Environmental conservation measures for construction of a power plant

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Abstract

A pilot seawater pumped-storage power plant (maximum output 30 MW) was recently completed in Okinawa Prefecture, Japan. The plant site is located in the northern part of the main island of Okinawa, and many natural areas remain. Numerous precious organisms, on the verge of extinction, inhabit the area of the plant and its environs. The current study describes environmental conservation measures undertaken before construction, under construction and after construction of a power plant in a natural green space.

The environmental conservation measures implemented during the construction of the power plant focused on noise, vibration, and sanitary wastewater. However, during construction, measures for controlling the red-soil sediment yield and protecting precious animals were more difficult to realize. The sediment yield was measured by a catch drain, minimized using a weir, sedimentation ponds, and slope protection. Provisions for the protection of nature included fences, the transplantation of vegetation, and the preservation of wild animals.
Keywords: power plant, environmental conservation, red-soil, precious animals.

1 Introduction

The geographical features of Japan, which is surrounded by the sea, are well suited to seawater pumped-storage power plants. However, previously, seawater pumped-storage power plants could not be developed because of difficulties in resolving a number of technical and environmental problems associated with the

use of seawater. The Ministry of International Trade and Industry (MITI) decided to conduct a preliminary study and a survey of a seawater pumped-storage power plant in 1981. The seawater pumped-storage power plant was shown to be technically reliable and mitigation of the associated environmental problems was shown to be feasible. MITI demonstrated a test project using a 300-MW pilot power plant on the main island of Okinawa in 1987. The Electric Power Development Co., Ltd. (EPDC) carried out the detailed design and supervised the construction of the pilot seawater pumped-storage power plant. Construction of this project began in 1990 and was finished in 1999 (Komatsu et al. [1]). Since then, demonstration testing was conducted until March of 2004 by the EPDC (ANRE [2]). The pilot seawater pumped-storage power plant is located in the northern part of the main island of Okinawa, which remains an area rich in natural diversity. Many precious and endangered species are also found on and nearby the construction site. In addition, the land is covered with a thick layer of red soil, which can have a serious impact on the nearby coral reefs. Both protection of precious species and the prevention of sediment yielding of the red soil are necessary, both during and after construction of the pilot seawater pumped-storage power plant. The construction of the pilot seawater pumped-storage power plant was performed in a manner consistent with maintaining biodiversity. In addition, restoration of the native environment and the creation of an area in which nature can be enjoyed were undertaken. The present study describes the environmental conservation measures that were carried out before, during and after construction of the pilot seawater pumped-storage power plant.

Table 1: Specifications of the plant.

Item	Specifications	Item	Specifications
Upper pond		**Water way**	
Type	Earth-fill dam (rubber-sheet lining)	Penstock	Inside dia. 2.4 m Length 314 m
	Height 25 m	Tailrace tunnel	Inside dia. 2.7 m
	Crest length 848		Length 205 m
	Dam vol. 420×10^3 m^3	**Power house**	Width 16.4 m Height 32.8 m
	Max width 251.5 m		Length 40.4 m
High water level	Max water depth 22.8 m	**Power generation**	
Low water level	EL 152 m	Max discharge	26 m^3/s
Available draw down	EL 132 m 20 m	Effective head Max output	136 m 30 MW
Gross storage capacity	590×10^3 m^3		

2 Outline of the pilot seawater pumped-storage power plant

The pilot seawater pumped-storage power plant was constructed at Churasaku near Kunigami village, in the northeast part of the main island of Okinawa facing the Pacific Ocean. Table 1 shows the specifications of the plant. Figure 1 shows the profile of the waterways. The upper pond was constructed on a plateau 150 m above sea level and 600 m inland. The pond is 25 m deep and 252 m wide and has a simple octagonal shape. The penstock, powerhouse and tailrace tunnel are underground.

