to prepare a regulation map for each Colonia or Barrio, or for each unit in which AMDC conducts awareness-raising activities related to the Regulation.

The following is a draft regulatory map as prepared in Barrio El Eden. As it is explained above, the regulation map shall be prepared for each type of disaster: landslide and slope failure/rockfall.



Categoría de regulación

ZONA A
- Prohibición de nuevaconstrucción, ampliación y remodelación
- Recomendación a la Reubicación

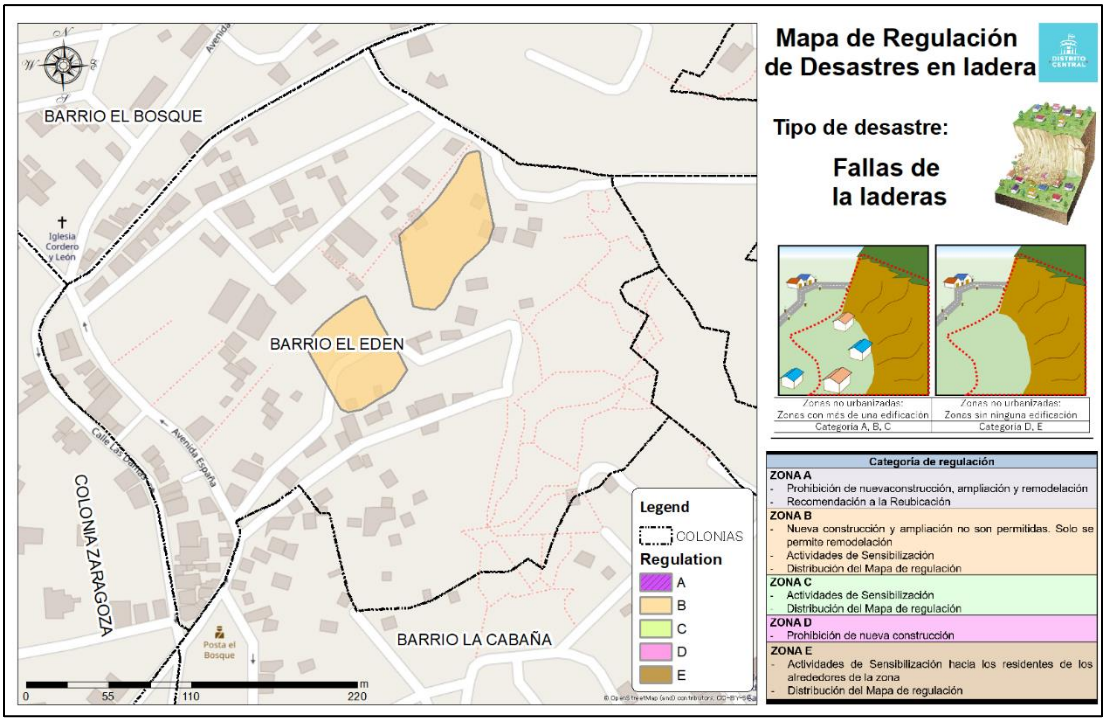
ZONA B
- Nueva construcción y ampliación no son permitidas. Solo se permite remodelación
- Actividades de Sensibilización
- Distribución del Mapa de regulación

ZONA C
- Actividades de Sensibilización
- Distribución del Mapa de regulación

ZONA D
- Prohibición de nueva construcción

ZONA E
- Actividades de Sensibilización hacia los residentes de los alrededores de la zona
- Distribución del Mapa de regulación

Figure 14 Regulation map for landslide to be distributed to resident (JET)



Zonas no urbanizadas: Zonas con más de una edificación	Zonas no urbanizadas: Zonas sin ninguna edificación
Categoria A, B, C	Categoria D, E

Categoría de regulación

ZONA A
- Prohibición de nuevaconstrucción, ampliación y remodelación
- Recomendación a la Reubicación

ZONA B
- Nueva construcción y ampliación no son permitidas. Solo se permite remodelación
- Actividades de Sensibilización
- Distribución del Mapa de regulación

ZONA C
- Actividades de Sensibilización
- Distribución del Mapa de regulación

ZONA D
- Prohibición de nueva construcción

ZONA E
- Actividades de Sensibilización hacia los residentes de los alrededores de la zona
- Distribución del Mapa de regulación

Figure 15 Regulation map for slope failure/rockfall to be distributed to residents (JET)

Chapter 3. Regulated zones and regulatory content.

3.1 Description and Scope of the zones

Article 10 provides definitions for each regulation category. The contents of the Regulation for slope disaster contents are composed from 2 categories: i) regulations for urbanized zones and ii) regulations for non-urbanized zones.

Regulations for urbanized zones aim to reduce possible future damage to residents through restricting construction activities and providing information on slope disasters. Regulation categories for urbanized zones are divided into 3 categories according to hazard level: high hazard zones (Zone A), medium hazard zones (Zone B) and low hazard zones (Zone C).

- ✓ **Inhabited zone of high risk for slope disasters (Zone A):** this is a zone where countermeasure works are required. Until the countermeasure works are implemented, the zones will be classified as uninhabitable, and construction activities (new construction, amplification and remodeling works) will be prohibited. The zone will also become a zone where existing residents will be advised to relocate after being informed of the risk of slope disasters.
- ✓ **Inhabited zone of middle hazard for slope disasters (Zone B):** this zone are considered a zone where no urgent countermeasure works are required, but continuous monitoring is necessary. The zone has the potential to move to high hazard (level 1) in case that the slope conditions of the zone change, new construction and amplifications are not allowed, as action that may affect the slope condition. AMDC conducts effort to decrease the future population in the zones. Remodeling works are permitted as long as they comply with the structural restriction specified by AMDC. The structural restrictions are based on the condition that the dwelling is not more than two stories in height, taking into account the floor-area ratio and other factors.
- ✓ **Inhabited zone of low hazard for slope disasters (Zone C):** the zone is considered a zone where no countermeasure works are required, and new construction and amplification are permitted in Zone C. However, due to the presence of hazards, new construction and amplifications are only permitted in the zone for buildings up to two stories in height.

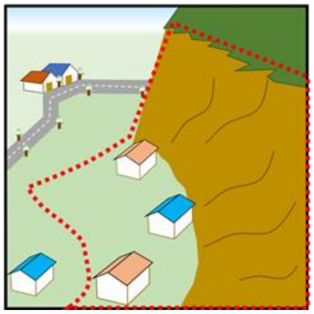
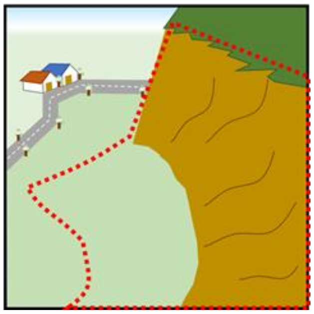
In all regulation category, regulation maps will be distributed to residents within the regulated zone and to residents in the vicinity, and awareness-raising or socialization activities will be conducted on slope disasters.

