KYUSHU ELECTRIC'S ACTIONS TOWARDS BIODIVERSITY CONSERVATION IN DAM CONSTRUCTION FOR A LARGE-SCALE PUMPED STORAGE HYDROELECTRIC POWER STATION

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1. Introduction

Kyushu Electric's Omarugawa Power Station, which will be capable of pumped storage power generation with a maximum output of 1,200 MW (300 MW x 4 units), is under construction in Miyazaki Prefecture, located in the southeastern part of the island of Kyushu. Construction started in February 1999, and Unit 1 was put into commercial operation in July 2007 with 300 MW under Phase I-1. The civil engineering work is in its final stage, with the main focus currently being on electrical work toward the commercial operation of all four units slated for July 2011.

Based on the plan, the upper regulating reservoir was created by constructing an upper dam (asphalt-faced impervious walls, rockfill type; height 65.5m) at the uppermost stream of Oseuchitani River, a tributary of Omaru River, while the lower regulating reservoir was created by constructing a lower dam (concrete gravity type; height 47.5 m) in the mid-stream of Omaru River. These two reservoirs were linked by a 2.8 km-pipe to pump up river water to the head of 646 m and to be used for power generation. Fig. 1 shows the location of the plan, and Fig. 2 the top view of the plan.

Figure 1. Location of the Omarugawa Power Station in Miyazaki Prefecture, Japan

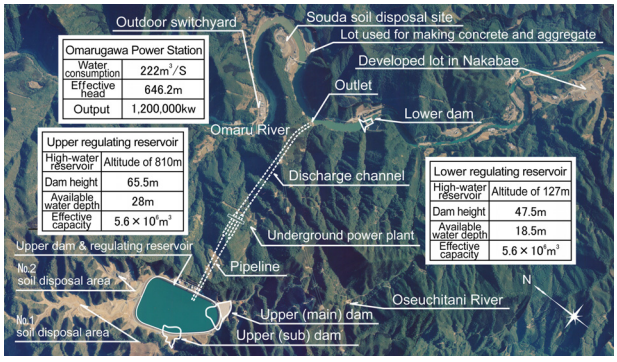


Figure 2. Top view of the plan

Kyushu Electric started environmental research after the decision regarding the sites was made in 1992, and submitted an initial environmental impact report in September 1995 and a revised report in February 1998 to the then Ministry of International Trade and Industry and related agencies. Our research confirmed the existence of Hodgson's hawk-eagle *(Spizaetus nipalensis)* near the lower dam, which is listed as a vulnerable species in the Red Data Book issued by the

Ministry of Environment. Also found were communities of Japanese umbrella pine *(Sciadopitys verticillata)* in and around the construction site of the upper regulating reservoir, which is listed as a near-threatened species in the Miyazaki Prefecture Red Data Book. Kyushu Electric has proceeded with the construction while implementing effective conservation measures to minimize the effect on the natural environment and to achieve harmonious coexistence with local communities whenever possible.

In this paper, the authors focus on several of Kyushu Electric's unique approaches to biodiversity conservation during the construction work for Omarugawa Power Station, as well as its achievements. Table 1 lists some of the environmental measures and their timeframes.

2. Outline of upper and lower dams

2.1 Outline of upper dam

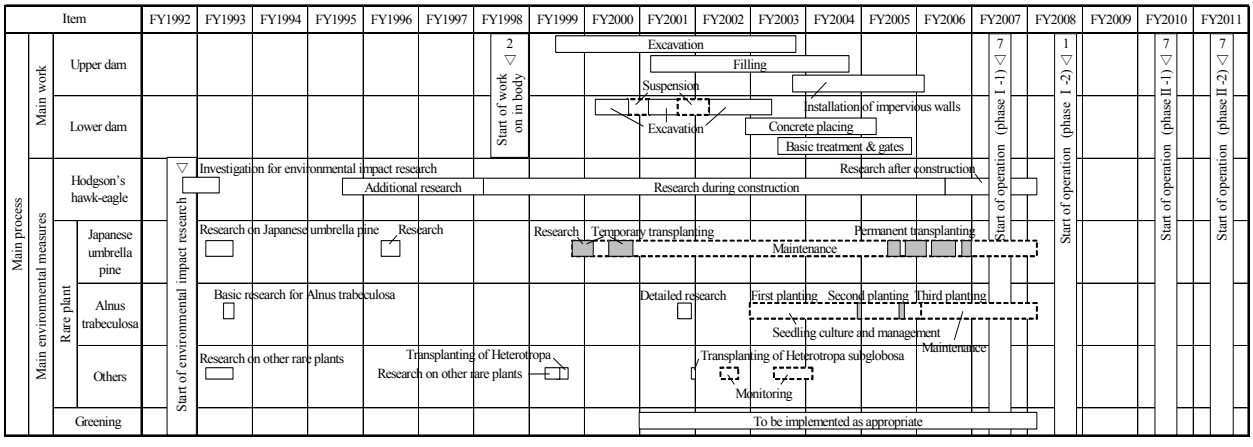
The site of the upper regulating reservoir is at the uppermost stream of Oseuchitani River, near the top of a large mountain. Due to its location, severe weathering was seen in the mountain ridges whose thickness had been reduced to minimum of 50 m in some places. There are some highly permeable zones of 20 Lu or more within the mountain ridges on the right and left banks. To address these issues, we adopted asphalt facing to be used for the entire area of impervious walls of the reservoir.

