Part III

Pilot Projects

and Capacity Building

Chapter 8

Pilot Projects

8 Pilot Projects

8.1 Plan of Pilot Project

8.1.1 Objectives

The pilot projects have the following objectives:

1. To strengthen the SWM capability of the PPWM
2. To verify the practicability of the Master Plan
3. To execute an operational plan and verify its practicability
4. To demonstrate improvement measures to residents and authorities concerned with SWM
5. To raise public awareness on solid waste management and gain public cooperation
6. To acquire basic data to devise the design outline of the F/S.

8.1.2 Selection of Pilot Projects

The study team proposed four pilot projects to achieve the above objectives based on the in-depth discussions with the C/P during the first field study in Cambodia, and the projects were approved by JICA.

PP1: Improvement of the SMC Disposal Site
PP2: Improvement of the Waste Collection System
PP3: Development and Promotion of the Urban Waste Compost Market
PP4: Development of the Data Management System for SWM

8.2 Improvement of the SMC Disposal Site

8.2.1 Background

The Stung Mean Chey disposal site (SMCDS) is the only disposal site in the Municipality of Phnom Penh (MPP), which receives 700 tons of wastes a day. Unregulated landfill operation has continued for 38 years, since 1965. The municipality possesses a land plot of only 6.8 ha, which is too small for a city with a population of 1.2 million, and waste spreads out of the municipal area to the surrounding private land.

Since waste is piled up to a height of more than 5 m on average, it is getting more and more difficult for the collection vehicles to access to the working face (waste unloading or dumping area). Accessibility to the site is particularly poor in the rainy season, when waste disposal must occasionally cease. Improving accessibility is an urgent issue.

The most serious matter is that the remaining service life of the SMCDS is very little (less than two years) within the municipal land and construction of a new disposal site will take at least three to four years since it needs to follow a procedure, i.e. a feasibility study, a financial provision, approval of an environmental impact assessment (EIA), a detailed design and tender. Therefore, the expansion of the current landfill area is indispensable.

The site is a typical open dump, having serious negative impacts on the surrounding environment, such as air pollution from smoke caused by fire, waste scattering, odor, surface

and underground water contamination, etc. In addition, the residential area is approaching less than 100 m away from the site due to rapid urbanization.

Around 500 waste pickers (WPs) are working regularly without any rules or control[1]. The waste pickers provide an important role in solid waste management by recovering recyclable materials and reducing waste volume; however, their activities interfere with landfill operations and put their lives at risk. Separation of the working area of waste pickers and the working area of heavy machinery and waste collection vehicles is urgently required so as to realize efficient landfill operation and safe material recovery. It is also necessary to provide basic healthcare opportunity to WPs since they are under the threat of occupational diseases due to awful working conditions.

Taking the above-mentioned situation into consideration, PPWM and the JICA study team decided to urgently improve the SMCDS and JICA allocated part of the budget for the implementation of the project.

a. Expansion of the SMC Disposal Site

MPP/PPWM accepted the proposal made by the study team and obtained the lease of an adjacent plot of land of 3.6 ha to expand the landfill area after negotiating with landowners. The expansion area is shown in the figure below.

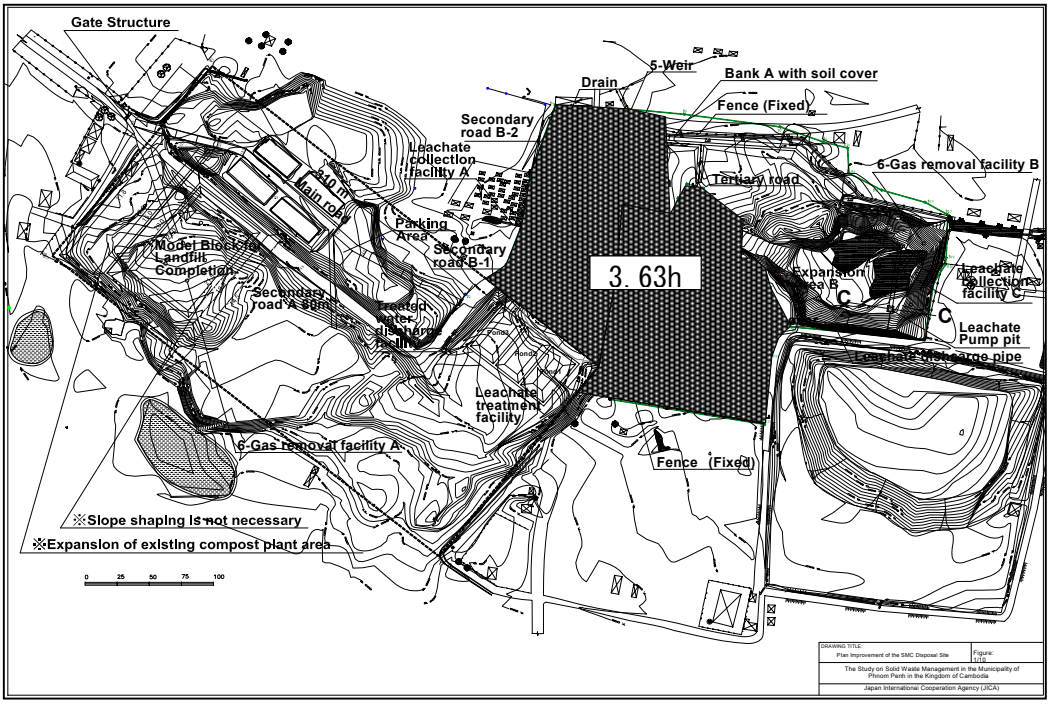


Figure 8-1: Expansion area

The disposal site and its surrounding area are also shown in Figure 8-2.

[1] As of June 2003, the average number of waste pickers who worked at the disposal site was 420 during weekday and 510 during weekend, but the number decreased in the past year. According to the observation survey in November and December 2004, the total number of waste pickers at the disposal site were 197 and 274 respectively.

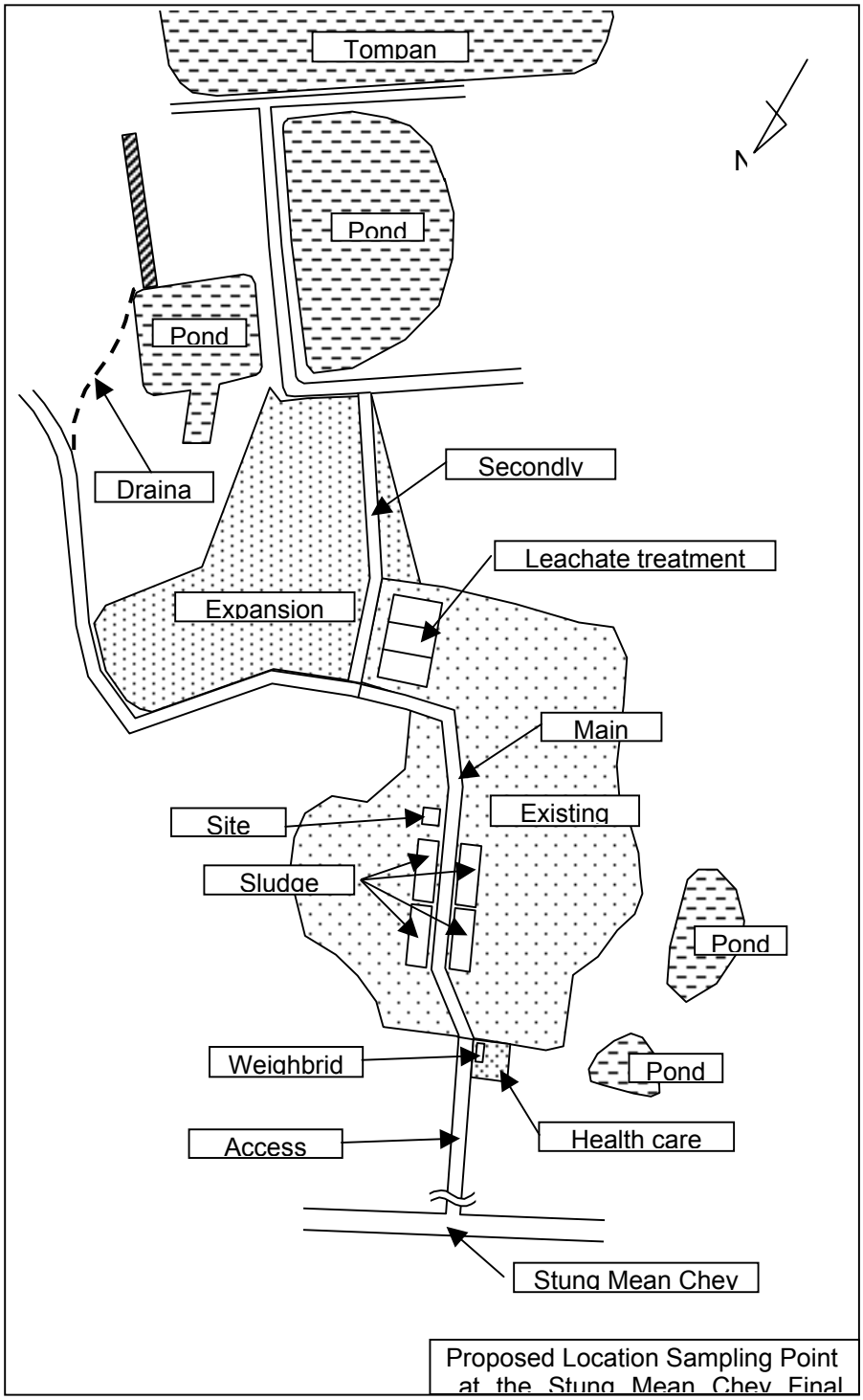


Figure 8-2: SMC disposal site and its Surrounding Area

b. Remaining service life of the SMC Disposal Site

b.1 Landfill Capacity of the SMC Disposal Site

The total area of the existing disposal site including the roads on the premises is 7.5 ha. The expansion area is 3.6 ha. The lease of the expansion area has the following incidental conditions.

- The lease lasts two years

- The height of the landfill area should not exceed 4m from the surrounding road.

The remaining capacity of the disposal site was calculated according to the current and planned final shape of the disposal site, consisting of the existing landfill area and expansion landfill area, after the completion of landfill. The results are shown in Table 8-1. The remaining capacity of the SMCDS is estimated at 380,000m^3 as of January, 2004.

Table 8-1: Landfill Capacity of the SMC Disposal Site

Area	Landfill Capacity (m^3)
1. Existing landfill area	210,000
2. Expansion landfill area	170,000
Total	380,000

b.2 Required Capacity of Landfill Section

The SMCDS is designed to receive waste for a period of three years from 2004 to 2006.

The estimated annual amounts of waste disposed of in the SMCDS are presented in the following table.

Table 8-2: Estimated Annual Amount of Waste Disposal in SMCDS

Year	Waste Disposal		Disposal Site
	Annual Total (ton/year)	Accumulated Amount (ton)	
2004	261,012	261,012	SMCDS
2005	280,685	541,697	
2006	301,928	843,625	

The required capacity of the landfill was determined by the following equation:

$V = V1 + V2$

$V2 = V1 \times 0.04$

where,

V: required volume

V1: volume of waste in a stable state (apparent density = 1.2ton/m^3)
(Considering the amount of recovered waste by waste pickers at SMCDS, the volume of waste one year after the final disposal is used as V1.)

V2: volume of soil required for covering waste dumped

In order to calculate the required capacity of the landfill sections, the following assumptions are made:

- The required amount of soil for covering the waste is assumed at 4% of the waste amount in a stable condition.
- The unit weight of the waste just after dumped in a landfill is 0.5 tons/m^3.
- The unit weight of waste in a stable state after filling is 1.2 tons/m^3.
- The water content of waste when discharged is 68.3wt% (according to WACS study); the content of decomposable matter is 24.2wt%, non-decomposable matter is 7.5wt% and when in a stable state it is 50wt%.
- The decomposition rate of organic material in a stable state is 15%.
- Therefore, if the weight of the waste just after discharged in a landfill is 1 ton, the waste weight after half a year, which is calculated in accordance with the above mentioned condition, is 0.511 tons.

The required capacity of landfill sections are presented in the following table.

Table 8-3: Required Capacity of Landfill

Year	Weight of Discharged Waste	Waste Weight in Stable State	V1	V2	V	Accumulated Volume
			Waste Volume in Stable State	Cover Soil	Total Volume	
	Wd	Ws= Wd x 0.511	V1= Ws/1.20	V2= V1x 0.04	V=V2+V3	
	ton/year	ton/year	m^3/year	m^3/year	m^3/year	m^3
2004	261,012	133,377	111,148	4,446	115,594	115,594
2005	280,685	143,430	119,525	4,781	124,306	239,900
2006	301,928	154,285	128,571	5,143	133,714	373,614

b.3 Remaining service life

According to the trial calculation conducted by the team under the above conditions, the duration of landfill operation using this land is only 3.0 years. The SMCDS has a enough capacity to accept waste from 2004 to 2006, provided that PPWM conducts a proper landfill operation.

8.2.2 Plan of Experiment

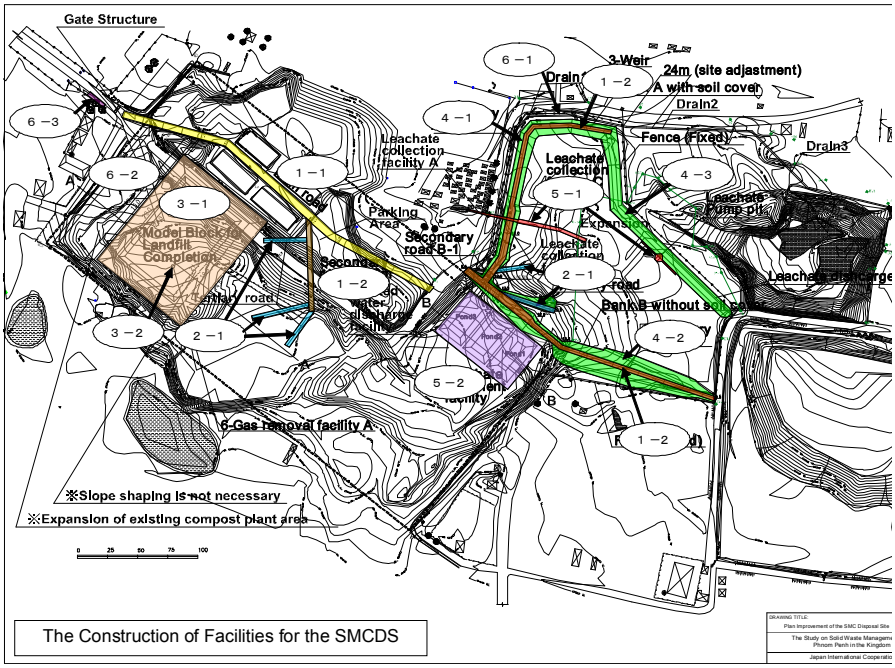
The urgent improvement mainly consists of three elements: (1) construction of facilities, (2) improvement of operation, and (3) waste picker management. The improvement plan of the SMCDS is summarized in the table below.

Table 8-4: Experiment Plan of the SMCDS

Items	Main Target	Responsible Bodies
1. Construction of Facilities		
1.1 Installation of a weighbridge	Data collection for landfill management	JICA
1.2 Securing of land for expansion	Expansion of the landfill	PPWM
1.3 On-site road	Secure the access	JICA
1.4 Working face	Separation of landfill operation (LO) and waste picking work	JICA
1.5 Model block for landfill completion	Demonstration of sanitary landfill	JICA
1.6 Enclosing bank	Demonstration of sanitary landfill Expansion of the landfill	JICA
1.7 Leachate collection and treatment	Demonstration of sanitary landfill	JICA
1.8 Others	Demonstration of sanitary landfill	JICA
2. Waste Picker Management		
2.1 Registration of WPs	Separation of LO and waste picking work	PPWM and JICA
2.2 Issuance of permission cards	Separation of LO and waste picking work	PPWM and JICA
2.3 Control of the entrance of WPs	Separation of LO and waste picking work	PPWM
2.4 Provision of jackets	To support WPs to organize themselves	PPWM and JICA
2.5 Provision of vaccinations	To establish a reliable relation with WPs and to improve their health conditions	MOH, DOH
3. Improvement of Operation		
3.1 Operation of the weighbridge	Establishment of data base for landfill	PPWM and JICA
3.2 Preparation of operation plan	Demonstration of sanitary landfill	JICA
3.3 Preparation of technical specification	To supervise landfill operation done by the contractor	JICA
3.3 Operation of improved landfill	Demonstration of sanitary landfill	JICA, PPWM

a. Technical improvement

The construction of facilities is being conducted mainly by a contractor entrusted by the JICA study team according the construction plan as shown in Figure 8-3.



Work Item
1. On-site Road
1-1 Main road
1-2 Secondary road
2. Working Face
2-1 Tertiary road
3. Model Block for Landfill Completion
3-1 Model block
3-2 Gas removal facility
4. Enclosing Bank
4-1 Bank A (with soil cover)
4-2 Bank B (without soil cover)

Work Item
5. Leachate Collection & Treatment Facility
5-1 Expansion Area A
(1) Leachate collection facility
(2) Leachate pump pit
(3) Pump
(4) Leachate discharge pipe
(5) Gas removal facility
5-2 Exiting Area (southern area)
(1) Leachate collection facility
(2) Leachate pump pit n
(3) Pump
(4) Leachate discharge pipe
5-3 Leachate Treatment Facility
(1) Pond (1-3 ponds)
(2) Pumping station
(3) Treated water discharge pipe
6. Others
6-1 Fence (Fixed type) and gate
6-2 Expansion of Existing compost plant area
6-3 Weighbridge

Figure 8-3: Construction Plan of Facilities for the SMCDS

b. Operational improvement

A model landfill area shall be prepared in the expansion area and an appropriate landfill operation shall be demonstrated there.

b.1 Landfill operation

A safe and proper landfill operation system shall be established by separating the waste picking area from the heavy vehicle operation area (landfill area) as follows.

