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Hillside Works - Guidelines on the Restoration of Vegetation on Wasteland -

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概　要

山腹工を計画する際に必要となる、整備目標の設定、整備手法、整備目標に対する評価について論じる。
また、わが国における最近の山腹工実施事例を収集・整理し、各現場で行われている山腹工の実例を紹介し、山腹工を導入する際の手引きとして導入することを目的としてとりまとめたものである。

キーワード：山腹工、植生回復

Synopsis

The methods for setting goals, installing and assessing hillside works were discussed in this report. Some recent hillside works and the procedures of installations were also collected and introduced as a guideline for installing them.

Key Words: hillside works, restoration of vegetation

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Hillside Works

Guidelines to the Restoration of Vegetation on Wasteland

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1. Before execution hillside works

1.1 What are hillside works?

(1) Restoring vegetation to control constant sediment runoff.

- *Sabo* projects have long been carried out as hillside works and torrent works executed as part of flood control projects to prevent sediment disasters along downstream rivers. Hillside works that are positioned as hillside projects are a type of work that can be defined as the foundation of *sabo* that controls the constant sediment runoff by restoring vegetation on collapsed land in water resource areas and deforested land where sediment is produced.
- Hillside works are categorized as 1) hillside foundation work that stabilizes slopes on hillsides and prevents erosion of the slopes, 2) Hillside revegetation works to restore greenery by transplanting trees to prevent or mitigate the occurrence or expansion of ground surface erosion or the collapse of surface layers on collapsed land and deforested land, and 3) Hillside slope reinforcement to increase the resistance to collapsing of collapsed ground or a collapse itself. Executing these individually or in appropriate combinations controls the production of sediment.

(2) First restricting the motion of sediment on the hillside slope by hillside foundation work or hillside slope reinforcement work is counted on to encourage the natural invasion of vegetation.

- First, the movement of sediment is controlled by hillside foundation works to stabilize the hillside slope, guaranteeing the foundations of a habitat for vegetation. After the hillside foundation work has been executed, the hillside is monitored in expectation of the natural invasion of vegetation.

(3) When it is not possible to count on the natural invasion of vegetation, further hillside revegetation work is performed.

- When rapid revegetation is necessary to control sediment, or when the natural formation of vegetation cannot be counted on because of local conditions (there are no nearby stock trees for example) further hillside revegetation work is done to help establish vegetation.

Tsuchiyabara hillside work: Early stage of execution in 1989

Tsuchiyabara hillside work: 2001
The natural recovery of grasses and trees can be seen.

1.2 To avoid failure

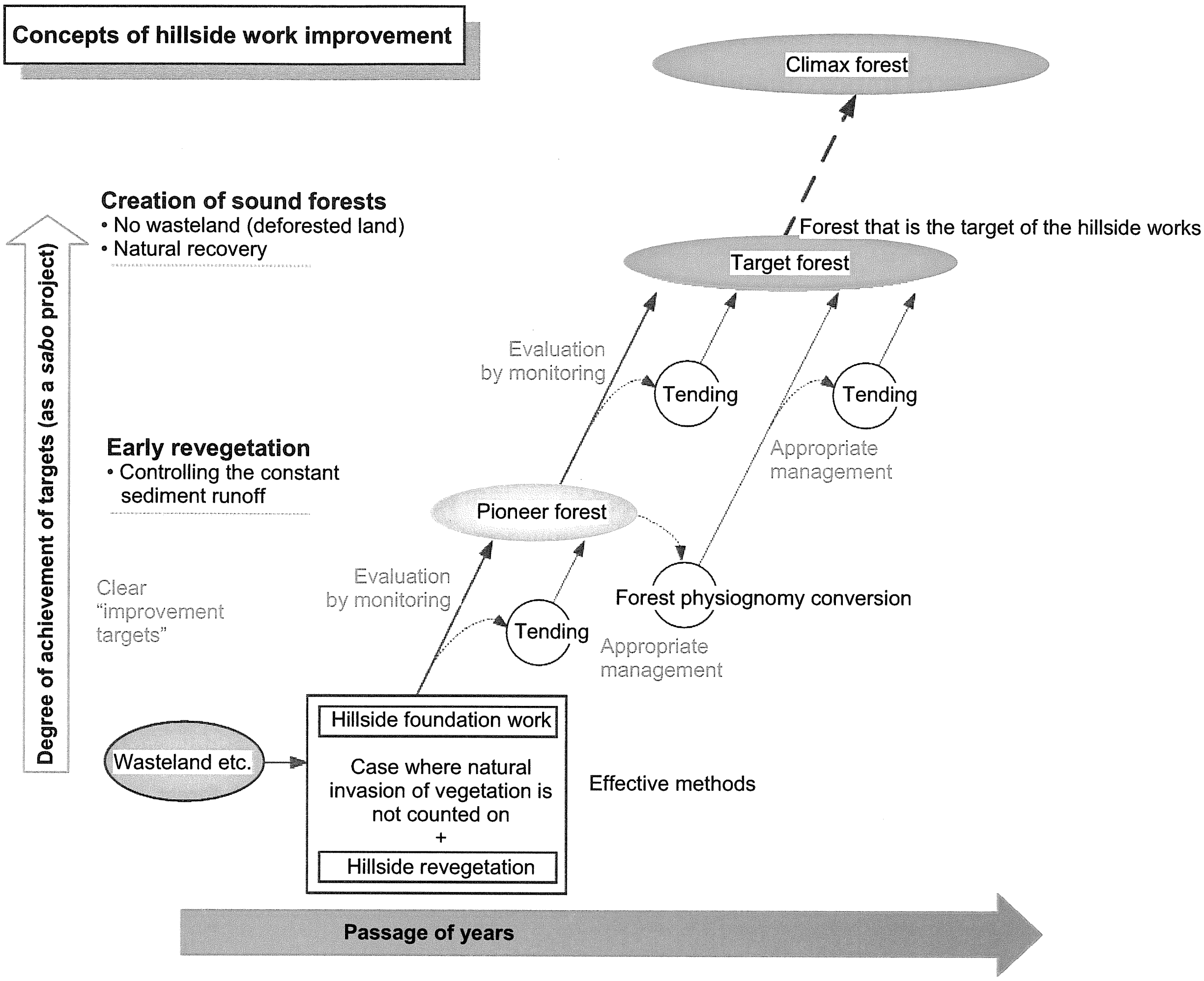
(4) Clarifying the improvement targets.

(5) Selecting effective "methods"

(6) Evaluating the degree of achievement of the goals over years

(7) Performing management appropriate to conditions

- Hillside works unavoidably have unexpected results, because the improvement is done taking advantage of the effectiveness of vegetation (living organisms) according to the characteristics of the work method. Measures necessary to avoid failure are clarifying the improvement targets of the *sabo* project, initially selecting effective methods to achieve these targets, evaluating the degree of achievement by observing the state of the vegetation over years, and to support the achievement of the targets according to circumstances, introducing appropriate management such as tending the vegetation or forest physiognomy conversion.



Pioneer forest: a forest of early maturing deciduous broad-leaved trees such as Japanese alder (*Alnus japonica (thunb.) steud*) or oleaster (Elaeagnus) that are resistant to drying and oligotrophic conditions and have nitrogen fixing capacity.

Target forest: a forest that has moved from the pioneer forest stage to a stage where it consists mainly of deciduous broad leaf trees such as *konara* oak (*Quercus serrata Thunb. ex. Murray*) and sawtooth oak (*Quercus acutissima Carruthers*).

Climax forest: Forest that has stabilized in dynamic equilibrium so that its structure and species configuration (species configuration varies according to environmental conditions) remain unchanged.

2. Improvement targets

2.1 What degree of improvement is considered as a *sabo* project

(8) First, considering early revegetation as a transitional point in the improvement.

(9) Simultaneously improving with the formation of the target forest as the first target.

- It is assumed that control of the constant sediment runoff can be almost achieved when, following the execution of the hillside foundation work, the pioneer vegetation has been established either by natural invasion or by hillside revegetation work, or by covering the slope surface. In the past, improvement was done from this perspective by considering early revegetation to be the first step.
- On the other hand, because trees that are primarily pioneer vegetation lack diversity and are unstable, according to circumstances, it is possible for this vegetation to deteriorate, allowing the restoration of wasteland conditions. There is also a demand for efforts to conduct projects to achieve genuine natural restoration as a consequence of the recent growing concern with the natural environment. Consequently, as a *sabo* project, its object must be the creation of a sound forest consisting of stabilized vegetation, and the improvement must be undertaken with the creation of the target forest that is the bridge to formation of the climax forest as the goal.

Target forest and secondary forest

The working group previously used the term "secondary forest" as the forest that is the target of hillside work, in the sense that the goal is a vegetation colony of the constituent species that are identical to those in a secondary forest.

Because the original meaning of "secondary forest" is a forest that naturally recovered after the virgin vegetation had been destroyed by a forest fire, intensive rainfall, or insect pests etc., in this case, it means a forest growing on preexisting forest soil. Because the term "secondary forest" may cause misunderstandings, "secondary forest" has been replaced by "target forest" as the word to define the target of hillside works.

2.2 To the formation of the target forest

(10) The constituent species of the target forest differ according to whether it is a warm or cool area, even under an identical temperate climate.

- Japan is classified as a temperate climate zone, but depending on whether it is a warm area or a cool area, the colonies established later vary. The transition of the large trees is generally the creation of the climax forest by the process—pioneer vegetation → deciduous broad leaf trees → coniferous broad leaf trees in a warm zone. But in a cool zone this process is the transition: pioneer vegetation → deciduous broad leaf trees followed by the replacement of these species to create the climax forest. As pioneer vegetation, the coniferous broad leaf medium and low trees (*Eurya japonica Thunberg*, longstock holly (*Ilex pedunculosa*)) the large trees (camphor tree (*Cinnamonum camphora*), *arakashi* (*Quercus glauca Thunb*), *shirakashi* (*Quercus myrsinaefolia*)) are established but these represent a transitional phase in the process.

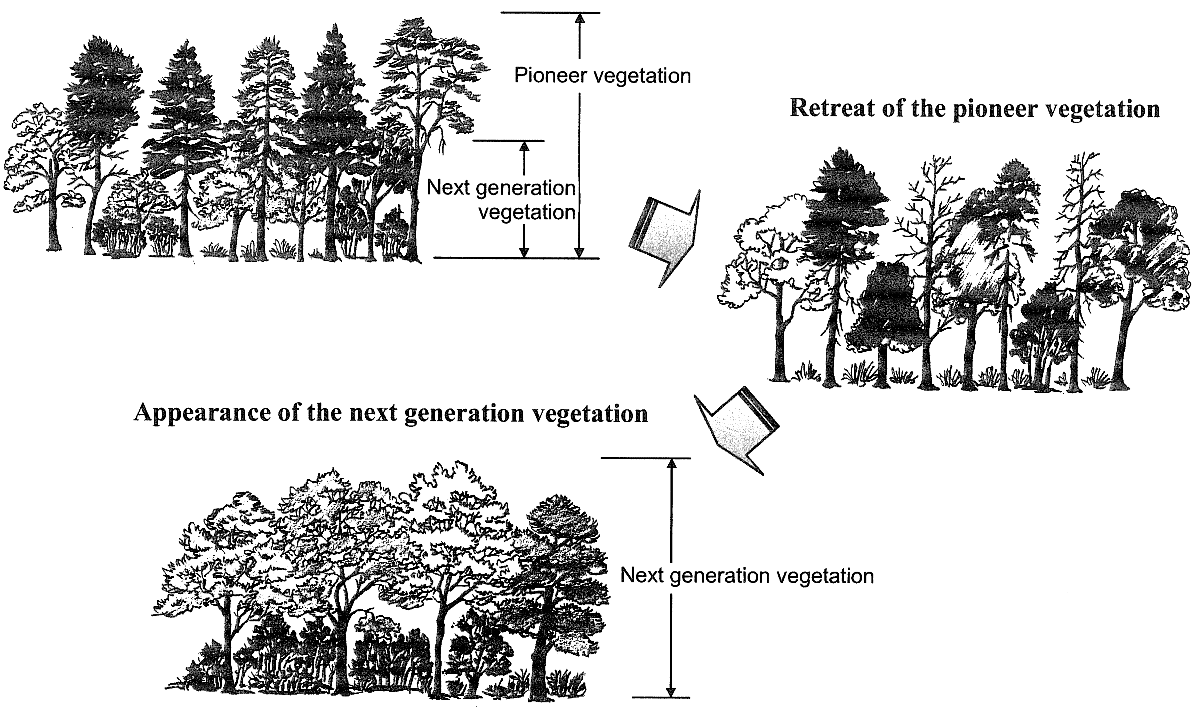
- The large trees of the target forest are, in warm areas, mainly *konara* (*Quercus serrata Thunb. ex. Murray*) but including sawtooth oak (*Quercus acutissima Carruthers*) and *abemaki* (*Quercus variabilis blume*), and in warm areas, the target forest consists generally of *mizunara* (*Quercus crispula Blume*), hornbeam (*Carpinus laxiflora*), or *itayakaede* (*Acer pictum*).

(11) Supplementing the formation of soil with pioneer vegetation to support the invasion by the next generation species.

- After execution of the hillside work, the soil conditions are not completely provided, so the formation of soil is supplemented by the pioneer species to support the invasion of the next generation species. In order that this be done effectively, it is necessary to select species suited to local conditions.

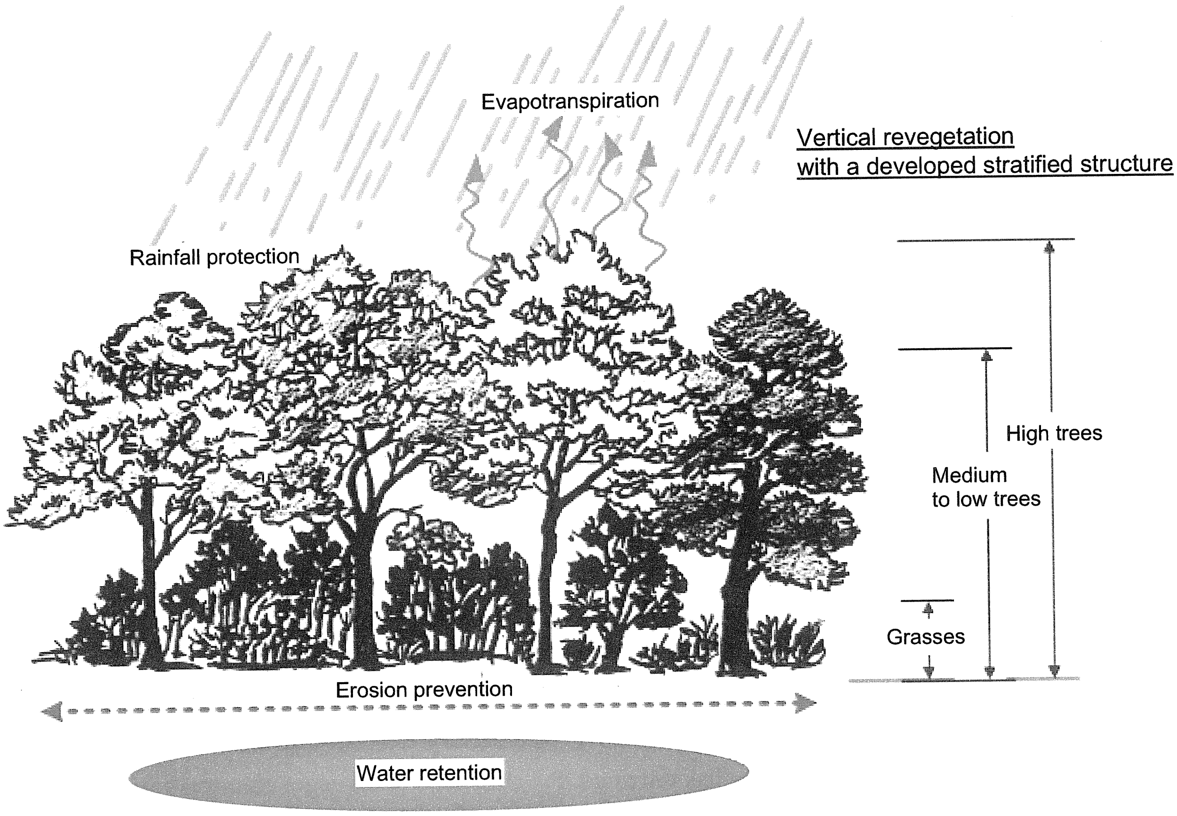
(12) Forming a diverse forest physiognomy

- In order to prevent a reversion to wasteland, it is necessary to form a diverse forest physiognomy so that when the pioneer vegetation has retreated, the next generation vegetation can appear.



(13) Forming a stand with a developed stratified structure.

- In order for the sediment runoff control function, water retention function and other functions of a forest to be effective, it is necessary to form a stand with a developed stratified structure.

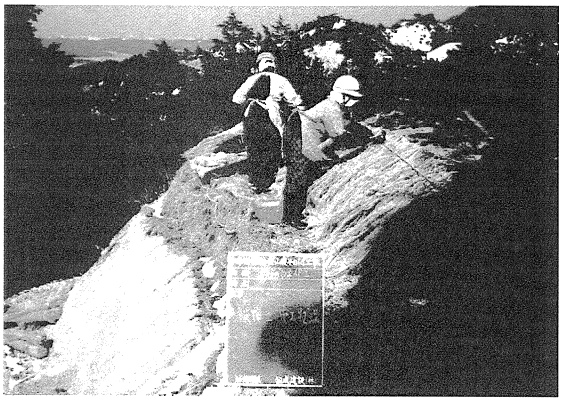


3. Selecting an effective method

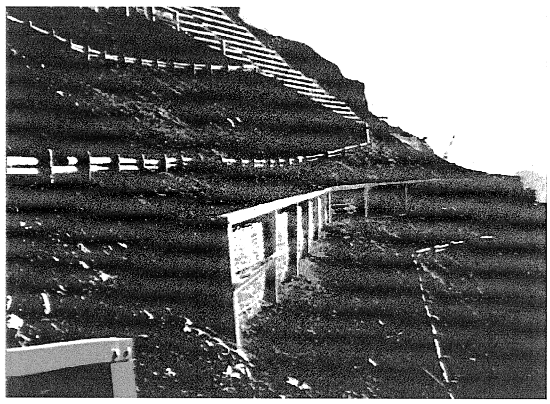
3.1 To restore greenery on hillside slopes

(14) The study is based on a work method that can guarantee flat land on terraces with a slope gradient of 10° or less.