The upper regulating reservoir was formed by four curved surfaces by cutting and filling the mountain, to increase the thickness of the ridges on the right and left banks, and to reduce the area of impervious walls and convex areas of the construction base (as convex areas weaken impervious walls). The soil excavated was about 6.7 million m^3 in total, about 4.25 million m^3 of which was used as fill for the upper dam.

The asphalt-faced impervious walls were created after shaping the mountain. With an area of about 300,000 m^2, it became the largest regulating reservoir with walls to be entirely faced. The walls have a five-layer structure (two upper impervious layers, a middle drainage layer, a lower impervious layer, and a leveling & macadam layer) for the slope as shown in Fig.3 with a thickness of 30 cm. The bottom is made up of three layers (an upper impervious layer, a middle drainage layer and a lower impervious layer) with a thickness of 26 cm.

The details of the upper dam and regulating reservoir are shown in Table 2, and the top view of the upper regulating reservoir and standard side view of the upper dam in Fig.4 and Fig. 5, respectively.

Table 1. Timeframes for main environmental measures in Omarugawa Power Station construction (as of July 2008)



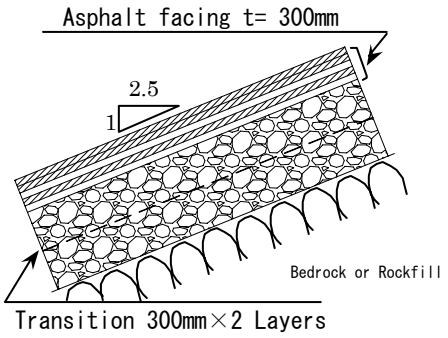


Figure 3. Composition of transition layer and asphalt facing on the slope area

Table 2. Upper regulating reservoir design details

Item	Upper Regulating Reservoir	
Name	Upper Dam (Main Dam)	Upper Dam (Secondary Dam)
River Name	Omarugawa River System, Oseuchi River	
Basin Area	1.7km^2	
Dam Type	Facing Type Rockfill Dam	
Dam Height × Length	65.5m×166.0m	42.5m×140.0m
Dam Volume	860,000m^3	390,000m^3
Normal Water Level	EL. 810.0m	
Available Depth	28.0m	
Reservoir Capacity	6,200×10^{3}m^3	
Active Storage Capacity	5,600×10^{3}m^3	
Reservoir Area	0.27km^2	
Outlet Facilities	Side Overflow Stilling Basin Type 113m^3/s	—