In the original idea, the landfill operation area is divided into the following four areas:

1. Waste unloading area
2. Waste picking area
3. Waste compaction area
4. Waste covering area

These areas are shifted every half-day. The rotation of working areas is shown below.

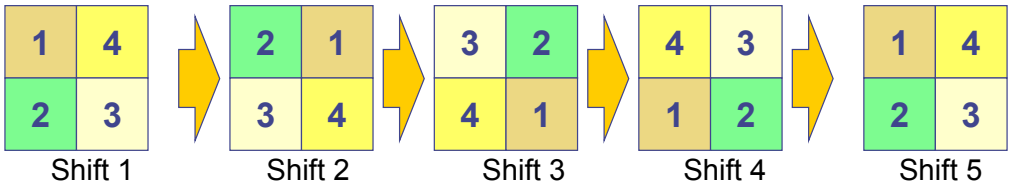


Table 8-5: Rotation of Working Areas (Original Plan)

Waste pickers are only allowed to enter the waste picking area (2). They are prohibited from entering the other three areas where heavy vehicles are operated, and this separation would considerably enhance the safety of waste pickers at the disposal site. When the first shift of landfill operation finishes, waste pickers are requested to move from area (2) of Shift 1 to the next area (2) of Shift 2, where the unloading operation has just finished, as shown in .

b.2 Introduction of waste picking rules for waste pickers

Introducing waste picking rules at the disposal site is one of the critical elements for the "Improvement of SMC Disposal Site". The team tried to introduce waste picking rules at the SMCDS. The details procedure and its result are reported in Annex 10 of the Supporting Report.

In order to realize these rules at the disposal site, first of all, it is necessary to control the entrance of waste pickers. The introduction of a registration system is a key measure to control their entrance. In addition, it is necessary to organize waste pickers in order to maintain these rules in a sustainable way.

During the first phase of the JICA study, several meetings were organized along with the interview survey with waste pickers and ordinary people living around the disposal site. According to the survey, it is likely that the majority of waste pickers agree with the introduction of the registration system. However, there are some serious obstacles left to introducing such a system and to organizing waste pickers. These problems are as follows:

- The number of waste pickers that are working at the disposal site is huge and they are considerably diversified in terms of income, working status (the frequency of work at the disposal site), age, and living status. In particular, the large difference in income would make it difficult for waste pickers to make a consensus among themselves.
- A large number of children are working at the disposal site and they contribute to their household incomes. This would make it difficult for PPWM to decide how to deal with these child waste pickers when the registration system is introduced.
- At present, there are neither organizations nor leaders among waste pickers. A long-term approach is necessary to make them understand the importance of organization and to encourage them to organize themselves.
- PPWM has little experience in communicating with waste pickers. Therefore, before PPWM and waste pickers establish a mechanism in which they maintain regular communication to discuss their problems, it is necessary, for a certain period, that people of authority such as village chiefs and VDC members work as leaders of waste pickers and that an independent organization or personnel works as a mediator between PPWM and waste pickers.

Considering the above-mentioned obstacles, the team took the following approaches to introduce the registration system and waste-picking rules smoothly.

- to utilize an existing mechanism
  -cooperation with village chiefs and VDC members
- to take a realistic and gradual approach
  -setting an age limit of 7 years olds

In addition, the team proposed to take different approaches according to the age of the waste pickers

- All the waste pickers that are 16 years and over can be registered and get ID cards, regardless of their working status (full-time or part-time).
- Children who are between 7 years old and 15 years old are registered on the list after a brief interview and get ID cards. PPWM and JICA assistants or local partners will regularly contact them and make an effort to ensure that all of them go to school in cooperation with NGOs.
- Children who are 6 years and under are not allowed to enter the disposal site.

b.3 Demonstration of Landfill Operation

In the pilot project, the Team constructed and repaired working faces and enclosing banks with heavy vehicles as a demonstration, aiming at transferring technology to PPWM.

The team decided to rent a wheel loader for the demonstration work for half a year. The reason of renting a wheel loader was that a landfill operator already had a skill in operating a bulldozer well and that a wheel loader is capable of a small sharp turn and has a high mobility.

Since PPWM started to excavate soil inside the disposal site and soil became available for free, final covering work was included in the operation plan

b.3.1. Preparation of working face

In the completed fill, it is necessary to build up the final shape of disposed waste. In the pilot project, the final shape was constructed only in the expansion area by using a wheel loader.

Waste piled up higher than the planned height (12.5m in altitude) was moved and leveled (shown in the photo below) until the height of the layer waste layer became within the planned level (the final level of the layer was decided considering the effect of subsidence).

In the next step, the Team has a plan to build up the similar block using relatively fresh waste. The location of the final block will be changed due to the movement of the working face. This plan was agreed by PPWM at a weekly meeting organized every Monday at the disposal site.

Photo


Spreading work of waste


After spreading work

b.3.2. Final covering in the completed fill

In the completed fill, the area where waste was build up until the planned height was covered with soil excavated inside the disposal site as a demonstration.

The soil for final covering was excavated by a power shovel, transported to the completed fill by a dump truck, and spread by a wheel loader. In this project, PPWM could acquire skills in conducting final covering with excavated soil.

Photo

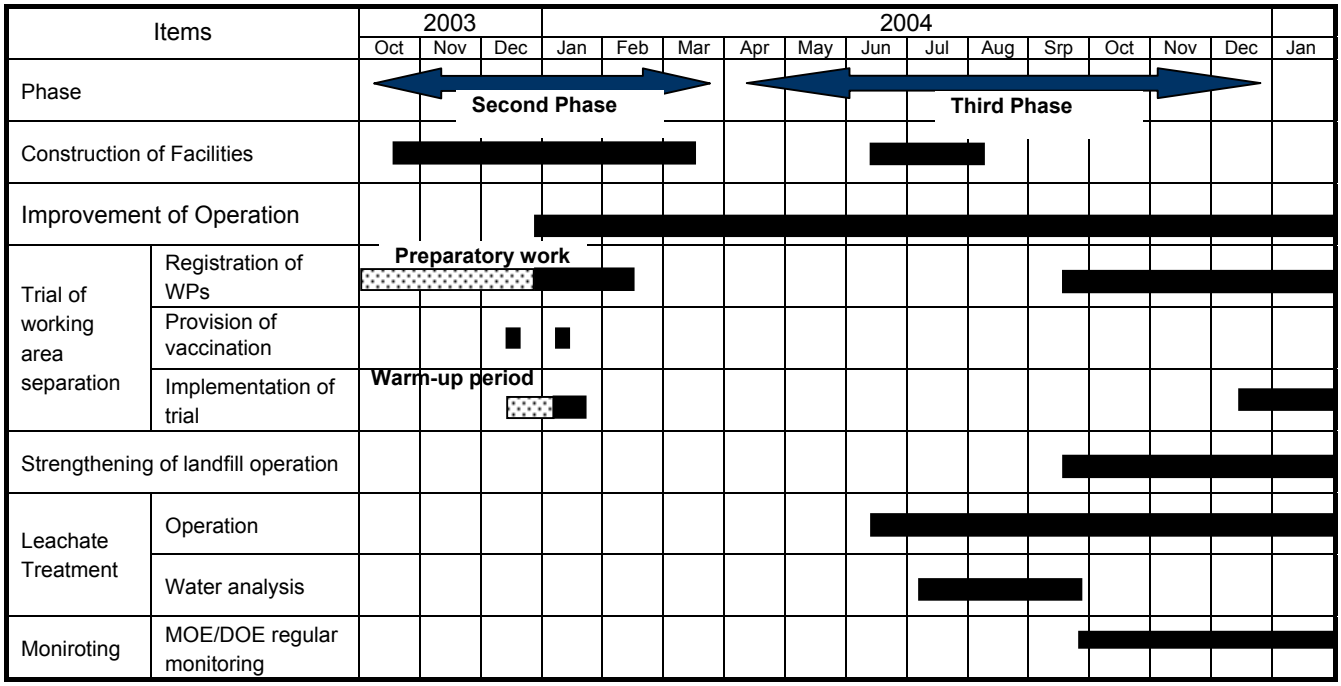
After final covering

c. Schedule of the Experiment

Pilot project for the improvement of the SMCDS was implemented during the Phase 2 and 3. The main items of the second phase were the construction of the facilities and trial of working area separation, while leachate collection facilities were constructed and the demonstration of landfill operation was conducted in the existing area during the third phase. Work items of the second and third phase are summarized below.

Phase	Work Items
Phase 2	1. On-site road
	2. Working face
	3. Model block for Landfill completion
	4. Enclosing Bank
	5. Leachate Collection and Treatment Facilities
	(1) Expansion area
	(2) Leachate treatment facilities
	6. Others
	(1) Fence and Gate
	(2) Expansion of Existing compost plant area
Phase 3	1. Leachate Collection facilities for Existing area
	2. Demonstration of Sanitary Landfill operation

Table 8-6: Schedule of the Experiment



8.2.3 Implementation of the Experiment

a. Facilities improvement

a.1 On-site Road

The following types of on-site road were the targets of the facilities improvement.

- Main Road
  The main road is used not only by vehicles for the landfill operation but also by local residents for their daily life even after the closure of the disposal site
- Secondary road (a linkage between the main road and the working face)
  The secondary road is used only by landfill operation vehicles

a.1.1. Main road

♦ **Before Improvement**

The main road ran through the center of the disposal site, which was the lowest part in the disposal site. In addition, since the road was not paved, collection vehicles often got stuck in the mud during the rainy season and faced extreme difficulties to reach to the working face. Even in the dry season, the surface of the road was so bad that it was still difficult for collection vehicles to reach to the working face.

♦ **After Improvement**

In order to solve the above mentioned problems, the study team decided to change the route of the main road, by using another on-site road (the old Secondary Road 3 that will be mentioned in the following sub-section) that connected the gate and the septage sludge treatment ponds, which were located on the east side of the disposal site and 5m above the level of the gate. The team improved the roadbed of the new main road and extended its route to a public road which runs along the east side of the disposal site in order to maintain the role of the main road as a public road for local residents.

In order to cope with the difficulty of the access to the working face during the rainy season, steel plates were laid on some parts of the main road, where the roadbed was not hard enough. For the inclined part of the main road, steel plates with a device to prevent slipping were used.

Location and Structure

The location and structure of the main road is shown in Figure 8-4 and Figure 8-5 respectively.

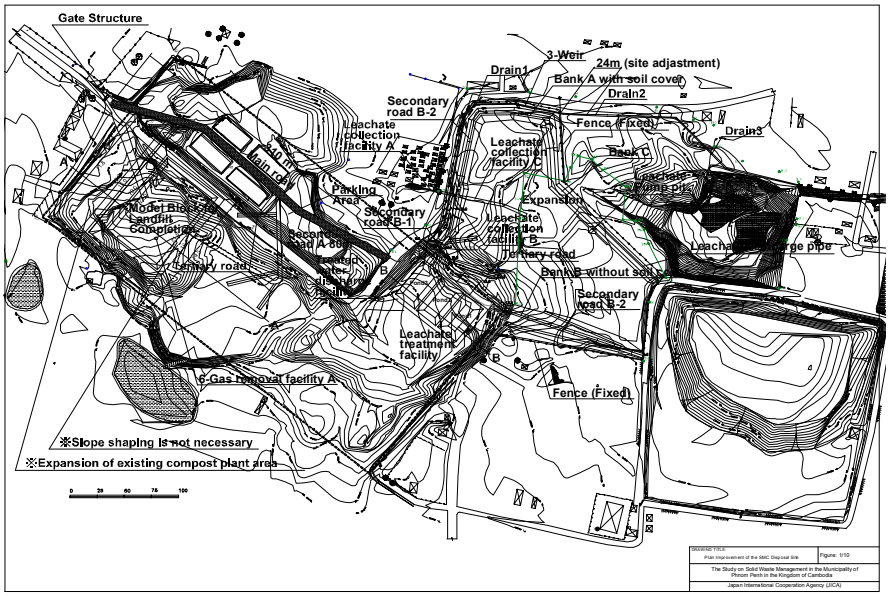


Figure 8-4: Location of the Main Road in the SMCDS

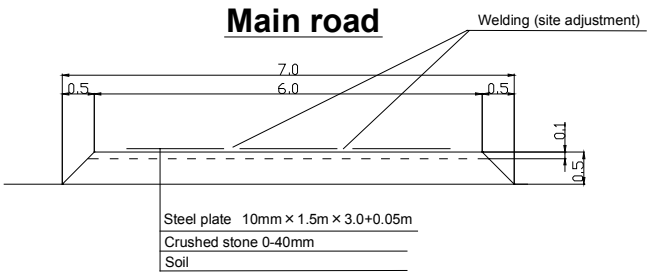


Figure 8-5: Structure of the Main Road

Photo

Before

After

Main Road

a.1.2. Secondary road

♦ **Before Improvement**

There were the following three secondary roads before the improvement. The bad condition of these secondary roads was one of the major obstacles to proper operation.

(1) **Secondary road 1:** a road of around 100m, which connected the old main road near the gate and the biggest waste heap located on the west side of the disposal site (the top of the pile is about 10m above the gate).

This road was constructed by piling up soil on the landfilled waste. As a result, during the rainy season the road surface became too muddy for collection vehicles to reach to the working face.

(2) **Secondary road 2:** a road which connected the old main road 250m south of the gate and another waste heap that was located on the east side.

The structure of secondary road 2 was the same as that of secondary road 1, and the condition during the rainy season was also the same as road 1.

(3) **Secondary road 3:** a road which connected the old main road near the gate and the septage sludge treatment ponds.

Since secondary road 3 had a gentler slope than the other two roads and the condition of its roadbed was also better, it was used as an alternative road to secondary road 1 and 2 when these roads could not be used because of heavy rain. (At this time, waste was disposed of near the ponds)

The relatively good condition of secondary road 3 is the main reason for the study team to decide to improve and continue to use it as the new main road.

♦ **After Improvement**

Two secondary roads were newly constructed in order to connect the new main road with the working faces. The route of these secondary roads will be moved periodically due to the progress of the landfill plan. Therefore, the secondary roads should be simple enough to change the route easily, while durable enough to be used for a certain period. In order to meet these specifications, the team constructed the secondary roads by raising the ground level with soil and laying steel plates on the surface of the road.

Location and Structure

The location and structure of the secondary roads are shown in Figure 8-6 and Figure 8-7 respectively.

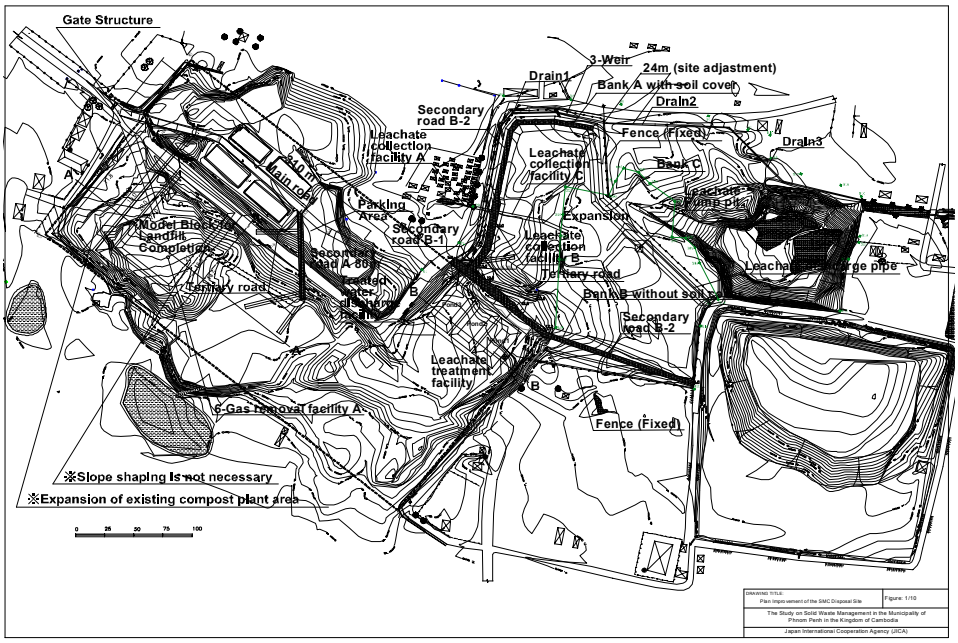


Figure 8-6: Location of the Secondary Roads in the SMCDS

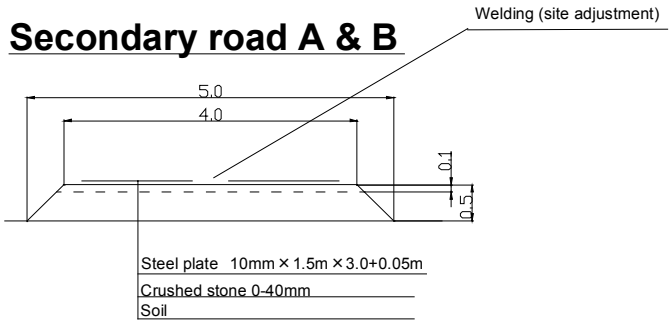


Figure 8-7: Structure of the Secondary Roads

Photo

Before

After

Secondary Road

a.2 Working Face

The working face is the final area for collection vehicles to unload waste. It consists of a tertiary road, a dumping stage and a landfill area. Its main functions are to guide collection vehicles smoothly to the dumping stage and to increase the efficiency of unloading work.