Regulations for non-urbanized zones aim to prevent possible future slope disaster by applying restrictions on new construction activities in zones where there is no existing land use. The regulations for non-urbanized zones consist of two categories: high and medium hazard zones (Zone D) and low hazard zones (Zone E).

- ✓ **Vacant zone of high and middle hazard for slope disasters (Zone D):** this is the zones considered as high hazard (level 1) and medium hazard (level 2). These zones are not suitable for land use until countermeasure works are implemented. Therefore new construction is prohibited.
- ✓ **Vacant zone of low hazard for slope disasters (Zone E):** it is classified as a zone where no countermeasure works are required and new construction is permitted as long as it complies with the structural restrictions set by the AMDC.

Although there are no existing residents in Zones D and E, it is necessary to inform the people living around the zones about the dangers of slope disasters. Socialization activities will be carried out for the residents living in the vicinity of these districts.

Table 5 Regulation contents (JET)

	 Zones with more than one building	 Zones without any building
Hazard level	**Regulation category**	
High	**ZONE A** - Prohibition of new construction, amplification and remodeling - Relocation recommendation - Awareness activities - Distribution of regulation map	**ZONE D** - Prohibition of new construction
Middle	**ZONE B** - New construction and amplification are not allowed. Remodeling is allowed. - Awareness activities - Distribution of Regulation map	
Low	**ZONE C** - New construction, amplification, remodeling works are allowed. - Awareness activities - Distribution of regulation map	**ZONE E** - New construction works are allowed. - Awareness activities to people around the zone - Distribution of regulation map

The Article 13 defines that AMDC is able to recommend local residents living in high hazard zones (Zone A) to relocate from the land currently they occupy as the slope disasters are supposed to occur and the land is not suitable for settlement. The recommendation on relocation is understood as the method that request local residents to carry out their voluntary actions to reduce the risk on slope disaster, which means it is residents has definitive decision if they relocate or not.

Since the decision to keep living in high hazard zone does not increase the risk of slope disaster to other people, the restriction of private rights must be kept to a minimum. It is not appropriate to force relocation, but only to encourage voluntary actions.

AMDC shall promote effectiveness of relocation program by implementing measures to support the voluntary relocation based on recommendation (e.g., mediation for acquisition of new land).

3.2 Type of land use that can be implemented in each regulated zone

Articles 15, 16, 17, and 18 provide for the classification of land uses that are considered implementable within the regulated zones as permitted uses and land uses that are considered non-permissible as non-permitted uses. In the regulated zones, only the activities classified as "permitted use" can be carried out and any activities classified as "not permitted use" are not allowed.

The permitted use and not-permitted use are listed in the regulation. Simplified list is as shown below:

Table 6 Permitted use and not-permitted use in Category A, B and C (JET)

	Category A	Category B			Category C		
GENERAL USE	NEW CONSTRUCTION	NEW CONSTRUCTION	AMPLIFICATION	REMODELING	NEW CONSTRUCTION	AMPLIFICATION	REMODELING
STRUCTURAL AND NON-STRUCTURAL MITIGATION WORKS	P	P	-	-	P	P	P
HABITATIONALS/ UNIFAMILIAR LIVING	NP	NP	NP	P	P	P	P
EQUIPMENT	NP	NP	NP	P	P	P	P
GENERAL BASICS	NP	NP	NP	P	P	P	P

Table 7 Permitted use and not-permitted use in Category D and E (JET)

	Category D	Category E
GENERAL USE	NEW CONSTRUCTION	NEW CONSTRUCTION
STRUCTURAL AND NON-STRUCTURAL MITIGATION WORKS	P	P
HABITATIONALS/ UNIFAMILIAR LIVING	NP	P
EQUIPMENT	NP	P
GENERAL BASICS	NP	P

Regarding the land use which as not listed above, in high and middle hazard zones such as Category A, B and D, any type of land use is not allowed. In low hazard zones, any type of land use is permitted even though it is not mentioned in the list.

In addition, the land use classified in "DE SERVICIO", "PRODUCTOS", COMERCIO" and any other type of land use not listed is considered as non-permitted use in the zones A, B and D. The work license is not issued for any type of land use classified in these categories.

In medium and low hazard zones, even when land uses that are considered permitted uses are implemented, hazards still exist and rapid evacuation is required if necessary. Therefore, the number of stories for building structures is restricted and buildings must be no more than two stories high.

Chapter 4. Dissemination Activities Protocol

4.1 Identification of actors

Dissemination and awareness process is essential in the execution of any programs or projects, in order to ensure the involvement of the interested parties, as well as to ensure the successful execution and subsequent environmental and social sustainability of the projects or programs.

The key actors in terms of the dissemination activities of the regulation are listed in the following table. AMDC conducts the dissemination activities with not only collaborating the listed actors but also other necessary actors.

Table 8 Classification of actors (JET)