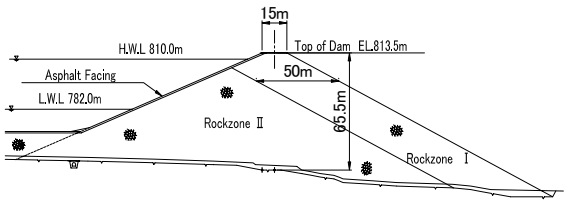


Figure 4. Cross section of the Main Dam of the upper regulating reservoir

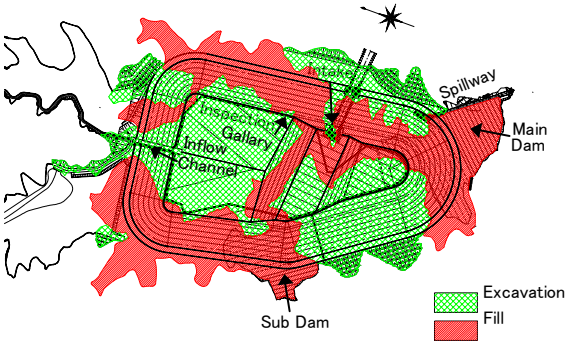


Figure 5. Plan of the upper reservoir

2.2 Outline of lower dam

Since the rockbed had enough strength to serve as a foundation for a dam with a height of 50 m, it was decided to construct a gravity type dam, with due consideration given to the dam's scale, design flood discharge and economic feasibility. One of the characteristics of the site is the large design flood discharge of 4,400 m^3/sec (based on discharge with a once-in-200-year probability, which is rare for regulating reservoirs of pumped storage power plants in Japan.

As for the discharge facility, Kyushu Electric decided to install four crest gates as well as two conduit gates to secure accuracy when discharging small amounts of water, after taking into consideration the operation of the pumped storage power station in addition to the handling of flood discharge.

The crest gates are among the largest in Japan, each gate being 16 m in height and 10 m in width, and fitted with hydraulic cylinder-type switching. The details of the lower dam are given in Table 3, with its top view and standard side view given in Fig. 6 and Fig. 7, respectively.

Table 3. Lower dam design details

Basin Area	329.0km^2
Type of Dam	Concrete Gravity Type
Dam Height ×Length	47.5m×185.0m
Dam Volume	134,200m^3
Normal Water Level	EL. 127.0m
Available Depth	18.5m
Reservoir Capacity	6,900×10^{3}m^3
Effective Storage Capacity	5,600×10^{3}m^3
Reservoir Area	0.41km^2
Outlet Facilities	Front Overflow Type Performance: 4,400m^3/s (Design Flood Discharge) Outlet Conduit Performance: 100m^3/s (at Minimum Water Level)

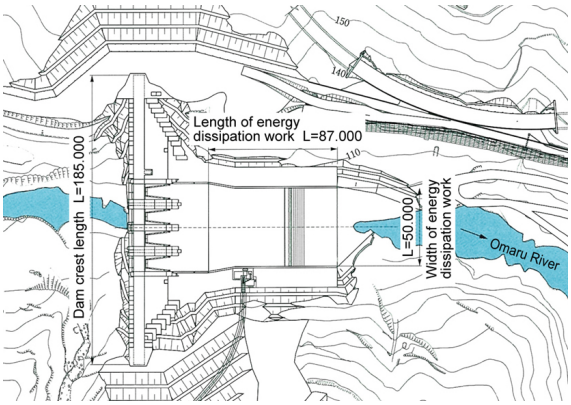


Figure 6. Top view of lower dam

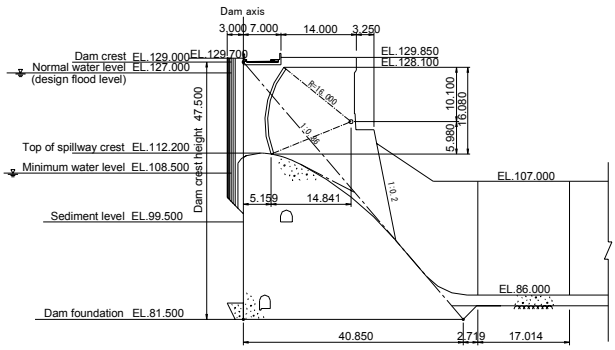


Figure 7. Standard side view of lower dam (overflow section)

3. Conservation of rare bird of prey

3.1 Rarity and habits of Hodgson's hawk eagle

Hodgson's hawk-eagle had been identified near the lower dam and is designated as one of the rare, wild fauna of Japan under the Law for the Conservation of Endangered Species of Wild Fauna and Flora, and also as a vulnerable species in the Red Data Book compiled by the Ministry of Environment and Miyazaki Prefecture (Photo 1). It lives in wooded mountainous areas from Hokkaido to Kyushu. These large birds of prey create nests on tall trees growing out of steep slopes, and usually live as pairs of male and female. Its food varies somewhat depending of the area, ranging from mammals and birds to snakes caught in woods including wild rabbits, copper pheasants and Japanese fore-striped rat snakes.

Photo 1. Hodgson's hawk-eagle living near lower dam

Hodgson's hawk-eagle is on the top of an ecological pyramid and needs a rich natural environment for its survival. The continuation of a bird's breeding activity without abandoning its nest during the construction period indicates that a rich ecosystem is being protected.