- **Before Improvement**

The working face was constructed by piling up soil at the edge of the secondary road. The soil used for the construction of the working face was soon buried in dumped waste and could not be reused for the construction of another working face. Since it cost PPWM a lot to buy soil, it was necessary to modify the construction method of the working face in order to save on expenses.

♦ **After Improvement**

The study team tried to construct the working face without using soil. In addition, since the working face will be shifted frequently due to the progress of the landfill operation, it is preferable to make the structure of the working face simple.

The new working face consists of a tertiary road and dumping stages which are covered by iron plates. The team instructed PPWM staff and bulldozer operators (staff of a private company) on an appropriate layout of steel plates and how to lay and maintain steel plates by using a wheel loader and bulldozer.

Even though they learned the method of laying steel plates through practice with the study team, it is obvious that PPWM cannot maintain the working face by itself after the pilot project because there is only one bulldozer available.

Concept of the Working Face

The concept of the working face is shown in Figure 8-8.

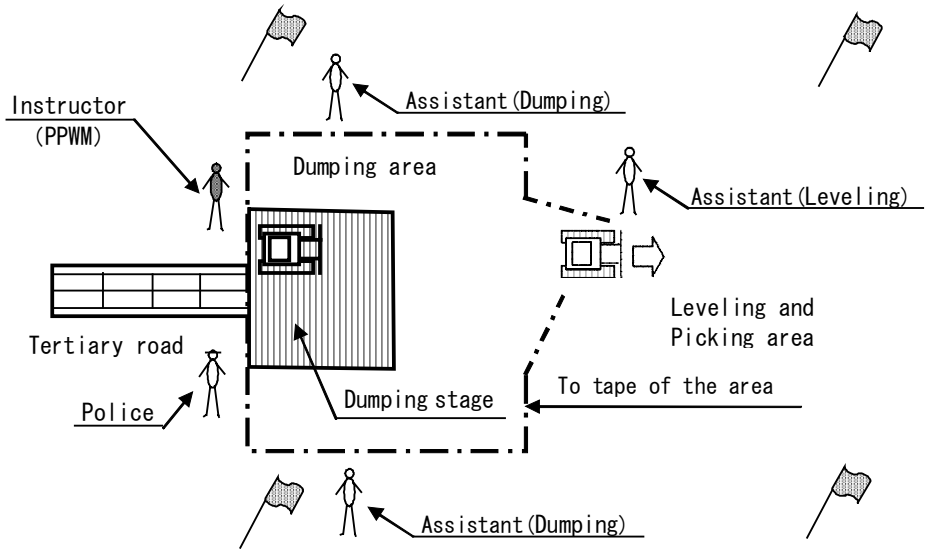


Figure 8-8: Concept of the Working Face

Location of the Working face

In this pilot project, five working faces were constructed in the following locations shown in Figure 8-9.

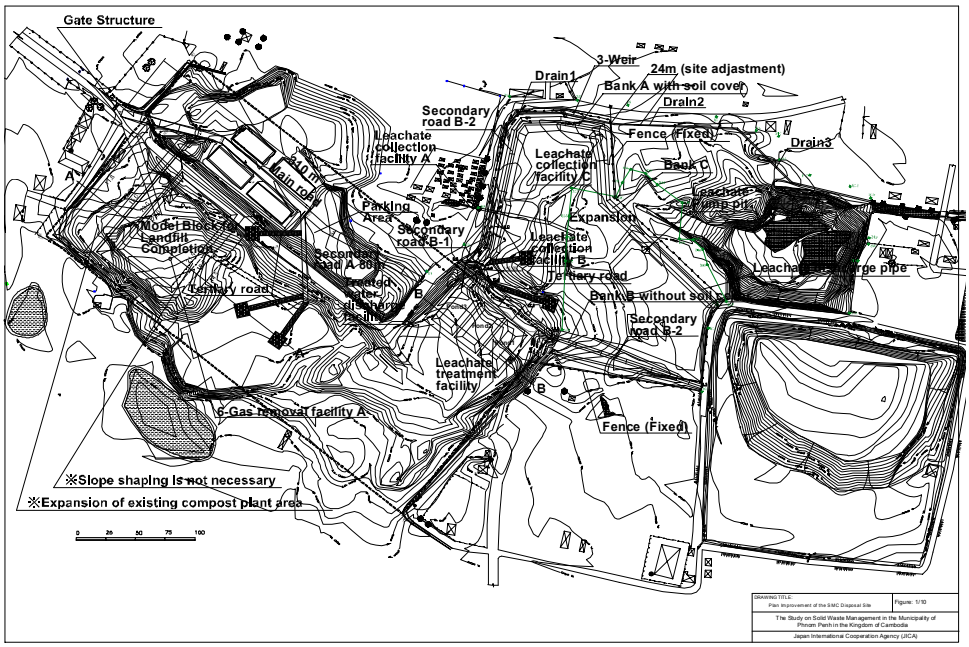


Figure 8-9: Location of Working Faces in the SMCDS

Photo

Before

After

Working Face

a.3 Model block for Landfill Completion

♦ **Before Improvement**

PPWM did not have a landfill plan, and waste was dumped anywhere it could be dumped. There was no clear idea how to close the disposal site. It was possible that there would be no place for dumping waste in the near future.

♦ **After Improvement**

It is critical for PPWM to formulate a proper landfill plan and to conduct daily operation based on the plan in order to improve its operation in the disposal site. The team drew an ideal final shape of the disposal site and formulated the landfill plan based on its final shape.

In the pilot project, the team constructed the model block for landfill completion. It is not the final shape, but a tentative one in progress. PPWM is required to carry out the landfill plan and to shape the whole landfill area into the final form that is shown in the plan. PPWM will be able to learn how to utilize the limited landfill area effectively and to acquire the operational skills such as leveling, filling and compacting waste through this operation.

Location and Structure

The height of the model block is set at 22 m above sea level (12 m above the level of the gate), and the shape of the block was designed with a gentle slope, as shown in Figure 8-10. According to the landfill plan, the length of the final block is 330 m. In this pilot project, a model block with a length of 90 m, 27% of the final one, was constructed.

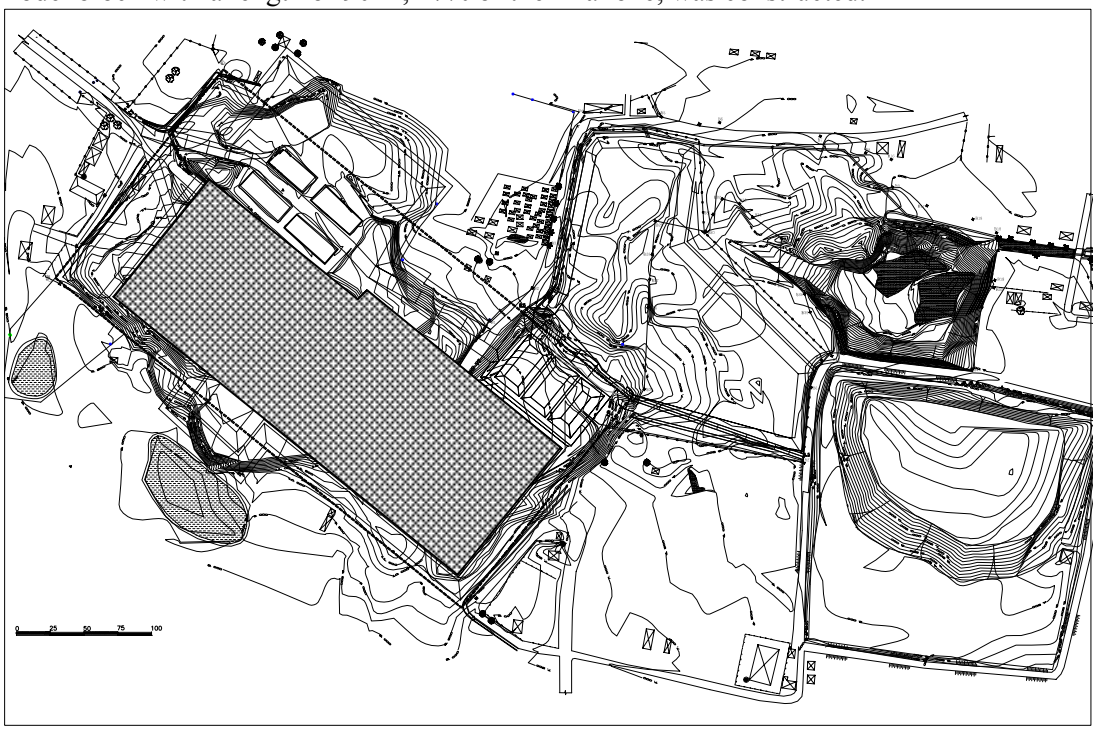


Figure 8-10: Landfill Completion of SMCDS

Other items with Model Block for Landfill Completion

Due to the progress of the landfill operation, the following works need to be implemented in order to maintain the disposal site properly and to preserve the environment surrounding the disposal site. The team strongly recommended PPWM to make sure funds are available each year to carry out these works.

(1) **Final cover**: The final landfill area needs to be covered by soil. The model block is covered by soil with a thickness of 50 cm on the top and 15 cm on the slope.

(2) **Laying turf**: After the surface is covered with soil, the area is further covered by turf. In the model block, turf will be laid on 33% of the soil covered area in April, 2004.

(3) **Leachate collection facilities**: It is necessary to install leachate collection facilities to prevent ground water contamination.

In the model block, along the bottom of the pile and brim of the pile a drain made of rubble stones was buried in the waste (under the soil cover). In addition, on the slope, two drain lines made of rubble stones were also buried under the soil cover to collect leachate from the top and brim, as shown in Figure 8-11 and Figure 8-12.

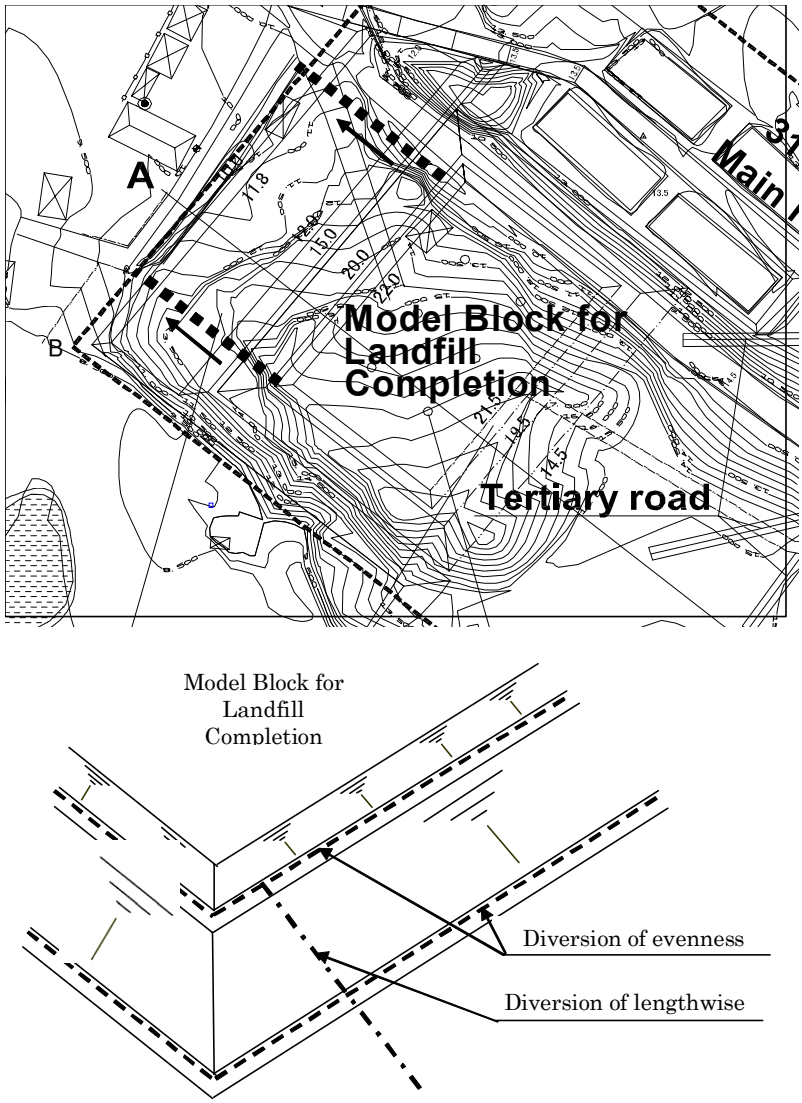


Figure 8-11: Location of Leachate Collection Facility

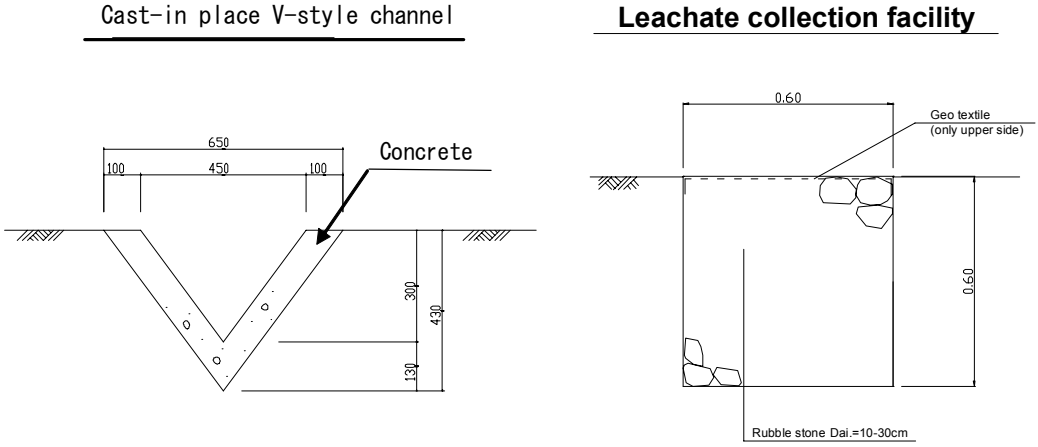


Figure 8-12: Structure of Leachate Collection Facility

(4) **Drainage of rain water**: To drain off rainwater on the soil covered block to a neighboring canal, a drainage system was constructed with concrete mortal along the bottom of the pile and brim of the pile (on the soil cover). As with the leachate collection

facilities, two drainage lines were installed on the soil cover on the slope. The structure of the rainwater drainage system is shown in the following figure.

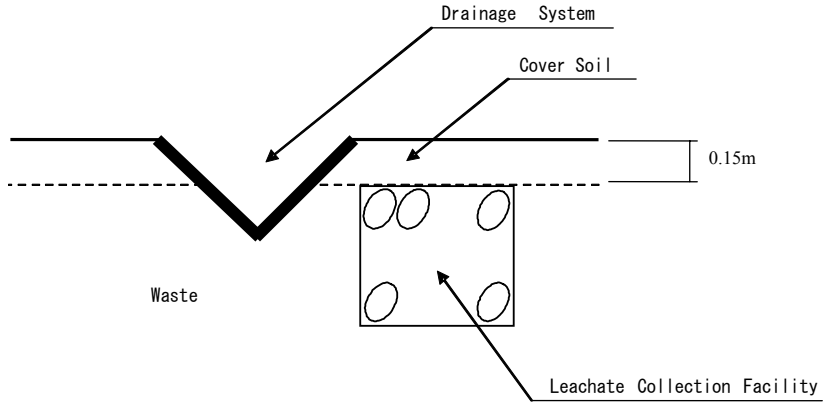


Figure 8-13: Structure of Drainage of Rain Water

(5) **Gas removal facilities**: Six gas removal pipes were installed to vent generated gases, mainly methane gas, and steam into the atmosphere smoothly. Considering the difficulty of installing pipes deep in the ground, the team set the length of the pipe at 5 m. The density of pipe installation was around 800m^2/pipe. The location of pipes and its structure are shown in the following figures.

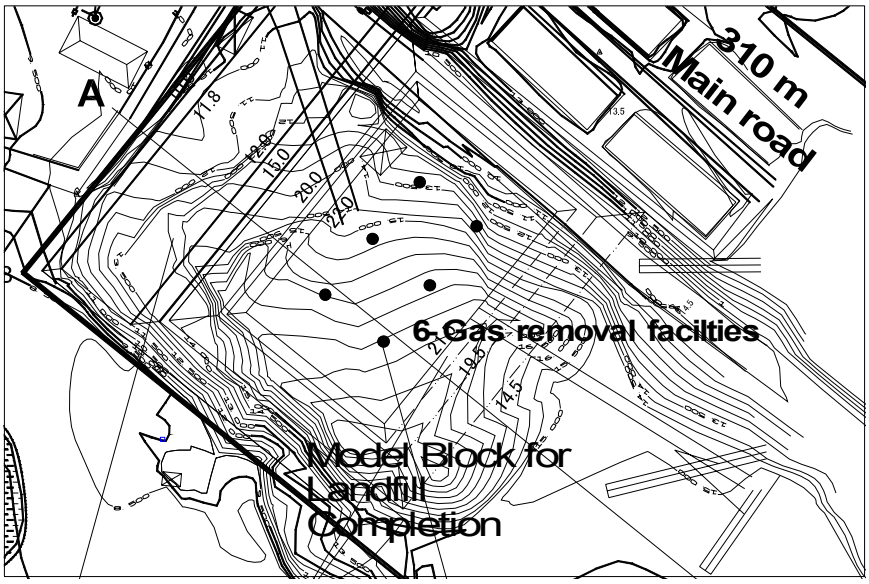


Figure 8-14: Location of Gas Removal Facilities in the SMCDS

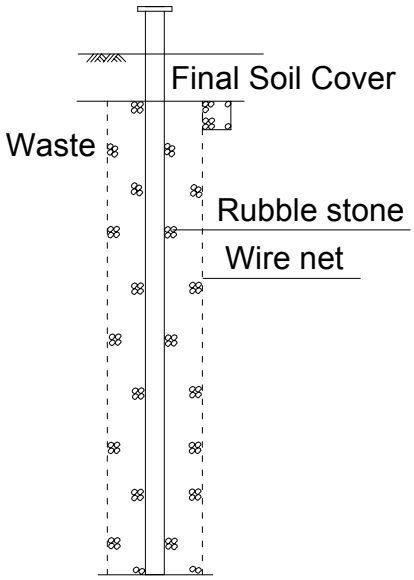


Figure 8-15: Structure of Gas Removal Facility (L = 5m)

Photo

Model Block for Landfill Completion

Gas Removal Facilities

a.4 Enclosing Bank

♦ **Before Improvement**

There was neither fence nor enclosing bank to separate the existing disposal site from adjacent plots of land. As a result, waste was dumped in some of the adjacent areas and the land was contaminated by leachate.