ACTOR	CHARACTERISTICS AND ITS ROLE	POSSIBLE PARTICIPATION IN TERMS OF DISSEMINTION OF THE REGULATION
INHABITANTS	**Local**: All natural and legal persons who live in the Central District	- Integration of CODEL, and interested in the development of their community. - Interlocutors with the AMDC for the choice of the most appropriate interventions. - Collaborators of the AMDC for the convening of meetings, councils, etc.
LOCAL EMERGENCY COMMITTEE CODEL	**Local**: It is the legal structure protected by the Law of the National System of Risk Management (SINAGER), coordinates and responds to the Municipal Emergency Committee (CODEM). It is the grass-roots community organization, which is organized and trained to assist its community in preventing, mitigating and rehabilitating emergencies or disasters, whether natural or man-made.	- Coordination of the dissemination activities with AMDC and residents - It supports and provides strategic information to AMDC in identifying landslide area. - It participates in socialization/implementation of measures - It develops and implements community-based risk management plans (PCGR).
GUÍAS DE FAMILIA	**Local**: groups of five persons responsible for identifying, supporting and training families living in poverty, extreme poverty, vulnerability and social risk and integrating them into the various programs of care, prevention, social assistance, social security and protection services.	- It supports for AMDC to collect the baseline information in the community - It supports local residents to participate in the dissemination and socialization activities.
MUNICIPAL UNIT FOR INTEGRAL RISK MANAGEMENT UMGIR	**Municipal**: General Coordinator of the dissemination activities. It shall ensure the proper implementation and fulfilment of its objectives and components by coordinating the participation of each and every one of the main actors and others involved in the implementation of the regulation.	- It coordinates the dissemination activities with COPECO and Mi Ambiente if necessary. - It provides to UGA, DOT, CODEM, DGCDH and IDEM with information on high hazard zones and any preliminary information that may be used for the implementation of the dissemination. - It is responsible for ensuring that improvements suggested by the community are implemented.
CIVIL WORKS MANAGEMENT GOC	**Municipal**: It carries out the specific technical supports. It coordinates with the Cadastral Management of the Directorate of Territorial Planning.	- It issues the cadastral reports of each site where the dissemination activities are carried out. - It submits periodic reports to UMGIR and special reports when requested by UMGIR
COMMUNITY MANAGEMENT AND HUMAN DEVELOPMENT DIRECTORATE DGCDH	**Municipal:** It is in charge of coordinating the social aspects of the dissemination and implementation of the regulation.	- It is responsible for the dissemination and awareness of the regulation. - It will be accompanied by IDEM and CODEM when the dissemination is to be done.
ENVIRONMENTAL MANAGEMENT UNIT UGA	**Municipal:** It is responsible for overseeing all environmental matters	- It gives the explanations on environmental assessments to the location where the structural measures will be implemented. - It gives the explanation on licensing processes or environmental certificates that are required for the execution of some construction activities.
DIRECTORATE FOR FINANCE AND ADMINISTRATION DAyF	**Municipal:** It is responsible for the coordination and regular preparation of budget projections for investments, and procurement.	- It is responsible for Budget management and request for disbursements.
MUNICIPAL MANAGEMENT PLANNING AND EVALUATION UNIT UMPEG	**Municipal:** It is responsible for managing the progress of public works projects implemented by AMDC and issue instructions to each agency to ensure that there are no discrepancies between plans and actual results.	- It is responsible for monitoring and follow up of the implementation of the projects or programmes related to socialization.
MUNICIPAL EMERGENCY COMMITTEE CODEM	**Municipal**: It is responsible for coordinating all actions oriented to prevention, response and recovery for emergencies or disasters occur in the Municipality.	- It certifies the Local emergency committee CODEL. - It supports with the dissemination and awareness of the regulation. - It support the collection of baseline information of the communities.
Gerencia Instituto de Desarrollo Municipal IDEM	**Municipal**: It is responsible for following up the activities of the Economic, Political, Educational, Environmental and Cultural projects and programmes of the residents in the Municipality.	- It contribute to collect the information especially demographic information on the regulated zones. - It supports other actors to implements the socialization activities.

4.2 Dissemination and awareness methods

The objective of the dissemination and awareness activities is that the population and communities in the Central District understand correctly the Regulation for slope disaster, and that AMDC applies smoothly the Regulation for slope disaster by obtaining the cooperation from the population and communities. In order to achieve these objectives, the effective dissemination and awareness is necessary. It is effective to conduct following dissemination methodologies that generate acceptance, awareness and social support.

The appropriate methodology shall be selected according to target's needs and characteristics (gender, mobility, literacy, disability, among others). The DGCDH, CODEM and IDEM will be in charge of planning and implementing dissemination and awareness activities. Followings are the example of the dissemination activities.

(1) Community meeting

The communities meeting shall be held by inviting groups of 20 -25 people representing the communities where each intervention regarding the Regulation for slope disaster is taken place. It helps the communities to understand the contents of the Regulation for slope disasters, and actions to be taken by the residents, as well as to have opportunities to express their opinions. It contributes to establish an ownership of the community in the regulation implementation.

(2) Call to 100 line

AMDC has a citizen service line called "Line 100", which is completely free in order to improve communication between the community and the institution. Through this service, communities are able to make their complaints and suggestions in term of the Regulation implementation.

(3) Social network service (SNS)

AMDC, taking into account the trend towards the use of SNS by residents and aiming to transmit effectively the message and information regarding the regulation, have the accounts in the following services: Facebook, Twitter, Instagram and Blogger. These services are managed by the Communications Unit who will transfer the query to the focal point.

(4) Face-to-face Attention

Citizens will have the opportunity to make inquiries and make suggestions, in person, by contacting the offices of the DGCDH through AER Citizen Service Management, all located in the offices of the executive building, La Ronda neighborhood.

4.3 Things to keep in mind when talking to residents

During the hazard evaluation or socialization activities, it is important that the participants understand the contents of Regulation for slope disaster and actions to be done by residents in regulated zones.

To talk to residents in regulated zones and acquire their clear understanding, AMDC shall take following points into account during socialization activities:

- ✓ All the actors must be invited (involved institutions, residents and organizations).
- ✓ Clear and concise information on existing problems in regulated zones due to landslides should be transferred without causing residents to panic or confuse.
- ✓ The contents of socialization shall include the key aspects of regulation such as type of slope disasters, regulation category, regulation map, action to be taken by residents.
- ✓ Socialization activities shall be implemented with dynamic participation by generating spaces for questions and answers.
- ✓ AMDC shall prepare informative documents to be distributed during the socialization activities such as poster, leaflet, etc.
- ✓ Installation of printed documents and information at the visible location of the regulated zone should be considered

Chapter 5. Application flow and formats

5.1 Formats for the work license

The GCC regulation[2] (commonly known as the GCC regulation) stipulates that work license is required when residents want to carry out construction activities in the Central District, regardless of whether or not there was a hazard on slope disaster. Therefore, a work license is required to be obtained for any construction activity in the zones regulated by the Regulation for slope disaster. The Regulation for slope disaster contributes to prevent or mitigate the damages due to the slope disasters by clarifying the regulated zones and not issuing the work license for activities that might increase the probability of slope disaster.

When construction activities are conducted in a regulated zone, the work license is required. The prerequisites for construction activities are provided in the Article 6. There are four (4) prerequisites for the work license that the owner of the property shall accepts. Conditioning factors may be required for four reasons:

1. Those conditions required to ensure compliance with the law, this regulation, other municipal regulations and special regulations.
2. Those conditions required to minimize negative impacts on neighbors and passers-by.
3. Those conditions required to ensure that damage to roads and other community infrastructure or equipment caused by the work execution process is repaired by the owner.
4. Those conditions required to minimize the negative impacts that the project may cause on the transportation of the sector where a project will be developed.

The criteria for work license for construction activities in each regulation category are also described later.

5.2 General explanation about the process flow in the AMDC

The flow on the regulation application is as shown below.