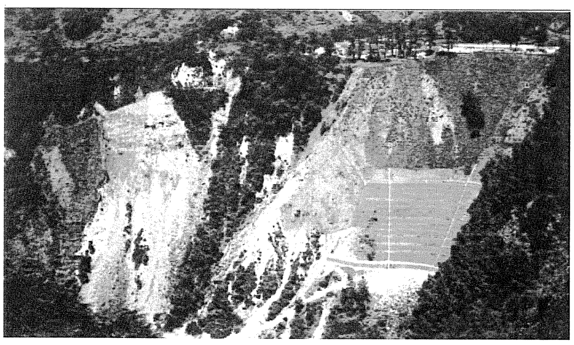
- To guarantee the foundation for the growth of vegetation, it is important to create the foundation in the form of terraces along the contour lines of the hillside foundation work to create flat surfaces with a slope gradient of 10° or less. This increases the certainty of the formation of a future forest. But if it is difficult to guarantee flat parts on the top of the slope for example, stabilizing it with net work etc. will be unavoidable, and work methods suited to circumstances are selected.



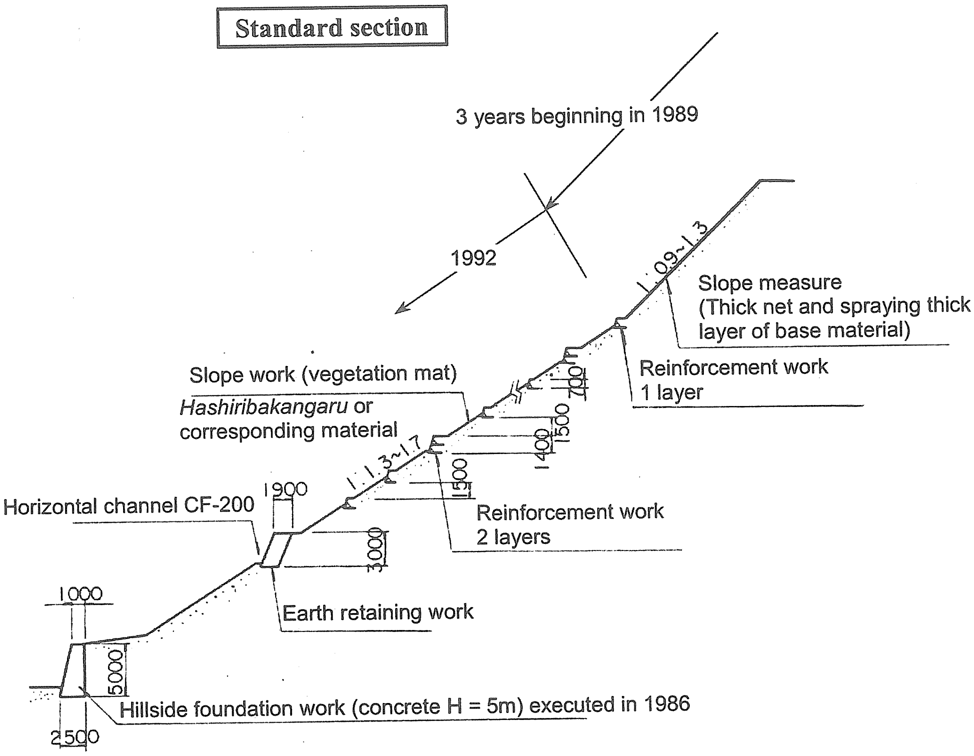
Tanakami hillside work: Initially slope surface treatment between seedling terracing work was not done, but because the seedling terracing work was buried by sediment, straw covering was done beginning in 1960. This stabilized of the slope and the trees grew normally.



Onagi hillside work: on the earth retaining work,scoria that is easily moved by the wind etc. was firmly solidified.

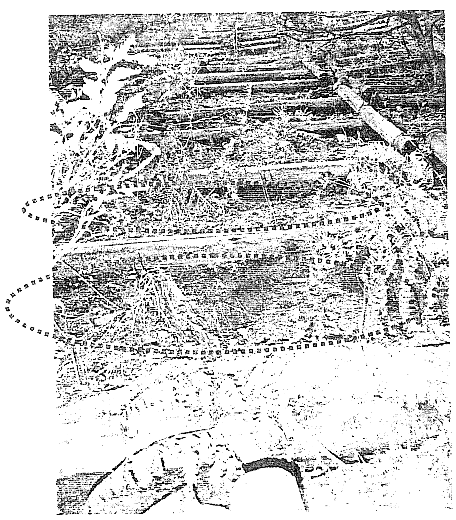


Mizutani hillside work:	**hillside foundation works are selected according to the slope gradient.**
Gentle slope:	**earth returning work + vegetation mat**
Steep slope:	**net work + spraying a thick layer of base material**

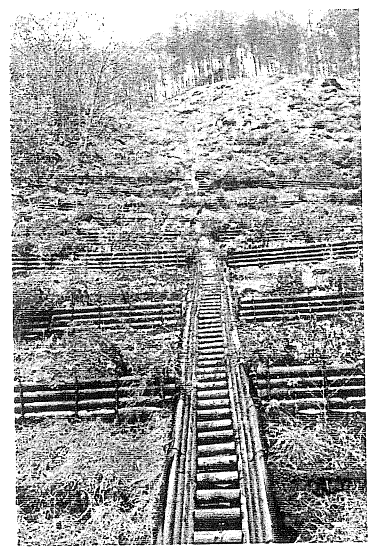


> (15) The topography is accurately assessed to perform dependable treatment of the surface water and the underground flow on the slope.

- In order to more firmly establish the greenery, it is important to accurately assess the topography to treat the surface water and the underground flow on the slope.



Tsuchiyabara hillside work: The surface flow on the slope scours the ground under the thinned material so that is above the ground, allowing the sediment to move. This delays the recovery of the vegetation.
*** Countermeasures are now completed.**



Nomugi Pass hillside work: As in the case of the Tsuchiyabara hillside work, thinned material is used to make the foundation work, but the surface and underground water flows are appropriately performed so that no scouring can be seen.

(16) This a soil dressing work method with extremely good vegetation growth base improvement effects.

- If the soil particle diameter on the site of the base for the vegetation is too coarse or dense, the water content falls, encouraging the fall of voids, creating a shortage of water or air needed for the growth of vegetation. Soil dressing is an improvement method that restores the appropriate particle diameter constituency, and the more soil dressing provided, the more effective it is. But it is necessary to consider the importance of the land and the cost of using the method to decide to use it.

(17) Considering the years of service until the vegetation is firmly established and the strength of the hillside foundation work materials.

- When thinned wood and bags of soil are used to execute hillside work, their service life until the vegetation is firmly established is considered.

Nomugi Pass hillside work: example of the use of wood obtained by thinning trees

Tsuchiyabara hillside work: Use of bags of soil Professor Ote studied the use of soil cement as material to fill soil bags in the Kyoto University Forest.

(18) Basically fertilizer is not used.

- While fertilizer does speed maturation, it creates vegetation with low resistance, and other damage is caused by the stress on the vegetation when fertilization is stopped.
- If fertilizer is used, the following points should be considered.
  - It should be organic material such as straw that provides gradual and gentle effects.
  - To guarantee voids in the soil (improving the physical properties of the soil) the use of bark fertilizer (wood chips) or other material with effects other than fertilization should be considered.

(19) Hill side revegetation work is done considering the growing period.

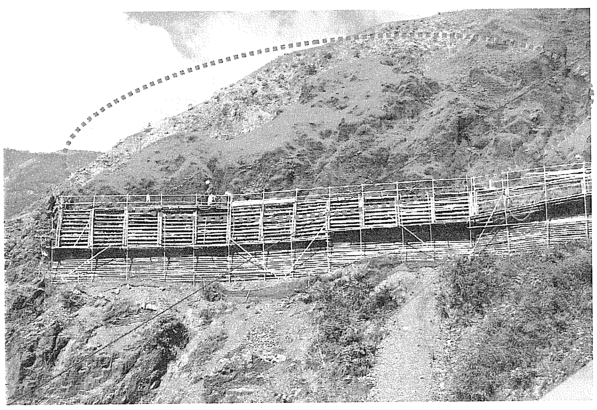
- Revegetation work should be done considering the period when newly introduced species grow (the two normal growing periods of vegetation are spring (March to June) and autumn (September to October)).

(20) Planting (seeding) must be performed in three stages, collecting → storing → sowing based on a thorough knowledge of the individual properties of the seeds themselves.

- Planting (seeding) must be performed in three stages, collecting → storing → sowing based on a thorough knowledge of the individual properties of the seeds themselves. Simple collection and simple seeding can be done for all kinds of seeds, but to perform simple seed collection, the maturating period of the seeds is clarified, and to perform simple seeding, the basic steps are removing the raw humus from the ground surface, sowing the seeds, and placing enough soil to cover the surfaces of the seeds.

(21) Basically revegetation of rock ground is not done.

- Basically this is not done, because it often creates unnatural scenery and there are few cases where it is necessary to carry out emergency measures to control sediment runoff.



Matsuki hillside work: example of rock revegetation
Rock revegetation is done as a measure to prevent surface erosion of weathered rock under harsh climatic conditions such as freezing and cold wind damage during the winter.
As a measure to prevent falling rocks during the work on the lower slope, net work is often done on exposed rock near the top of the slope, but simple revegetation is avoided whenever possible.

3.2 To encourage the transition to the target forest

(22) Problems such as delayed transition of species by vegetation with excessive fecundity.

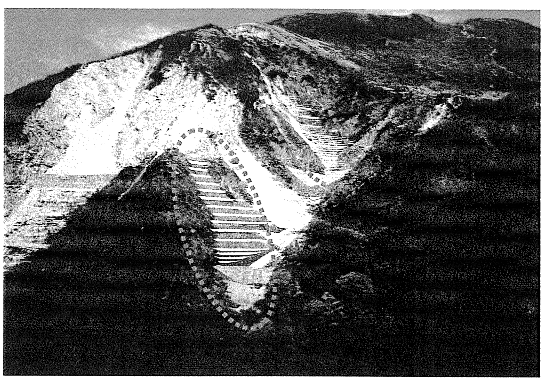
- The following are conditions for the early introduction species when the first priority is early revegetation.

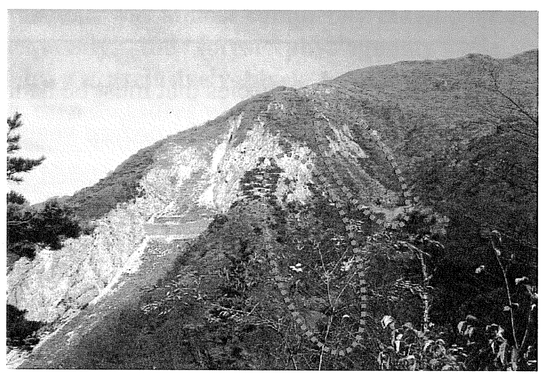
- From the start of its growth, it is highly adaptable to direct sunlight, drying, freezing and other climatic conditions and to the soil texture.
- There are many seeds from stock trees and they are widely available.
- It grows quickly.

But carrying out improvements looking ahead to the formation of the target forest must be done carefully, because the high fecundity (competitiveness) of the early introduction species may cause problems such as delayed transition.

- Coniferous trees such as pine and Japanese red cedar are often used because of their high fecundity, but their needles do not decompose easily so that soil does not form for a long time. And the needles that are not decomposed cover the ground, preventing the invasion of other species, also delaying the transition.

Tanakamiyama hillside work: A clear cutting experiment was done to simulate a case where all pines dried up leaving the land almost bare, but because there were no stock trees, vegetation did not invade even though the light conditions were good. Later broad-leaved trees were planted at the same location, but they did not grow. It is hypothesized that this failure occurred because the pine needles were deposited in a lower layer without decomposing, so that soil is not formed.





Otomikawa hillside work: Example of the impact of early introduction planting work over a long period
A long period of time passed without any transition from the transplanted trees that were introduced early. Then 50 years after the execution, the originally planted trees had declined and completely disappeared, allowing a low forest to form by natural invasion.

(23) To introduce early introduction species, it is necessary to give careful thought to the constituent species when the transition to the target forest has been completed.

- The early introduction species should be selected by giving careful thought to the constituent species when the transition to the target forest has been completed.
  - From the start of the execution, the pioneer vegetation and the next generation vegetation should be mixed.
  - The initial introduction species are selected according to local conditions with reference to nearby transition processes without necessarily being limited to the normal vegetation transition process (annual grasses → perennial grasses → low trees → high trees).
  - Native species (if possible, locally produced species) should be used whenever possible.

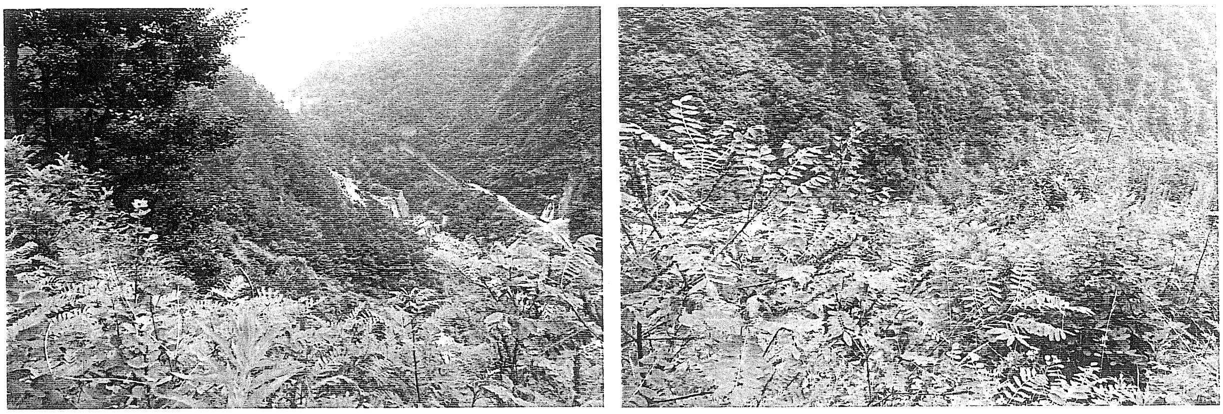
(24) Japanese alder (*Alnus japonica (thunb.) steud*) or firma alder (*alnus firma*) that have nitrogen fixing bacteria that help the growth of vegetation are selected as early introduction species.

- Selecting species with nitrogen fixing bacteria effectively establishes vegetation. Until now, legume vegetation that includes black locust (*Robinia pseudo-acacia*) and false indigo (*Amorpha fruticosa*) has been widely used. However, considering later vegetation transition, these should be avoided as much as possible, and at the same time Japanese alder (*Alnus japonica (thunb.) steud*) or firma alder (*alnus firma*) that have nitrogen fixing bacterial may be selected.

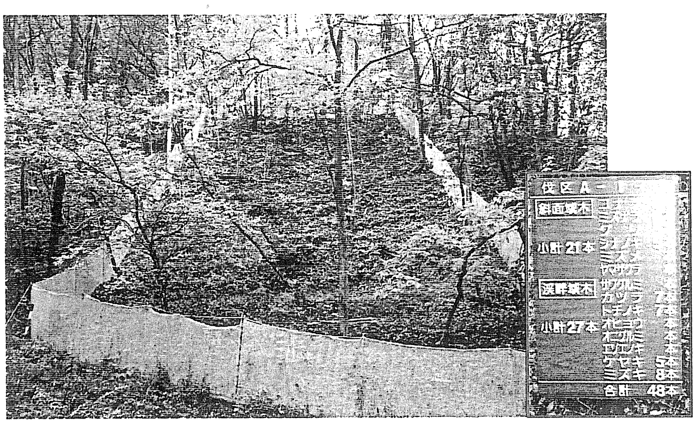
(25) Species that must be handled carefully are legume vegetation that include false indigo (*Amorpha fruticosa*) and black locust (*Robinia pseudo-acacia*), and exotic gramineous vegetation typified by Kentucky 31 fescue.

- The followng are species that must be handled carefully when they are introduced.
  - If too many seeds of *Lespedeza* vegetation such as false indigo (*Amorpha fruticosa*) are sowed, their roots are thickly concentrated near the surface, delaying the transition by preventing the invasion of other vegetation.
  - Because *Lespedeza* vegetation such as false indigo (*Amorpha fruticosa*) have nitrogen fixing bacteria, if too much is spread, the soil acquires excessive nitrogen. This results in the ground being dominated by gramineous vegetation or bamboo grass that thrive on nitrogen, delaying the transition by preventing the invasion of other vegetation.
  - The fecundity of black locust (*Robinia pseudo-acacia*) is extremely high, delaying transition by preventing the invasion of other vegetation. And because its roots are shallow so that it is easily toppled, it should not be selected because it is not suitable for slope stabilization.
  - Exotic grass vegetation typified by Kentucky 31 fescue requires a large quantity of fertilizer, and when the fertilizer is exhausted, it dries up. Another reason it should not be selected is that

because its color is unnaturally blue when it is flourishing, it often seems in disharmony with the surrounding scenery.



Upper slope of the Mizutani hillside work: overall luxuriant growths of Chinese lespedeza (*Lespedeza juncea*), bush clover (*Lespedeza bicolor*), and false indigo (*Amorpha fruticosa*) introduced as early introduction species have appeared more than 10 years after execution, but no conspicuous transition can be seen.



Ushibushi hillside work: Case of problems caused by black locust (Robinia pseudo-acacia) Initially, red pine, himeyashabushi alder (Alnus pendula matsumura), and black locust (Robinia pseudo-acacia) were planted, but later the ground was almost completely taken over by black locust (Robinia pseudo-acacia). Consequently, the forest physiognomy was transformed in order to prevent disasters caused by an exclusively black locust (Robinia pseudo-acacia) forest and resolve ecological problems, then measures were taken to encourage a native species forest consisting mainly of the exotic species, konara (Quercus serrata Thunb. ex. Murray), oak (Quercus crispula Blume), Japanese chestnut (Castanea crenata), Japanese linden (Tilia japonica), sawagurumi (Pterocarya rhoifolia), and Japanese katsura tree (Cercidiphyllum japonicum).