♦ **After Improvement**

It is urgent for PPWM to stop such an improper operation to prevent further environmental degradation. However, due to the limited time schedule and budget, an enclosing bank was constructed only for the expansion area as a model case under the pilot project.

The team strongly recommended PPWM to construct a fence or enclosing bank surrounding the existing disposal site in the future, referring to the expansion area.

The enclosing bank has two functions. One is to clearly show the boundary and the other is to prevent leachate from flowing into surrounding areas. Therefore, the top and the outer side of the enclosing bank along the outside road were constructed from waste and covered by soil, while other parts that were not exposed to the outside, were constructed from decomposed waste without covering.

Location and Structure

The location and structure of the enclosing bank are shown in Figure 8-16 and Figure 8-17 respectively.

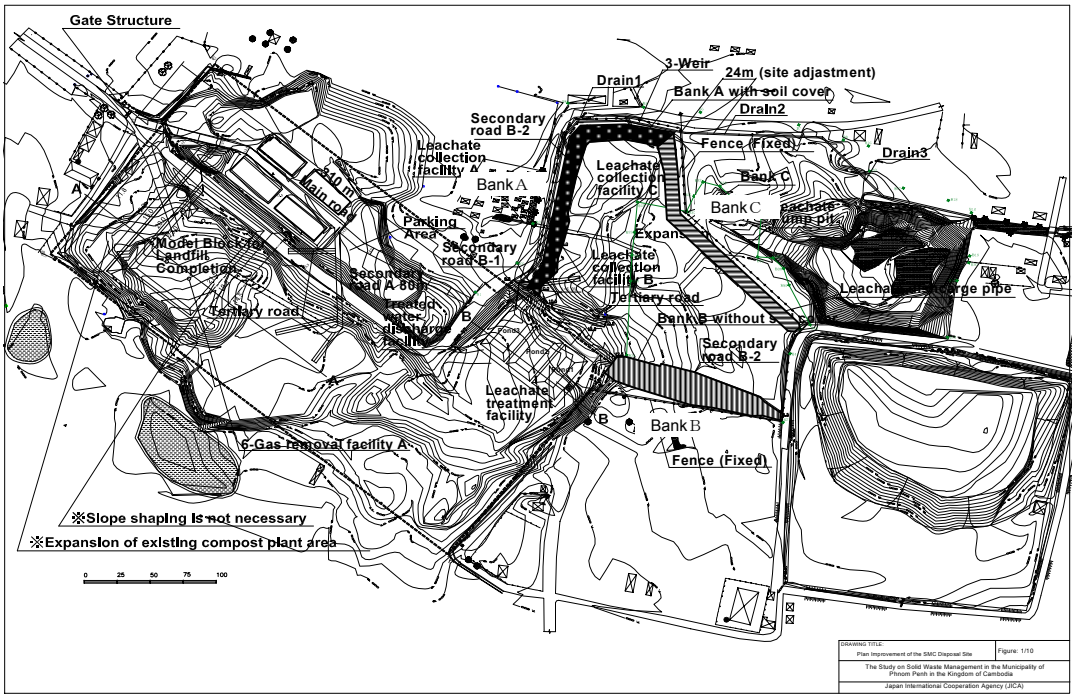


Figure 8-16: Location of the Enclosing Bank in the SMCDS

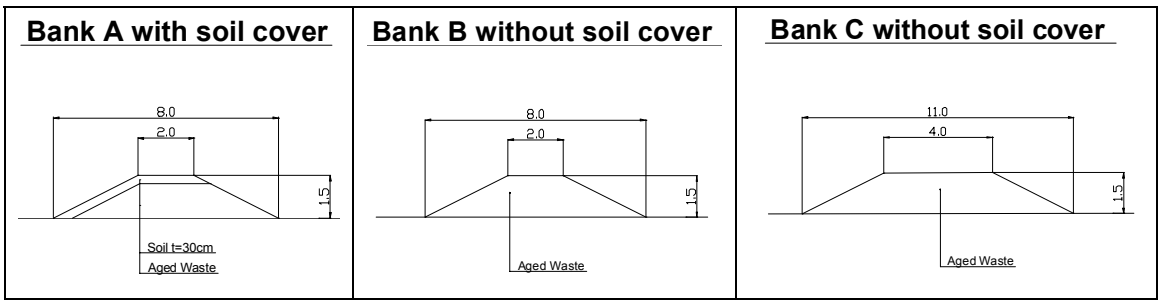


Figure 8-17: Structure of the Enclosing Bank

Photo

Before

After

Enclosing Bank

a.5 Leachate Collection and Treatment Facilities

a.5.1. Expansion Area A

♦ **Before Improvement**

At the existing disposal site, there were no leachate collection systems except a canal in a limited part of the disposal site. In addition, the destination of effluent from the canal was unclear, and the effluent was often discharged to the neighbouring residential area, a natural pond and a soil excavation area.

There were no leachate treatment systems at all. The flow of leachate during the rainy season is summarized below. During the dry season, little leachate is discharged to the surrounding area and there seems to be little problem.

- **West side of the disposal site**: The leachate and rainwater flowed into two natural ponds which are adjacent to the disposal site. The waste of the ponds was used for rice cultivation.
- **South side of the disposal site**: The leachate and rainwater flowed into the existing canal, and the canal ended up a big pool. Some of the leachate flowed out to an adjacent soil excavation area.
- **North side of the disposal site**: The leachate and rainwater flowed into the existing canal. Rainwater and waste waster along the access road also flowed into the canal through a drain. In some cases, overflow from the septage sludge treatment ponds flowed into the canal. The canal did not have a discharge route, and ended up as a small pond. As a result, most of the effluent flowed into a soil excavation area through a residential plot.
- **East side of the disposal site**: The leachate and rainwater flowed into an adjacent soil excavation area.

♦ **After Improvement**

In order to make a leachate collection and treatment facility plan, it is necessary to consider the topographical conditions of the whole area and the rainwater mixed with wastewater flowing in from surrounding areas, in particular a drain along the access road, as well as the leachate and rainwater inside the disposal site.

One of the basic ideas was to separate leachate from domestic waste water from the north and east side of the disposal site as much as possible. Leachate collection facilities were installed only in the expansion area. The basic design is summarized below.

- Domestic waste water is discharged into the existing canal (Boeung Tompon) through an open channel and a concrete pipe.
- Leachate is collected by newly installed collection facilities in the expansion area and treated in simple oxidation ponds. Leachate facilities are constructed in the existing landfill area considering the future operation and management by PPWM after closure.

a.5.2. Existing area (Southern area)

In the Phase2, leachate collection and treatment facilities in the expansion area were constructed. In the Phase 3, the remaining leachate collection facilities both in the existing and expansion areas (bank B) were installed. However, these facilities were installed in the

limited areas where waste were not disposed of beyond the boundary with the private land, because there was not enough time to negotiate with landowners. It is necessary for MPP/PPWM to construct leachate collection facilities in other areas later on, referring to this pilot project.

The areas where leachate collection facilities were constructed (area A, area B, area c) were shown below.

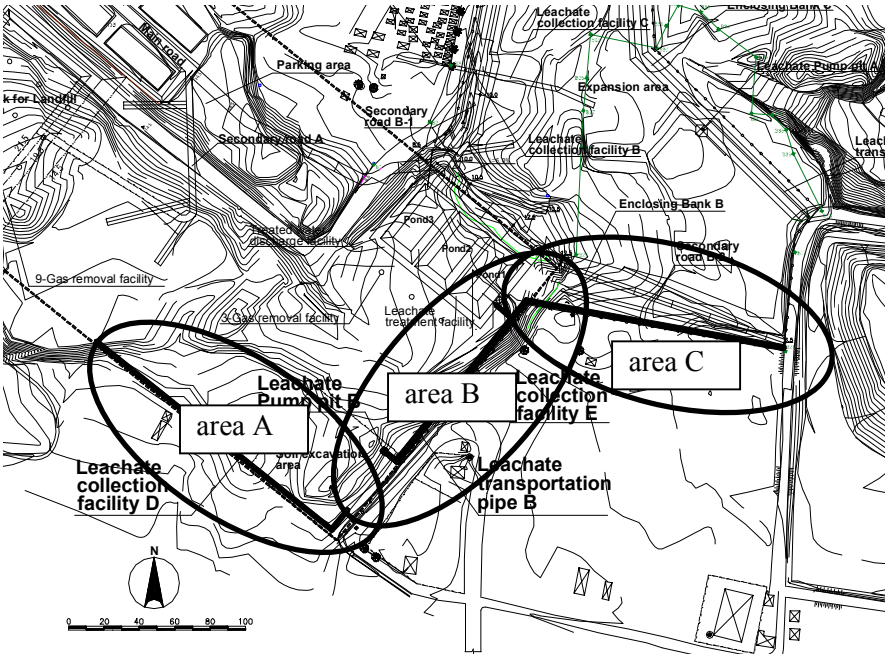


Figure 8-18: Location of constructed leachate collection facilities

♦ **Before Improvement**

In the area A and C shown in the Figure 8-18, there were no leachate collection facilities, while there was a simple canal in the area B. The canal in the area B did not carry through, stopped by houses on the way, and the overflow ran into the residential areas and a natural pond nearby.

♦ **After Improvement**

The leachate along with rainwater is collected and pumped up to the leachate treatment ponds that were constructed during the Phase 2.

As mentioned in the previous sub-section, in order to make a comprehensive plan to deal with rainwater it is necessary to consider the precipitation amount in the neighbouring areas and the volume of waste water discharged from households, as well as precipitation inside the disposal site. Therefore, In this pilot project, the comprehensive measure for rainwater was excluded from the plan.

Outline of the improvement plan

- Construction of leachate collection facilities in each area (area A: leachate collection facility D, area B and area C : leachate collection facility E)
- Collection of leachate to the leachate pump pit B
- Pumping up collected leachate to the leachate treatment ponds, which were constructed during the Phase 2
- Treating leachate at the oxidation ponds.

Before the pilot project, at the target area water with the same colour of leachate run through on the surface. After the installation of the collection systems, most of leachate is collected and its color is diluted. The team proposes MPP/PPWM install the same facilities in the remaining areas of the disposal site.

Item of Leachate Collection Facilities for Existing area (southern area)

The leachate collection facilities in the Existing area (southern area) consist of the following equipments. The locations of equipments are shown in the figure below. The flow of the leachate collection facility B is shown in Figure 8-20.

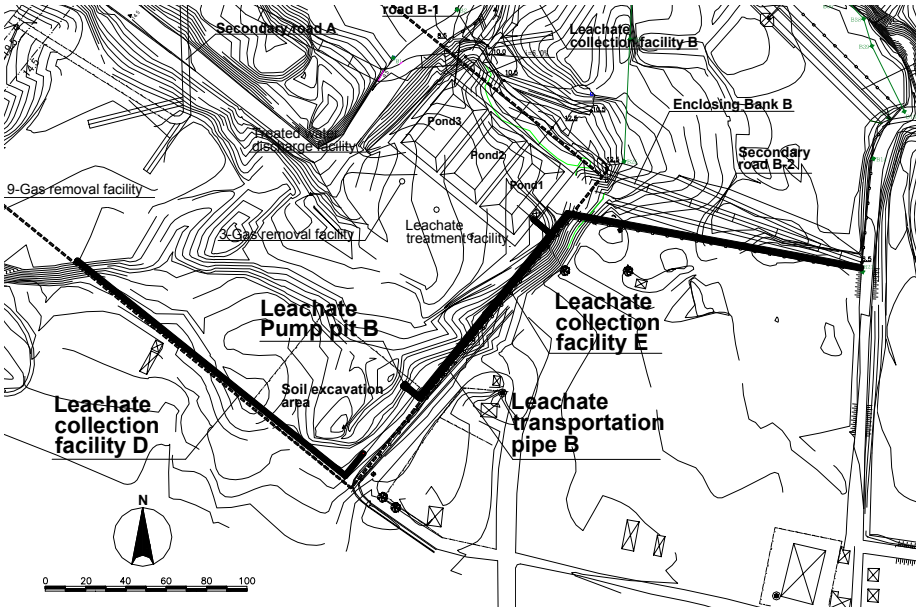


Figure 8-19: Location of the Leachate Collection Facilities for Existing area

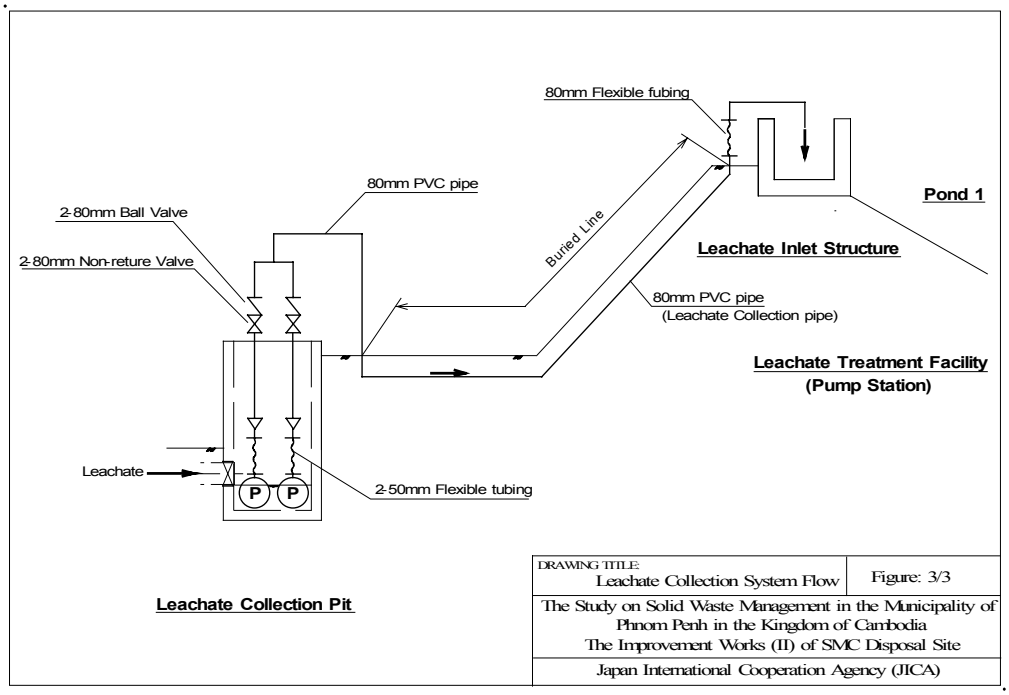


Figure 8-20: Flow of Leachate collection facility B

leachate collection facilities :

The following two types of facilities were installed.

- Leachate collection facility D: It consists of perforated concrete pipes and rubble stones.
- Leachate collection facility E: It consists of perforated concrete pipes, rubble stones and cover soil. Its structure is shown below.

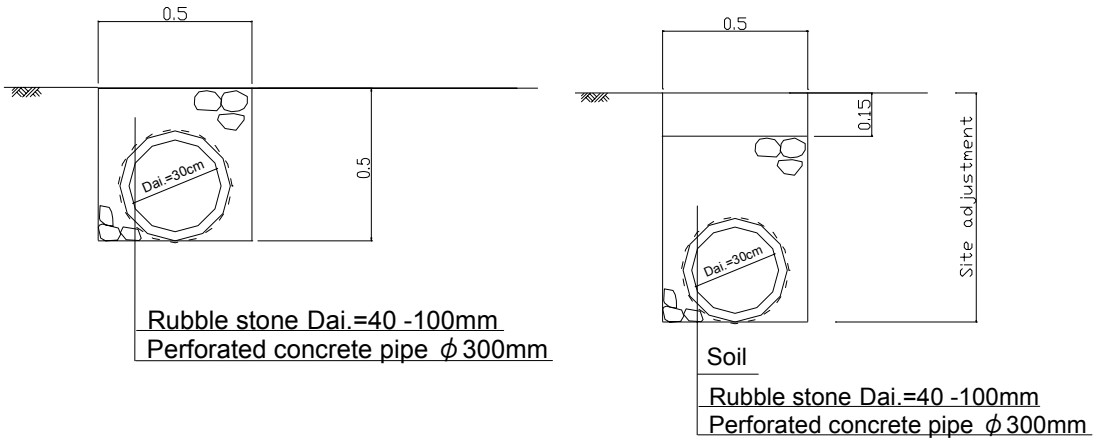


Figure 8-21: Structure of Leachate Collection Facility D, ED

Leachate pump pit B and Pump B

Leachate pump pit and Pump B were installed at a leachate collection point. Leachate at the collection point is pumped up to the treatment facilities by Pump B. The structure of the pump pit and pump B is shown below.