Table 9 Process and department in charge (JET)

Phase		Department, Unit in charge
1	Selection of the evaluation site	Detailed explanation is given in the manual of Output 3
2	Implementation of the hazard evaluation	Detailed explanation is given in the manual of Output 3
3	Designation of regulated zone and regulation category and establishment of regulation map	DOT and GER
4	Application of regulation contents	DOT, GCC, GER, UMGIR, CODEM, IDEM, and DGCDH

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[2] Articles 24 and 25 of the Construction Regulation (GCC Regulation)

1. Selection of the evaluation site

The sites where the hazard evaluation is conducted should be selected based on the Inventory map (Inventario Deslizamientos JICA). The detailed methodology is explained in the Manual for the Creation of Hazard Map/ Risk Map of Slopes prepared by Output 3.

2. Implementation of the hazard evaluation

GER will conduct the hazard evaluation. AMDC's team for the hazard evaluation shall bring the evaluation sheet and conduct the hazard evaluation by checking the geological, topographical situations in the zones.

3. Designation of regulated zone and regulation category and establishment of regulation map

DOT checks and approves the contents of hazard evaluation. After the approval, DOT instructs GER to clarify the regulation catgory and to make the regulation map of the evaluated zone in order to officially apply the Regulation for slope disaster.

Apart from the hazard evaluation, it is necessary to confirm if there is an existing building or more in the evaluated zone in order to decide the regulation category. If there is more than 1 existing building, the zone shall be classified as Zone A, B or C according to the hazard level. But if not, it is classified as Zone D, or E. Following table shows the relation between hazard level and existence of building in the evaluated zone.

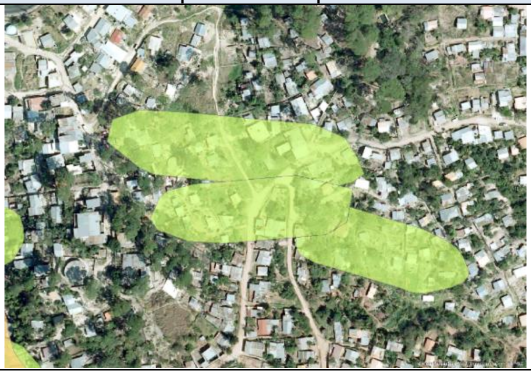
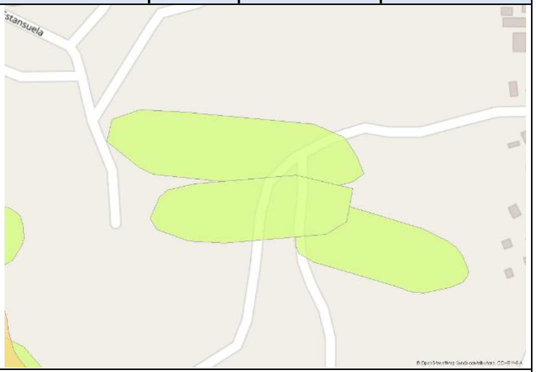
Table 10 Hazard evaluation and Regulation category (JET)

	Urbanized zones: Zones with more than one building	Non-urbanized zones: Zones without any building
Hazard level	**Regulation category**	
High	**ZONE A**	**ZONE D**
Middle	**ZONE B**	
Low	**ZONE C**	**ZONE E**

In order to confirm if there is an existing house in the evaluated zone, a map with aerial photo shall be used on the ArcGIS application. Map with aerial photo shows the latest condition of the regulated zone and helps to calculate the number of houses in the zones more accurately. So, the regulation category shall be defined based on the aerial photo. Even though map with OpenStreetMap© is not convenient to calculate the number of houses, it shows the location of roads and regulated zones more clearly than aerial photo. So, the socialization activities shall be conducted with regulation map with OpenStreetMap©.

In this background, AMDC need to prepare the regulation map with 2 different type of base maps according to the purpose. Following table shows the case of a zone in the Central District with 2 different base map.

Table 11 Sample of the regulation map of the same place (JET)

	Map with aerial photo	Map with OpenStreetMap©
Image		
Points	It is convenient for calculating the number of houses in the regulated zones.	It is convenient for explanation of the principal routes in the community.

N.B.: Sample images are not correspond to the actual hazard level nor regulation category.

4. Application of regulation contents

Once the regulation map is established and published to residents, the Regulation for slope disaster is officially applied. GCC is in charge of issuance of the work license which is required for the construction work in the regulated zone. GCC shall check whether the application documents submitted by the residents comply with the requirements and whether the construction activities are in the regulated zones.

The buildings which are partly included in the regulated zones must be subject to the regulation. Following figure shows the buildings to be regulated as ▨ and building not to be regulated as □.

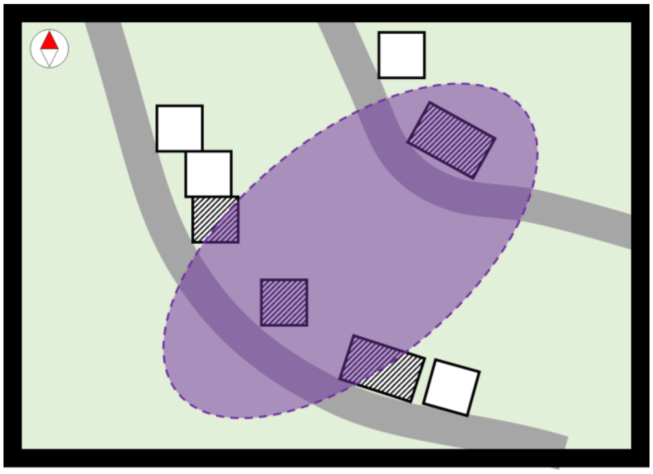
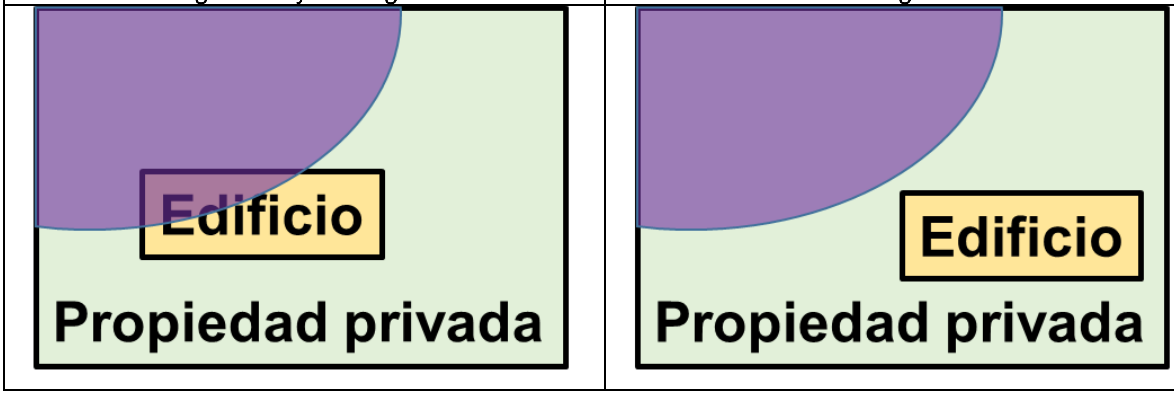