4. Evaluation and appropriate management of the degree of achievement of the improvement target

4.1 Why is an evaluation necessary?

> (26) In order to prevent unwanted results such as restoration of the wasteland, it is necessary to clarify the process of the growth in order to evaluate the degree of achievement of the improvement target.

- Several decades are necessary to complete transition to the target forest, and in order to prevent unwanted results such as the restoration of wasteland, it is important to clarify the process of growth. This means that various monitoring surveys must be performed every 3 to 5 years to evaluate the degree of achievement of the improvement target at the time of each survey. The results also provide basic information to determine the need for management and management methods.

4.2 What is the object of the evaluation?

> (27) The evaluation is done by performing monitoring to determine how firmly the vegetation has been established and the state of transition of the vegetation, formation of soil, control of the runoff of sediment and so on to find out how much progress is being made to reach the target.

- The principal items evaluated are:
  - State of establishment (growth) of species } Vegetation survey
  - Transition (invasion) of vegetation } Vegetation survey
  - State of development of the soil ➔ soil hardness survey, ph test
  - State of control of sediment runoff ➔ sediment runoff survey

  And as necessary, surveys of the change over time of species of biological communities and number of each species are performed to evaluate the degree of the restoration of the natural environment by the hillside work based on indices of similarity.

- ○ Confirming the vegetation foundation stability (degree of rot survey)
  - Clarification of the degree of rot using a Yamanaka type soil hardness meter
  - Observing and recording the degree of rot by visual examination
- ○ Confirming the establishment of the vegetation
  - Hillside work introduction effects (observing and recording the establishment of the vegetation)
  - Relationship with the characteristics of collapsed ground (measuring the soil layer thickness and the slope gradient)

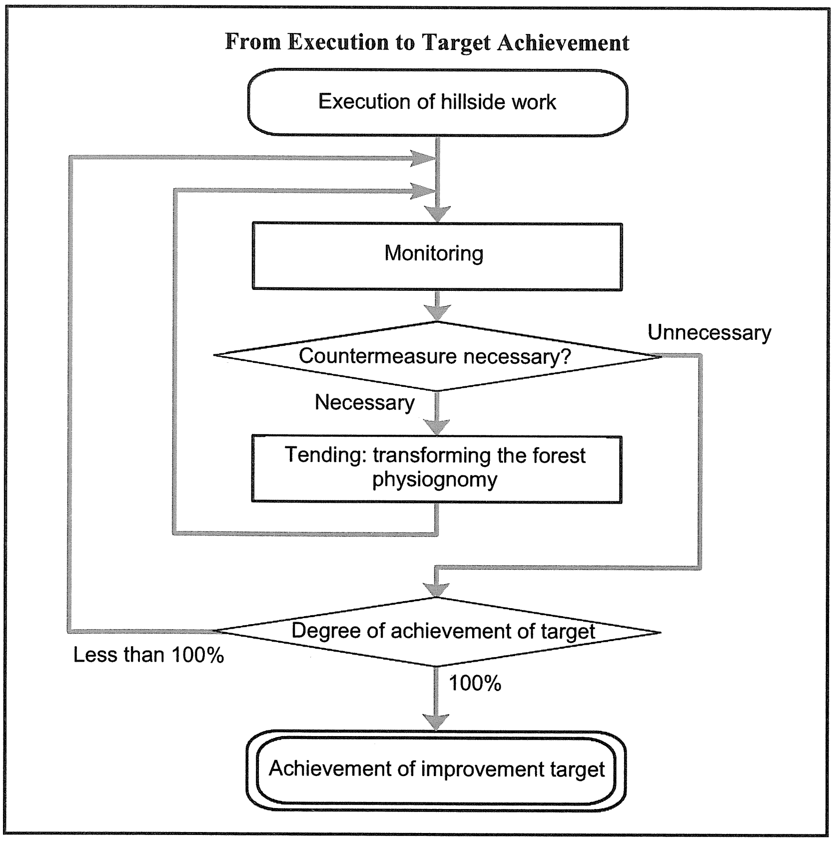
Tsuchiyabara hillside work: Various surveys shown on the left are performed after execution to verify the effectiveness of introduction and to study the effective application of the method according to local characteristics.

4.3 What is appropriate management?

(28) When the transition to the target forest has been obstructed, its cause must be discovered to perform suitable management to resolve the problem.

- When the results of an evaluation of the degree of achievement of the improvement target reveals any of the following signs of the obstruction of the transition to the target forest, it is necessary to perform appropriate management to encourage the transition to the target forest.
  - The vegetation is not established.
  - The vegetation has deteriorated (return of wasteland conditions)
  - Clear delay in the vegetation transition considering the elapsed time is revealed.
  - Sediment runoff control effects have not improved.
- The following appropriate management is performed according to the cause and urgency.
  - The situation is not serious and its cause is not specified ➔ continued observation of the process
  - Light conditions are poor so that grasses and next generation vegetation do not grow (or do not invade) ➔ thinning trees, forest physiognomy conversion etc.*
  - Confinement by grasses ➔ mowing grass, mulching
  - Poor growth caused by soil conditions (soil particle diameter, dryness) ➔ soil improvement by wood chips, mulching
  - Pest (insects/vermin etc.) ➔ nets, installation of vegetation protection pipes

Forest physiognomy transformation* --- In order to qualitatively improve the existing forest, new vegetation is introduced and aggressively managed on land where existing trees have been removed by thinning or clear cutting to encourage the growth of a more stable forests.



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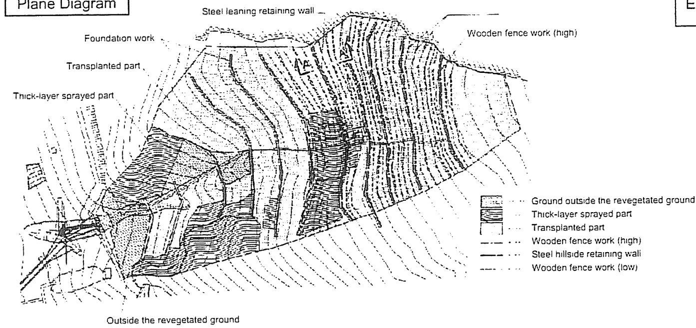
  Nagano Prefecture, Matsumoto Construction Office
- Guideline to Forest Physiognomy Transformation of Black Locust (*Robinia pseudo-acacia*) Forests on the Ushibuse River (Revised Edition)
  Nagano Prefecture, Matsumoto Construction Office 2003
- Sabo Works on the Otomi River, Implemented by Shiga Prefecture (Pamphlet)
  Shiga Prefecture, Nagahama Public Works Office 1986

Case 1 Matsuki Hillside Work

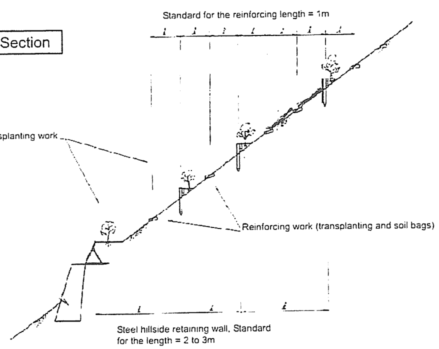
The mountains upstream from the Ashio Check Dam in the highest section of the Watarase River are now reddish brown mountains covered with exposed topsoil without grass or tree covering as a result of repeated forest fires and smoke damage caused by the large quantity of sulfuric acid gas emitted by Ashiodozan Mountain and by uncontrolled cutting to obtain wood to make charcoal and for use as railway supporting materials. In these mountains, surface soil containing organic material has been washed away eliminating their moisture and fertilizer retention capacity as a result of the brittle geology consisting mainly of Metazoan layers and severe climatic conditions such as repeated freezing and thawing during the winter. Additionally, whenever heavy rain falls, more soil is washed away. Public revegetation projects conducted as part of mountainside erosion control work and flood control work have been underway for more than a century since they were begun in 1897. Since the nineteen-fifties, the smoke damage has ended and full scale projects have been undertaken. Revegetation projects carried out by the Ministry of Land, Infrastructure and Transport, Forestry Agency, and Tochigi Prefecture have restored greenery to about 50% of the mountainsides. Residents have taken part in extensive reforestation projects, with the Restore Trees to Ashio Society carrying out its first tree planting in May of 1996 as a citizens activity. Revegetation projects were carried out 9 times from that year until 2004. In addition, tree planting was incorporated as part of educational tours and open-air schools that appeared gradually after 1993, and the increase in repeat visits by schools and word-of-mouth expanded into hands-on environmental education activities. Part of the tree planting was performed as revegetation by volunteer groups sponsored by the NPO, Restore Trees to Ashio Society, but in recent years, it has become increasingly difficult to obtain transplanting locations where volunteers can work safely.

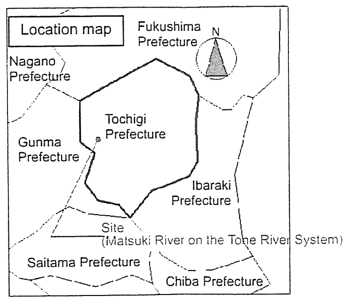
Purpose of improvement		Revegetation of deforested ground
Geology		Metazoan layer zone
Soil		Conglomeratic soil, rock
Execution location		Tochigi Pref., Kamitsuga-gun, Ashiomachi
Work method, form		Earth retaining work Transplanting work, spraying deep layer base material
Slope	Direction	SW
	Gradient	Average gradient 30°
Jurisdiction		MLIT, Kanto Regional Development Bureau, Watarase River Office
Execution years		1988 to present day

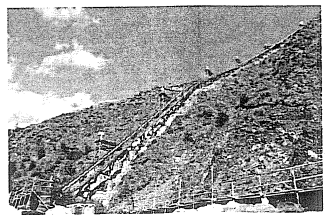
Plane Diagram



Standard Section







Construction of a large scale materials reception facility (Super carrier system: labor-saving and increased efficiency)

The Ministry of Land, Infrastructure and Transport (Watarase River Office) formed a committee of scholars and representatives of concerned organizations to compile the Guideline to Matsuki Hillside Work Revegetation (Draft). It is working to restore greenery through links with the local residents according to the Guideline. The following are the major features of the Guideline.

- Its major goal is to revegetate the hillside slopes to control of the runoff in order to guarantee the safety of the region and its aim is to restore nature by forming zones of forested land suited to the Matsuki District.
- It calls for regular monitoring surveys to increase the effectiveness of the revegetation methods under harsh revegetation conditions. It also offer guidelines to carrying out revegetation project while revising them based on the results of the monitoring.
- In the future, links with volunteers will be strengthened to perform revegetation while maintaining a cooperative organization.
- The successful results of revegetation projects will be used as opportunities for sabo and environmental education and as a tourist resource in order to contribute to the region.

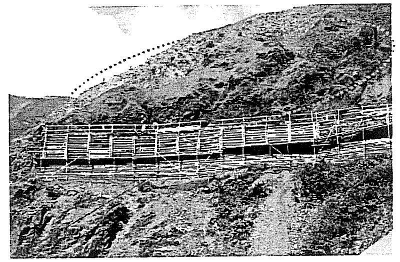
Types and density of the vegetation introduced * Density/m²

Name	Part where deep layer base material was sprayed	Reinforcing work g/bag
Kentucky 31 fescue	0.026	2.84
Orchard grass	0.012	0.50
Creeping red fescue	0.012	0.76
Chinese lespedeza	0.042	0.57
Japanese mugwort	0.018	0.16
Shrubby lespedeza	-	0.07
False indigo	0.488	0.32
Alder	0.064	-
Total	0.662	5.22

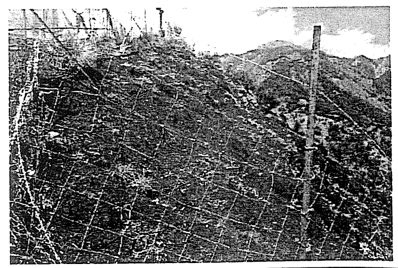
Types and density of the vegetation initially introduced * Done at 10m intervals

Name	Tree height
Black pine	H=0.5 – 0.8m
Alder	"
Manchurian alder	"
Japanese kerria	"
Chinese redbud	"
Weeping forsythia	"
Japanese spirea	"

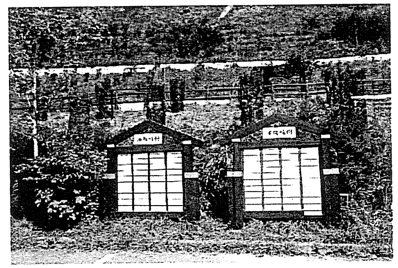
(Photo 1) State of vegetation on the slope:
Recovery of vegetation caused by natural invasion is seen at the location where sediment movement is controlled above small check dam work.



(Photo 2) Revegetation of rock:
On the Matsuki hillside work, rock revegetation was done as a measure to prevent erosion of the surface of weathered rock under harsh climatic conditions including freezing/thawing and cold wind damage during the winter.



(Photo 3) Measure to prevent damage by deer:
A protective net installed to prevent damage by Japanese serow and Japanese deer.



(Reference photo 1) Ohatazawa Green Sabo Zone
Actively revegetated by volunteers

Advice from Professor Ote

Concerning the soil
There was fear that heavy metals in the soil at this location would obstruct the growth of vegetation. It is assumed that soil dressing is effective in such cases, but the deep layer base material spraying method that is now used can only guarantee soil to a depth of 10cm, so that it is difficult for tall trees to take. To be sure that tall trees will take, from 30 to 50cm of soil is necessary, and considering the slope gradient, it is difficult unless terraces are cut into the slope.

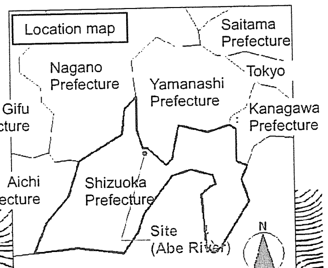
Concerning rock revegetation
Revegetation of rock often creates unnatural scenery, so its use must be studied carefully. A method often used to prevent rocks from falling when performing work at the bottom of a slope is to spread net work over the exposed rock at the top of the slope, but simple revegetation to prevent this should be avoided.

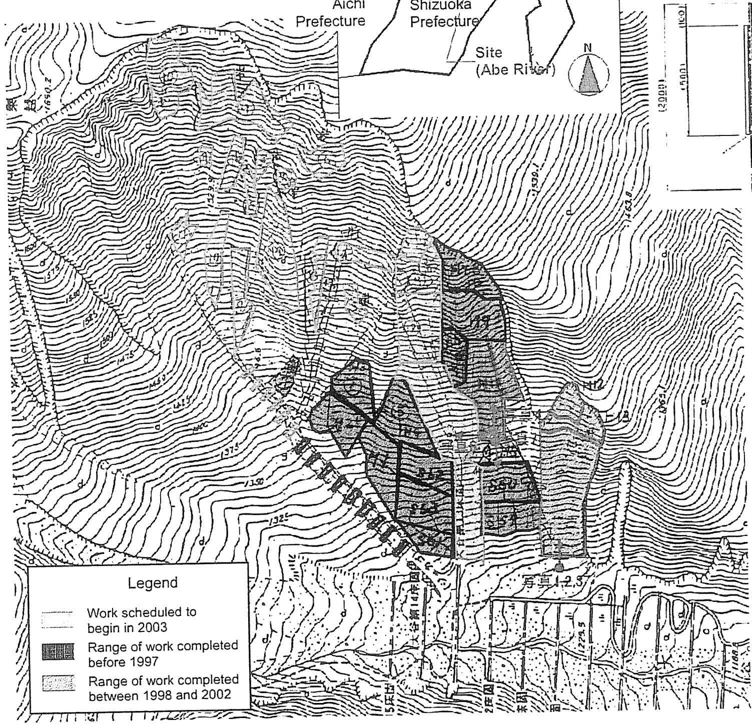
Case 2 Oya Hillside Work

Outline

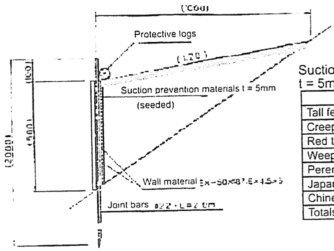
Mt. Oyarei that is the source of the Abe River is the site of the Oya Slide, one of Japan's three most massive slides. The Oya Slide, a massive event occupying 1.8km^2 with width of 1.0km and an elevation difference of 800m, is estimated to have discharged 120 million m^3 of collapsed soil. The geology in this zone is alternating layers of shale and sandstone in the Palaeogene period, includes remarkable crushing caused by faults and folds produced by structural movement, is severely cracked, and bedrock separation has advanced. Fan-shaped slide topography exists at the bottoms of slopes. The Oya Slide was triggered by a large earthquake in 1707 and the sediment it produced triggered a severe disaster caused by later intensive rainfall. Therefore, hillside revegetation was done to stabilize the unstable north-south slope on the collapsed ground. Because vegetation can be restored by artificial introduction and a vegetation introduction technology is established, this is considered a model for the application of the method in other locations in the jurisdiction. The hillside work on the Oya Slide was undertaken to (1) form stabilized scenery by revegetation, (2) control sediment production from hillsides, and (3) supply the unstable sediment to the river. The characteristics of the work method were terracing work executed on the talus and spraying special mortar (Rock-ment) on broken parts of exposed rock. As a result of the hillside work, between 40% and 70% of the trees have taken thanks to the use of this method.