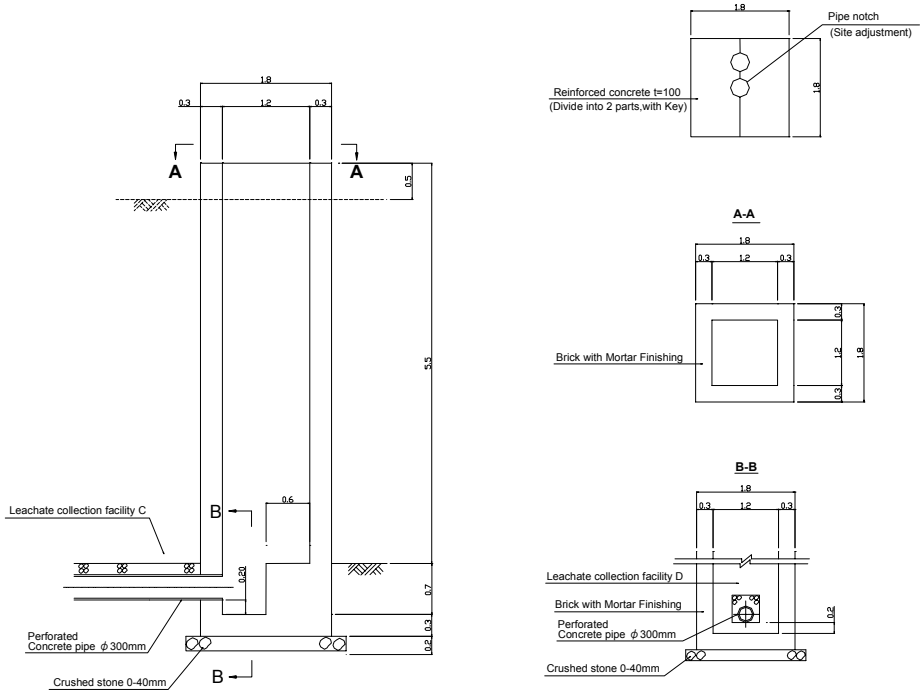


Figure 8-22: Structure of Leachate Pit B

Leachate Discharge pipe

A discharge pipe, a PVC pipe with diameter of 80mm, was installed to send leachate from the pump to the treatment facilities.

Photo

Before

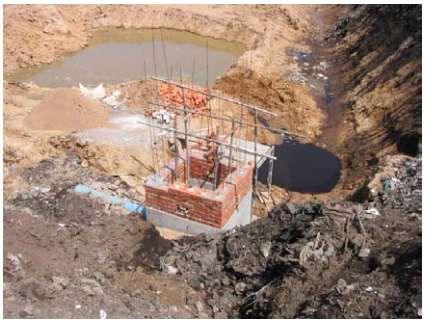
After

Leachate collection Facility

Area B

Area C

Leachate collection Facility B (under construction)



under construction

completion

Leachate Collection Pit B

a.5.3. Leachate Treatment Facilities

Leachate treatment facilities consist of the following facilities

- Leachate Treatment Ponds
- Wetland (canal covered with water grass)

The leachate treatment systems consist of three ponds with the capacity to receive the largest monthly average of daily leachate for three days (the details are explained later).

The first pond is for storing leachate. Leachate is treated in the two following ponds, which have a depth of 1 m and are shallow enough to promote convection and enhance aerobic reaction. Water grass is also expected to grow naturally and decrease the load of leachate. During the dry season, leachate is mainly generated by compression of the disposed waste, and its amount is very small. Therefore, these ponds are used as evaporation ponds.

Treated water is discharged to Boeung Tompon 450 m away through the canal along the enclosing bank by natural gravity and mixed with miscellaneous wastewater discharged from houses on the north and east side of the canal. Water grass is expected to grow and treat the leachate further.

Capacity of Leachate Treatment Facilities

<Catchment area>

The following two areas are assumed to be the catchment area of leachate.

- a quarter of the existing landfill area (1.88 ha)
- the entire landfill expansion area (2.25 ha)
  Total area : 4.13 ha

<Conditions for calculation>

The team set the conditions for calculation as follows:

1) The precipitation rate and evaporation rate are obtained from the EIA report.

Table 8-7: Average Precipitation and Evaporation

unit : mm/month

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average Precipitation	32.7	2.2	67.5	69.1	134.8	178.0	183.0	171.8	228.3	288.8	82.8	92.1	1,531.1
Average Evaporation	126	146	179	177	146	131	115	108	100	96	110	126	1560
Precipitation - Evaporation	-93.3	-143.8	-111.5	-107.9	-11.2	47	68	63.8	128.3	192.8	-27.2	-33.9	-28.9

Source: Department of Meteorology, Office of Climate, Station Pochentong

2) All the rainwater is collected and treated as leachate (runoff rate = 0 %).

3) The evaporation rate is assumed to be 70%.

<Leachate quantity>

i. Leachate generation originated from rainfall

The daily leachate quantity is determined by the following equation:

$$V = A1 \times L + A2 \times (L \times (1- Lr) – E \times - Er))$$

where ;
V : Leachate quantity (m^3/day)
A1 : Area of the completion landfill (ha)
A2 : Area of the operating landfill (ha)
L : Precipitation (m/day)
Lr : Runoff rate (-) (= 0 %)
E : Evaporation (m/day)
Er : Evaporation rate (-) (= 70%)

The average daily leachate quantity of each month was calculated using the average daily precipitation and evaporation amount. The average daily amount of leachate is largest, 421m^3/day, in October, as shown in Table 8-8.

Table 8-8: Leachate Quantity

Month	m^3/day	Month	m^3/day
Jan.	-33	Jul	136
Feb	-140	Aug	124
Mar	-78	Sep	219
Apr	-74	Oct	421
May	41	Nov	45
Jun	116	Dec	45

The leachate flow in October is shown in the figure below.

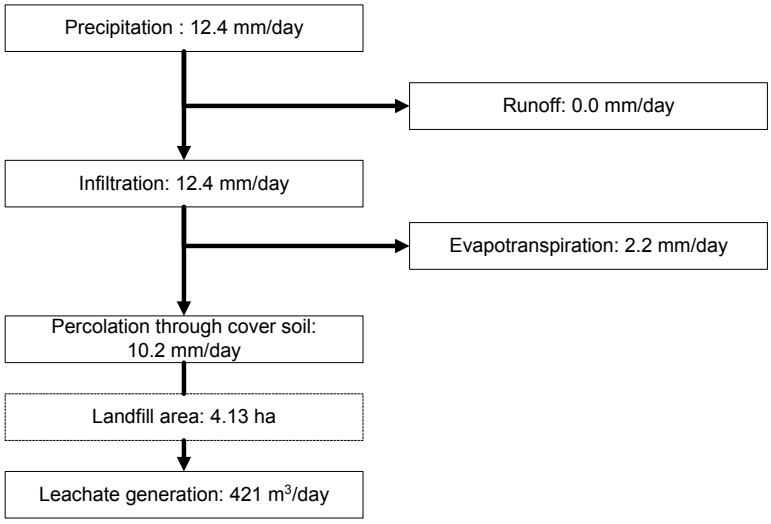


Figure 8-23: Leachate Flow

ii. Leachate amount generated from disposed waste

(1) Preconditions

1) Amount of collected waste: 923 tons/day [in 2007]
2) Water content of collected waste: 60% [actually measured at SMCDS[2]]
3) Solid amount of waste: 369 kg-DS/day [= 923 x (1-0.6)]
4) Water content of disposed waste (2 months later)l: 45% [measured at SMCDS]
5) Ratio of water content to solid amount of collected waste: 1.50 kg-H_2O [= 0.6 / (1 – 0.6)]
6) Ratio of water content to solid amount of disposed waste (2 months later) : 0.82 kg-H_2O [= 0.45 /(1 – 0.45)]
7) Water amount which is used for organic decomposition: 0.165kg-H_2O/kg-degradable organics[3].
8) Content of degradable organics of waste: 56.9% [projected based on the result of the WACS. Kitchen waste, trees and plants are classified as degradable organics.]
9) Loss by evaporation: estimated in the section of leachate treatment capacity.
10) Leachate generated from disposed waste is supposed to flow out without delay.

[2] Refer to Appendix 19 of the Supporting Report
[3] Integrated Solid Waste Management, Irwin/McGraw-Hill, 1993

(2) Predicting Leachate generated from collected waste

1) Leachate amount generated from disposed waste

The leachate amount generated from disposed waste can be traced as the difference in water amount between waste just brought to the disposal site and disposed waste. Since the daily solid amount of waste in 2007 is 369 ton-DS/day, the leachate generated from disposed waste is estimated as follows.

Leachate amount generated from disposed waste: Wg = 369 x (1.5 – 0.82) = 251 tons/day

2) Water consumption amount used for organic decomposition

Water consumption amount: We = (369 x 0.569) x 0.165 = 35 tons/day

3) Leachate amount generated from collected waste

Leachate amount generated from collected waste = Wg – We = 251 – 35 = 216 tons/day

iii. Total leachate generation amount

The total leachate generation amount by month is shown in the table below.

Table 8-9: Total leachate generation amount (unit:m^3/day)

Generation source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	0	0	0	0	41	116	136	124	219	421	45	45
Waste	216	216	216	216	216	216	216	216	216	216	216	216
Total	216	216	216	216	257	332	352	340	435	637	261	361

<Capacity of leachate treatment ponds>

The team set the minimum capacity of leachate treatment ponds at the largest monthly average of daily leachate amount for four days, as described below.

Capacity of Leachate Treatment Ponds = 637 m^3 x 3 days = 1,911 m^3

The total capacity of three ponds was determined by multiplying the minimum capacity by the Safety Factor (1.05). The capacity of each pond is shown in the table below.

Table 8-10: Capacity of Each Leachate Treatment Ponds

Items	Leachate Treatment Pond			
	Pond 1	Pond 2	Pond 3	Total
Capacity (m^3)	860	590	590	2040

The pictures of ponds and layout of the leachate treatment facilities are shown below.

Pond 1

Pond 3

Leachate Treatment Facilities

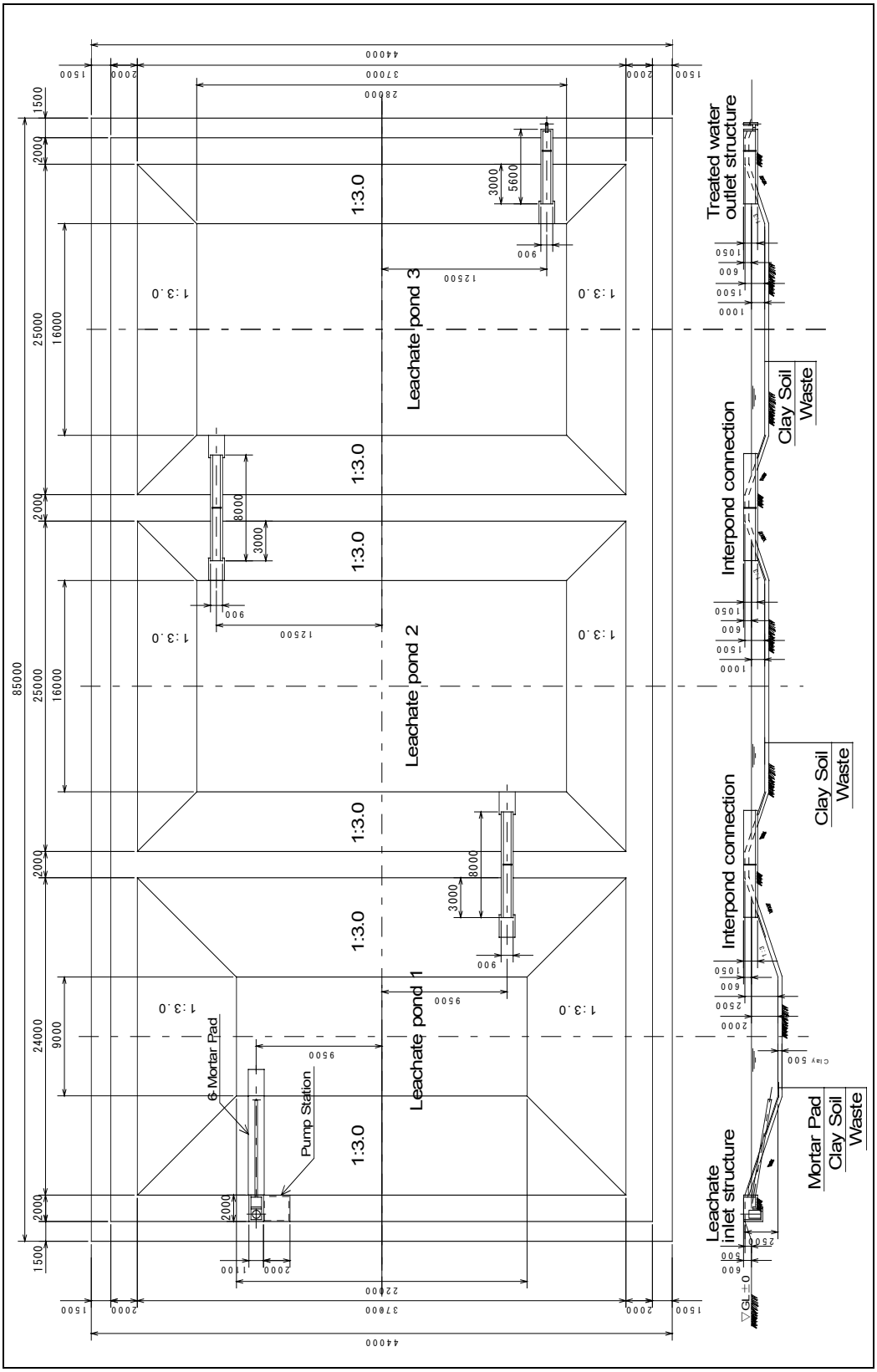


Figure 8-24: Layout of the Leachate Treatment Facilities

a.6 Other Experiment Items (Fence and Gate)

♦ **Before Improvement**

There were no facilities to separate the disposal site from the surrounding areas except a lifting gate at the entrance.

♦ **After Improvement**

Two gates were constructed at the main entrance in the existing landfill area and another exit of the main road in the expansion area along with cabins for a guard. In addition, a fence was installed along the whole landfill area.

Location and Structure

The location of the fence and gates are shown below.

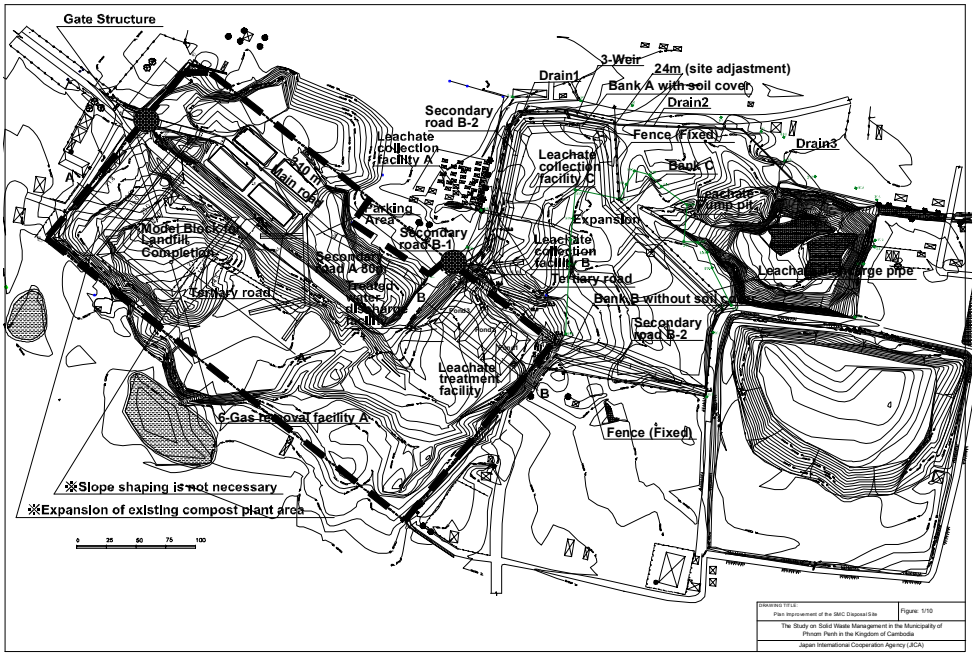


Figure 8-25: Location of Fence and Gate

The structure of the fence and the details of the gate at the main entrance are shown in Figure 8-26 and Figure 8-27 respectively.

