Report on the "Extension of Sewerage System to Everyone who Needs it" Project

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Abstract: To extend sewerage service to a large population under the tight budgetary condition, the government of Japan started a project to encourage the application of new and ambitious ideas to the works of sewerage system. This paper, after the brief introduction on the state of wastewater management in Japan, describes the project including results of efforts made for cost reduction, and some cost reduction ideas prepared by PWRI.

Keywords: Sewerage system, Unconnected population, Construction cost, Cost reduction

1. Background and Purpose of the Project

The ratio of the population connected to sewerage system in Japan is 68% at the end of March in 2005, because of the intensive efforts done by the national government, local governments and related organizations. Wastewater management through sewerage system has contributed to the improvement of not only everyday life but also water quality in rivers and seacoasts.

Sewerage system has been constructed mainly in bigger cities and in many local cities having social needs of such a system. Therefore there exists a difference in connection ratio to sewerage system among municipalities; the difference has become a kind of social problem now. There are 24.7 million people left in Japan who are supposed to be covered by sewerage system, but cannot use it at present.

The expenditure on sewerage system construction is expected to be more efficient, because the budgetary conditions of both national government and local governments are quite tight. The national government has started a project to promote sewerage system construction with less cost and less time. In the project, the procedures and the technical standards for planning, design and construction of sewerage system are to be revised from the viewpoint of cost reduction and time saving.

2. Outline of unconnected population

Figure-1 shows the state of unconnected population. In this paper, "unconnected population" means the number of people who live in the areas that should be covered by sewerage system but still not due to the delay in construction. The term "sewerage population" is used for the population that is equal to the sum of unconnected population and the population that is already covered by sewerage system. In Figure-1, each municipality is classified into seven classes according to the total population size.

The ratio of unconnected population to total population is 19% in Japan, and 77% of the unconnected population belongs to the classes of 30 to 500 thousand. Sewerage population in Japan is 88% of the total population. The ratio of unconnected population to sewerage population (uncovered ratio) is 22% in average in Japan.

Figure-2 shows the relationship between population of each municipality and uncovered ratio. The figure does not include the municipalities that have no sewerage population, i.e., no plan of sewerage system. The biggest municipality that shows 100% of uncovered ratio has a population of 80 thousand. The uncovered ratio is low in the municipalities whose population is less than 3 thousand or more than 300 thousand.

From the data mentioned above, we can assume that the unconnected population in Japan is mainly in the municipalities whose population is 30 to 500 thousand.