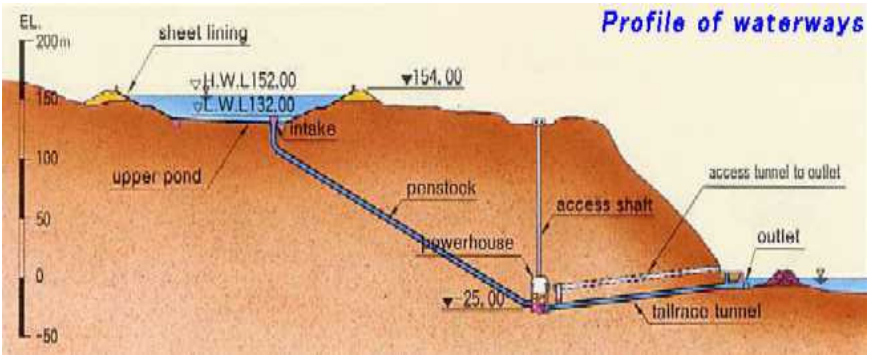

Figure 1: Profile of waterways.

3 Natural characteristics of Yanbaru

The northern area of the main island of Okinawa is called Yanbaru. This area has mountains of approximately 400 m in height that traverse north to south. The subtropical forest of Yanbaru is composed of unique vegetation, and a variety of environments are formed by both the intricate terrain and unique vegetation. Therefore, Yanbaru is home to numerous species of animals, including rare species and sub-species that are original to Okinawa. Sixteen species of precious animals were found in a special natural reserve area surrounding the construction site, including four species of birds, two species of mammals, six species of amphibians, three species of crustaceans, and one species of insect. The vegetation in the construction site is either secondary forest or natural broadleaf evergreen-tree forest, and this area contains many plant species that are native to Okinawa or that grow wild naturally. Yanbaru is covered with a thick layer of unique soil called *Kunigami-Mahji* (commonly called *red-soil*) of pH 4 ~ 6. *Red-soil* is easily discharged by rainfall into the sea and quickly sinks into the sea due to its relatively high specific gravity of 2.6 ~ 2.8. *Red-soil* can seriously damage coral reefs.

4 Environmental conservation measures

The EPDC started the *Precious Animals Conservation Committee* in 1989. The committee is made up of people of experience or academic standing regarding the ecosystem, flora, or fauna of Okinawa. The committee investigated and verified the effects of environmental conservation measures that had been taken up until March 2004.

4.1 Precious animal conservation measures

4.1.1 Capture and transfer of precious animals

Before construction of the pilot seawater pumped-storage power plant, conservation measures were undertaken with respect to precious animals to ensure that these animals would be able to migrate from the construction site to safe areas by themselves. However, since these measures were insufficient for animals that are unable to migrate easily, such as frogs, these animals were transferred to safe areas artificiality. Migration was achieved in three stages, while investigating and confirming the results as follows:

Migration site selection ⇒ *Confirmation by migration test* ⇒ *Practice migration and conservation before beginning construction*

4.1.2 Installation of fences to prevent animals from entering the construction site

Animals such as land turtles and frogs, which travel slowly, can be easily run over by vehicles when they intrude into the construction area. Therefore, polyethylene fences (height: 30 cm) were installed for over 8 km around the construction site, so that small animals could not enter the construction area.

4.1.3 Development and installation of the trapezoidal gutter

Generally U-shaped gutters are installed along roads. However, small animals such as land turtles and young birds may fall into the gutter, and, not being able to escape, these animals will eventually die. Therefore, a trapezoidal gutter that allows small animals that have fallen into the gutter to climb out by way of a slope was developed and installed.

4.2 Red-soil overflow prevention measures

First, the reduction of muddy water was attempted, and various muddy-water treatments were performed according to the work progress based on the following principle:

All muddy water produced at the work site is treated at the work site.

4.2.1 Reduction of muddy water

(1) Separation of rainwater and muddy water by surrounding catch drains

Surrounding catch drains at the boundary were installed between the disposal area and forests (total length: 1.4 km) so that the rainwater from outside the construction area and the muddy water produced in the disposal area would not

be mixed. The rainwater was discharged directly to the swamp. In addition, steel pipe pole culverts were installed along the swamp for approximately 1.1 km in order to discharge the water gathered from the small swamp surrounding the disposal area to the downstream swamp through the disposal area.
(2) Measures for excavated surfaces
Seeds were scattered and areas of excavated turves were covered immediately. Moreover, temporarily excavated surfaces were covered with asphalt emulsion and vinyl sheeting.