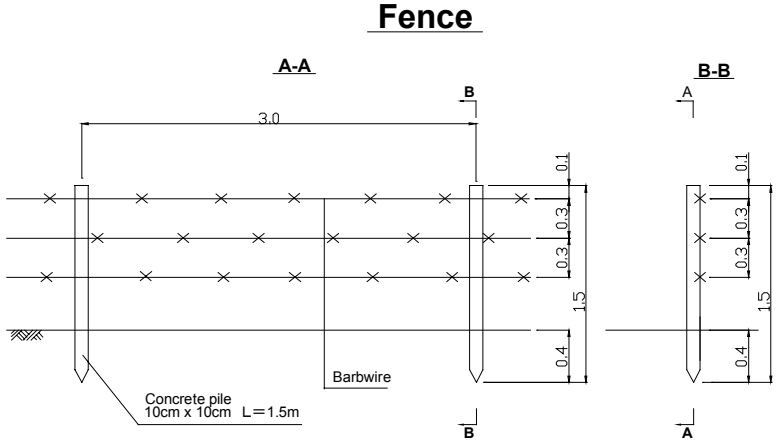


Figure 8-26: Structure of Fence

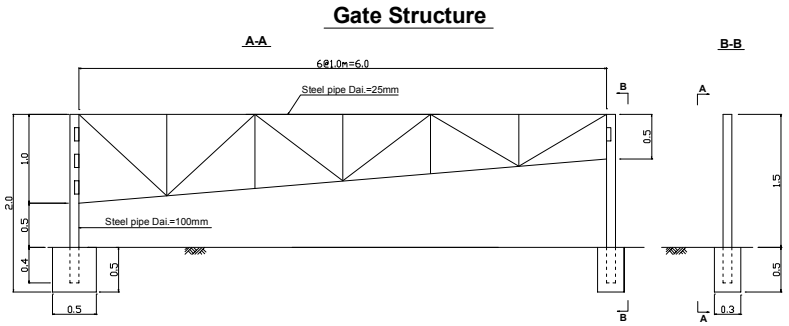


Figure 8-27: Structure of Gate (Entrance of landfill)

Photo

Fence

Gate

b. Landfill Operation (Introduction of working area separation)

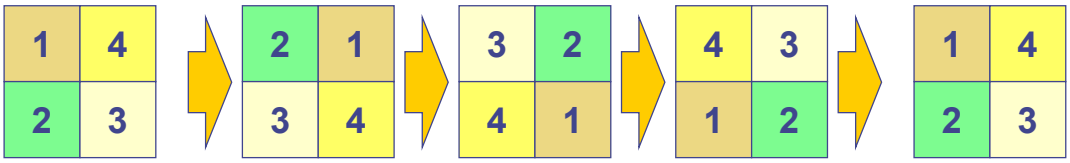
It is critical to improve the landfill operation along with construction of various facilities in order to minimize environmental and social problems. In the pilot project, the team tried to introduce the separation of working areas during the second phase as an experiment, in order to increase the safety and the efficiency of the landfill operation.

b.1 Objectives

One of the main objectives was to examine the applicability of working area separation with the current limited staff and equipments. To check how much the working area separation increase the safety and efficiency of the landfill operation was another main purpose.

b.2 Outline of Waste Picking Rules

In the original plan, the team proposed to separate the landfill area into four different types of working areas, i.e. a waste unloading area (1), a waste picking area (2), a waste leveling area (3), and a waste compaction area (4), and rotate them every half day, as shown in Figure 8-28.



1. Waste unloading area
2. Waste picking area
3. Waste compaction area
4. Waste covering area

Figure 8-28: Rotation of Working Area

However, due to the lack of heavy vehicles, the team decided to decrease the number of working areas from four to three, combining the waste leveling and compaction areas into one area, as shown in the following figure. These working areas are rotated after a certain period of time.

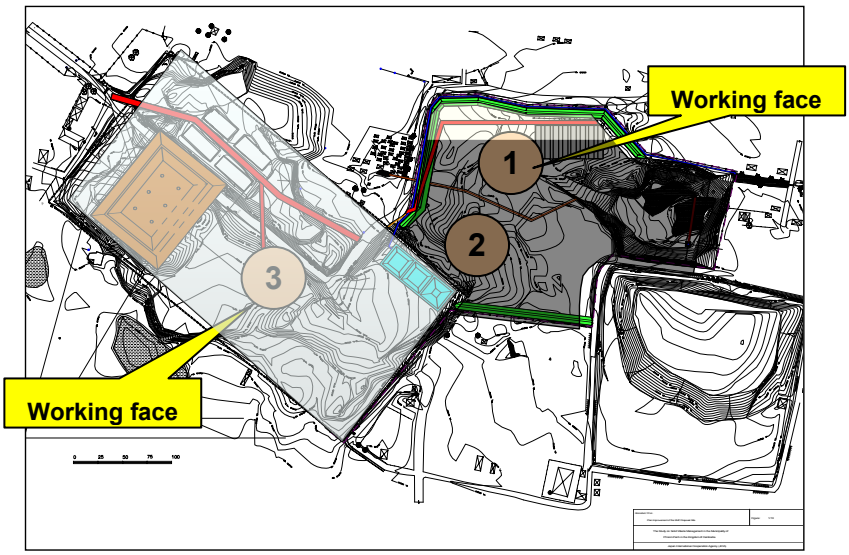


Figure 8-29: Original Plan of Working Separation

b.3 Outline of Landfill Operation

The outline of each working area is shown below.

(1) Waste unloading area

- The waste unloading area is roped off.
- Waste picker assistants stand at all corners of the area (outside the area).
- An instructor (PPWM) and a policeman are arranged near the dumping stage.
- After several collection vehicles unload waste, a bulldozer levels the unloaded waste.
- The bulldozer pushes the waste outward from the dumping stage.
- The thickness of the levelled waste is 20 – 30 cm.
- The police are in charge of getting the waste pickers who enter the waste unloading area out of the area

(2) Waste Picking Area

- Collection vehicles and the bulldozer cannot enter the waste picking area.

(3) Waste Leveling/Compaction Area

- After the waste picking work is finished, waste is compacted by the bulldozer.
- An additional bulldozer is arranged.
- Waste pickers are not allowed to enter the waste leveling/compaction area.
- The bulldozer starts its operation after making sure that no waste pickers are left.

c. Introduction of waste picking rules (waste picker management)

In the second phase, the team tried to separate working faces in order to improve the landfill operation. It is impossible to realize the working area separation without controlling the activities of waste pickers. The waste picking rules were introduced to control their activities at the landfill area.

c.1 Preparation

It is impossible to realize the working area separation and waste picking rules without cooperation of waste pickers. The working area separation could increase the safety of waste pickers, while improving the landfill operation. It is important for PPWM to show clearly the benefit of the working area separation and waste picking rules to waste pickers in order to make a consensus about the working area separation and waste picking rules with waste pickers.

In order to make waste pickers understand the importance and benefit of the working area separation and to realize cooperation with them, the following preparations were made.

- Organization of a dozen community meetings in each village
- Registration of waste pickers and formulation of a database
- Preparation and distribution of ID cards and jackets
- Preparation and distribution of rule books
- Selection of waste picker assistants by VCAO (NGO) (three groups of five persons)
- Arrangement of police (three groups of four person)
- Organization of meetings to explain about the separation of working areas to all the parties concerned, including PPWM, VCAO, the police, a bulldozer driver, waste picker assistants, and SOM (a construction company), and to make the roles and responsibilities of each party clear
- Implementation of demonstration (on the 26th of December)
- Installation of two signboards (an advance announcement)
- Preparation of the waste dumping stage for collection vehicles and the tertiary road in each three areas

c.2 Demonstration of waste separation

Working area separation:

Start of demonstration: 12:30

Waste unloading time in each working area:

Area 1: 12:30～19:00 6.5h
Area 2: 19:00～ 6:00 8.0h (rest from 23:00 – 2:00)
Area 3: 6:00～12:30 6.5h

The outline of each working area is summarized below.

(1) Waste unloading area

- The waste unloading area is roped off.
- Waste picker assistants stand at all corners of the area (outside the area)
- An instructor (PPWM) and a policeman are arranged near the dumping stage.
- After several collection vehicles unload waste, a bulldozer levels the unloaded waste.
- The bulldozer pushes the waste outward from the dumping stage.
- The thickness of the leveled waste is 20 – 30 cm.
- The police are in charge of getting the waste pickers who enter the waste unloading area out of the area.

(2) Waste Picking Area

- Collection vehicles and the bulldozer cannot enter the waste picking area.

(3) Waste Leveling/Compaction Area

- After the waste picking work is finished, waste is compacted by the bulldozer.

- An additional bulldozer is arranged.
- Waste pickers are not allowed to enter the waste leveling/compaction area.
- The bulldozer starts its operation after making sure that no waste pickers are left.

c.2.1. Method of separating the unloading area from others areas

Regarding safety, the most difficult issue is how to prevent waste pickers from rushing to collection vehicles just after the vehicles unload waste. Therefore, all the staff is assigned to the waste unloading area.

The way of separating the unloading area from the other areas is summarized below.

- Put up stakes with interval of around 5m and rope off the area
- Station waste picker assistants around the unloading area
- Install a signboard, showing the area is the waste unloading area
- Display green flags around the area

The outline of these three areas is shown below.

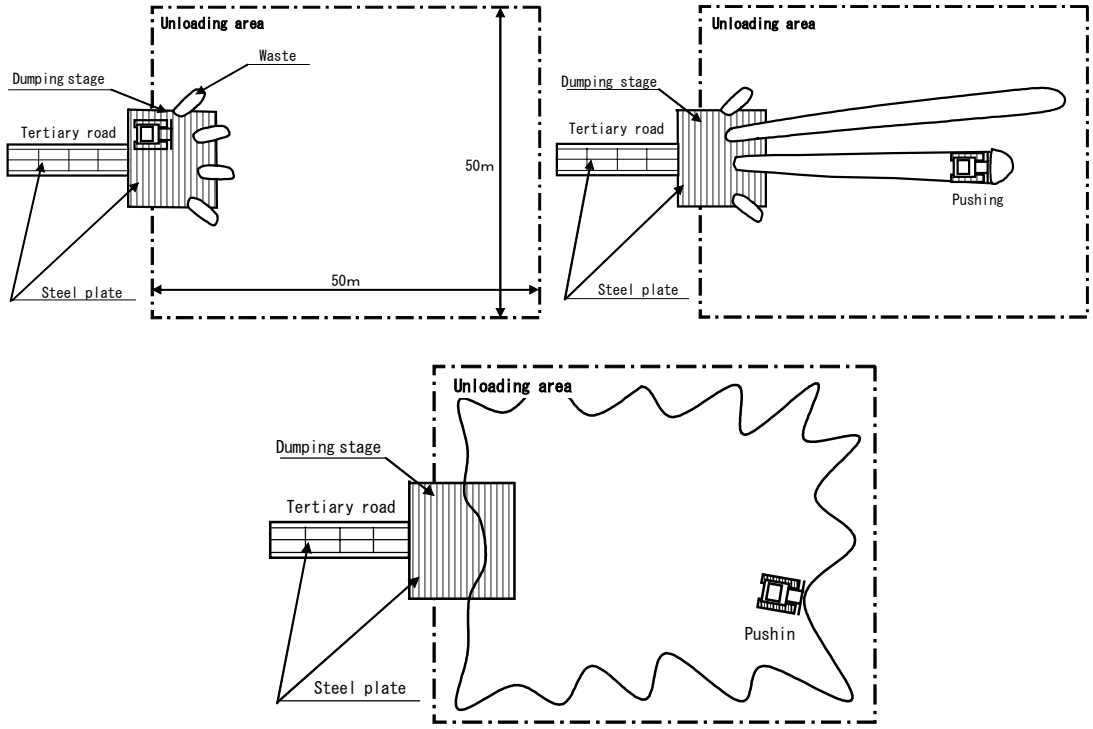
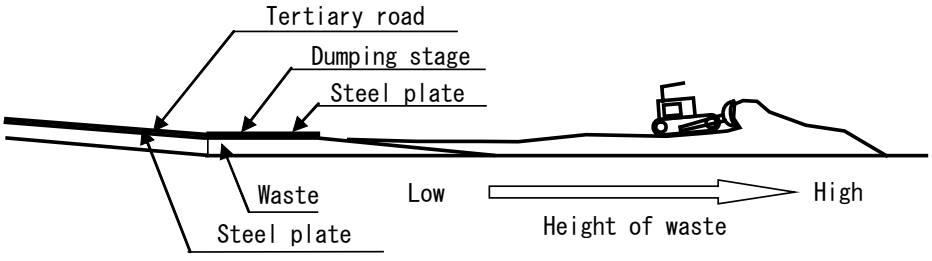


Figure 8-30: Waste Unloading Area

Process of Pushing



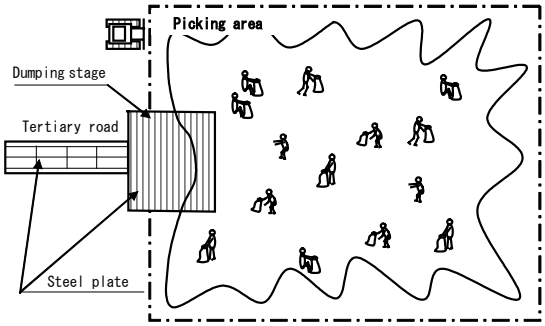


Figure 8-31: Waste Picking Area

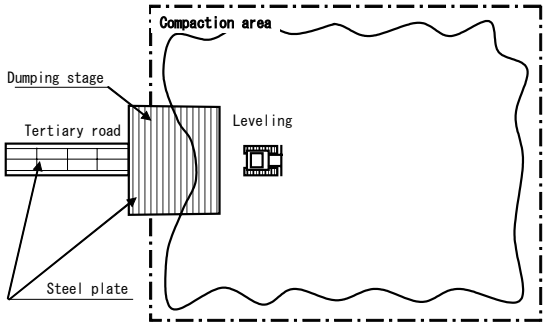


Figure 8-32: Waste Compaction Area

The position of the instructor, police and waste picker assistants at the waste unloading area is shown below.

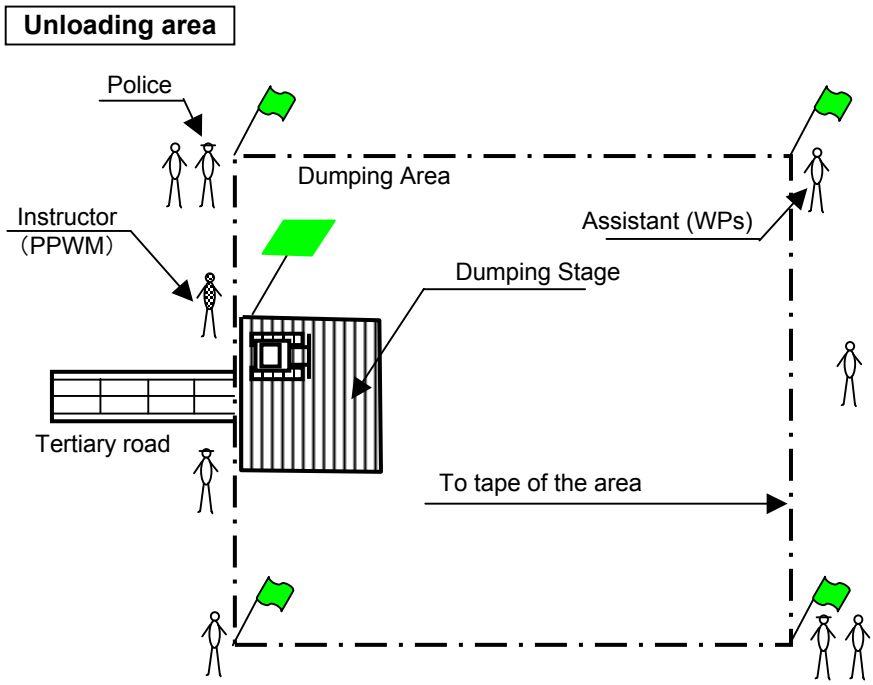


Figure 8-33: Position of Instructor, Police and Assistants

Table 8-11: Shift of work

	item	head count	6	12	18	24
1G	Instructor(Unloading)	one				
	Instructor(Entrance)	one				
	Policemen(Unloading)	three				
	Assistant(Unloading)	five				
2G	Instructor(Unloading)	one				(break)
	Instructor(Entrance)	one				
	Policemen(Unloading)	three				
	Assistant(Unloading)	five				
3G	Instructor(Unloading)	one				
	Instructor(Entrance)	one				
	Policemen(Unloading)	three				
	Assistant(Unloading)	five				

※1 :working hours
:lead time

c.3 Start of Waste Picking Rules

c.3.1. Roles and Responsibility of Each Group

The roles and responsibilities of the study team, PPWM, the PPWM instructor, the police and assistants are summarized by each step of the procedures.

1. Preparation

	Roles and Responsibilities
PPWM	• Preparation of working areas such as the Waste Unloading Area • Distribution of jackets • Arrangement of police • Selection of waste picker assistants based on the candidate list made by VCAO
JICA	• Preparation of Work Plan
VCAO	• Selection of candidates for waste picker assistants
SOM	• Preparation of equipment such as ropes, stakes, flags and signboard to set up working areas

2. During the Trial of Waste Picking Rules

(1) Brief Orientation

	Roles and Responsibilities
PPWM	• To explain the waste picking rules • To explain how to start the waste picking rules

(2) After starting waste picking rules

To keep all the waste pickers out of the Waste Unloading Area

	Roles and Responsibilities
PPWM	• To check the waste pickers that enter the site (checking ID card and jacket) • To instruct waste pickers to the Waste Picking Area
Police	• To keep a watch on waste pickers • To keep waste pickers out of the Waste Unloading Area
Waste Picker Assistant	• To keep a watch on waste pickers • To inform the police if any waste pickers try to enter the Waste Unloading Area

To conduct a proper operation

	Roles and Responsibilities
PPWM	• To instruct collection vehicle drivers to the Waste Unloading Area • To instruct drivers where to unload waste
Collection Vehicle Drivers	• To follow the instruction of PPWM and to unload waste in the proper place
Bulldozer Driver	• To level and compact waste

Monitoring

	Roles and Responsibilities
PPWM	• To conduct a follow up survey in cooperation with JICA study team assistants (3 days and 2 weeks after the start) • To modify waste picking rules based on the result of the monitoring
JICA	• To formulate a monitoring plan including a questionnaire sheet • To modify waste picking rules based on the result of the monitoring
VCAO	• To monitor the work by waste pickers

Here is the relationship of all the parties concerned.