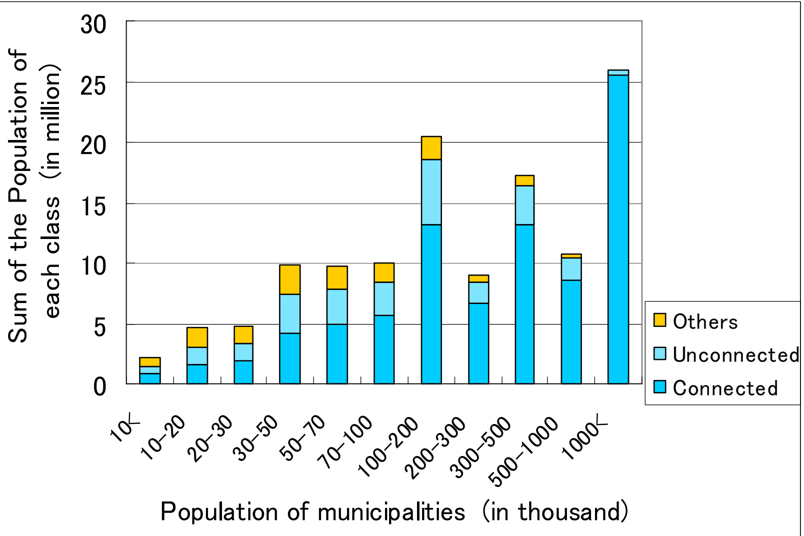

Figure-1 State of Unconnected population

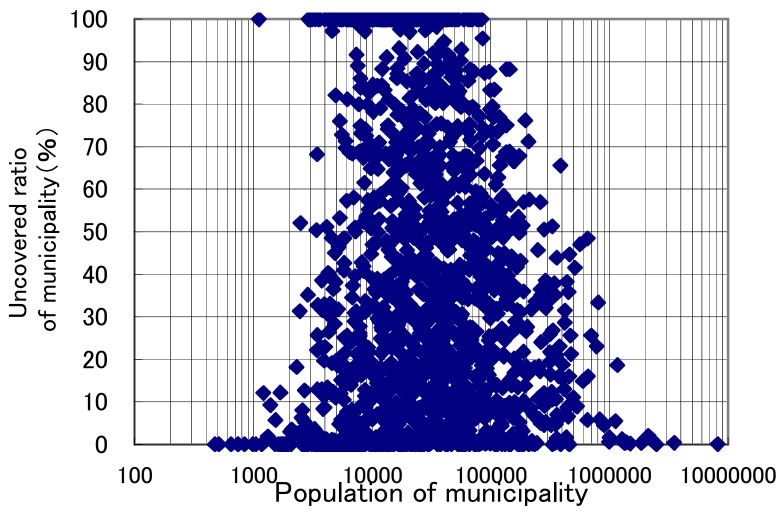

Figure-2 Population & uncovered ratio of municipality

3. Efforts toward cost reduction and their results up to now

The government of Japan started the organized program toward cost reduction of public works in January 1997. In the field of sewerage system construction, national government published the documents to encourage the efforts toward cost reduction in 1997, and announced action programs in 2001 and 2005.

Among the results up to now, a good example is the revision of the standard for installation of sewer pipe under public roads. The revision in 1999 allowed sewer pipe to be buried more shallowly than before: Pipes with a diameter of 300 mm or less should be covered at least 60 cm of filling under the surface of roadway and 50 cm under sideway, while 100 cm was required before the revision.

To evaluate the effect of the efforts toward cost reduction, an installation works of sewer pipe in K city was taken as an example. The outline of the works is shown in Table-1.

Table-1 Outline of Installation works of sewer pipe

Items	Content
Diameter	200 mm
Length	200 m (not straight)
Construction method	Open cut
Gradient of road	23 to 72 ‰
Number of connections	20 houses
Related works	Repair of road is included
	Temporary displacement of other pipes is excluded

The change in price and wage and the revised design parameters affected the cost. The cost of the works was estimated under three sets of conditions as listed in Table-2. Cases-1 and -2 used the same design parameters as the city actually used then, while in Case-3 some parameters were changed to achieve cost reduction.

Table-2 Design parameters for Cost comparison and the results

Design parameters & Cost	Case-1	Case-2	Case-3
Year of Price list	1996	2006	2006
Minimum depth of pipe	120 cm	120 cm	70 cm
Type of pipe	VU pipe	Plastic rib-pipe	Plastic rib-pipe
Filling material around pipe	Sand (around pipe)+ Improved excavated soil	Sand (under pipe) + Improved excavated soil	Sand (under pipe) + Improved excavated soil
Width of trench	110 cm	110 cm	85 cm
Width of road base repair	170 cm	110 cm	85 cm
Retaining wall	Installed	Installed	Not installed
Type of manhole	Type-1 in 7 sites	Type-1 in 7 sites	Type-1 in 1 site Small type in 5 sites Curved pipe in 1 site
Depth of inlet to sewer	80 cm	80 cm	60 cm
Total Cost	32.6 million yen	19.5 million yen	12.7 million yen
Cost per pipe length	163,000 yen/m	97,400 yen/m	63,400 yen/m
Relative value of cost	100	60	39

The conditions in detail and the results of calculation are listed in Table-2. From the results of Cases-1 and -2, the cost in 2006 is estimated to be 60% of the cost in 1996. The revision on road repair and filling material contributed most to the cost reduction. If further changes were made as indicated in Case-3, the cost would be reduced to 39% of the cost in 1996.

4. Construction Cost of Sewerage System

To promote the project, construction cost of sewerage system was studied. The average cost can be obtained from the total expenditure and the number of new customers. From the data of the period from 1998 to 2002, the average construction cost per customer in Japan is calculated to be 980,000 yen.

The construction cost per customer can be calculated from the data of the municipalities that are almost completing construction of sewerage system. Using the national statistics of 2003, 18 municipalities which satisfy the following conditions were selected for the study.

Condition-A: Ratio of the population covered by sewerage system to total population is equal to or more than 80%.

Condition-B: Construction works started after 1990.

Condition-C: Both sewers and treatment plants are owned by one municipality.

Condition-D: No investment to rain water control.

Selected 18 municipalities are all located in non-urbanized area, and their population was 1,881 to 17,806 in 2003.

The relationship between sewer pipe length per customer and construction cost per customer of both sewers and sewerage system in 18 municipalities is shown in Figure-3. Linear relation can be obtained for both. In the case of 10 m per customer, the construction cost per customer is 1.5 million yen for sewerage system, and 1 million yen for sewers. The construction cost of sewers per unit length in the studied 18 municipalities is 100 thousand yen per meter on average.