Purpose of improvement		Prevent expansion of the collapsed ground
Geology		Tertiary zone
Soil		Conglomeratic soil
Execution location		Shizuoka City, Shizuoka Prefecture
Work method, form		Hillside terracing work (steel fence work), transplanting, spraying special mortar
Slope	Direction	SE
	Gradient	30°
Jurisdiction		MLIT, Chubu Regional Development Bureau, Shizuoka River Office
Execution years		1986 to present day





Section Diagram



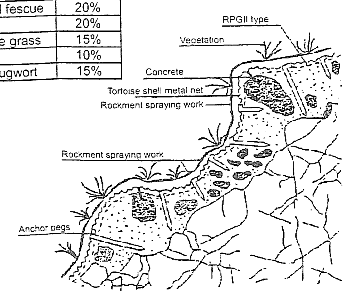
Suction prevention material t = 5mm (seeding)

	Per 1m^2
Tall fescue	10g
Creeping red fescue	3g
Red top	1g
Weeping love grass	1g
Perennial rye grass	4g
Japanese mugwort	1g
Chinese lespedeza	1g
Totals	20g

Rockment spraying (sprayed 6kg/m^2) Standard execution diagram

S = 1 : 20

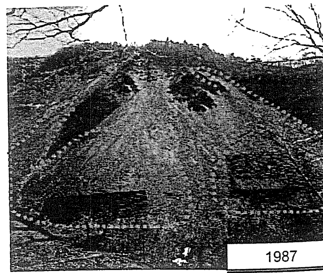
	Seed mix
Tall fescue	20%
Creeping red fescue	20%
Red top	20%
Weeping love grass	15%
White clover	10%
Japanese mugwort	15%

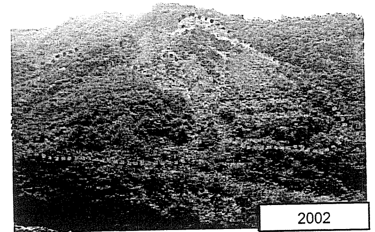


Rockment Spraying Work (sprayed 6kg/m^2) Materials Table

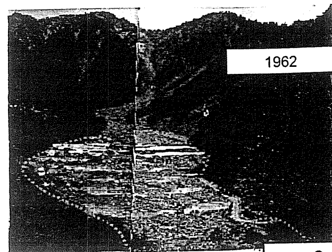
Per 100m^2

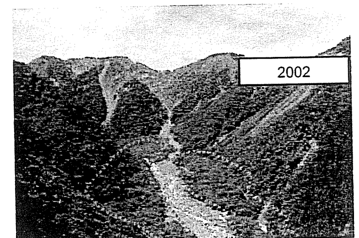
	Standard	Unit	Quantity	Remarks
Rockment	Mix: 1:3:5	kg	600	
Tortoise shell metal net	Wire diam. 1.2mm, meshes 10mm	m^2	140	
RPB (type II)	Thickness 1.0mm, palm-net	m^2	110	
Anchor pegs	Diameter 13mm X 600mm	-	60	
Anchor pegs	Diameter 13mm X 400mm	-	60	
Anchor pegs	Diameter 9mm X 200mm	-	300	



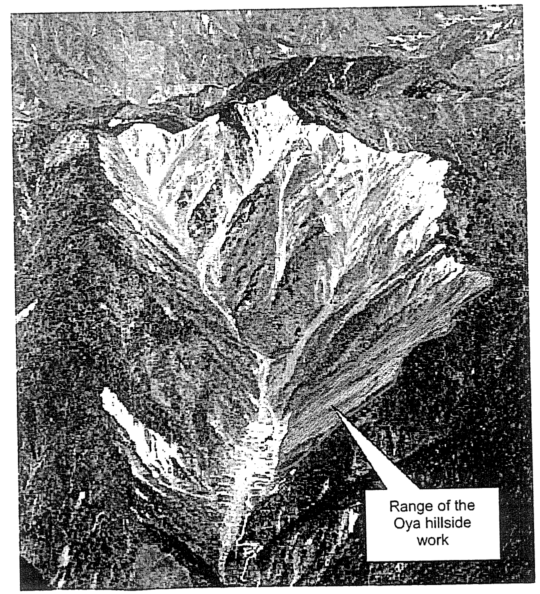


Oya hillside work
(Change of the work locations)





Oya groundsill work
(Change of the work locations)

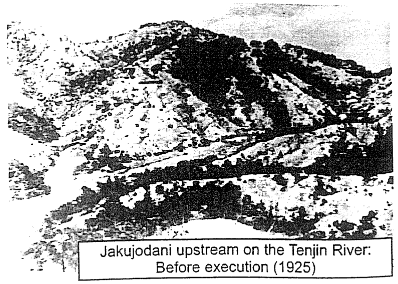


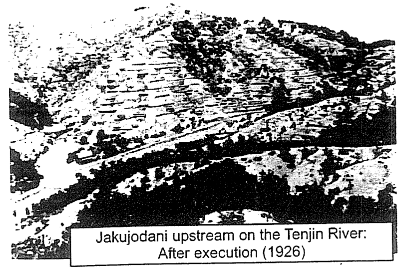
Case 3 Tanakami Hillside Work

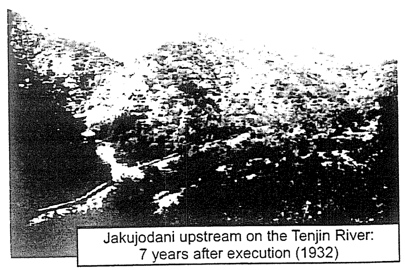
Outline

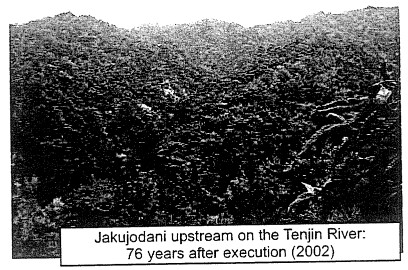
More than one-thousand years ago, the Tanakami Mountain zone was a vast beautiful of luxuriant Japanese cypress, Japanese cedar, and evergreen oaks. Later during the Asuka and Nara Periods (seventh century), the arrival of Buddhism and the continental culture spurred the establishment of palaces, shrines, and temples, requiring that vast numbers of Japanese cedar and other trees be cut and transported by water to locations where they were used as lumber. In this way, a primary beautiful forest of Japanese cedar and evergreen oaks was replaced by secondary forest (pines). Later as the arts and crafts advanced, pine was cut excessively to provide fuel to make ceramics. And as a key point on transportation routes, the province of Omi was at the center of frequent wars accompanied by attackers burning their enemies' towns and setting continuous forest fires. Because the geology of the Mt. Tanakami region consists of deep layers of weathered granite, once its trees were removed by the above actions, every rainfall ran off its surface soil, increasing the destruction of its land. By the seventeenth century, the sides of the mountain were so completely devastated that not one tree remained, inflicting the downstream residents with constant sediment disasters. Mt. Tanakami has been revegetated and hillside works done to stop surface erosion from running off sediment. Tanakami hillside work projects have been underway for more than 120 years beginning in the late nineteenth century. Sediment production source measures have been extremely effective, and the methods used have matured. The methods used have been earth retaining work as hillside foundation work (block panel terracing work and block panel stepped terracing work), hillside terracing work as hillside revegetation (sod seedling terracing work, straw seedling terracing work, sod stepped seedling terracing work), covering work (slope revegetation), transplanting work (black pine, *himeyashabushi* alder). And as a way of encouraging the growth of seedlings after transplanting, hillside tending method A and hillside tending method B have been established. And to guarantee that the sediment production reduction measures continue to be effective far into the future, it is essential to transform it from a forest consisting of only pine trees to a forest physiognomy that will not cause it to return to its devastated condition.

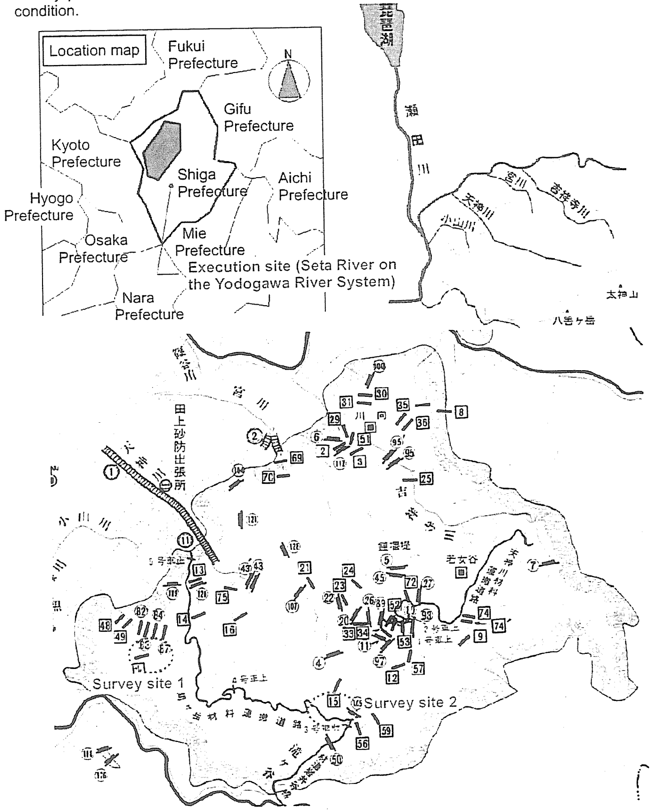
Purpose of improvement		Revegetation of deforested ground
Geology		Granite zone
Soil		Weathered rock
Execution location		Otsu City in Shiga Prefecture
Work method, form		Earth retaining work Hillside terracing work (for details see the standard section), transplanting work
Slope	Direction	All directions
	Gradient	-
Jurisdiction		MLIT, Kinki Regional Development Bureau, Biwako River Office
Execution years		1878 to the present

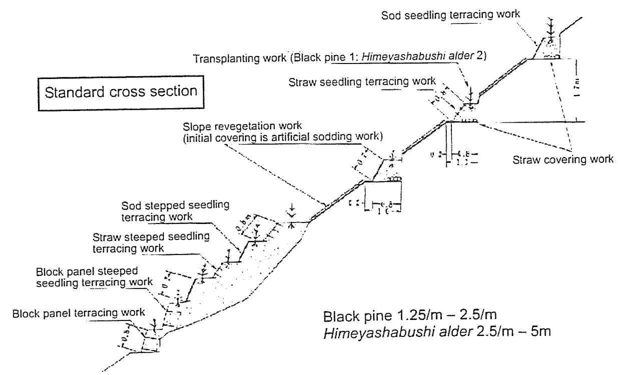

Jakujodani upstream on the Tenjin River: Before execution (1925)

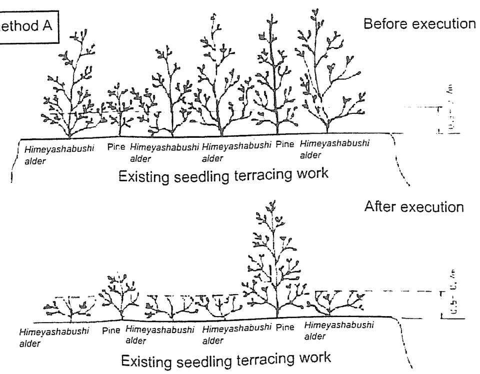

Jakujodani upstream on the Tenjin River: After execution (1926)

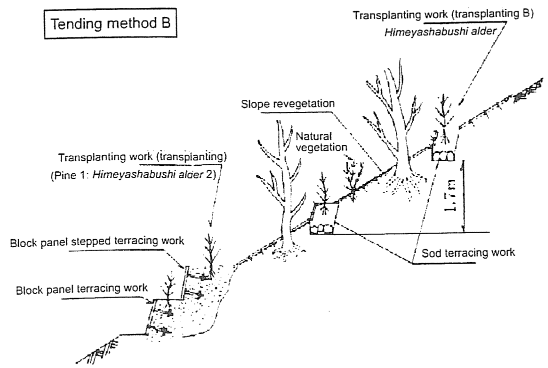

Jakujodani upstream on the Tenjin River: 7 years after execution (1932)


Jakujodani upstream on the Tenjin River: 76 years after execution (2002)









Tending pattern A: After transplanting, the *Himeyashabushi alder* are truncated to height between 0.5 and 0.7m in the 4th, 7th, and 10th years to encourage sprouting and prevent them from overwhelming the pines.

Tending method B: The roots of the existing trees are trenched and and fertilized.

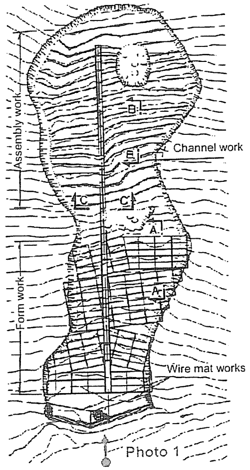
Case 4 Tsuchiyabara Hillside Work (Shorenji River Hillside Work)

Outline

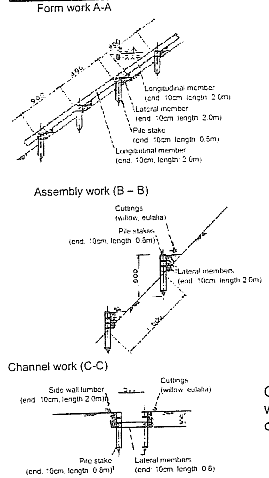
The mountains in the Kizu River Basin were once covered with huge luxuriant forests, but the advance of civilization destroyed them as, during the Nara Period in particular, unrestricted cutting to obtain lumber to build temples and shrines deforested the land. As the deforested area expanded to 4,500 hectares, the sediment runoff from its surface caused frequent disasters in the downstream river basin. To resolve this problem, beginning in the late nineteenth century, the government undertook sabo projects consisting mainly of hillside work to revegetate the deforested land. By 1959, hillside work had been completed on 2,600ha in the Kizu River Basin. But in the upstream Kizu River Basin, torrential rainfall including that brought by the Ise Bay Typhoon of 1959 collapsed slopes at many places (2,490) because of the granite topography in the region. Many of these were extremely small with surface areas less than 0.1ha on steep mountain slopes with gradient between 30 and 40° where work conditions are poor. The Upstream Kizu River Office has executed hillside works (earth retaining work) to stabilize hillsides by using gravity concrete retaining walls and concrete secondary products etc., but it has faced cost problems and difficult executions. It has developed hillside work reduction methods based on the concept: stop the movement of sediment on the surface and then perform green sabo that does not require the use of concrete. It is an economical easily executed method that prevents the movement of sediment by combining thinned Japanese cedar and Japanese cypress logs and anchoring them to the slope with wooden stakes.

Purpose of improvement		Prevention of the expansion of collapsed ground
Geology		Granite zone
Soil		Rock pebbles
Execution location		Uda-gun, Nara Prefecture
Work method, form		Slope cutting, earth retaining work, hillside drainage channel work, peaked roof form work, wooden form work, transplanting work (cuttings)
Slope	Direction	-
	Gradient	-
Jurisdiction		MLIT, Kinki Regional Development Bureau, Upstream Kizu River Office
Execution years		1989 to 1991

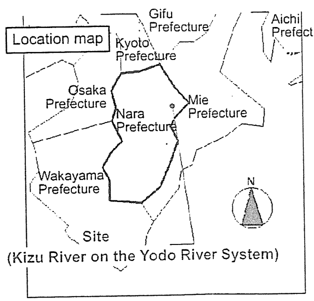
Survey Location 1 | Plane diagram



Standard section



Location map



Cuttings (Willow, eulalia, azalea, and other fascine) brushwood were placed at lateral intervals of 30cm and longitudinal intervals of 90cm.

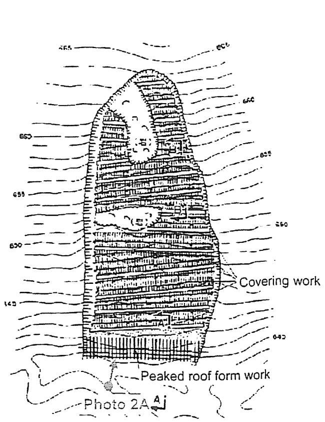

Immediately after completion (1989)


One year after completion (1990)

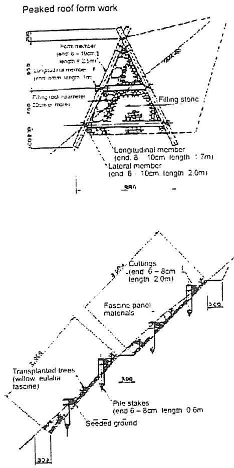

Three years after completion (1993)


Twelve years after completion (2002)

Survey Location 2 | Plane diagram

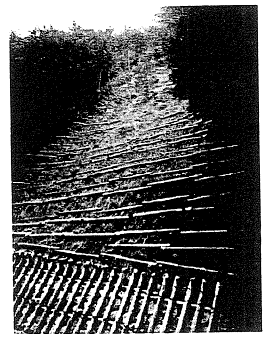


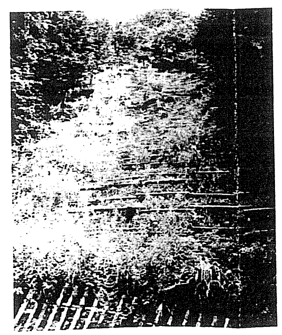
Standard section



Fascines were inserted at lateral intervals of 30cm and longitudinal intervals of 0.66 cm.