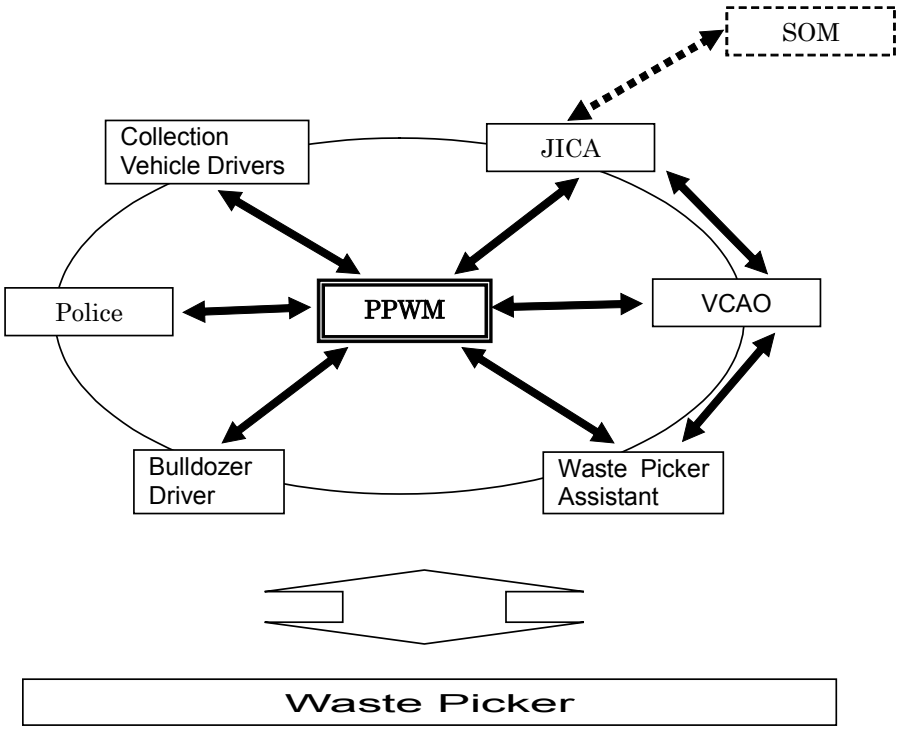


Figure 8-34: All the Party Concerned

Problems that arose during the trial and possible countermeasures
During the trial, a lot of problems arose. The problems and their possible countermeasures are summarized below.

Items	Problems	Possible Countermeasures
1. Level of understanding of waste picking rules by waste pickers	• Even though a dozen meetings were arranged to explain the waste picking rules to waste pickers, there were still many waste pickers who did not know the rules well or even never heard of them. • Some of the waste pickers are afraid that the waste picking rules will affect their income. • PPWM did not distribute rulebooks before the trial started and missed the chance to give the final notice of the start of waste picking rules. As a result, some waste pickers were surprised by the start of waste picking rules.	• Since there are a large number of waste pickers and most of them are not familiar with social rules in general, it is necessary to show the importance of waste picking rules at any chance available in order to realize the safety of picking work. • After the second phase finishes, it is impossible for PPWM to continue to employ assistants and police. It is important to ask local officials and waste pickers themselves for cooperation. • During the trial period, 2 of the 3 instructors from PPWM are tentatively assigned from the weighbridge staff. After the trial, it is impossible for them to continue to work as instructors. In the long term, PPWM needs to assign 3 personnel in addition to a manager to make waste picking rules work smoothly. • It is necessary to take additional measures to deal with waste pickers during the weekend and at night. • At least two dumping areas are necessary and in each area two dumping stages are prepared.
2. PPWM Management Systems	• Since new instructors have limited experience, they cannot give proper directions to the collection vehicles and bulldozer driver. • The level of understanding of waste picking rules by waste picker assistants; they do not cooperate well with each other. • The existence of police have less impact on waste pickers than the team expected	
3. Problem waste pickers	• There are several problem waste pickers, and they control other waste pickers by force. Waste picker assistants cannot control them. • They buy waste from collection vehicles and keep it to themselves. They try to sort waste in their way, and this becomes a serious obstacle for working area separation	• PPWM organized two meetings inviting Sangkat chiefs and discussed how to deal with these waste pickers. The Sangkat chiefs of both Stung Mean Chey and Beung Tompum made a promise to talk with them in person and ask for their signatures on the written pledge to follow the rules.
4. Unloading time	• The unloading time in the first trial (6 hours) was too long for waste pickers. In addition, the layer of waste was too thick and waste was compacted hard. This made the waste picking work very difficult. • At the following trials, the unloading time was getting shorted. There were more support from waste pickers, but a shorter unloading time required at least two bulldozers. • The work of waste pickers has several patterns, manly waste picking and sorting work. The rotation time of 6 hours apparently did not match these working patterns.	• In the short term, the appropriate length of time for unloading is 20 – 30 minutes or equivalent to 5 collection vehicles. In the long term, the period is preferably extended to 2 hours, so that PPWM can spend enough time to level and compact waste properly. • Some types of waste (organic waste and glass) need to be collected before the leveling work and other types of waste can be collected later on. The appropriate working time should be decided considering the working patterns.
5. Physical obstruction	• Although two bulldozers are needed, only one is available due to the fuel shortage and mechanical troubles. • The working areas in the expansion area cannot be used because of the dispute between PPWM and some landowners.	• In order to continue the waste picking rules, at least two bulldozer should be operated constantly. • PPWM should take responsibility for negotiating with the landowners. • At least two dumping areas should be prepared, and two dumping stages should be prepared in each area.
6. Waste pickers for the weekend and at midnight	• For the weekend, the number of part-time waste pickers considerably increases. Many of them, in particular children, have not been instructed on the waste picking rules yet.	• The landfill supervisor should confirm whether or not the incoming waste pickers know the picking rules and ask if they agree to follow them. For those who agree to follow the rules, the supervisor should give instructions. Those who don't agree to follow the rules should not be allowed to enter.

c.4 Schedule for the installation of waste picking rules

Date	Day of week	Work description
26/12	Friday	Explanation of the waste picking rules to all the parties concerned Demonstration of working area
27/12	Saturday	Monitoring of the installation work of the dumping stages and the tertiary road
28/12	Sunday	Monitoring of the installation work of the dumping stages and the tertiary road
29/12	Monday	Start of the rules
30/12	Tuesday	-Suspension of the use of Area 1 in the expansion area due to the dispute between PPWM and some landowners - Start of the rules in Areas 2 and 3 -Cancellation of the night operation because of its difficulty -Improvement of the rules
31/12	Wednesday	General meeting（PPWM, instructors from PPWM, assistants from waste pickers, policemen, VCAO(NGO), the Study Team）
01/01	Thursday	Operation of the improved rule which is reviewed unloading time
02/01	Friday	General meeting（PPWM, instructors from PPWM, waste picker assistants, policemen, VCAO(NGO), the Study Team）
03/01	Saturday	-Modification of the rules -Distribution of the rulebook -Suspension of the use of Area 2 in the expansion area due to disapproval by the land owners -Rearrangement of the dumping stage in Area 3
04/01	Sunday	-Modification of the rules -Distribution of the rulebook -Rearrangement of the dumping stage in Area 3
05/01	Monday	Operation of the modified rules
05/01	Tuesday	Operation of the modified rules
06/01	Wednesday	Operation of the modified rules
07/01	Thrsday	Operation of the modified rules
08/01	Friday	-Operation of the modified rules -Observe the meeting between PPWM and Sangkat chiefs as for trouble-making waste pickers
09/01	Saturday	Operation of the modified rules
10/01	Sunday	Operation of the modified rules
11/01	Monday	General meeting（PPWM, instructors from PPWM, waste picker assistants, policemen, VCAO(NGO), the Study Team）
12/01	Tuesday	Operation of the modified rules
13/01	Wednesday	Operation of the modified rules
14/01	Thrsday	Operation of the modified rules
15/01	Friday	-Operation of the modified rules -Completion of the pilot project

c.5 Conclusion

The trial of working area separation showed that the landfill operation, in particular unloading work of collection vehicles, considerably improved. However, due to the limited personnel and equipments of PPWM, it was difficult for PPWM to continue it by itself and the working area separation halted due.

In the third phase, PPWM changed the contractors of landfill operation, and this increased the level of landfill operation ability with more heavy vehicles. At the end of the third phase, PPWM tried to resume the working area separation by a simple style by itself.

d. Participatory Assessment

In order to evaluate the pilot project, the participatory assessment was conducted before and after the construction work, inviting local authorities, local residents and NGOs along with environment authorities.

d.1 Assessment method

d.1.1. Schedule

The first participatory assessment was conducted on October 10, 2003, while the post assessment was arranged on March 9, 2004.

d.1.2. Participant

The numbers of participants for the assessment of pre and post construction work were 25 and 20 respectively. The breakdown of the participants is shown below.

Table 8-12: Participants of PP Assessment

	Pre PP	Post PP
Local authorities	4	3
Local residents	9	7
NGOs working at SMC	4	3
Environment NGOs	4	3
Environment authorities	4	4
Total	25	20

d.1.3. Assessment Methods

After the brief explanation of the pilot project, all the participants made a round of SMCDS for assessment and filled in the questionnaire sheet.

d.2 Result

The result of the assessment is summarized below.

Table 8-13: Result of Participatory Assessment

	First Assessment					
	Acceptable	Medium	Terrible	Blank	Total	Point*
Environment Effect						
A1 Fire and smoke	12%	32%	56%	0%	100%	**1.56**
A2 Offensive order	0%	12%	88%	0%	100%	**1.12**
A3 Wastewater	0%	4%	96%	0%	100%	**1.04**
A4 Waste scattering	4%	4%	92%	0%	100%	**1.12**
A5 Animals (dogs, birds, etc)	12%	40%	40%	8%	100%	**1.70**
A6 Vermin (flies, worms, etc)	4%	12%	84%	0%	100%	**1.20**
A7 View	0%	16%	76%	8%	100%	**1.17**
Operational Conditions						
A8 Working situation of waste pickers	0%	8%	68%	24%	76%	**1.11**
A9 Heavy vehicles (collection vehicles and bulldozer)	4%	28%	40%	28%	72%	**1.50**
A10 Pile of waste	0%	24%	48%	28%	72%	**1.33**

	Second Assessment					
	Acceptable	Medium	Terrible	Blank	Total	Poin*t
Environment Effect						
A1 Fire and smoke	10%	57%	29%	5%	100%	**1.80**
A2 Offensive order	14%	67%	14%	5%	100%	**2.00**
A3 Wastewater	19%	62%	14%	5%	100%	**2.05**
A4 Waste scattering	10%	71%	10%	10%	100%	**2.00**
A5 Animals (dogs, birds, etc)	29%	52%	5%	14%	100%	**2.28**
A6 Vermin (flies, worms, etc)	19%	38%	19%	24%	100%	**2.00**
A7 View	29%	43%	10%	19%	100%	**2.24**

Operational Conditions						
A8 Working situation of waste pickers	19%	48%	19%	14%	100%	**2.00**
A9 Heavy vehicles (collection vehicles and bulldozer)	33%	48%	14%	5%	100%	**2.20**
A10 Pile of waste	10%	62%	14%	14%	100%	**1.94**

Note: Acceptable 3points, Medium 2 points and Terrible 1 point
Those who did not response were eliminated for the calculation.

Table 8-14: Result of Participatory Assessment (Facilities)

	Second Assessment					
Function of Facilities	Functioning	Medium	Not-functioning	Blank	Total	Point*
B1 Weighbridge	86%	10%	0	5%	100%	**2.90**
B2 On-site road (Main road)	48%	52%	0	0	100%	**2.48**
B3 On-site road (Secondary road)	29%	62%	0	10%	100%	**2.32**
B4 Working face	14%	43%	24%	19%	100%	**1.88**
B5 Gas removal facilities	62%	33%	0	5%	100%	**2.65**
B6 Security Fence	14%	62%	14%	10%	100%	**2.00**
B7-1 Leachate collection facilities	33%	43%	24%	0	100%	**2.10**
B7-2 Leachate pump pit and discharge pipe	57%	29%	14%	0	100%	**2.43**
B8 Leachate treatment facilities	43%	33%	24%	0	100%	**2.19**
B9 Drainage systems	43%	48%	10%	0	100%	**2.33**
B10 Composting plan	62%	29%	5%	5%	100%	**2.60**

Note: Acceptable 3points, Not-functioning 2 points and Terrible 1 point
Those who did not response were eliminated for the calculation.

8.2.4 Performance of Leachate Treatment facilities

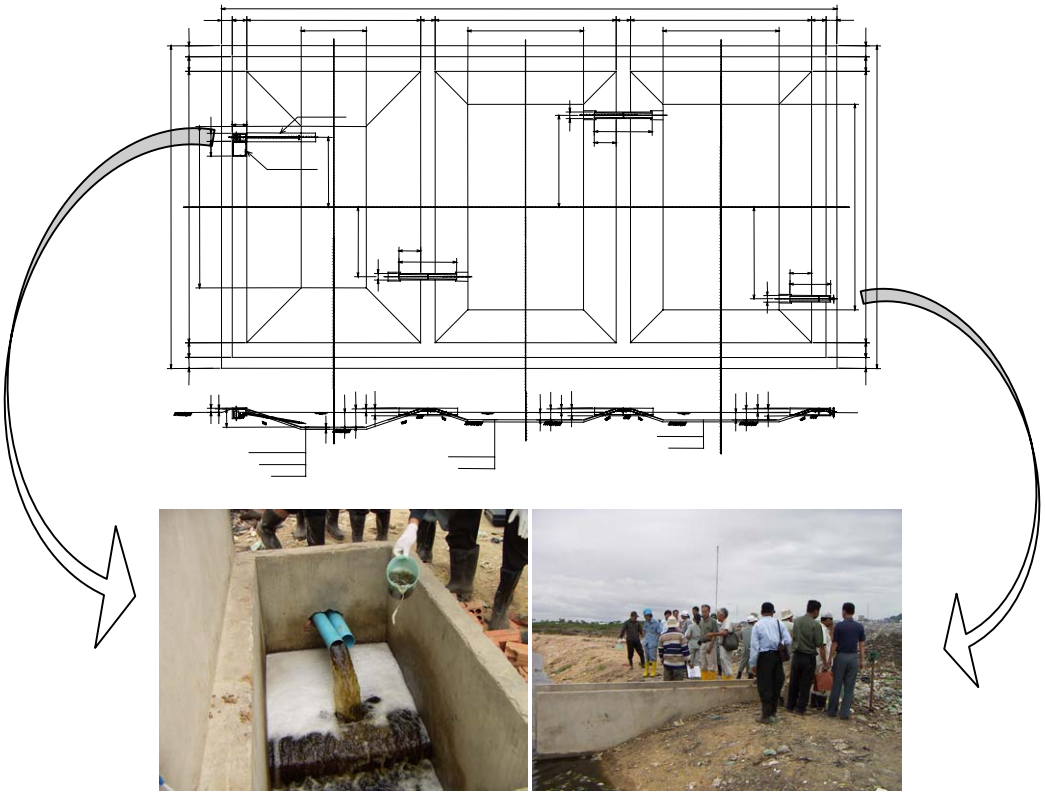
a. Purpose of water quality survey of leachate treatment facility

Generally, leachate is highly contaminated by pollutants especially organic matter so the treatment of leachate is indispensable before discharge to the outside.

The purpose and function of the leachate treatment facility in SMC are to improve water quality of the leachate that is collected by the leachate collection facility in order not to pollute the discharge area of public water. To evaluate the performance of the leachate treatment facility, raw water and treated water of the leachate were sampled and water quality was analyzed.

b. Location of sampling points

Samples were collected from the inlet and outlet of the facilities in order to compare their water quality. Location of sampling points is shown below.



Inlet of raw water Outlet of treated water

Figure 8-35: Location of sampling points

c. Results of water quality analysis

c.1 Methodology

The MOE lab in Phnom Penh was selected for conducting water quality measurement and analysis. The pH was measured in the field.

The method of measurement and analysis were as per the standard method for the examination of water and wastewater.

Table 8-15: Analysis Method for Each Parameter

No.	Parameters	Method	Laboratory
1	pH	4500-H B Electrometric Method	Field test
2	Oil Content	5520.B Partition Gravimetric	MOE lab
3	BOD5	5120.B 5-day BOD Test	MOE lab
4	COD	5220.C Closed Reflux Titrimetric	MOE lab
5	SS	2540.B Total Solids Dried	MOE lab
6	Cl-	4500.B Argentometric method	MOE lab
7	Iron	3111.B AAS	MOE lab

c.2 Results

The results of the water quality analysis are as follows.

Table 8-16: The Results of the Water Quality Analysis

Analysis parameters	PH	BOD5 (mg/L)	COD-Cr (mg/L)	Oil & Grease (mg/L)	SS (mg/L)	Iron (mg/L)	Chloride (mg/L)	Flow (L/sec)
Sampling 1 (26 July 2004)								
ITF	7.52	380	720	59*	100	2.3	1,900	38
OTF	NO sampling due to a mechanical problem of pump in the facility							
Proportion(%)	N/A							
Sampling 2 (20 August 2004)								
Inlet	7.57	190	540	11	99	2..3	2,200	41
Outlet	8.26	300	640	7.8	1,100	< 0.3	1,400	
Proportion(%)	109	158	119	71	1111	13	64	
Sampling 3 (10 September 2004)								
Inlet	7.44	320	1,100	9.1	130	0.97	1,700	35
Outlet	8.40	180	570	5.3	375	0.45	1,200	
Proportion(%)	113	56	52	58	288	46	71	
Sampling 4 (22 September 2004)								
Inlet	7.22	360	5,100*	7.5	244	0.53	1,800	30
Outlet	8.76	110	590	4.8	195	< 0.3	1,100	
Proportion(%)	121	31	12	64	80	57	61	
Sampling 5 (28 September 2004)								
Inlet	7.36	410	760	9.7	138	0.52	950	32
Outlet	9.05	160	630	6.0	318	< 0.3	1,100	
Proportion(%)	123	39	83	62	230	58	116	

*Data are suspected

From these data, the performance of the leachate treatment facility was found as mentioned below. However, the following issues should be considered before evaluating the results.