Fig. 8 shows the life cycle of Hodgson's hawk-eagle (one year) obtained from monitoring results before and during the construction. The courtship period starts in mid-October, when the bird displays its courtship behavior such as perching on a branch with another as a pair and mating with the partner. Breeding may not occur every year. However, in the years when eggs are laid, the bird becomes active around the nest site starting in November. From mid-December through to the end of March, the bird creates its nest and lays eggs while repeating courtship displays. January and February is the time of the year that the bird is most active and is often seen defending its territory, courting, nesting and hunting during this period. The female usually broods the eggs, which hatch in the latter part of April. The chicks grow up in the nest until late June and then leave the nest. Based on this knowledge, November through June is an important period for breeding for Hodgson's hawk-eagle. Thus, this period was divided into two sections for the implementation of conservation measures; a critical period (Nov. to mid-Feb.) and the most critical period (mid-Feb. to mid-Jun.) when the birth and early growth of the chicks takes place.

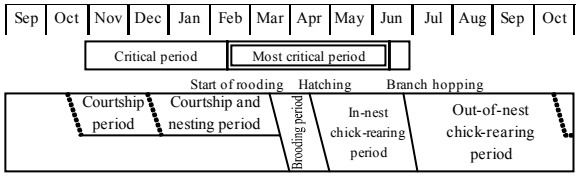


Figure 8. Life cycle model of Hodgson's hawk-eagle at the site

3.2 Conservation measures for Hodgson's hawk-eagle

Hodgson's hawk-eagle becomes active and more sensitive to the environment in the critical period of November through June of the following year. It was important to minimize the impact that the construction might pose on Hodgson's hawk-eagle in this period. During the construction of the lower dam, Kyushu Electric prepared by mid-October, before the critical period starts, (1) the construction plan for the following year, (2) conservation measures, and (3) a plan for monitoring the impact of the construction work on the bird. The company then discussed these plans in meetings of the investigation committee comprised of academics, ornithologists, local government and Kyushu Electric. The conservation measures decided on by the committee were checked for their

effectiveness by monitoring the habits of the bird (Table 4), and reviewed at any time impact on the bird was suspected. Throughout the construction, the work was carried out with this kind of active management (adaptive management). The main pillars of the measures during the critical period are (1) not to implement any large-scale modification, (2) to give visual consideration such as in the use of construction material and equipment of low brightness and chroma, and (3) to maintain tranquility around the nesting areas.

Table 4. Details of monitoring survey (during the peak of construction)

Survey	Purpose	No. of surveys
Wide-range survey	Following the appearance and characteristic activities over entire home range	Twice/mo. (Nov. - Jun.) Once/mo. (Jul. – Oct.)
Survey around nesting areas	Following breeding-related activities in breeding territory	Once/mo. (Jul. - Oct.)
Survey of nesting valley	Following status of breeding, especially egg laying and brooding in nesting valley	Twice/mo. (Nov. - Apr.)

* To be modified depending on breeding status.

There have been various measures implemented so far. In particular, in the early excavation stage, the excavation and reinforcement of the slopes was suspended for a total of 14 months between 2000 and 2002, due to the need for noisy equipment on high-altitude slopes of the lower dam, since breeding was expected during that time (Table 5).

The main work for the lower dam was divided into two stages. The first stage included excavation and reinforcement of slopes, and the second stage concrete placement for the dam body. Since the equipment used and the work situation differed considerably, corresponding conservation measures were implemented. The measures for each respective stage are listed below:

a. Conservation measures during the excavation and reinforcement of slopes

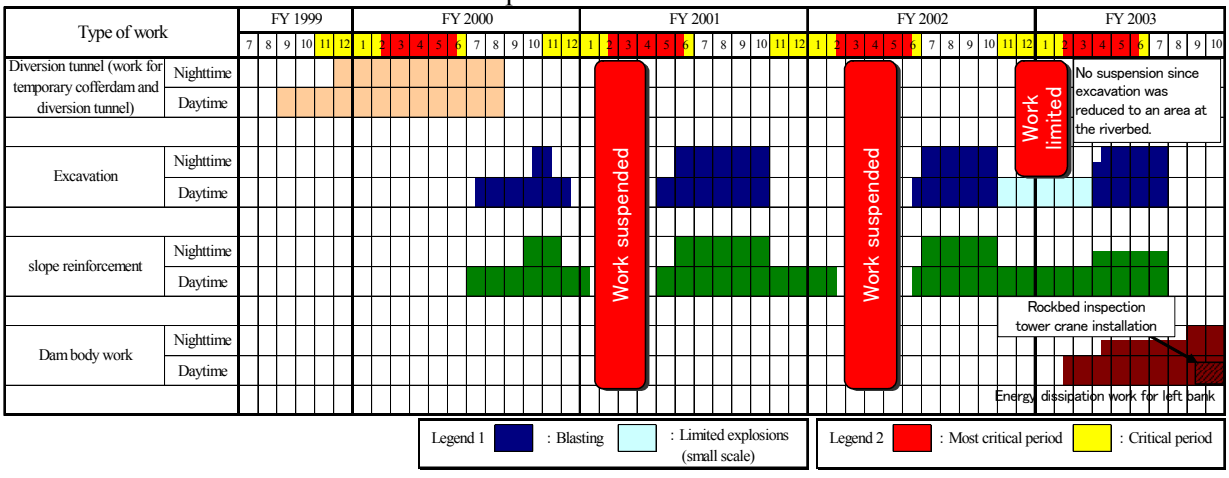
The construction included excavation of about 0.4 million m^3 and reinforcement of slopes, starting in July 2000 and finishing in July 2003. The excavation was done mechanically using bulldozers as much as possible. However, explosives were used on a limited basis for the hard sandstone foundation. Table 6 shows the conservation measures.

Table 6. Conservation measures during excavation and slope reinforcement

	Item	Content
Noise measure	Use of low-noise equipment	Applicable to construction equipment in general, i.e. backhoe
	Installation of silencer	Applicable to air bleeder of mortar sprayer
	Restriction on transport of excavated dirt	Restriction on height of loading bucket of backhoe from load-carrying platform of dump
	Installation of noise-reduction cover	Applicable to boring machine (Photo 2)
	Vehicle speed limit	Speed limited to 30km/h or less around site
	Limited blasting	Restriction on amount of explosives used per blasting
Visual measure	Installation of low brightness net	Applicable to mortar-sprayed slopes and concrete structures
	Selection of lamps	Adoption of eco-friendly, sodium lamps
	Lighting direction	Lamps arranged to avoid shining on the nesting area

Photo 2. Installation of noise- reduction cover

Table 5. Suspension of work for lower dam



b. Conservation measures during concrete placement for dam body

Concrete for the dam body was transported from the batching plant in a tailgate dump track, and transfer car, then transferred by bunker lines to a bucket ($4.5m^3$), which was then carried by a tower crane with an operating radius of 85 m and rated load of 10.7 t. Table 7 shows the conservation measures for the work:

Table 7. Conservation measures during concrete placement for dam body

Item		Content
Noise measure	Use of motor-driven equipment	Applicable to transfer car, boring machine, etc.
	Use of low-noise equipment	Applicable to vibrator and crawler crane, etc.
	Restrictions on equipment used	Limited use of small breaker and pick hammer, etc. (at nighttime during critical period)
		Limited use of whistle and siren, etc.
Visual measure	Restriction on lamp height	Limited lighting from high locations
	Restriction on lit area	Reduced lit area based on work conditions
	Installation of hood/louver	Preventing light leakage from sodium lamps and adjusting beam direction
	Lighting direction	Lamps arranged to avoid shining on nesting area
	Use of localized lighting	Localized lighting during grouting
	Installation of low-brightness nets	Applicable to scaffold and concrete structures
	Adoption of low-brightness painting	Applicable to machinery such as tower crane and temporary building (Photo 3)
	Use of low-brightness mats	Applicable to mats used for curing of placed concrete

Photo 3. Low-brightness painting of tower crane

3.3 Results of conservation measures

Our conservation measures were evaluated positively to a certain degree by the investigation committee, because the satisfactory growth of chicks hatched in September 2002 during the construction period was confirmed.

The construction was completed and started filling water to the lower dam in March 2006, and currently monitoring is carried out to verify that the natural environment is being maintained as it was before construction commenced. Most civil engineering works have been completed now, and the hawk-eagle still inhabits the area with no noticeable change. Kyushu Electric believes that it has successfully minimized environmental impacts during the construction.