Figure 16 Building to be regulated and not to be regulated (Case of Zone A) (JET)



Regulated by ther reguted

Not regulated

Figure 17 Building to be regulated (JET)

5. Action to be taken after the slope movements

The regulation can be applied only based on the result of hazard evaluations. AMDC shall conduct the hazard evaluation in the affected zones immediately after the slope movement because the slope condition has changed. AMDC shall immediately apply the regulation and creates or updates the regulation map.

5.3 Case study for regulated zones

5.3.１ Basic procedures for construction work in the Central District

The basic procedures for construction work in the Central District proceed as follows. When an application for a work license is received from a resident, GCC is in charge of the department that will deal with the application, referring the application to the relevant department and deciding whether a work license can be issued.

In the case of construction work in zones without risk for slope disaster, GCC instructs residents to obtain the necessary documents for obtaining a work license from the following departments.

Table 12 Basic flow to request the work license (JET)

Actions	Responsible department
Presentation of the document (receiving the document from the residents)	GCC
Creation of cadastral code is done	Catastro
Risk Assessment Report is issued	GER
Environmental Permission is issued	UGA
Work license is issued	GCC

5.3.２ Case study

At the application phase, the restriction and limitation of the construction activities are applied according to the regulation category. Following table shows the regulation contents applied in each regulated zone.

Table 13 Case study for impelementation of regulation (JET)

Case Study		Zone A	Zone B	Zone C	Zone D	Zone E
1	Relocation	X				
2	New construction in ZONA A, B and D, and amplification in Zone A and B	X	X		X	
3	New construction 2 (ZONA C and E)			X		X
4	Amplification (Zone C)			X		
5	Remodeling (ZONA B and C)		X	X		
6	Socialization 1(informative meetings)	X	X	X	X	X
7	Socialization 2(installation of regulation map)	X	X	X	X	X
8	Modification	X	X	X	X	X
The cells checked as “X” corresponds case study						

1. Case 1: Relocation recommendation to existing houses in ZONE A

For the existing residents in the zone A, AMDC is able to recommend relocation. The relocation recommendation to the existing residents can not be enforced. The recommendation is only given to request residents to carry out voluntary actions. So the residents are able to decide whether or not to follow the recommendation.

AMDC visits to the houses in the zone A one by one in order to conduct the explanation and recommendation by giving the official letters. Following table shows the necessary actions related to the recommendation.

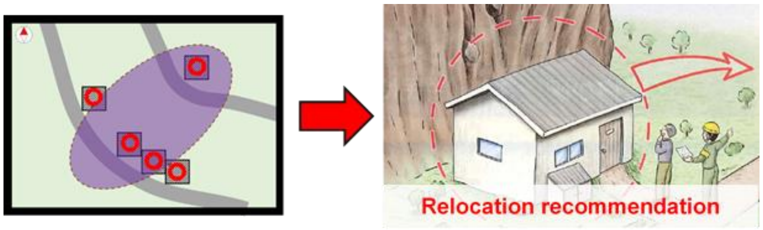


Figure 18 Relocation recommendation (JET)

Table 14 Action flow to reques the relocation (JET)

Actions	Responsible department
Establishment of regulation map	DOT and GER
Establishment of socialization schedule	DGCDH, UMGIR, CODEM, and GER
Preparation of the official letter on relocation	Legal and DOT
Arrangement of the visit to residents	DGCDH, CODEM, and GER
Implementation of the visits to residents	DGCDH

2. Case 2: New construction in ZONA A, B and D, and amplification in Zone A and B

Before the issuance of work license, GCC checks whether a new construction is allowed in the zone. New construction on any type of land use is not allowed in ZONE A, B, and D. Amplification work in not allowed in the Zones A and B.

Table 15 Action flow to dismiss the application for work license (JET)

Actions	Responsible department
Presentation of the document (receiving the document from the residents)	GCC
Revision of the documents	GCC
Decision not to issue the Work license	GCC

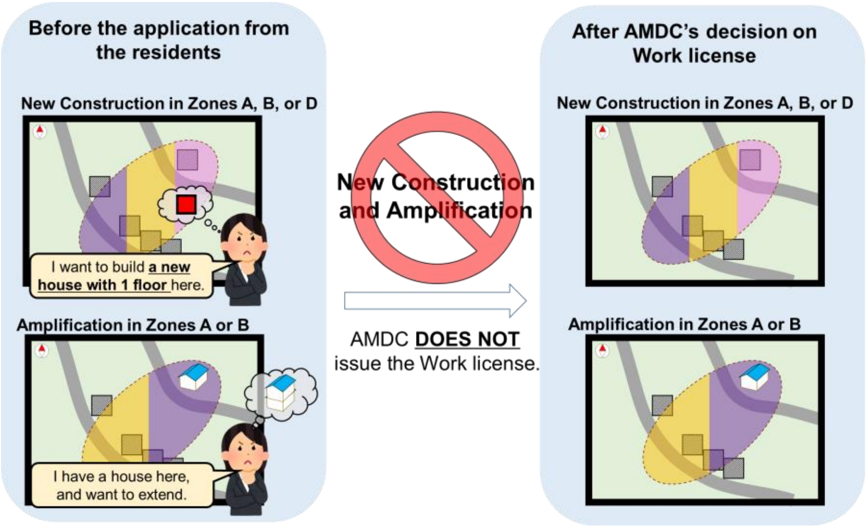


Figure 19 Decision on if the work license is issued for new construction and amplification work in zones A, B, and D (JET)

3. Case 3: New construction 2 (ZONA C and E)

Before the issuance of work license, GCC checks whether the type of land-use is classified as "Permitted use" or "Not-permitted use" and the structure of the building to be constructed. In Zones C and E, new construction of any type of land use is allowed in case that the building to be constructed is no more than 2 stories.

In case that the application for the building more than 3 stories is submitted and that GCC verified contents, the application for work license is immediately dismissed. In addition, if a house is built in Zone E, the applicable regulation category is changed into Zone C, as it falls within an urbanized zone (where there is more than one building). The GER will therefore have to update the regulation map.