First of all, the results of Sampling 2, dated the 26th of July 2004, show a different tendency from the other samplings. This is because the activities of waste pickers in the 3rd treatment pond, such as washing used plastic bags, stir the pond and make mixed sediment at the bottom of the pond. As a result, the outlet shows higher concentrations of BOD, COD and ten times higher in the case of SS.

Secondly, two questionable values were found in the results: the concentration of oil & grease in a sample of the inlet from Sampling 1 and the COD concentration in a sample of the inlet from Sampling 4. Even though we re-checked the raw data, the reason could not be found so they have been excluded from average calculations.

Figure 8-36: The Picture of Samples

As an overall evaluation, the facility could improve the water quality of leachate. The facility could improve the water quality of BOD, COD and iron effectively as well as chloride also to a certain extent. The picture (on the right) clearly shows the difference in water quality between the inlet and the outlet.

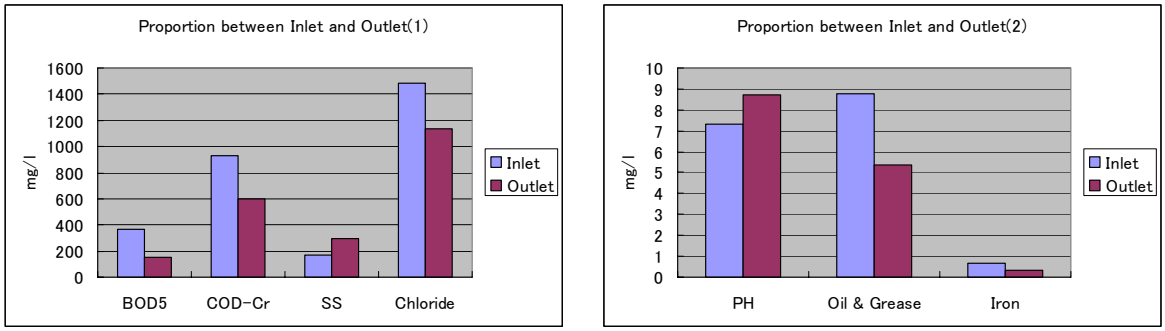


Figure 8-37: Average Proportion of the Concentration of Each Parameter

As for SS, it is notable that the concentration of the outlet was higher than the inlet in spite of our expectation that it would decrease after treatment. The reason is that the SS originated from organic matter in the leachate was surely decomposed. However, algae have occurred in the treated leachate instead because of strong sun exposure in Cambodia. (See following picture.)

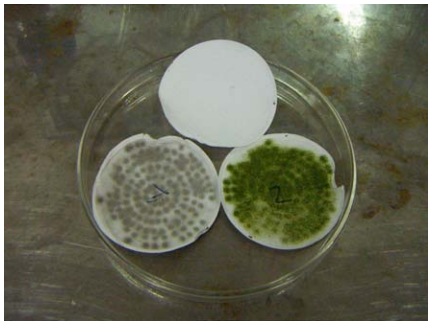


Figure 8-38: SS tested filter-disks for Inlet (left, gray) and Outlet (right, green)

8.2.5 Establishment of Regular Monitoring System

Before the pilot project, MOE/DOE had never conducted the environmental monitoring at the SMC disposal site. The regular environment monitoring by the regulatory organizations is indispensable for the proper pollution control.

On the other hand, in the development plan of the DK disposal site, the team proposed to organize the monitoring committee to control the operation of PPWM. In order to guarantee the regular monitoring by the monitoring committee at the DK disposal site, MOE/DOE should start to prepare for the regular monitoring system now. Therefore, under the pilot project, the team decided to support MOE/DOE to initiate the regular monitoring system at the SMC disposal site.

Due to the lack of the budget, it is almost impossible for MOE/DOE to start the same regular monitoring system as the development plan proposed. The team decided to exclude some monitoring items which are not affordable for MOE and DOE. Even though the newly established regular monitoring system is primitive, MOE and DOE could accumulate knowledge and experience through the regular monitoring which includes such tasks as sampling, analysis, data compiling, and data analysis.

a. Monitoring committee

In the initial stage, the team emphasized to put the regular monitoring activities by MOE/DOE on the track, because they never had conducted the environmental monitoring before.

After they conducted the monthly monitoring by themselves several times, the team proposed them to organize the monitoring committee inviting local authorities, residents and NGOs.

The monitoring committee has the following function.

- The committee members shall join in the monitoring and observe the environmental condition of the site and its surroundings.
- If the operation is suspected of having an effect on environmental conditions, the committee members shall be able to request a survey for it and be able to join on-site inspection.
- In order to proper operation of the disposal site, the committee shall hold discussions whenever necessary.

The committee may includes:

- MPP
- MOE
- DOE
- Village Development Committee
- NGOs

MOE, MPP/DOE and PPWM already started internal monitoring and after it will go smoothly, the monitoring committee mentioned above will be established.

b. Monitoring Items

Before starting the monitoring, MOE, MPP/DOE and PPWM dully discussed about the monitoring items because analysis items are costly and their budget for it is quite limited. Finalized monitoring items and the locations of monitoring are shown below.

Table 8-17: Monitoring Items

Monitoring Items and methods		Monitoring points*	Stage	
			Operation	Closure
Ground Water (from wells)	Electric conductivity, Cl-, pH	2	√	√
Surface Water (from leachate treatment facility)	Electric conductivity, Cl-, pH	2	√	√
Noise	Noise level	2	√	
Proper operation	Personal check	-	√	
Landfill fire	Personal check	-	√	√
Offensive odor	Personal check	-	√	√
Vermin and rats	Personal check	-	√	√
Waste scattering (Spill over from the site)	Personal check	-	√	

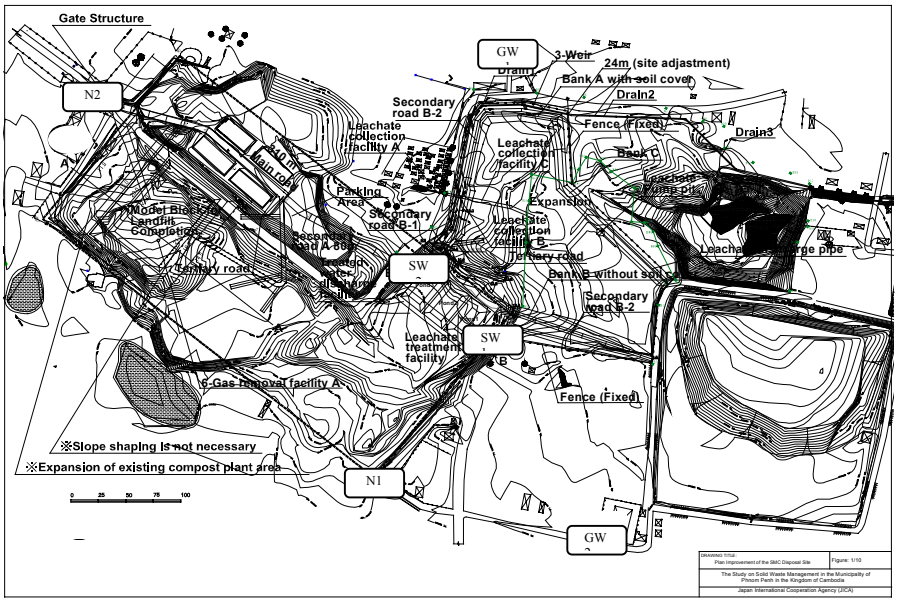


Figure 8-39: Monitoring Location of the SMC Disposal Site

c. Results of Monitoring

The results of monitoring of SMC until 28th September 2004 are shown below.

Monitoring Items and points		Monitoring date and results		
		26th Jul. 2004	1st Sep. 2004	28th Sep. 2004
Ground Water 1	Electric conductivity (μ S/cm)	1980	880	880
	Cl- (mg/l)	40	41	32
	pH	7.2	7.2	7.2
Ground Water 2	Electric conductivity (μ S/cm)	The pump of well has broken	The pump of well has broken	690
	Cl- (mg/l)			17
	pH			7.1
Surface Water 1 (Inlet of the facility)	Electric conductivity (μ S/cm)	20700	10350	7010
	Cl- (mg/l)	2000	1700	890
	pH	7.6	7.4	7.8
Surface Water 2 (Outlet of the facility)	Electric conductivity (μ S/cm)	No flow	No flow	5660
	Cl- (mg/l)			1100
	pH			7.7
Noise 1	Noise level (dB)	58 (AM)	44 (AM), 53 (PM)	54 (AM), 44 (PM)
Noise 2	Noise level (dB)	60 (PM)	46 (AM), 70 (AM)	76 (AM), 46 (AM)
Proper operation	Personal check	No good -Broken road -Waste pickers are not follow the picking rules	No good -Waste scattering in canals	No good -illegal tire-burning
Landfill fire	Personal check	No good -Smoke could be seen	No good -Illegal tire-burning	No good -Illegal tire-burning
Offensive odor	Personal check	No good - Offensive odor could be recognized	No offensive odor	No good -Offensive odor could be recognized
Vermin and rats	Personal check	No good - Vermin and rats could be recognized	No vermin and rats	No good -Vermin and rats could be recognized
Waste scattering (Spill over from the site)	Personal check	No good - the canal is clogging	Moderate -the situation was improved	No good -Spill over from the site

c.1 Ground Water

The purpose of ground water monitoring is to check the water quality and its change. The change in quality indicates the change of groundwater environment. Two wells around the disposal site are used for the ground water monitoring.

c.2 Surface Water (Leachate)

The leachate monitoring aims at checking the leachate quality and its change. The change in leachate quality indicates the change of groundwater environment. In addition, the change in quality before and after treatment by leachate treatment facility reveals the efficiency of the facility.

Here are the measurement points of surface water quality.

- Inlet of leachate treatment facility
- Outlet of the leachate treatment facility

c.3 Noise

The monitoring of noise level by a noise level meter indicates the surrounding environment for noise. Two measuring points for noise, the entrance of SMC and the southern boundary which closes to the residences, are used for the noise monitoring.

c.4 Others

Proper operation, landfill fire, offensive odor, vermin and rats and waste scattering are monitored by personal check because these don't need equipment for monitoring.

8.2.6 Findings

a. On-site road

Main road

1. One of the most important elements to manage and operate the disposal site properly is to make the on-site road always accessible. In order to make the main road accessible even during the rainy season, the new main road was constructed on the higher position, and steel plates were placed to protect the surface of the road. As the result of the improvement project, the main road was always accessible, and this made it easy for PPWM to operate and manage the landfill operation properly.
2. A part of the main road was constructed on the site of the previous main road and the remaining was constructed on the disposed waste. It takes time before the completed landfill area becomes stable, and it is necessary for PPWM to continue to maintain the conditions of the road by burying additional materials such as construction waste and placing steel plates on proper positions.

Secondary road

1. The secondary road was constructed at the site where disposed waste was heaped up and steel plates were also place on the secondary road. The condition of the secondary road was not as good as that of the main road. The result of the pilot project showed that it is necessary to prepare plural secondary roads and to use them in turn.

2. The secondary road is to be extended according to the change of location of the tertiary road and the working face. While one secondary road is used, PPWM have to raise the level of the remaining roads by burying with soil and construction waste, so that these roads can be gotten ready for the next use.
3. The secondary roads should be constructed according to the short and long term landfill operation plan.

b. Working face

1. The working face is a place where waste is dumped and disposed of, connecting the secondary and tertiary road. Unloaded waste should be spread and disposed of immediately by a bulldozer and other equipments. Therefore it is necessary to formulate the operation and management plan, including the maintenance plan of heavy equipments and emergency measures to cope with such accidents as a breakdown of heavy vehicles.
2. The preparation of the working face should be made due to the construction of the secondary road.

c. Model block for landfill completion

Location and Structure

During the pilot project, in a part of the existing area a model block covered with soil and turf was constructed to show the completed landfill area as a reference. After the pilot project, PPWM is required to extend the model block in the existing area and construct a new block in the expansion area, referring to the model block.

The model block was constructed both with decomposed waste and fresh waste, while the future landfill operation will dispose of only fresh waste. The landfill operation plan should be formulated considering the difference in subsidence rate.

Other items with Model Block for Landfill Completion

<Final cover>

1. The thickness of the final cover on the top and slope are 500 mm and 150 mm respectively. A large part of the soil covering the slope was washed away and the layer of the compacted waste was exposed. Therefore, it can be said that the thickness of the final cover on the slope should be at least 500 mm. The regular maintenance of the final cover is also necessary.
2. The result showed that the final cover was effective to prevent fire and mitigate environmental impact considerably. It is important to conduct the final covering final cover soon after the landfill operation is completed in each cell. It is necessary to use soil available at the SMCDS or DKDS to minimize the cost.
3.

<Laying turf>

- Since the result revealed that the turf planted on the slope had an effect to prevent the collapse of the slope, laying the turf is included in the operation plan. In order to minimize the cost, some of turf will be moved from the model block.

<Leachate collection facilities>

1. The effect of the leachate collection facilities was examined at the pilot project. They could keep the leachate inside the disposal site. PPWM should construct similar leachate

collection facilities in other landfill areas in order to prevent leachate from flowing out of the disposal site.

2. The leachate collection facilities also had an effect to prevent the collapse of the slope of the landfill area.

<Drainage of rain water>

1. The drainage of rain water was installed along the small terrace of the slope and the lowest terrace, and this facility was effective to prevent the collapse of the slope.
2. The drainage was installed horizontally, according to the original plan. Eroded soil from the final cover was not carried and piled up in the drainage in the beginning. However, due to the subsidence of the model block, some part of the drainage was inclined and this made piled soil flow down with rain water. The result showed that the drainage needs to have the slope of around 1.2 degree.

<Gas removal facilities>

1. The result showed that the gas removal facilities were effective to remove gas and vapor generated from the landfill area and could make the landfill area stable faster.
2. In the pilot project, gas removal facilities were installed in the completed fill. When new landfill area start its operation, it is preferable to install gas removal facilities before the start of the operation. If it is difficult to install facilities before the start of the landfill operation due to the limited budget, gas removal facilities would be installed in the completed fill before the final cover.
3. Landfill gases include an inflammable gas, and it is possible to construct a facility to utilize the gas. (the property of landfill gases was analyzed at a different project.).

d. Enclosing bank

1. The enclosing bank was constructed along the border in the expansion area. The bank showed the landfill area clearly.
2. The enclosing bank constructed in the pilot project was made of disposed waste and will continue to subside until disposed waste is stable. In particular, the part of the bank, which was made of fresh waste, would subside considerably. It is necessary for PPWM to repair the enclosing bank regularly.
3. The enclosing bank A was covered with soil. It is preferable that other parts of the bank are covered with soil from the hygienic point of view. In the plan, the whole bank would be covered with soil. If possible, turf would be planted on the outer side of the bank.

e. Leachate Collection and Treatment Facilities

<Leachate collection facilities>

1. Along the landfill area, two types of leachate collection facilities were installed: one was the combination of perforated concrete pipe and rubble stone and the other was made of only rubble stone. Both types of collection facilities could collect leachate properly. It takes more to install the former type and it is important to select an appropriate type considering the conditions of the site.
2. It was almost impossible to examine the effect of the leachate collection facilities installed inside the landfill area.

<Leachate pump pit and pump>

1. Rubble stones were installed around the leachate pump pit in order to prevent the blockage by waste, but the blockage was observed. In the future plan, it is necessary to widen the area (width) of rubble stones.
2. The leachate pump pit had two types of structures: one was made of bricks and the other was made of concrete pipe. Both types did not show any structural problems.
3. Plural pumps were installed, so that PPWM could cope with the breakdown of a pump and conduct a regular maintenance work.

<Leachate discharge pipe>

1. PVC pipe with a diameter of 80mm was used as drainage pipe. There were no problems in installing discharge pipe.
2. Discharge pipes were laid underground as an antitheft measure, but this made the maintenance work difficult. It is better to install discharge pipes on the ground.
3. If discharge pipes are constructed along the waste layer, it is necessary to install flexible tubing considering the effect of subsidence.

<Gas removal facilities>

1. According to the original plan, gas removal pipes were to be installed in the expansion area, but due to the request of the landowner their locations were changed. The outline was the same as that of gas removal pipes at the model block.

<Leachate treatment facilities>

1. Leachate treatment facilities were constructed using soil, and a part of the slope was collapsed. Therefore, a regular maintenance is necessary. To enhance the strength of the bank by planting water grass is also effective to prevent its collapse.
2. Waste, scattered by wind, were piled up on the surface of ponds, so it is necessary to clean these ponds regularly.
3. Waste pickers sometimes entered ponds to wash collected plastic. It is necessary to take a measure to keep them out from the area.

f. Other Experiment Items (Fence and Gate)

<Fence>

1. The fences were useful to show the border of the disposal site clearly.
2. In the pilot project, fences consisting of concrete poles and bared wire were constructed, but it was turn out to be easy to remove or move these parts. The result of the pilot project shows that it is necessary to construct immobile fences with higher strength. Otherwise, it is impossible to prevent outsiders from entering.

<Gate>

- The construction of the gate made it possible for outsiders to recognize the boundary of the disposal site.