4.2.2 Treatment of muddy water

In Okinawa, strong rainfalls occur frequently, which tends to produce a great deal of muddy water. Therefore, a sedimentation pond was constructed and a chemical treatment plant was constructed. The capacity of the sedimentation ponds is 73,400 m^3 for 20 years of stochastically predicted rainfall. Two sedimentation ponds were constructed both in the disposal area and in the upper pond. The capacity of the sedimentation pond in the disposal area was 46,400 m^3, and that in the upper pond was 27,000 m^3. Muddy water around the disposal area flows naturally into the sedimentation pond. On the other hand, the muddy water around the upper pond is fed temporally by water pumps into the sedimentation pond in the upper pond and is then transported into the sedimentation pond in the disposal area. The muddy water in the sedimentation pond in the disposal area, which sunk naturally, was treated at a treatment plant until reaching pH 5.8 ~ 8.6 and SS10 ppm and was then discharged to the neighboring swamp.

4.2.3 Installed weir

Five weirs made of stone were installed at each swamp in order to prevent muddy water from overflowing into the sea. The non-woven cloth attached to the front of the weirs worked as an effective filter.

4.2.4 Patrols

When the rainfall was 10 mm or more, or whenever required, patrols between the work site and the sea were carried out to verify that the muddy-water prevention measures were working efficiently.

4.3 Greening measures against road slope

The low wild woods were transplanted from the work area to the slope shoulder for the purpose of preventing the harvested forest from storm damage. The mild soil slope was covered with nets, and seeds were scattered. Saplings were planted in areas of hard soil. Before planting, a plant testing was performed. Long slopes were covered with nets and were re-covered by grass, an easy practice that requires little maintenance and is cost efficient. The greening nets facilitated grass growth and prevented red-soil discharge by rainfall. As a secondary effect, small animals that had fallen into the gutter could use these nets to climb to safety.

4.4 Education and information propagation

Environmental preservation was stressed to all construction workers, and the workers were responsible for conservation measures during the construction period. A poster with the slogan, "*Take care of the occupants of the forest*", was created and notices were placed throughout the work site. In addition, a handbook titled "*Gentle to nature*" was produced and handed out to all of the workers. During the construction period (1990 ~ 1997), 177 papers were written, detailing important data concerning the living distribution of precious animals. Construction workers were appointed to be in charge of nature conservation and these workers patrolled for animals. In addition, discussion regarding precious animals was always open, which raised worker awareness regarding precious-animal preservation.

5 Environmental monitoring

5.1 Environmental monitoring during construction

Environmental monitoring was carried out during the construction period (1990 ~ 1997), for the purpose of confirming both the impact on the surrounding environment of the construction and the effects of the various conservation measures.

The monitoring results were reported to the *Precious Animals Conservation Committee*, and if a problem was encountered, the problem was diagnosed and the appropriate conservation measures were improved.

5.1.1 Monitored items

The monitored items are listed in Table 2. Amphibian, reptiles, land animals, water creatures, coral, and birds were selected as animals that would be most affected by construction because of their inability to migrate easily.

Table 2: Items monitored during construction.

Item	Object, location, and frequency
Land animal	Amphibians, Reptiles: three lines at the swamp surrounding the site once / year
Water creature	Fish, Benthos, Water creatures, etc.: four lines at the swamp surrounding the site once/year
Soil animal	four points in the forest surrounding the site once/year
Bird	six line-census and five points in the forest surrounding the site once/year
Coral	five points in the sea around the outlet twice/year

5.1.2 Monitoring results

The amphibians, reptiles, and soil animals were confirmed to be of the same species before and after construction. The number of these animals varied yearly, most likely due to the influence of the weather at the time of monitoring. The species of water creatures and coral were confirmed, and the number had increased compared to that before construction. The species and numbers of birds were confirmed to be the same before and after construction, and most of the species of birds living in Yanbaru forest were observed.

5.2 Environmental monitoring after construction

Environmental monitoring has continued after construction (1998 ~ 2003) for the following purposes:

a. Investigation of the impact of the new seawater pumped-storage power plant on the environment.

b. Investigation of the best methods by which to restore the environment surrounding the pilot power plant after construction.

5.2.1 Monitored items

The monitoring items are listed in Table 3, in which vegetation, marine creatures, and salt content in the air are added for the construction period.

5.2.2 Monitoring results

The forest around the pilot power plant was damaged very little by construction and operation, and the vegetation at the *kankyo-souseichi* (described later) grew well. Precious animals were found every year. These animals returned to the construction site area, and various creatures continue to live on and near the pilot power plant site. Coral was damaged by a warm water stream in 1998, but other marine creatures have not been affected by operation. With respect to the salt content in the air, the seawater of the upper pond has had no impact on the surrounding environment because the effect of the seawater from the surrounding sea was much greater.