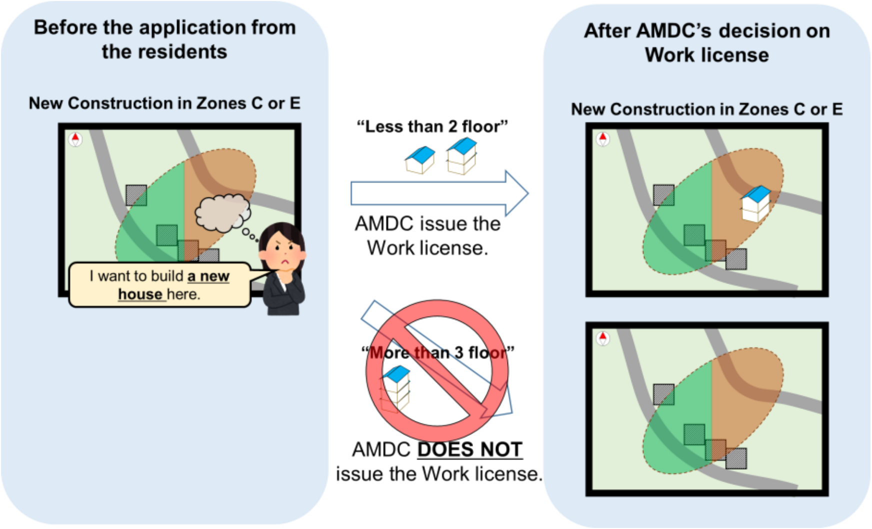


Figure 20 Decision on if the work license is issued for new construction in zones C and E (JET)

4. Case 4: Amplification (Zone C)

When an application for amplification work is submitted from resident, GCC checks whether the type of land-use is classified as "Permitted use" or "Not-permitted use". In zone C, amplification work for any type of land use is allowed in case that the building to be constructed has less than 3 floors. It should be also noted that other regulations, such as the GCC regulations, which set building coverage and height limits, also are applied, so GCC must take into account when it checks application documents from the residents.

In case that the applied land-use is classified as "Not-permitted use" or the applied building will have more than 3rd floors, the work license is not issued.

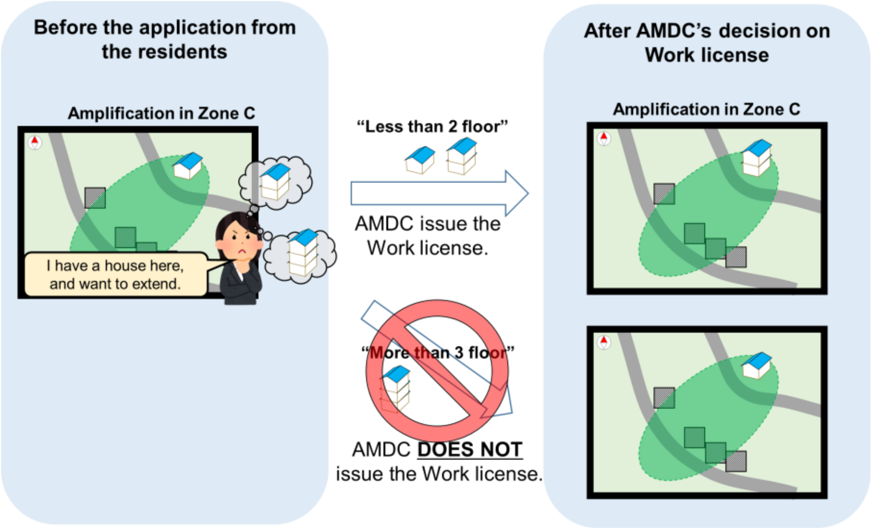


Figure 21 Decision on if the work license is issued for amplification in zones C (JET)

5. Case 5: Remodeling (ZONA B and C)

Before the issuance of work license, GCC checks whether the applied land-use is classified only as remodeling work. The term 'amplification' means 'adding additional floor space' to an already existing building. Constructing a separate building is also regarded as an amplification work. The term 'remodeling work' refers to the partial or total demolition and rebuilding of structural parts of an original building. Increasing floor space is an amplification work.

In zone B and C, remodeling work for all type of land use is allowed. The remodeling work to existing building in the zone A is not allowed.

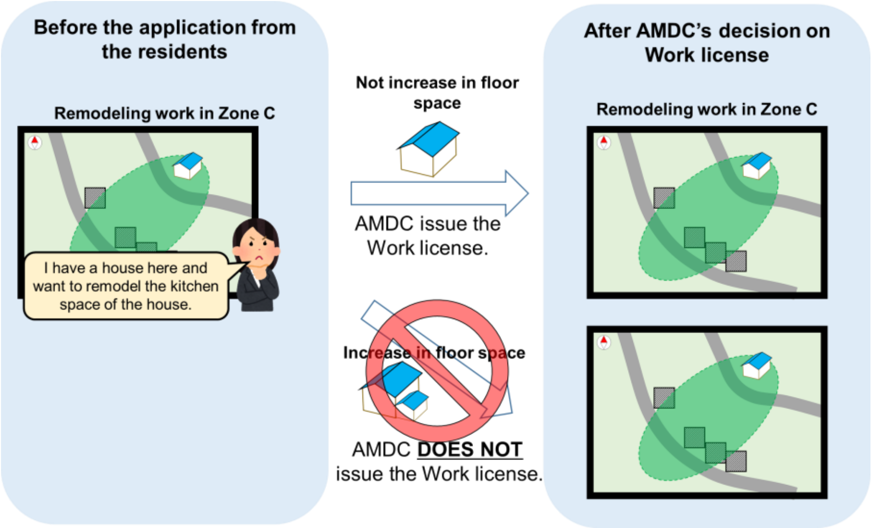


Figure 22 Decision on if the work license is issued for remodeling work in zones C (JET)

6. Case 6: Socialization 1(informative meetings)

Dissemination and awareness activities are conducted to the residents living in all the regulated zone and those who living around the zones D and E. Following actions shall be implemented for the dissemination and awareness activities.

Table 16 Action flow to implement the informative meetings (JET)

Actions	Responsible department
Establishment of regulation map	DOT and GER
Distribution of regulation map	CODEM, IDEM, and DGCDH
Arrangement of the meeting schedule with residents	CODEM
Establishment of the explanation documents	CODEM and IDEM
Implementation of the informative meetings	CODEM, IDEM, and DGCDH

The table above shows an example of the informative meetings, but the methodology for socialization shall be selected according to the target characteristics.

7. Case 7: Socialization 2(installation of regulation map)

Regulation maps and informational signs regarding the regulation are installed around the regulated zones or at the entrances to the regulated zones. The required activities are shown in the table below.