Immediately after completion (1991)


Six months after completion (1991)


One year after completion (1992)

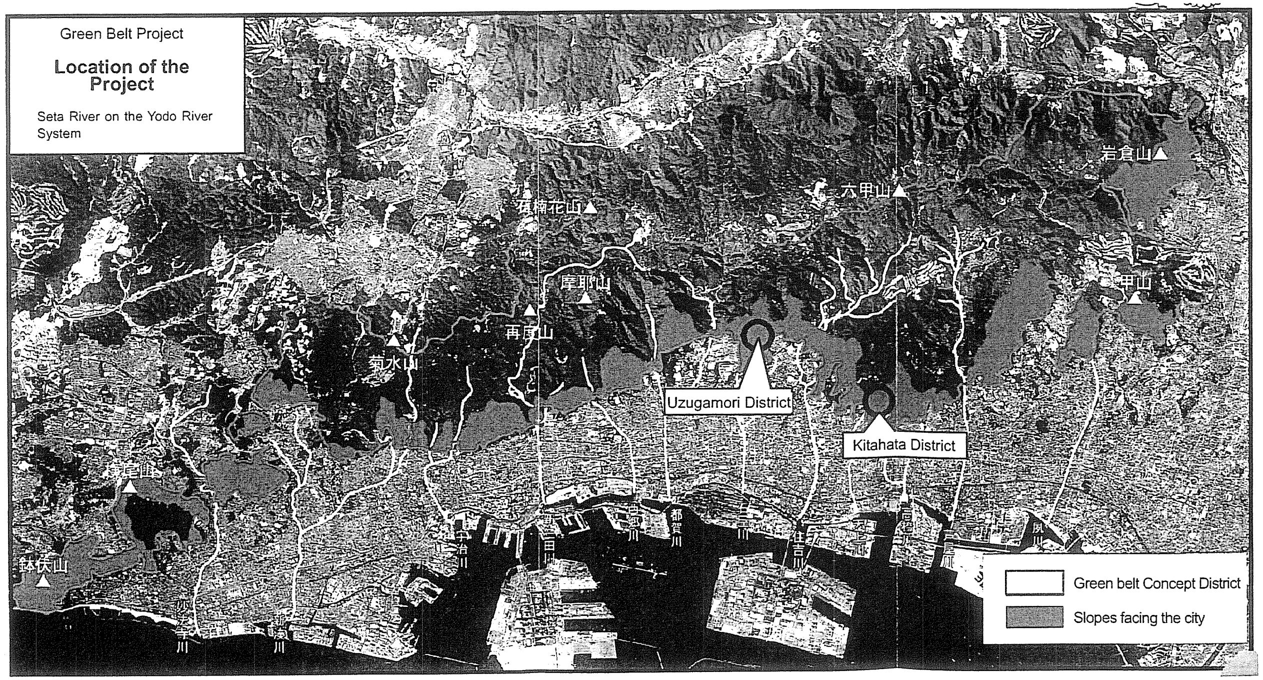

2002

Case 5 Rokkozan Chain Green Belt

Outline

In the late decades of the nineteenth century, the forests on the Rokkozan chain were devastated by unrestricted cutting of trees to obtain firewood. The slopes of the Rokkozan chain were naturally prone to collapse, because they consist mainly of granite and many of their slopes are extremely steep. Exposed to wind and rain, their devastation continued, with every intensive rainfall causing disasters. Sabo projects that were started in 1893 to protect the city from sediment disasters have now restored their vegetation. But the trees on the Rokkozan chain include red pine and black locust (Robinia pseudo-acacia) that die very easily; a situation detrimental to sediment disaster prevention. But because the Rokkazan chain is located directly beside the city and is closely related to the lives of its residents, it is essential to not only provide protection from sediment disaster originating on its slopes, but to guarantee other functions including permitting its recreational use. The Rokkozan Chain Green Belt Project positions the slopes facing the city in urban plans as districts where particularly aggressive measures are necessary, and at the same time, provides groves on the Rokkozan chain to create forests that fill four functions: (1) preventing sediment disasters, (2) preventing urban sprawl, (3) conserving and nurturing a good quality urban environment, elegant scenery, ecosystem, and biodiversity, and (4) providing suitable places for recreation. To carry out a green belt development, the first step is to undertake aggressive measures utilizing civil engineering structures with top priority on preventing sediment disasters caused by the collapse of slopes. A forest consisting of only a single species of tree, toppled trees etc. is transformed to a forest with a developed stratified structure and a mixture of various species of trees of diverse age, by providing and managing its trees. Where good quality trees are now growing, they are conserved and further improved by carrying out regular inspections of these locations and cutting weeds or thinning trees as necessary.

Purpose of improvement		Replace trees that obstruct disaster prevention with trees that effectively prevent disasters.
Geology		Granite zone
Soil		Weathered rock
Execution location		Kobe City, Hyogo Prefecture
Slope	Direction	SE ~ SW
	Gradient	-
Jurisdiction		MLIT, Kinki Regional Development Bureau, Rokko Sabo Office
Execution years		1997 – present (Manual from 2000)



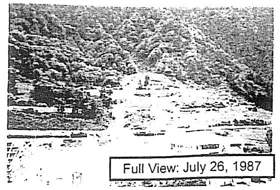
Need for and purpose of forest physiognomy transformation and tree introduction		Replace trees that now hamper sediment disaster prevention (communities of Japanese cedar, Japanese cypress, communities of eulalia and *nezasa* (*Pleioblastus chino var. viridis*), communities of black locust (*Robinia pseudo-acacia*), etc.) by introducing and managing trees that effectively prevent sediment disasters
Target forest		Forest with a developed stratified structure and a mixture of various species of trees of diverse age The tentative target is to replace the *nezasa* (*Pleioblastus chino var. viridis*), communities of black locust (*Robinia pseudo-acacia*) forest that are now introduced with a secondary forest consisting of deciduous broad-leaved trees (setting goals in stages)
Forest physiognomy transformation and tree introduction methods	Cutting	(Planted Japanese cedar and Japanese cypress groves) Thinning 20 to 30% (*nezasa* (*Pleioblastus chino var. viridis*) and black locust (*Robinia pseudo-acacia*) groves) Completely cutting the *nezasa* (*Pleioblastus chino var. viridis*) and black locust (*Robinia pseudo-acacia*) in belts
	Transplanting	(Transplanted tree species) *Konara oak (Quercus serrata Thunb. ex. Murray)*, hornbeam, Korean hornbeam, fagaceae, *Yamazakura* (*Prunus jamasakura Sieb. ex Koidz*), Japanese oak, Japanese zelkova (*Ulmaceae Zelkova serrata (Thunb.)*, *Mukunoki* (*Aphananthe aspera*), etc. Transplanted density (2,500 trees/ha)
Management method	Weeding and brushing	Once or twice a year, cutting bamboo grass, cutting black locust (*Robinia pseudo-acacia*) sprouts
	Thinning	Done as necessary. Scheduled to be done as necessary with reference to the staged target (10 years in the future for example)
	Fertilizing	Not done. Scheduled to be done as necessary with reference to the staged target (10 years in the future for example)
Follow-up survey		Done starting in 2001 • Height, branch spread, tree vigor of transplanted trees Starting in 2002, measurement of surface erosion of soil by tree type based on whether the forest is or not managed.
Challenges		• It is important to process the sprouts of black locust (*Robinia pseudo-acacia*) and to cut the *nezasa* (*Pleioblastus chino var. viridis*) • Because locations where forest physiognomy transformation is done are temporarily conspicuously almost completely bare of vegetation, it is necessary to explain the need and effectiveness of the project to residents to gain their understanding. • It is necessary to establish a stable seedling supply system in the region.
Planning forest physiognomy transformation and tree introduction (manual, guideline, etc.)		Rokkozan Green Belt Forest Improvement Manual (Rokko Sabo Works Office, 2000)

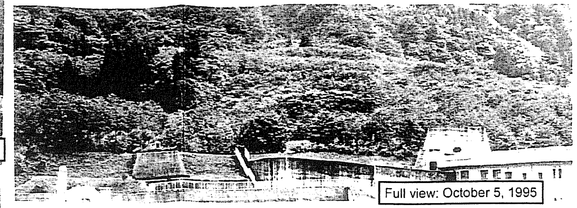
Case 6 Dashidaira Revegetation Work

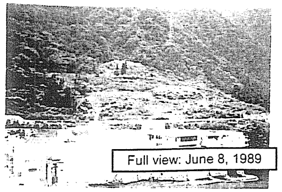
Outline

Work on the Otozawa Hydroelectric Power Station was started in September, 1982 by the Kansai Electric Power Company and started full operation 3 years later on September 27, 1985 as a result of the work of 900,000 people. Developed based on the concept of integrated river system development in order that it use the abundant flow volume regulated and discharged by the upstream Kurobe Dam, its maximum output of 124,000 kilowatts is the largest in the river system following the Kurobe No. 4 Power Station. It takes in a maximum of $74m^3$/sec. of water from the Dashidaira Dam, a concrete gravity dam with total height of 76.7m constructed at Dashidaira on the main course of the Kurobe River, to produce power by an effective drop of 193.5m. The construction of the Otozawa Power Station created the need for revegetation work on the right bank slope at the Dashidaira Dam. Because it is in a heavy snowfall zone, transplanted trees were damaged by snow avalanches and by deer and Japanese serow that ate their foliage in the winter, hampering the revegetation. The Dashidaira revegetation work was executed on the right bank slope at the Dashidaira Dam, and because it is inside a national forest and national park, it was necessary to quickly form communities as similar as possible to natural forest. Therefore, the plan stipulated that first pioneer species would be introduced to form communities followed by a later transition to natural communities. In order to transplant pioneering species of vegetation and selected species that are suited to the Dashidaira District, the pioneering species selected were Alder (*Alnus sieboldiana matsumura*) and Manchurian alder (*Alnus hirsuta*), and the selected species were *Itayakaede* (*Acer mono Maxim. var. marmoratum*), Japanese maple, *Katsura* tree (*Cercidiphyllum japonicum*), *Mizunara* (*Quercus mongolica var.grosseserrata*), *sawagurumi* (*Pterocarya rhoifolia*), *konara oak* (*Quercus serrata Thunb. ex. Murray*), Siebold's beech, and Cardinal red. The work was completed in 1987.

Purpose of improvement		Revegetation of a slope as part of an electric power plant construction project
Geology		Granite zone
Soil		Weathered rock
Execution location		Kurobe City in Toyama Prefecture
Work method, form		Flat ground A: complete soil dressing and plowing Flat ground B, slope: soil dressing, spraying, and plowing
Slope	Direction	W
	Gradient	-
Jurisdiction		Kansai Electric Power Company
Execution years		1986 - 1987


Full View: July 26, 1987


Full view: October 5, 1995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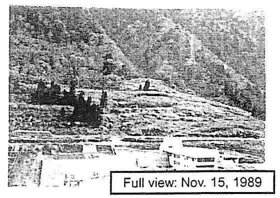
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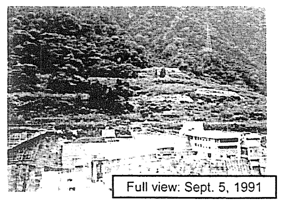
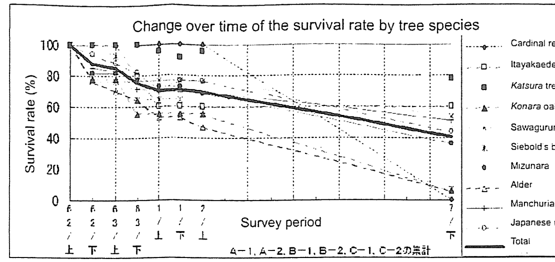
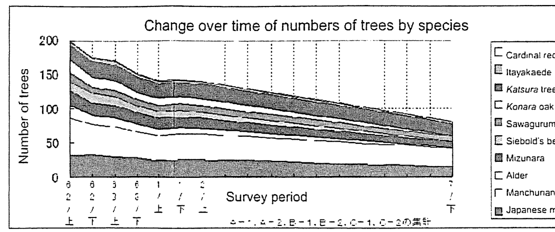
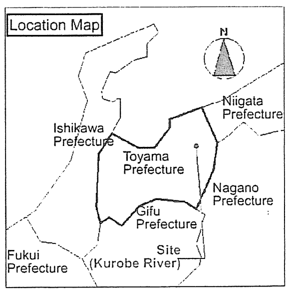
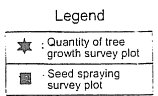

Full view: Sept. 5, 1991

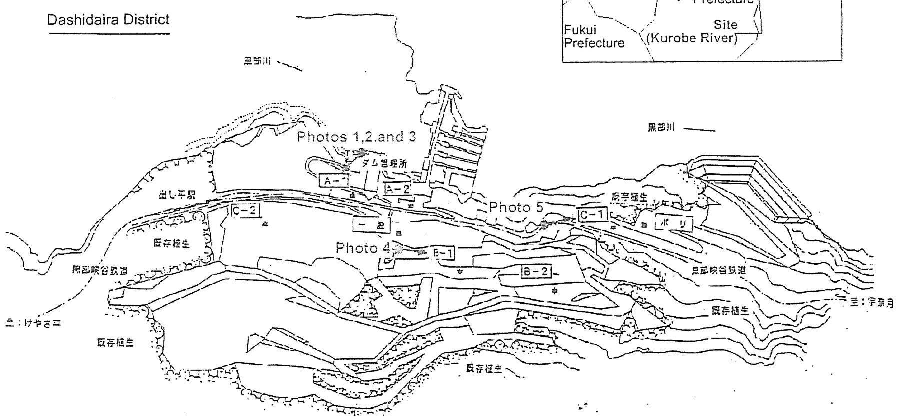




Map of the surveyed district

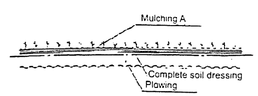






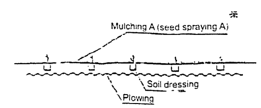
Transplantation method by revegetation category

Revegetation category A (flat)



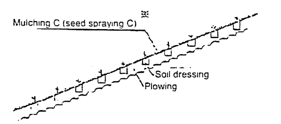
Planting	2 trees/m^2, Tree A: Tree B 2:8
Soil dressing	Complete soil dressing: depth 30cm
Soil improvement	Peat moss: 30 liters/m^2
	Keifun 3kg/m^2 or solid fertilizer 3.25kg/tree
Plowing	Depth 50cm
Mulching	Mulching A (straw mulch 3kg)

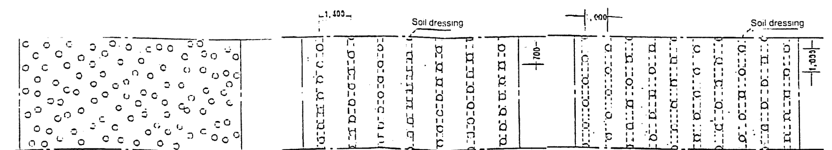
Revegetation category B (flat)



Planting	1 tree/m^2, Tree A: Tree B 8:2
Soil dressing	Soil dressing: width 30cm, depth 30cm, $0.004m^3/m^2$
Soil improvement	Peat moss: 35 liters/m^2
	Solid fertilizer 0.25kg/tree
Plowing	Depth 50cm
Mulching	Mulching B (Seed spraying: A)

Revegetation category C (Longitudinal slope)





Planting	1 tree/m^2, Tree A: Tree B 4:6
Soil dressing	Soil dressing: width 30cm, depth 30cm, $0.09m^3/m^2$
Soil improvement	Peat moss: 3.25 liters/m^2
	Solid fertilizer 0.25kg/tree
Plowing	Depth 50cm
Mulching	Mulching C (Seed spraying: B)

Seed spraying A, B: Comparison of Quantity Sprayed per m^2

		Seed spraying A	Seed spraying B
Curing agent (bark fertilizer)	Kg	0.2	2.0
Adhesive	"	0.003	0.3
Seeds	"	0.028	0.028
Fertilizer	"	0.2	0.15

General spraying is the same as seed spraying

Note
Tree A: Ratio of alder/Manchurian alder
Tree B: Equal numbers of *Itayakaede* (*Acer mono Maxim. var. marmoratum*), Japanese maple, *Katsura tree* (*Cercidiphyllum japonicum*), *mizunara* (*Quercus crispula Blume*), *sawagurumi* (*Pterocarya rhoifolia*), and konara oak (*Quercus serrata Thunb. ex. Murray*)

Case 7 Ushibuse River Forest Physiognomy Transformation

Outline

The Ushibuse River is a first class river that originates in the Hachibuse Mountain Yokomine to the east of Matsumoto City, converges with the Tagawa River inside the city, then flows into the Japan Sea as its name changes to the Narai River, Kuzu River, and finally to the Shinano River. The geology in the river basin is detritus of sandstone, mudstone, conglomerate etc. above an elevation of 1,300m, while below that elevation, it consists of volcanic rock such as fragile quartz diorite and granite diorite that are easily weathered and eroded. And because of its steep topography, the area has a long history of frequent sediment disasters. In particular, by the late nineteenth century most slopes in the water resource zone of the main course of the Ushibuse River, mainly those in around the Hikage Marsh and the Jigoku Gorge, were deforested and devastated. In response, the Sabo Division of the Home Ministry carried out Sabo works along the Ushibuse River for a five year period beginning in 1885. Then beginning in 1898, Nagano Prefecture took over Sabo works on the Ushibuse River with financial assistance from the national government, finally completing a series of projects in 1918. To restore the greenery on the devastated slopes along the Ushibuse River, red pine, black locust (*Robinia pseudo-acacia*) etc. were planted. Of these, the black locust, being a dominant species, are now distributed widely, but the black locust are near the end of their lifetime, and toppled trees have caused disaster prevention problems. And because they mature quickly, obstructing the germination and growth of other native species, they have been completely cut in order to transform the forest physiognomy to a forest of deciduous broad-leaved trees native to the region. Since 1996, forest physiognomy transformation work has been completed on about 32ha of the upstream region.