6 Kankyo-souseichi

The disposal area (45,000 m^2) was improved to create a new natural space called *kankyo-souseichi*, where wild creatures live in symbiosis and in which man can commune with nature, while enjoying its power and mystery.

6.1 Planning and construction of *kankyo-souseichi*

The basic concept for designing and constructing the *Kankyo-Souseichi* was as follows:

Effectively enable the balance of nature at the earliest possible time.

6.1.1 Layout

The flat area was reduced, and the shape of the area was designed to be in harmony with the surrounding area.

Table 3: Items monitored after the completion of construction.

Item	Object, location, and frequency
Vegetation	・Existence of every tree in a specified area: five points on and nearby the site ・Forest edge investigation: four lines at the boundary site Twice/year, before and after the typhoon season
Land animals	・Amphibians, Reptiles: same points as during construction ・Mammals: two line-census and two points on and near the site ・Insects: five line-census and two points on and near the site twice/ year
Water creatures	same points as during construction twice/year
Soil animals	same points as during construction twice/year
Birds	same points as during construction; addition of one line-census and two points twice/year
Marine creatures	・Coral: same points as during construction; addition of three lines ・Medio-littoral organisms, benthos, eggs: two points ・Seaweed, sea grass: three lines ・Flora and fauna, plankton: four points ・Fish, etc.: one line twice/year
Splashed brackish water	・Air salinity degree: automatic; five points, manual; six points ・Sank salinity volume: nine points ・Soil salinity degree: four points ・Leaf attached salinity volume: five points once/year ・Leaf attached salinity volume after typhoon: five points

The land surface was made to be uneven in order to prevent saplings from putrefying.

In order to recover the function of swamps, waterways and a number of meanders, shoals and stagnating areas were constructed as comfortable environments for small animals that live at the water's edge.

Two large ponds (500 m^2 and 150 m^2) on the way from waterways and 50 small ponds (approximately 10 m^2) were constructed in the *Kankyo-Souseichi.* The ponds were very effective for maintaining the humidity in the forest.

6.1.2 Considerations with respect to vegetation

Plant types were selected so as to aid in the succession of the forest. As a result of plant tests, preferred woods, pioneer woods and fruition woods were planted. Seeds from surrounding woods were gathered, and saplings were grown for 2 to 3 years. Based on the results of the plant test, the density of saplings was determined to be 1 sapling/1.5 m^2.

The inorganic soil was improved by a manure compost.

The surface was mulched in order to prevent *red-soil* discharge and soil drying.

6.2 Present condition

Trees planted in areas of weak wind grew to the same height as the surrounding forest. In contrast, trees planted in areas of strong wind grew slowly but steadily. An index of insect species indicated an increase in diversity since 2000, and the diversity of insect species has been re-established.

Other data indicates similar tendencies, and the characteristics of the *kankyo-souseichi* are approaching those of the forest.

7 Conclusions

Efforts to protect the natural environment were undertaken during three periods. Before construction, trial-and-error conservation measures were undertaken in order to protect the environment. During construction, *red-soil* conservation measures and environmental monitoring were the primary conservation measures. After construction, restoration of the construction area was undertaken in order to effectively re-establish nature's balance. Although small-scale environmental conservation measures are generally insufficient when dealing with the large-scale forces of nature, better results are achieved through the efforts of numerous workers carrying out various conservation measures. From the above, the optimum natural environmental conservation measures reduced the period of impact on the ecosystem, avoided severe damage to the ecosystem in order to enable restoration, and minimized the cost of environmental preservation measures. This program, which examined the behavior of animals before the start of construction in order to protect the precious animals living in the area surrounding to the construction site, is without precedent in Japan. In particular, the trapezoidal gutter is a unique development that allowed small creatures of the forest to escape from the construction area. The large-capacity sedimentation pond constructed as part of the red-soil overflow prevention measures (replacing chemical treatment) is also unprecedented. Moreover, the monitoring of ecosystems after construction is very rare. While the limitation of the strategy applied in the area of the power plant is to be taken a lot of time and much money for environmental measures to restore and manage the nature changed by the construction.

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