Table 17 Action flow to implement the installation of regulation map (JET)

Actions	Responsible department
Establishment of regulation map	DOT and GET
Decision on installation location of the regulation map	DODEM
Order for production and printing of maps for installation (Department to bear the budget)	DGCDH and UMGIR
Installation of the regulation map (Department to bear the budget)	CODEM and DGCDH

8. Case 8: Change in regulation category

As it is explained above, the hazard evaluation is conducted by GER and the result would be approved by DOT. Once the approval from DOT is issued, GER creates the regulation map with GIS application. This flow is the same in case that slope condition change due to natural or artificial event.

When countermeasure works are implemented in a regulated zone, the hazard evaluation is conducted and the regulation category applied in the zone is changed according to the evaluation results. For example, if countermeasure works are implemented in Zones A and B, and the hazard evaluation after the countermeasure works classify the zone as low hazard, the regulation category is changed to C. If countermeasure works are implemented in Zone D, and the result of hazard evaluation is low hazard, the regulation category is changed to E.

On the other side, it is also possible that the regulated category would get strict due to natural or artificial event that increase the probability of slope disaster. For example, if a landslide or slope failure occurs in Zones B and C, and that topography of the zone gets changed, the hazard evaluation should be conducted immediately after the event in order to identify the latest hazard level. In addition, the regulation category to be applied to the zone in question is changed according to the latest hazard level. In this case, if the hazard level is evaluated as high hazard after the event, the zone is changed to Zone A, or if the hazard level becomes medium hazard, the zone is changed to Zone B.

In the event of a confirmed violation, such as new construction activity in Zones A and D, AMDC will impose penalties in accordance with the Regulation, and will also handle the following

✓ Newly constructed buildings will be promptly demolished and vacated or relocated.
✓ Any additions to the building for non-permitted uses will be demolished as soon as possible.
✓ If other related regulations exist in the AMDC, they will also be applied.

5.4 Roadmap for the issuances of work license

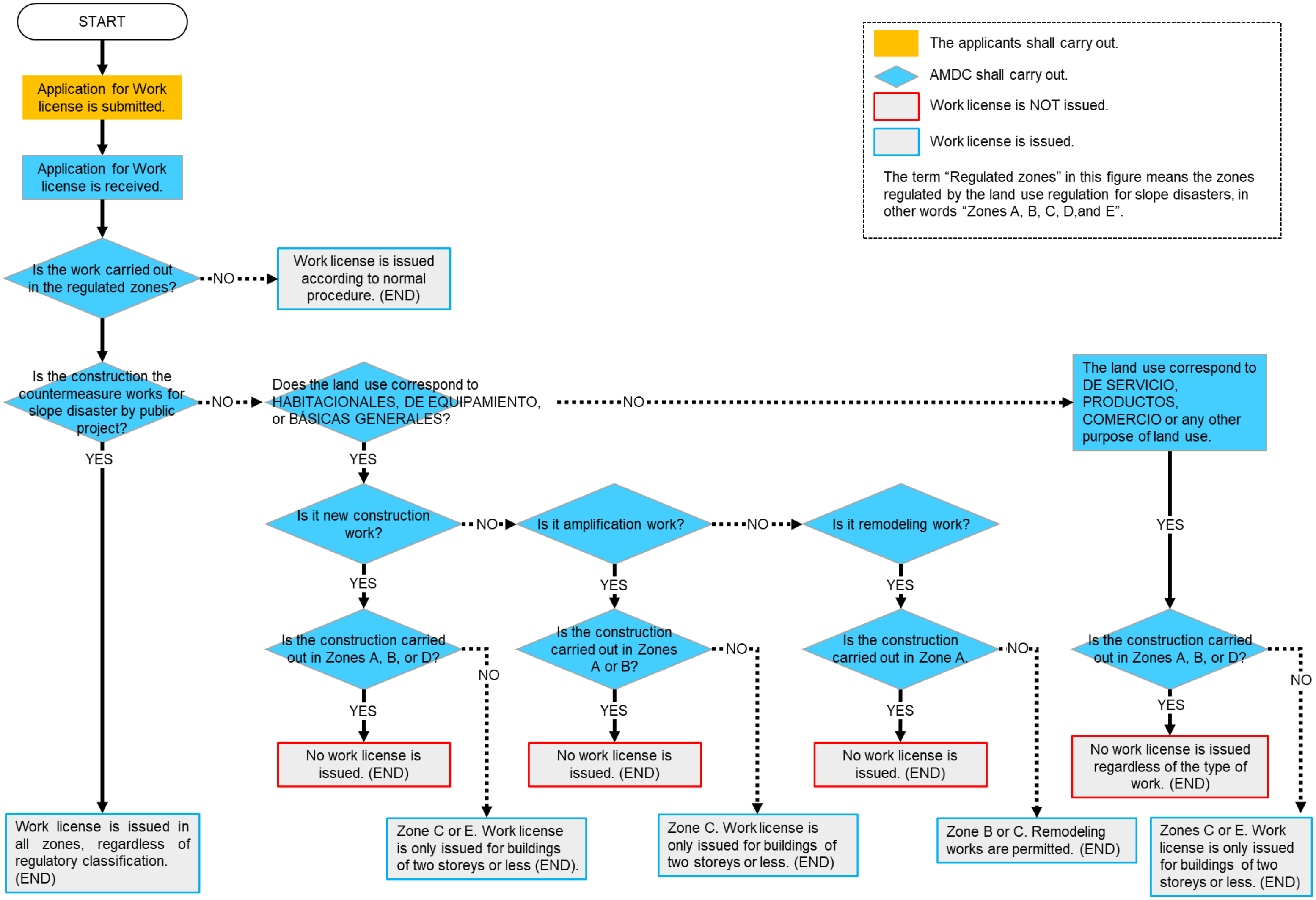


Figure 23 Roadmap for the issuances of work license (JET)

Chapter 6. Questions and Answers

The following table shows the example of Q&A.