Purpose of improvement		Forest physiognomy transformation from the existing black locust (*Robinia pseudo-acacia*) to a forest of native deciduous broad-leaved trees
Geology		Granite zone
Soil		Weathered rock
Execution location		Matsumoto City, Nagano Prefecture
Slope	Direction	All directions
	Gradient	-
Jurisdiction		Nagano Prefecture, Matsumoto Construction Office
Execution years		1996 to present day

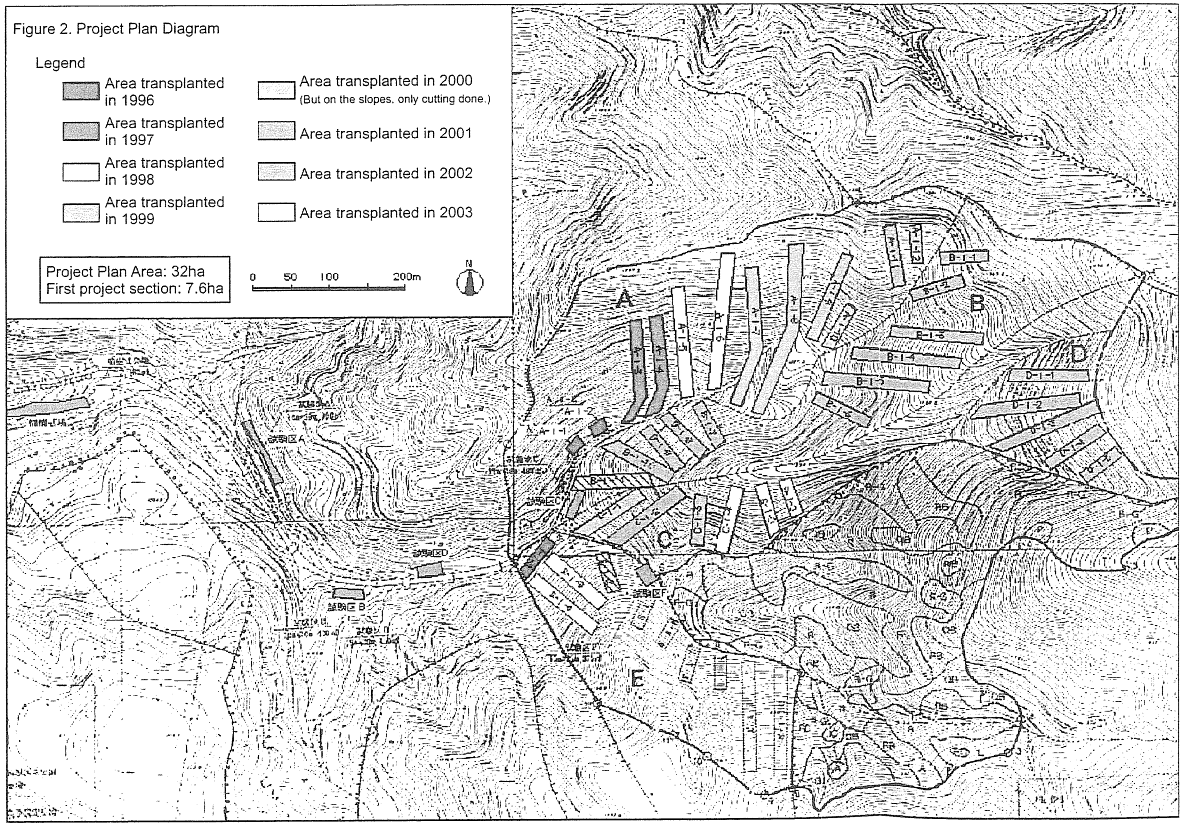


Figure 2. Project Plan Diagram

Need for and purpose of forest physiognomy transformation and tree introduction		The black locust (*Robinia pseudo-acacia*) that are now most of the tall trees in the region are aging and as they fall over, they increase the risk of disasters caused by collapsed soil and floating logs. And their high fecundity prevents the invasion of natural vegetation. The forest physiognomy transformation project was undertaken to resolve disaster problems and to protect the region's ecosystem
Target forest		Forest of a large variety of deciduous broad-leaved trees nature to the region (*konara* oak (*Quercus serrata Thunb. ex. Murray*), *mizunara* (*Quercus crispula Blume*), *sawagurumi* (*Pterocarya rhoifolia*), *Katsura* tree (*Cercidiphyllum japonicum*), etc.) (Secondary deciduous broad-leaved forest)
Forest physiognomy transformation and tree introduction methods	Cutting	Cutting all black locust (*Robinia pseudo-acacia*) in bands 15m in width
	Trans- planting	(Transplanted tree species) [torrent banks] *sawagurumi* (*Pterocarya rhoifolia*), *Katsura* tree (*Cercidiphyllum japonicum*), *tochinoki* (*Aesculus turbinata*), *ohyo* (*Ulmus laciniata*), *onigurumi* (*Juglans mandshurica var. sachalinensis*), *ezoenoki* (*Celtis jessoensis*), Japanese zelkova (*Ulmaceae Zelkova serrata (Thunb.*), and giant dogwood (*Cornus controversa*). (slope area) *konara* oak (*Quercus serrata Thunb. ex. Murray*), *mizunara* (*Quercus crispula Blume*), Japanese chestnut (*Castanea crenata Castanea*), Japanese linden (*Tilia japonica*), *mizume* (*Betula grossa Sieb. et Zucc*), Japanese hornbeam (*Carpinus japonica*), *Yamazakura* (*Prunus jamasakura Sieb. ex Koidz*) etc. Transplanted density (1,600 trees/ha)
Management method	Weeding and brushing	Cutting black locust (*Robinia pseudo-acacia*) sprouts once a year (summer) and cutting grasses
	Thinning	In principle, it is not done. It is expected that natural thinning will maintain the correct density.
	Fertilizing	Not done.
Follow-up survey		Are performed annually beginning in 1996. • Taking rate and growth of trees • Pest damage survey • Toppled trees and transition in areas where execution has not been done
Challenges		• It is important to process sprouts of black locust (*Robinia pseudo-acacia*) • Damage by foraging Japanese serow was a serious problem when the project began, but it has been almost completely resolved by installing protective nets. • Because the mortality of saplings is high, it is necessary to find the causes and study countermeasures. • It is necessary to establish a stable local sapling supply system.
Planning forest physiognomy transformation and tree introduction (manual, guideline, etc.)		Guideline to Forest Physiognomy Transformation of Black Locust (*Robinia pseudo-acacia*) on the Ushibuse River (Revised Edition) (Nagano Prefecture, Matsumoto Construction Office, 2003)

(Photo 1)
Black locust (*Robinia pseudo-acacia*) grove near a French type terracing work
Only about 3% of the trees were black locust at the time of the hillside work, but because of its high fecundity and because secondary cutting was repeated before the war, it is now mostly black locust

(Photo 2) Toppled black locust (*Robinia pseudo-acacia*)
Black locust have short roots and topple easily. The black locust in the Ushibuse area are aging, and as shown in the photograph, their toppled trunks are seen at various places in the river basin.

Appendix Chapter 7 Hillside Works

7.1 Design of hillside works

> **Hillside works shall be designed so that they can fully display their target functions and by accounting for safety and maintenance.**

Commentary

Hillside works introduce vegetation to deforested ground and collapsed ground to control the production of sediment by preventing the expansion of weathering, erosion, and collapse of the surface soil, and are designed with reference to Chapter 13 Part 7 of the Planning Volume.

Types of hillside works are broadly categorized as hillside foundation work and hillside revegetation work depending on their purpose. Hillside foundation work creates a foundation on the execution site for a future forest by stabilizing soil deposited after slope grading and preventing the formation of slope drainage channels and erosion by rainwater. Hillside revegetation works revegetate the execution site by directly introducing vegetation. The following are typical work methods included in both of these categories.

- Hillside foundation work
  - Small check dam work
  - Slope cutting work
  - Earth retaining work (block panel masonry work, concrete retaining wall work, concrete block masonry work, stone masonry work, wire mat work, concrete form work, etc.)
  - Hillside drainage channel work
    - Channel work (corrugated channel work, stone pitching channel work, sodded channel work, fume pipe channel work, U-shaped channel work, concrete channel work)
    - Culvert work (fascine culvert work, gabion culvert work, pebble culvert work, porous pipe culvert work, chemical product culvert work, etc.)
- Hillside revegetation work
  - Hillside terracing work
    - Fence work
    - Seedling terracing work (sod seedling terracing work, straw seedling terracing work)
    - Reinforcing work (sedge grass reinforcing work, sod reinforcing work, fascine reinforcing work)
    - Masonry work
    - Fascine masonry work
  - Covering work (fascine covering work, straw covering work, straw mat covering work, net covering work, seed bag work, vegetation foundation work)
  - Seeding work
  - Transplanting work
  - Contour line trench work

Hillside work methods are generally selected based on the following standards

1. Work method by the geological, climatic etc. environment
2. Work method by the form of devastation

   If the work method is selected according to the design procedure, it is done as follows.

   (1) Deforested ground

   (2) Collapsed ground

At locations where the surface has been eroded following the discharge of the soil and disappearance of vegetation caused by excessive cutting (deforested ground), the design prioritizes hillside revegetation work focused on trees and plants.

And at a location where part of a hillside has collapsed (collapsed ground), the design prioritizes hillside foundation work that is focused on structures that stabilize the soil.

Table 3. Design of Sabo Structures

Geological category / Climate	Mesozoic – metazoan strata zone	Tertiary - Quarternary strata zone	Granite zone	Volcanic sedimentary deposit zone
Normal zone	With priority on torrent works, hillside work minimizes earth retaining work	The soil on the collapsed surface is relatively good and vegetation is aggressively introduced.	Hillside revegetation work with soil dressing type elements is fully performed. Because the slope is easily eroded, it is completely covered.	Because the topography is steep, foundation work corrects the topography. There are places where complete covering is necessary.
Heavy rainfall zone (annual rainfall of 2,000mm or more)	Priority is on hillside work, but hillside foundation work is small and hillside revegetation work is stressed	It is necessary to perform complete hillside foundation work.	Same as in a normal zone.	This corresponds to a *shirasu* (light gray volcanic ash) zone (Southern Kyushu). The slope is cut vertically and revegetation work with soil dressing effects is performed.
Low rainfall zone (annual rainfall of 1,500mm or less)	Generally the devastation is light and simple reinforcement work is adequate.	The work is done at once as hillside revegetation work. Hillside foundation work can be relatively simple.	Hillside foundation work is minimized and priority is on revegetation of the hillside surface (particularly, soil dressing type revegetation)	
Heavy snow region	Hillside work must be designed considering snow avalanches.	Hillside drainage channels are executed at high density to achieve total drainage.	Hillside revegetation work considering snow avalanches is done.	
Freezing zone	The ground is covered by various kinds of covering works and by vegetation to prevent its temperature from falling. Because terracing work collapses easily, it is done as rarely as possible.			

Hillside work design is done as follows. However steps in ( ) are the work methods that are primarily used.

1. Deforested land

   Small check dam work → earth retaining work (block panel masonry work) → slope grading → hillside terracing (seedling work, reinforcing work) → covering work (fascine covering work, straw covering work, seed bag covering work, vegetation foundation work) → transplanting work

2. Collapsed ground

Small check dam work → earth retaining work (concrete retaining wall work, concrete block masonry work)

(Places where natural recovery can be counted on)
→ Hillside work completed

(Places where natural recovery cannot be counted on)
→ Hillside drainage work (corrugated pipe channel work, fascine culvert work) → Hillside terrace work (seedling terracing work, reinforcing work) → covering work → transplanting work

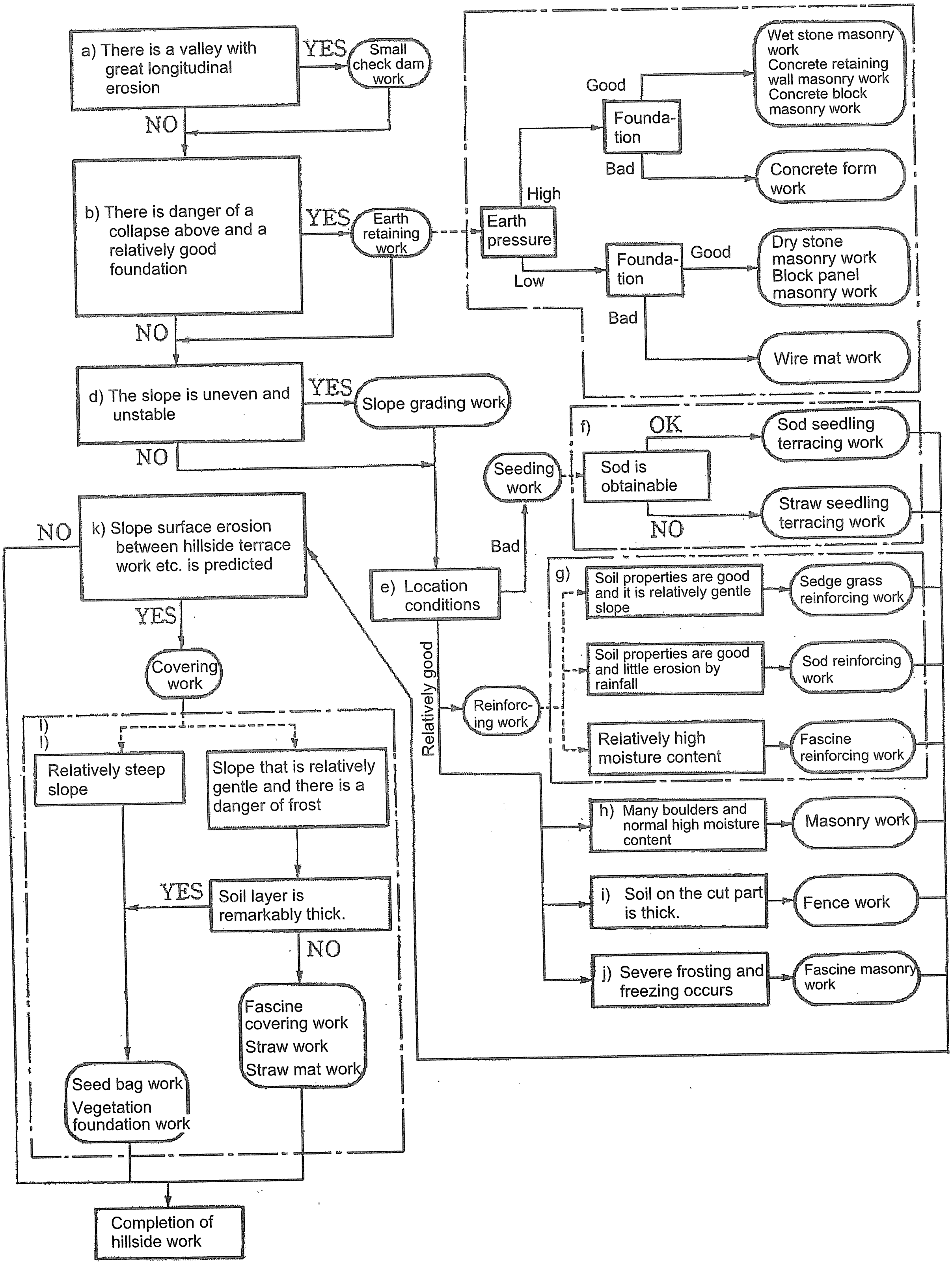
7.2. Small check dam work

Small check dam work shall be designed as stipulated in Part 2 of this chapter.