4. Conservation of rare flora

Within the planned construction site, there were many rare plants such as communities of Japanese umbrella pine, *Alnus trabeculosa*, *Heterotropa subglobosa* and *Angelica ubatakensis*. To protect and conserve them, Kyushu Electric has implemented various measures in cooperation with the related administrative organizations and under the guidance of academic experts. Below are some of the measures that have been taken.

4.1 Conservation measures for Japanese umbrella pine

The environmental research revealed communities of Japanese umbrella pine near the upper regulating reservoir, some of which were within the area subject to modification. Communities of umbrella pine are rare and seen only in this location in Kyushu. The area around the upper regulating reservoir is very close to the southernmost habitat of the communities. Since they were found in the area of large-scale land modification for the upper regulating reservoir, our best endeavor was made to protect the trees. During the construction period, about 2,800 pines were transplanted temporarily to the disposal area, and after construction was completed, they were moved to the developed area near the reservoir on a permanent basis. The locations where the pines were transplanted are shown in Fig. 9. As part of the conservation measures, the transplanting endeavor was extended to companion trees that grow near umbrella pine in order to recreate more natural communities. Currently, maintenance of the transplanted trees is being carried out. Excellent tree growth has been confirmed so far and the maintenance is planned to be discontinued three years from the final transplanting to let the trees grow naturally (Photo 4).

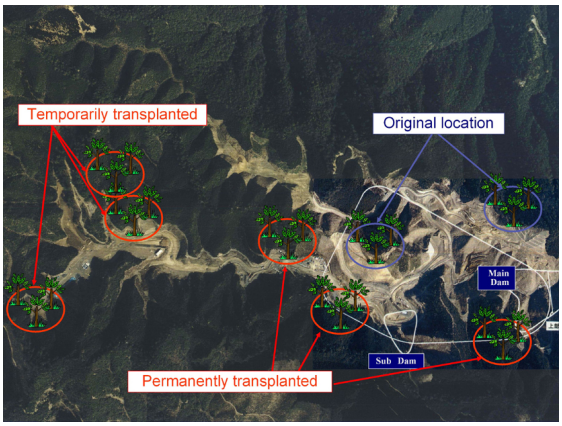


Figure 9. Locations where Japanese umbrella pine were transplanted

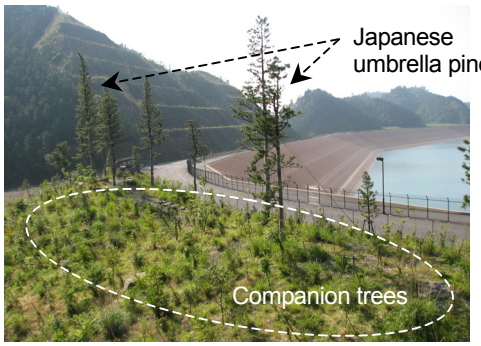


Photo 4. Transplanted Japanese umbrella pines


Photo 5. *Alnus trabeculosa* growing after transplantation

4.2 Conservation measures for *Alnus trabeculosa*

The environmental research confirmed the existence of communities of *Alnus trabeculosa* on the site of the lower regulating reservoir. *Alnus trabeculosa* grows in the west of the southern Tohoku area on Japan's main island of Honshu, and also in Miyazaki Prefecture in Kyushu. Due to its shrinking habitat, caused by land development, it is a rare plant that is listed as a near-threatened species in the Red Data Book published by the Ministry of Environment.

The conservation measures for *Alnus trabeculosa* implemented are listed below:

(1)Recreation of *Alnus trabeculosa* communities in a high altitude area of the lower regulating reservoir, since *Alnus trabeculosa* growing at a lower altitude in the reservoir area might be affected by stored water.

(2)Recreation of communities using seedlings grown from seeds and cuttings by taking into account genetic diversity, together with native trees collected from the communities within the lower regulating reservoir.

(3)Leaving unused *Alnus trabeculosa* in the area of the lower regulating reservoir in their natural state since they might survive after filling of dam.

The transplanted trees are currently monitored and have been confirmed as growing satisfactorily (Photo 5).

4.3 Conservation measures for other rare flora

Angelica ubatakensis (Photo 6) and *Heterotropa subglobosa* (Photo 7), which grow within the area subject to modification and its vicinity, were not considered rare at the time of the environmental research for the planned site. However, the Ministry of Environment designated them as a near-threatened species in the issue of the Red Data Book published after the start of construction. They were moved to an area unaffected by the construction and are being monitored to confirm satisfactory growth.