Table 18 Example of Q&A (JET)

	Questions	Answer
1	What to do if one property exists in a regulated zone (for example in zone A) and non-regulated zone?	In this case, the regulation for the A zone will be applied. As it is explained in 5.1, all the buildings which are partly included in the regulated zones must be subject to the regulation. As the regulation is applied in order to protect the life and property in the regulated zone, it is better to apply the rules more strictly.
2	When a resident wants to construct a new house in the zone C, what kind of procedure should he/she conduct apart from the work license?	The applicant shall conduct all the necessary procedure to construct a building. For the regulation, there is no additional procedure apart from the normal procedure. It is necessary to conduct the procedure for Cadastral code of Catastro, Risk Assessment Report of GER as well as Environmental permission of UGA before he/she requests the work license.
3	I want to build a house with 2 floors in C zone. Does AMDC issue the work license for this case?	When a building is constructed in the regulated zone, not only the regulation for slope disaster but also other regulations are applied. In this case, the height defined in GCC regulation shall be applied.
4	I want to build a house with 2 floors to fill the entire property (building coverage is close to 100%). Does AMDC issue a work license?	The work license is issued when the building does not violate the building coverage standards defined in the GCC regulation.
5	Does AMDC define the regulated zones and regulation category without resident's opinion?	The regulation category is decided only based on the hazard level. And the range of regulated zones is decided based on the affected zones. It is important that the residents in the regulated zones understand the danger of slope disasters and conduct necessary actions. AMDC explains the purpose and contents of the regulation to residents.
6	I'd like to know the locations of regulated zones in the Central District.	Once AMDC conducts hazard evaluation and designates the regulated zones, the regulation map is distributed to residents. It is also published on website. The residents can confirm the locations by contacting AMDC directly.
7	I have a land and a building such as apartment in regulated zone. But no one wants to live in my property anymore as AMDC declares that my apartment is in the zone B. I would like to request AMDC to give the compensation for the decline in the property value of my apartment.	AMDC designates regulated areas in order to identify and inform residents of the risk of their land to slope disaster. The regulated zones are designated based on the judgment that the protection of life and property takes precedence over the economic impact of the designation. For this reason, the AMDC does not provide any compensation against loss of property values.
8	I live in zone A, but the landowner lives in another area. If I relocate according to the regulation for slope disaster, am I not obligated to pay rent to the landowner from when I relocate?	As the regulation for slope disaster intends to protect life and property, the residents currently living in the regulated zones are subject to relocation recommendation. Since the recommendation is not enforceable, it is current residents who decide whether he/she relocates or not. The rent should not be charged after the relocation. But to avoid any problem, the current residents need to discuss with the landowner on this topic.

Chapter 7. Relevant laws and regulations

The following shows the national laws and municipal regulations related to the Regulation for slope disaster.

7.1 National law

1. Law on National Risk Management System (SINAGER)

SINAGER, enacted in 2010, aims to establish a legal framework for the development of national capacities to prevent and mitigate human and natural disaster risks, and to respond, rehabilitate, and recover from the damage caused by disasters. SINAGER is also subdivided into subsections. The SINAGER bylaw (Regamento de la ley del SINAGER) is a detailed regulation of SINAGER.

2. Territorial Planning Law

The law, established by Decree No. 180 of 2003, stipulates that the management of risk areas is the responsibility of the municipality and that the municipality has the authority to establish regulations required for the management of risk areas.

According to Articles 31 and 38, land use plans must be prepared at the national and municipal levels, and the identification of risk areas must be incorporated into theses plans. Furthermore, Article 88 stipulates that no residential or commercial construction or public works projects are allowed in areas identified by local governments as having a risk of exposure to slope hazards and flooding, unless approved by the municipality in question.

3. Municipal Law

Established by Decree No. 134-90 of 1990, this law regulates matters related to the establishment of local governments and the operation of local governments. According to Article 13, it is stated that the local government is responsible to make and implement the municipal urban development planning and has the authority to establish regulations for land use.

7.2 Existing regulation in AMDC

1. Regulations on zoning, works, and land uses in the Central District

This regulation was issued in the Official Gazette "La Gaceta" No. 33,415, dated April 30, 2014. This regulation establishes standards, procedures, and requirements for construction activities and land use in the Central District, and stipulates that it shall be applied to projects and land uses related to the new construction, amplification, remodeling work, relocation, and demolition of buildings or structures.

GCC is the department that conducts the survey, approval, reporting, and issuance of various documents related to construction activities and land uses in the Central District, and that is responsible for the enforcement of this regulation. Therefore, this regulation is known as the "GCC Regulation" or "Construction Management Regulation".

- ✓ Article 24, "Work Licenise": a work license in this regulation refers to a license issued by the municipality to carry out construction, reconstruction or demolition of buildings, work related to cut and fill, pave roads, construction of drainage facilities, and installation of structures or projects causing a change of land use.
- ✓ Article 25 "Obtaining a Work License": a work license from the GCC is required for any construction work carried out in the Central District. Any construction work started without a work license shall be stopped under the guidance of the AMDC's Civil Administration Department and shall not be resumed until a work license is obtained.

2. Regulation for Disaster Risk Reduction in the Central District

This regulation was issued in Official Gazette No. 34,469 of October 18, 2017. The purpose is to establish regulations on disaster risk reduction, climate change adaptation, and land use planning. It is also known as the "Risk Assessment Regulation" or "GER Regulation" because it requires that all construction and land use development projects in disaster risk areas in the Central District undergo a risk assessment by GER prior to the start of the project.

The assessment for the Risk Assessment Report is prepared by GER during the procedure to examine whether the work license can be issued. The assessment is carried out based on AMDC's multi-hazard maps, risk assessment manuals prepared by COPECO, and other document as well as field surveys.

On the other hand, the hazard evaluation of the Regulation for slope disaster is conducted based on the evaluation sheet which evaluate topography, geology, and countermeasure status of the target slope itself. After the evaluation, the regulation category is decided.

Therefore, when construction activities in zones where there is a hazard of slope disasters is carried out, the application submitted by residents for the work license shall be necessary to comply with the requirement of GER regulation too, since the materials referred to are different.

The following are excerpts from provisions related to the Regulation for slope disaster.

- ✓ Article 7 "Licenses and Permits": Persons conducting construction activities or land use in the Central District must obtain the following licenses and permits

A) Work License: A risk assessment of the area in question by the GER must be carried out prior to project implementation. The developer must implement the adaptation and mitigation measures required to reduce the risk in case that GER instruct so based on the risk assessment.

- ✓ Article 16 "Establishment of Affected Areas": Based on the risk assessment by the GER, the hazard and affected area, etc. shall be established for each area. UMGIR shall participate in this assessment, and DoT and GCC shall have the authority to change or determine land use objectives according to the results of the risk assessment by GER.
- ✓ Article 17 "Preparation of an Emergency Disaster Risk Reduction Plan": Any individual or legal entity that owns commercial real estate in a high hazard area for slope disasters or flooding must have an emergency disaster risk reduction plan approved by the CODEM and COPECO.

Chapter 8. Reference

NPO Sediment Disaster Prevention Publicity Center (SPC), https://www.sabopc.or.jp/ (Viewed on April 25th, 2023)