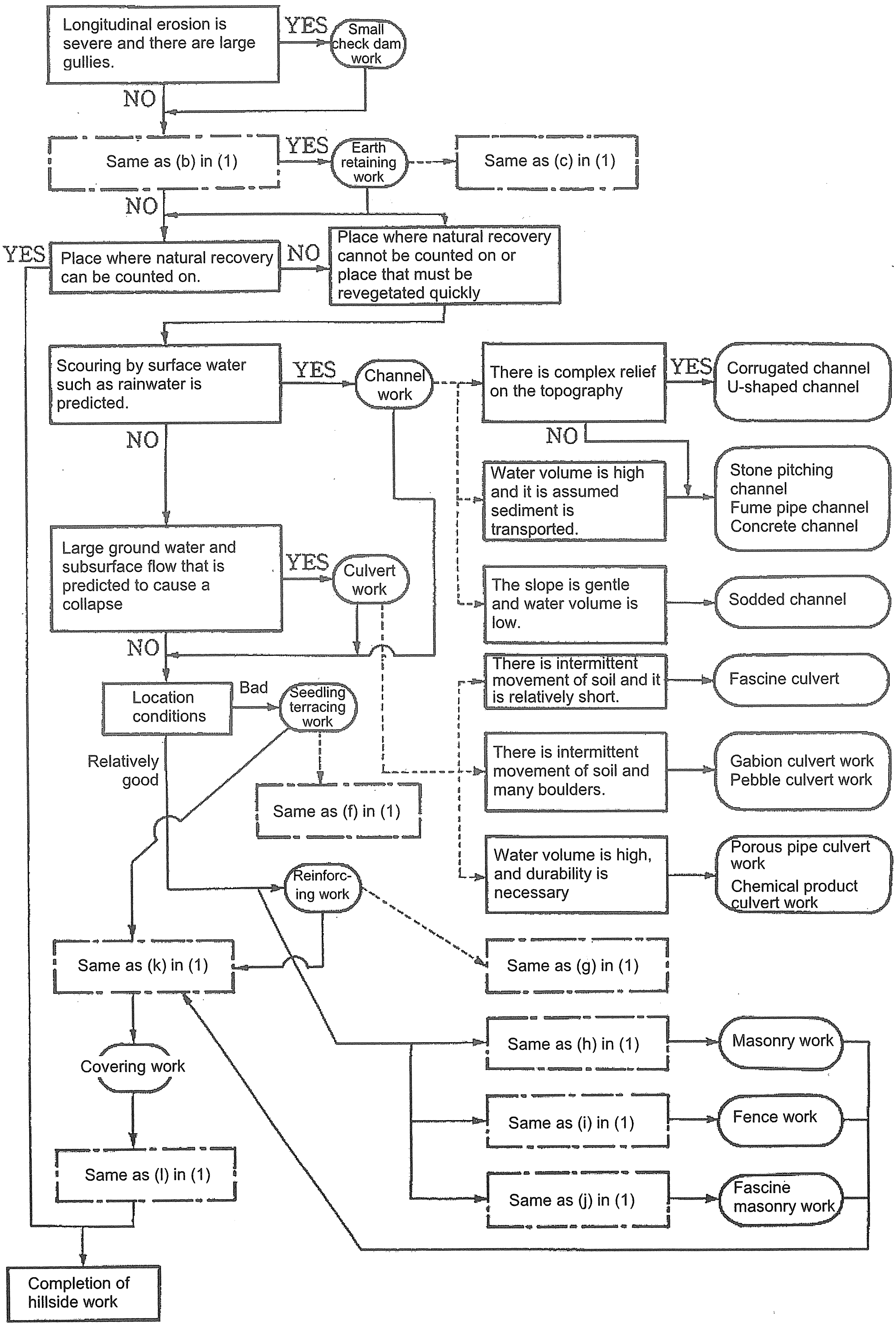
Commentary

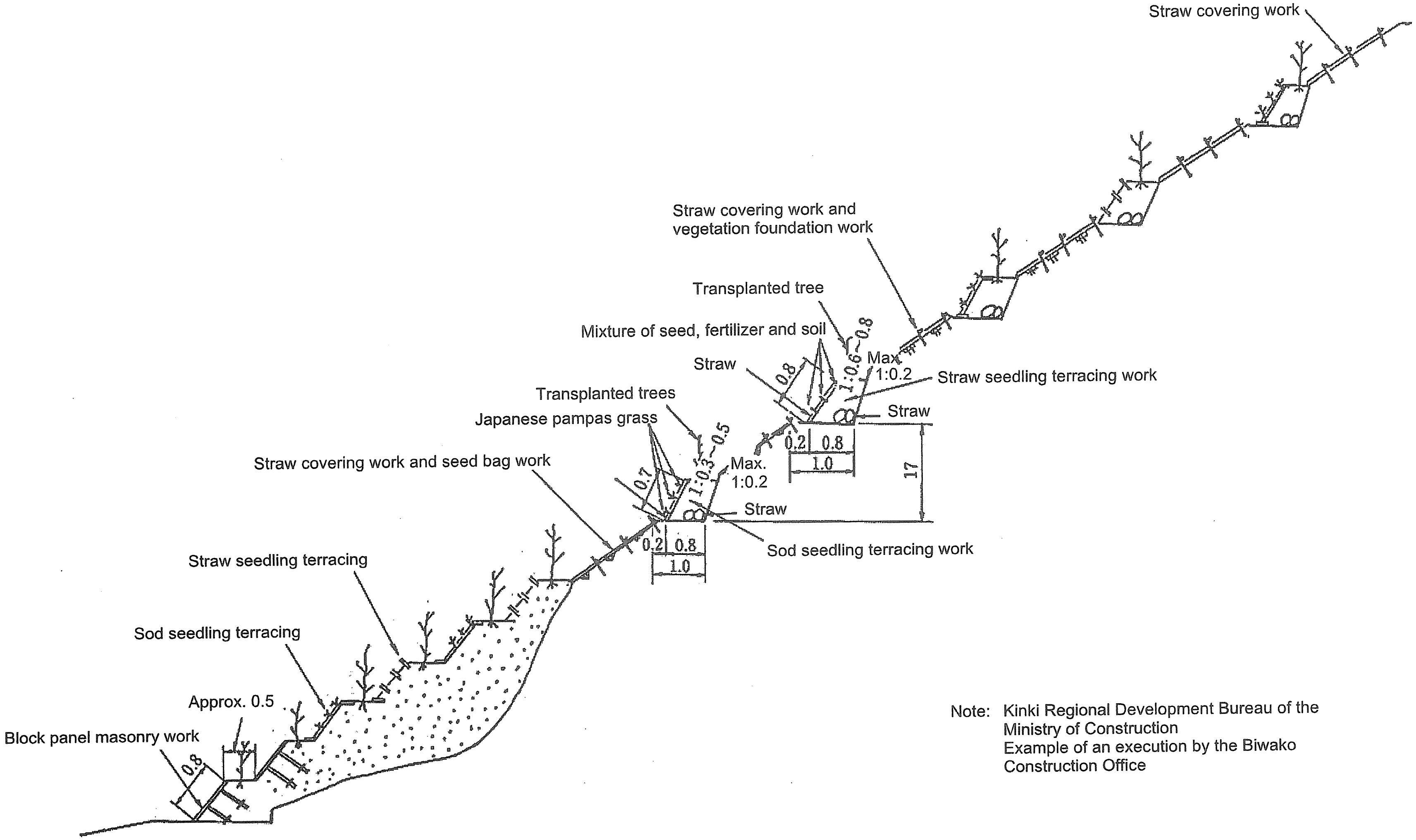
Small check dam work is a work method that prevents erosion and forms the foundation for other structures on deforested ground and collapsed ground where large scale erosion occurs.

(1) Deforested land



(2) Collapsed ground





Note: Kinki Regional Development Bureau of the Ministry of Construction
Example of an execution by the Biwako Construction Office

Figure 3-12. Section Drawing of Deforested Ground (Sample Execution) (unit: m)

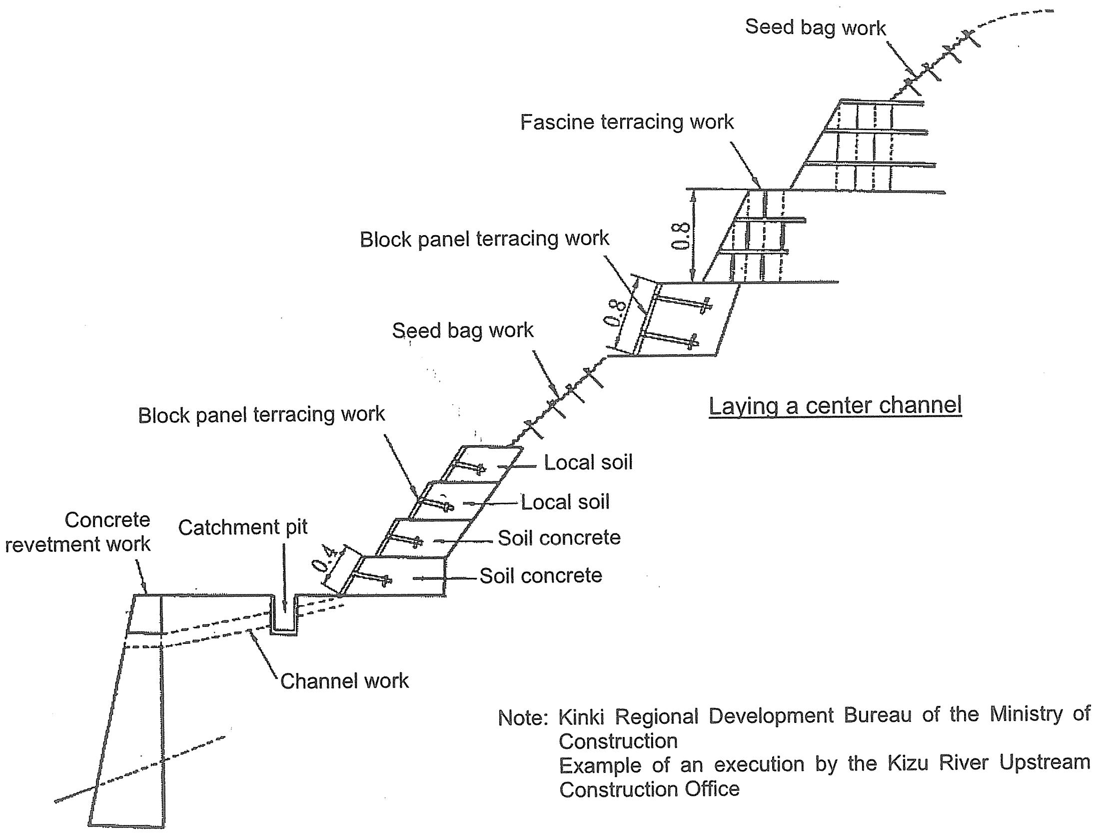


Figure 3-13. Sectional Diagram of Collapsed Ground (Sample Execution) (unit: m)

The design of small check dams is based on Part 2 of this chapter, but the crown width can be lower than the value in the commentary in 2.5.1 of this Chapter if it is considered suitable in light of conditions such as the flow volume and form of sediment transport.

7.3 Slope grading work

Slope grading work shall be designed as a structure that can stabilize the hillside slope.

Commentary

In the case of a steep hillside slope with irregular relief that is predicted to be unstable in the future if left as it is, slope grading work is done to smooth its relief and reduce its steepness. If the vertical height of the graded slope surface is high, in principle the top is finished with a steep grade and the bottom with a gentle grade, but the standard graded gradient is 15%.

In the case of large-scale grading that produces a large volume of excavated soil, counterweight fill may be executed to stabilize the slope. Counterweight fill is a method of creating a terraced slope by embanking using soil with stone masonry or wicker work as the foundation in order to stabilize a steep slope or a slope with irregular relief, and basically, if there are many rocks near the execution site, it is stone masonry work, and if there are few rocks it is wicker work.

7.4 Earth retaining work

Earth retaining work is designed considering topographical, geological, and climatic conditions and safety.

Commentary

When grading has produced a steep slope of sedimentary soil, the earth retaining work stabilizes the sedimentary soil and supports the hillside work executed at the top. And in the case of a steely graded slope on deforested ground or collapsed ground, or in the case of a steep forested slope at the top, planning earth retaining work can minimize the area of the slope grading and reduce the slope gradient.

According to the materials used, it is categorized as block panel terracing work, concrete retaining wall work, concrete block masonry work, stone masonry work, wire mat work, and concrete form work.

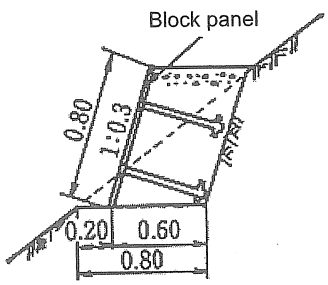
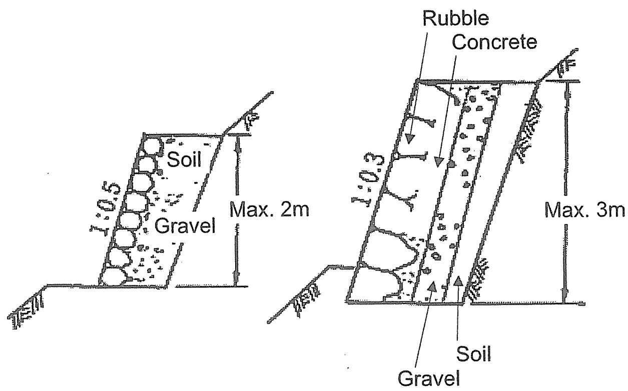


Figure 3-14. Block Panel Terracing Work (unit: m)



(a) Dry stone masonry work (b) Wet masonry work

Figure 3-15. Stone Masonry Work

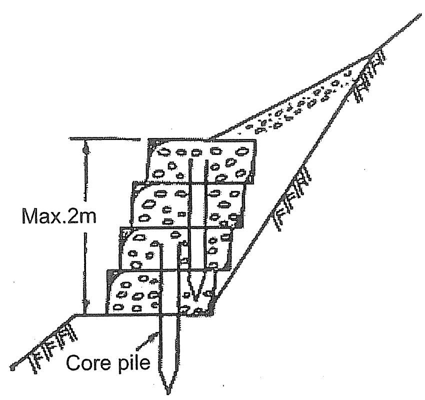


Figure 3-16. Wire mat Work

Block panel terracing work is unsuitable for places with high earth pressure, although the material is light and easy to transport and the work is easily executed (see Fig. 3-14).

Concrete retaining wall work and concrete block masonry work are used as they are in ordinary public works, but they can be used a locations with relatively high earth pressure (see fig. 3-9).

Stone masonry work includes dry and wet stone masonry work. Dry stone masonry work is limited to height of 2m and it is not done on a slope steeper than 5% (see Fig. 3-15(a)). Wet stone masonry is limited to a height of 3m and it is not done on a slope steeper than 3% (see Fig. 3-15(b)).

Wire mat work is not permanent work, and in principle, its maximum height is 2m. Its anchor piles are made of rot resistant wood, that are generally installed at intervals of 2m (see Fig. 3-16).

Concrete pile work is used at locations where the foundation ground is unstable (see Chapter 4 of this manual).

7.5 Channel works

Channel works are designed as structures that can quickly and safely drain flowing water outside the planning area.

Commentary

Channel works are installed to prevent erosion of slopes by flowing water. They are designed with a gentle gradient that does not abruptly change, they are fully embedded in ground with collapsed zone relief, and they easily gather the surrounding flowing water. The channel section must provide enough leeway to safely carry the flow volume. And in addition to the channel work, earth retaining work or band works are done at the bottom end. If the channel is long, band works are done every 20 to 30mm of the channel to stabilize it.

Types of channel works are categorized as corrugated, stone pitching work, sodding, fume pipe, concrete channel work according to the materials used.

See Figure 3-17 for an example of a corrugated channel.

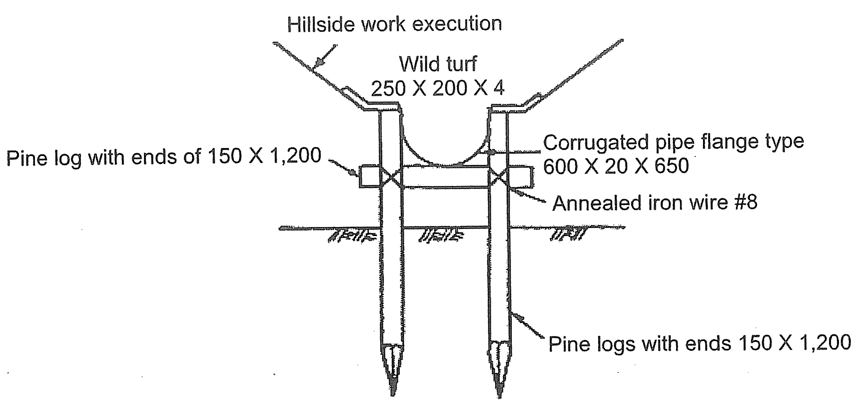


Figure 3-17. Example of corrugated channel work (unit: mm)

7.6 Culvert work

Culvert work shall in principle, be constructed above an impermeable layer and be designed with a structure that can quickly guide groundwater to the ground surface and drain it.

Commentary

Culvert work is done in order to drain ground water that might reduce the stability of the slope, is constructed above an impermeable layer in natural ground mass so that it can most easily drain groundwater from wet locations and at places where springs occur.

Culvert work is categorized as fascine, gabion, pebble, porous pipe, and chemical product culvert work according to the materials used. A fascine culvert is used as a small scale culvert. A gabion culvert is used so that it can work effectively even if the ground is unstable and moves, and generally cylindrical gabions are used. A pebble culvert is used where there ground water content is high and the pebble diameter ranges from 0.05 to 0.15m. Recently the porous pipe and chemical products etc. have been used.

As reference, Figure 3-18 shows a gabion culvert.

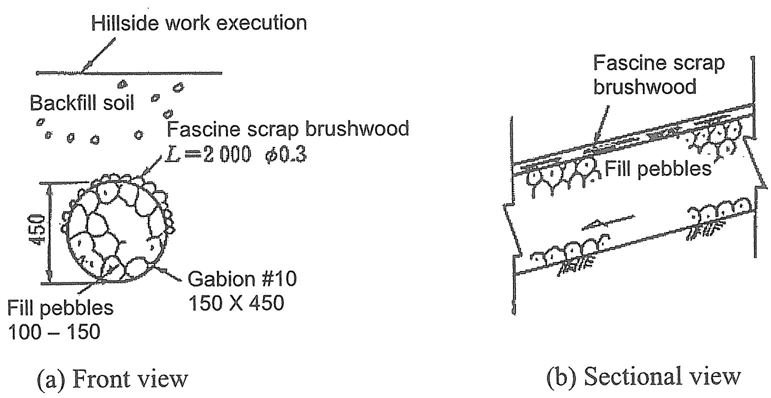


Figure 3-18. Example of a Gabion Culvert (unit: mm)

7.7 Fence work

Fence work shall be designed as a structure that can prevent the runoff of surface soil from the slope.
And fence work shall in principle be used at cuttings while its use on embankments shall be avoided.

Commentary

Fence work is used at locations where there is a shortage of natural sod or stones near the execution site, the soil on the hillside slope is relatively thick, and it is easy to introduce vegetation.

Fence work is categorized as wicker fence work and concrete slab work according to the materials used.

As reference, Figure 3-19 shows wickerwork fence work.

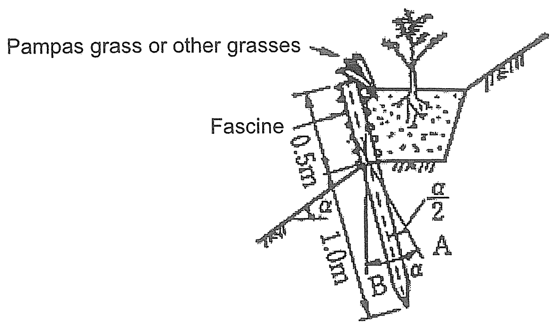


Figure 3-19. Example of Wicker Fence work

7.8 Seedling terracing work

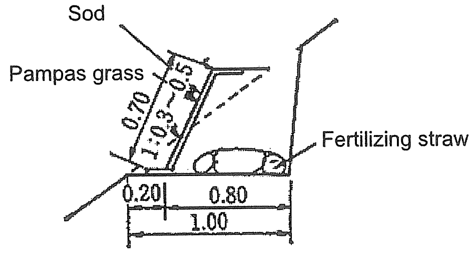
> **Seedling terracing work shall be designed as a structure that can stabilize a slope where the ground mass is exposed. This method shall be selected according to topographical, geological, climatic and other conditions.**

Commentary

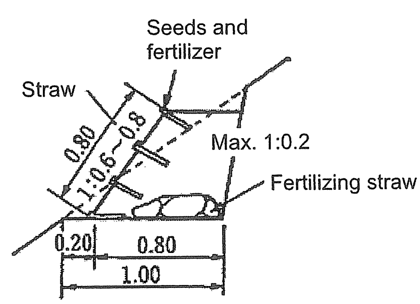
Seedling terracing work is executed by first forming a terrace with vertical height of about 1.5m and width of about 1m on the ground mass, then covering it with sod or straw and backfilling to create a transplanting bed.

Seedling terracing work is categorized as sod seedling terracing work and as straw seedling terracing work according to the materials used. Sod seedling terracing work is a typical seedling terracing work for devastated land in dry areas where there is little rain, and it is suitable for locations were sod is available (see Figure 3-20(a)). Straw seedling terracing work is constructed where there is a shortage of straw that is the major material used for sod seedling terracing work (see fig. 3-20(b)).

Stepped seedling terracing work is a method of executing seedling terracing work continuously in steps on a slope, and is mainly done above sedimentary soil.



(a) Sod seedling terracing work



(b) Straw seedling terracing work

Figure 3-20. Examples of Seedling Terracing Work (unit: m)

7.9 Reinforcing work

Reinforcing work shall be designed as a structure that can stabilize a slope, and this method shall be selected according to topographical, geological, climatic, and other conditions.

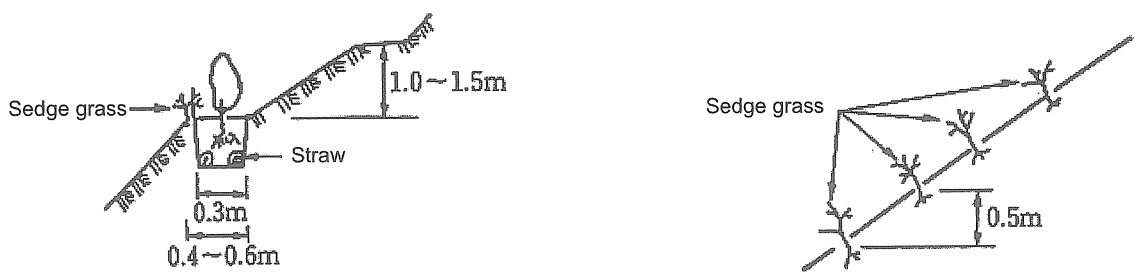
Commentary

Reinforcing works are categorized as sedge grass reinforcing work, sod reinforcing work and fascine reinforcing work according to the materials used.