Photo 6. *Angelica ubatakensis*


Photo 7. *Heterotropa subglobosa*

5. Greening of the modified area

Conventionally, fast-germinating, introduced species are used to cover excavated and filled surfaces for greening. However, over most of the construction site, afforestation has been done by applying native vegetation to the surroundings of this site.

The construction for the upper regulating reservoir required large-scale land modification leaving about 280,000m^2 of land bare. Before the modification, man-made forest of Japanese cedar and cypress had covered much of the area. However, precious natural environment had survived near Omaru River, especially around Mt. Osuzu, which fostered rare flora and fauna that was seen nowhere else in Japan.

Based on these findings, as a measure to restore

the rich natural environment, Kyushu Electric decided on a greening target to bring back the original natural environment unique to the upper regulating reservoir area with careful consideration to the preservation of biodiversity. The importance of preserving such diversity has been cited in laws and by scientific societies. The diversity can be preserved on an ecological, interspecific or intraspecific (genetic) level. In this instance, the restoration endeavor was made with deliberate consideration to genetic diversity based on the unique characteristics of the area, which is located at an altitude of 800 m.

As a specific method for bringing back the original natural environment of the upper regulating reservoir area, Kyushu Electric has conducted greening with the aim of-restoring the potential natural vegetation (best possible nature flora that the land can support, i.e. Japanese umbrella pine, fir or Japanese walnut forest in the case of this site). The basic policies for the greening of the area are listed in Fig.10.

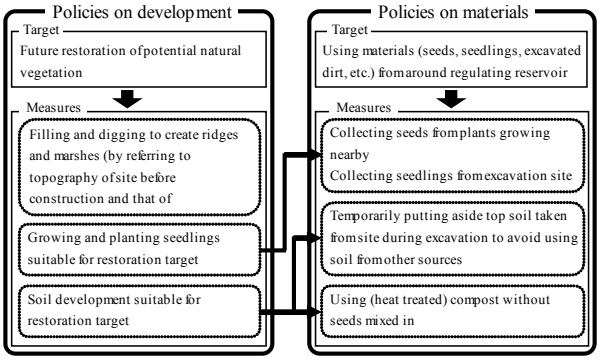


Figure 10. Basic policies in restoring natural environment with consideration to biodiversity

The excavated soil produced when developing the upper regulating reservoir was used as backfill soil for the ridges at the upstream area of the reservoir. For the land for backfilling, hills were created to match with the surrounding topography, channels with a natural setting were built, and seedlings suitable to the land were planted by referring to the natural environment before dam construction (Photo 8). For planting, about 100,000 seedlings were grown from plants collected in the nearby mountains or from seeds obtained from natural specimens, due to concern for the introduction of exotic species and the impact of genetic disturbance on the ecosystems. For backfilling to create landscape, the excavated top soil that was temporarily placed elsewhere was used. The compost used was either from trees that were cut down on the site and shredded or compost that was heat-treated to kill weed seeds to prevent the introduction of seeds from outside.

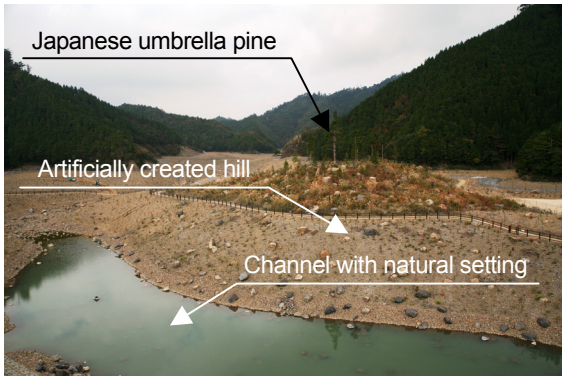


Photo 8. Artificially Created hill and channel with planted trees

6. Conclusion

Kyushu Electric has been promoting eco management by positioning its customers as the starting point of our business activities and pushing forward with measures to fulfill its corporate social responsibility (CSR). At the site concerned, we have strived to create a power station that can coexist in harmony with local communities and the environment. We have upheld all related laws and regulations, and spared no endeavor in protecting the natural environment with thorough consideration for biodiversity. Our endeavors have been highly praised and were granted the 2006 environment award by the Japan Society of Civil Engineers. It is our sincere hope that our measures will inspire and assist any activities for environmental protection in dam construction, as well as all other works that aim to achieve harmony with nature.

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