Sedge grass reinforcing work is generally executed on terraces with vertical height of 1.0 to 1.5m and width of 0.4 to 0.6m and using 0.2 or 0.3 bundles of sedge grass per 1m. At locations where sedge grass can be counted on to grow in a good quality sedimentary soil zone with a relatively gentle gradient, terraces need not be formed (see Fig. 3-21).

Sod reinforcing work is substituted for sedge grass reinforcing work at locations on deforested ground where rainfall causes little erosion (see Fig. 3-22).

Fascine reinforcing work is executed at locations with relatively large water content and where fascine is easily obtained. Generally, fascine reinforcing work forms terraces with vertical height from 1.0 to 1.5m and width of 0.6 to 0.8m, the fascine is placed to a height of about 0.4m, it is about 0.4 long, the diameter of the fascine bundles is about 1m, and sedge grass stalks or perennial grasses are placed between these bundles to prepare for the rotting of the fascine (see Fig. 3-23).



(a) When terraces are formed (b) When terraces are not formed

Figure 3-21. Sedge Grass Reinforcing

(a) When terraces are formed (b) When terraces are not formed

Figure 3-22. Sod Reinforcing

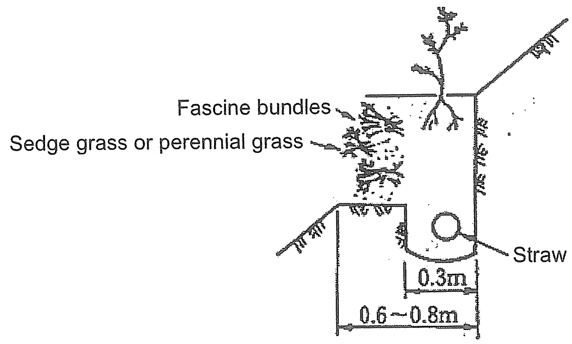


Figure 3-23. Fascine Reinforcing Work

7.10 Covering work

Covering work shall be designed as a structure that can prevent surface erosion on a slope between seedling terracing work and reinforcing work etc. and this method shall be selected according to topographical, geological, climatic and other conditions.

Commentary

Covering work includes fascine covering work, straw mat work, and net covering work.

Covering work is a method of preventing surface erosion of slopes on collapsed ground and on deforested ground, and because it stabilizes the slope until the materials used have rotted, it should be seeded with grass seeds. In this case, the methods mainly used are fascine and net reinforcing works.

To prevent the grass seeds that are directly sown from being washed away, at locations on the execution site with relatively good conditions, straw covering work and straw mat covering works are also used.

Fascine covering work is generally executed on relatively narrow deforested ground or on slopes where seedling terracing work or reinforcing work is done, and is used at locations where fascine is easily obtained and anchor piles can be firmly placed. Generally fascine covering work is done by placing the fascine in rows, installing vertical wood strips on them to hold them in place, then fixing these with anchor piles.

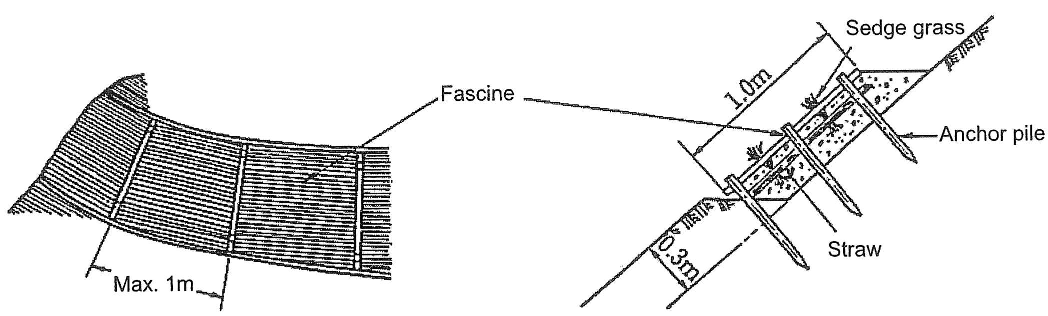


Figure 3-24. Fascine Covering Work

Net covering work is applied to soft hillside slopes with gentle gradient. The meshes are usually longitudinally 2m and laterally 4m rhombic shapes, and they are anchored either with bamboo skewers inserted at the joints and between the fascine or by piles (see Fig. 3-25). Inside the meshes, seedlings with luxuriant roots suited to the execution site are transplanted. Recently synthetic resin products have been used with seed bag work filled with grass seeds or vegetation foundation work executed inside them (see Fig. 3-26).

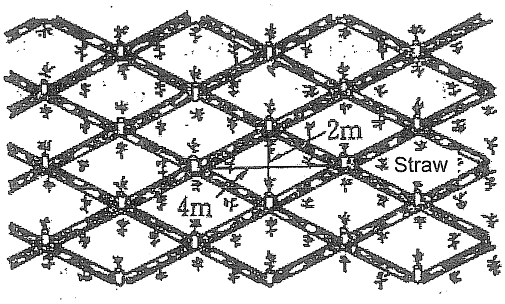


Figure 3-25. Seeding Work

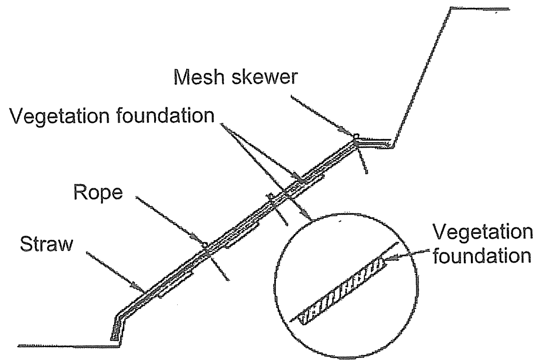


Figure 3-26. Straw Work and Vegetation Bed Work

7.11 Seeding work

Seeding work shall be selected in order to speed up revegetation by directly seeding with grass seed.

Commentary

Seeding work is used at locations where the hillside slope is gently graded and has good soil conditions in order to speed up revegetation by directly seeding the site with grass seeds. The types of grass used for seeding work are, in principle, selected with a variety of growing periods so they will not be unbalanced, and considering the state of surrounding vegetation, are types that can withstand dry ground and infertile ground, have rich root systems and above-ground stems, are perennials with good recovery capability, are low and spread widely, and grow from autumn to spring.

If seeding is done on a steep slope, it is generally necessary to be careful to do covering work to prevent the seeds and fertilizer from being washed away.

Standard grasses used for seeding work are shown in Table 3-9.

Table 3-9. Major Grasses Used for Hillside Sabo work

Species name	Growth period	Characteristics	Cold tolerance	Heat tolerance	Drought tolerance	Acid tolerance	Fertilizer requirement
Chinese fountaingrass	Perennial		Medium	Medium	Medium		Small
Chinese lespedeza	"		Strong	Strong	Strong		Small
Reynoutria japonica Houtt.	"	Suited to land damaged by smoke	Strong	Strong	Strong	Strong	Small
Wormwood	"		Strong	Strong	Strong		Small
Broomsedge bluestem	"		Strong	Strong	Strong		Small
Kentucky 31 fescue	"	Suited to many ground properties, evergreen	Strong	Medium	Medium	Strong	Large
Red fescue	"	Suited to cold areas	Strong	Strong	Strong	Strong	Medium
Red top	"	Large covering ability	Strong	Strong	Strong	Strong	Small
Timothy grass	"	Resistant to cold and dampness	Extremely strong	Weak	Weak	Strong	Large
Weeping love grass	"	Overwhelms other grasses	Weak	Strong	Strong	Strong	Small
Italian rye grass	Annual – biannual	Mixed as a supporting type in winter executions	Strong	Weak	Weak	Strong	Large
Bermuda grass	Perennial	Does not bud without high temperatures	Weak	Strong	Strong	Strong	Small
White clover	"	Sown mixed with gramineous grasses	Strong	Weak	Weak	Medium	Small
Orchard grass	"	Particularly strong shade tolerance	Strong	Medium	Medium	Strong	Large

7.12 Transplanting work

Transplanting work shall be selected to stabilize slopes through early revegetation. This work method shall be selected according to topographical, geological, soil, climatic, and other conditions.

Commentary

Trees used for transplanting work are those that can tolerate dry ground and infertile ground, those with flourishing root development that anchors them quickly to the ground, those with powerful sprouting capacity, and those with great resistance to various kinds of damage (pest, cold, frost damage, temperature change tolerance).

Standard trees used for transplanting work are shown in Table 3-10.

(Reference 3.1) Stone masonry terracing work

Stone masonry terracing work is a method suited to locations with constant high water content or places where strength is required because soil on the graded surface is easily washed away by intensive rainfall. It is substituted for seedling terracing work at locations where there are many loose boulders after grading or a place where the hillside has large relief and the soil is hard. The standard spare length of the stone is normally about 0.3m, the gradient of the slope between 3% and 4%, the height of the masonry work between 0.5 and 1.0m, and the berm is 0.15 to 0.2m.

Stone masonry work is designed with reference to figure 3-27.

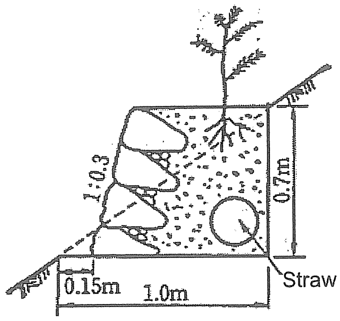


Figure 3-27. Example of Stone Masonry Work

(Reference 3.2) Fascine terracing work

Fascine terracing work is a method that is generally done to increase the quantity of water retained by a hillside slope in zones where freezing is severe, and its standard height is 1.0m.

Fascine terracing work is designed with reference to Figure 3-28.

Table 3-10. Major Trees Used for Hillside Sabo Work

Tree name	Applicability	Reforestation method	Characteristics							
			Rooting ability	Root system development	Infertile ground tolerance	Dryness tolerance	Moisture tolerance	Cold tolerance	Shade tolerance	Acid tolerance
Red pine	Used inland because of its poor resistance to sea breezes.	Transplanting and seeding	Good	Good	Strong	Strong	Weak	Strong	Weak	
Black pine	It is the most commonly used.	"	Good	Good	Strong	Strong	Medium	Strong	Weak	
Black locust	Collapsed ground, deforested hills that are a little fertile	"	Good	Good	Strong	Strong	Weak	Strong	Medium	Weak
Screw pine	Suitable for most devastated ground, but unsuited to cold locations and those with strong winds.	Transplanting, cuttings	Good	Good	Strong	Strong	Weak	Medium	Weak	Weak
Black locust		Cutting, branch spreading, seeding	Good	Good	Strong	Strong	Weak	Strong	Weak	Medium
False indigo	The most applicable species									
Shrubby bush clover	Same as false indigo	"	Good	Bad	Strong	Strong	Weak	Strong	Weak	Medium
Japanese alder	Dryness tolerant	Transplanting	Good	Medium	Strong	Strong	Strong	Strong	Weak	Strong
Manchurian alder	Suited to very cold locations	"	Good	Good	Strong	Strong	Strong	Strong	Medium	Strong
Alder (*Alnus pendula matsumura*)	Suited to locations other than cold locations	"	Good	Good	Strong	Strong	Weak	Strong	Weak	Strong
Alder (*Alnus sieboldiana matsumura*)	Suited to most devastated ground	"	Good	Good	Strong	Strong	Weak	Strong	Medium	Strong
Yamamomo (*Myrica rubra*)	Suited to warm locations	"	Bad	Good	Strong	Strong	Weak	Medium	Strong	Strong

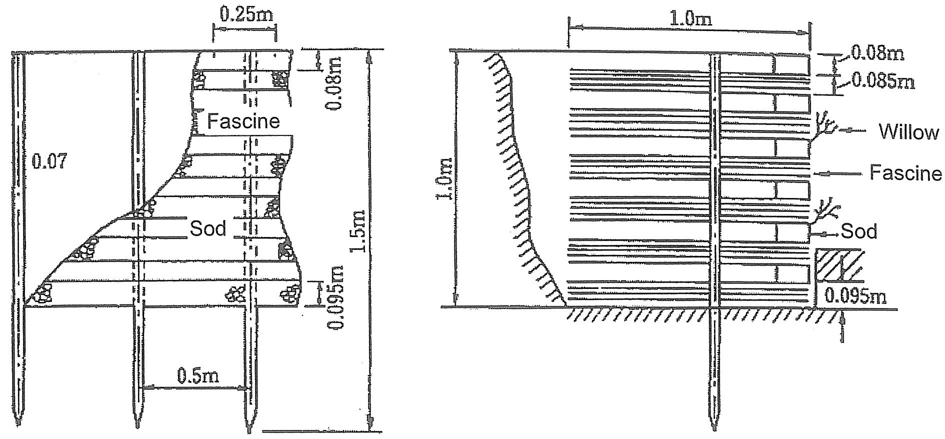


Figure 3-28. Example of Fascine Terracing Work

(Reference 3.3) Contour line trench work

Contour line trench work is a method of preventing the runoff of sediment by installing trenches along the contour lines of deforested ground and other devastated ground to retain and absorb snow and rainwater that have fallen on the slope in order to retain them on the hillside to permit the growth of grass.

The trenches are excavated horizontally along contour lines at a standard interval of 6 to 12m. The trenches are divided by banks at intervals between 6 and 12m, and their height is about 0.1m lower than the height of a bank in a trench on a torrent. The section of the trenches is adequate to prevent the retained water from overflowing the trenches considering the hillside gradient and the state of the surface soil.

If the trenches cross a relatively large gully (more than 0.6 X 0.6m), banks about the same height as those on the gully side are constructed on opposite sides of the gully.

Contour line trench work is designed with reference to Figure 3-29.

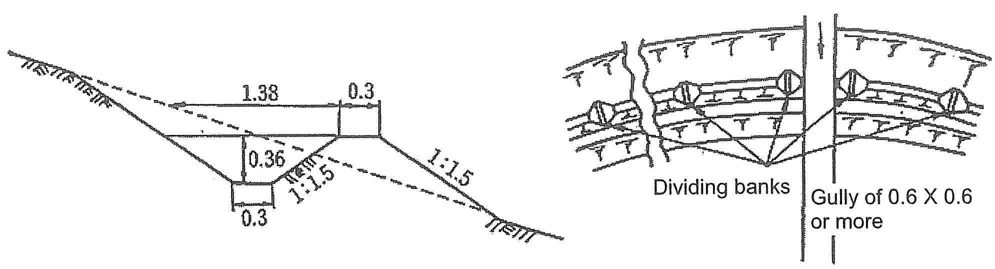


Figure 3-29. Example of Contour Line Trench Work (unit: m)

Part 8. Other structures

8.1 Other structures

Sabo structures shall, as necessary, be management use channels, access steps, fishways, fences, and so on.

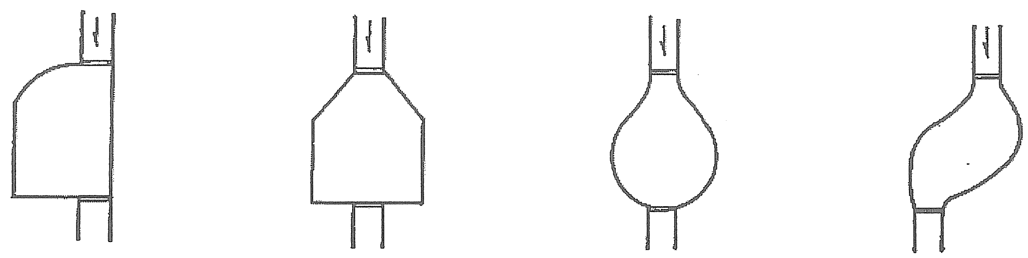
(Reference 3.4) Sand catching works

Sand catching works, that are upstream sabo works executed when it is impossible to reduce the quantity of sediment that is run off to the allowed quantity of sediment in the downstream channel, are designed to fully satisfy their purpose accounting for the topography, geology, and vegetation of the river basin, the riverbed gradient, form of sediment runoff etc., and also accounting for safety, cost, and maintenance.

Sand catching works that deposit soil, sand, and gravel by expanding part of the channel are often constructed at the top ends of areas subjected to debris flows, fans, and channel works.

The capacity of sand catching works is determined by the predicted quantity of sediment that will be deposited, but it should be at least the capacity that permits its function to be recovered by removal work done once a year, and considering the convenience of the deposited sediment removal work, a transport channel and other structures are designed.

The plane shape of sand catching works is designed considering topographical conditions, but there are cases where it is square or shaped like a shogi-piece, sake bottle, or a stomach. (see Fig. 3-30).



(a) Square (b) Shogi-piece (c) Sake bottle shape (d) Stomach shape

Figure 3-30. Examples of Plane Shapes of Sand Catching Works

To prevent excavation and removal of deposited sediment in sand catching works from obstructing the torrent banks upstream and downstream from the works, as necessary, sediment check dam work or groundsill work are executed as dividers in the upstream and downstream courses to maintain the torrent bed. If the inlet abruptly widens, sediment settles near the inlet and the deposition of the sediment advances upstream, reducing the river area in the upstream channel causing the water to overflow its banks. While it varies according to conditions of the torrent flow and the execution location, the widening angle θ of about 30° is appropriate based on past experience (see Fig. 3-31).

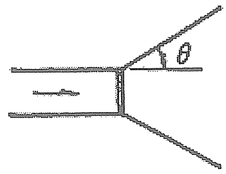
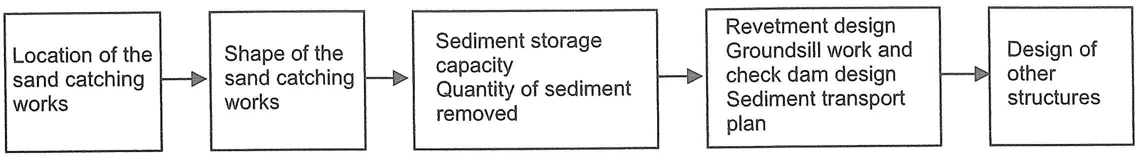


Figure 3-31. Widening Angle of Sand Widening Works

The following is the general sand catching works design procedure.

Table 3-11. Sand Catching Works Design Procedure



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