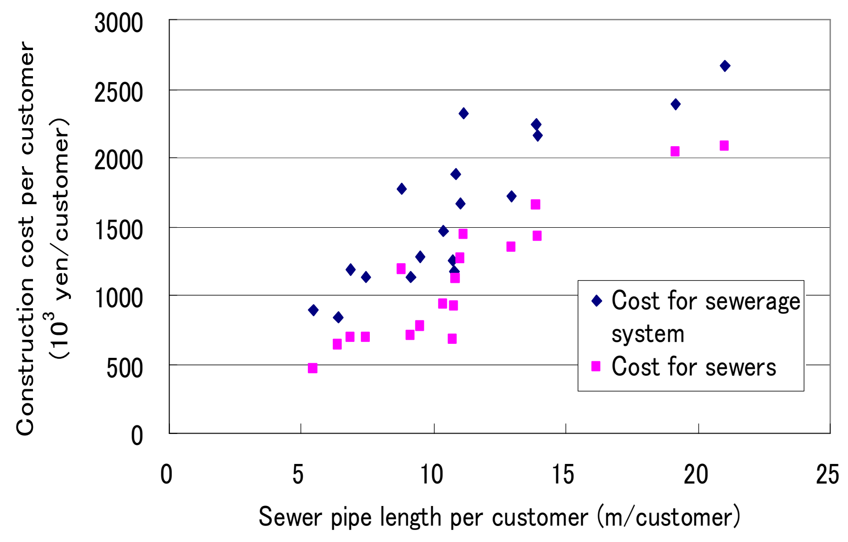

Figure-3 Sewer pipe length and Construction cost

5. Cost to be balanced with customers' charge

One of the important points for setting the target of construction cost is to balance investment with income. A trial calculation to balance capital investment with customers' charge was done using the data of the municipalities practicing good sewerage management. The conditions of calculation and the results are listed in Tables-3 and -4 respectively. The construction cost per customer that is balanced with customers' charge under the conditions of Table-3 is 766 thousand yen in the case that interest rate is 3%.

Table-3 Conditions of Calculation

Items	Conditions
Customers' charge	200 yen/m^3-wastewater
Maintenance cost	80 yen/m^3-wastewater
Water consumption	0.25 m^3/d/customer
Coverage by charge	Maintenance cost + half of Capital cost
Ratio of bond	50%, 60%, 70% of Total Investment
Interest rate	2, 3, 4%

Table-4 Calculated cost (in 10^3 yen/customer)

Interest rate	Ratio of bond		
	50%	60%	70%
2%	858	715	613
3%	766	638	547
4%	688	573	491

6. Promotion of the project

To promote the project, in September 2006 all the municipalities were asked to make proposals that contribute to the cost reduction in sewerage works of each municipality for unconnected people, and to try them in actual works. Municipalities can propose any ideas. The national government will choose both the acceptable ideas and the municipalities that will try them in actual works. After being constructed, these ideas will be evaluated by related municipalities, the national government and PWRI from the viewpoint of both cost reduction and the applicability to other municipalities.

Our institute prepared a list of ideas for reference that is shown in Table-5. The listed ideas were mainly taken from the answers to the questionnaire survey conducted in 2003.

Table-5 List of ideas for reference prepared by PWRI

Ideas	Description in present standards
Use of inverted siphon	No use in principle
Setting of sewer gradient at a starting point by velocity of 60 cm/s under half full flow	No description
Raise of upper limit of velocity in sewer	3m/s
Reduction of gradient of house connection	2/100 for a connection of less than 150 customers
Use of curved pipe	Not allowed
Raise of maximum distance between manholes	75 m for a pipe diameter under 600 mm
Reduction of diameter of inlet to sewer	20 cm or more
Reduction of HRT of bioreactor	24 hrs for Oxidation ditch

Among the ideas in Table-5, two examples, inverted siphon and curved pipe are explained briefly.

Figure-4 is a structure drawing of inverted siphon that is utilized to sanitary sewer in T city. The slope of both descending and rising pipe is usually 1 to 1 (vertical to horizontal) in Japan. Deposits such as sand or small stone accumulated in inverted siphon can be cleaned by water-jetting. By use of inverted siphon, downstream sewer pipe can be buried more shallowly, or manhole type pumping stations can be avoided.

Figure-5 is a part of sewer network map of K city. In several points of change of sewer direction, curved pipes are utilized instead of manholes. The angles of the curved pipes utilized in Figure-5 are 5.625, 11.25, and 22.5 degrees. These curved pipes were manufactured in factory.

Recently a new type of curved pipe was developed; a curved plastic rib-pipe as shown in Figure-6.

The results of the project will help not only the extension but also the reorganization of sewerage system.

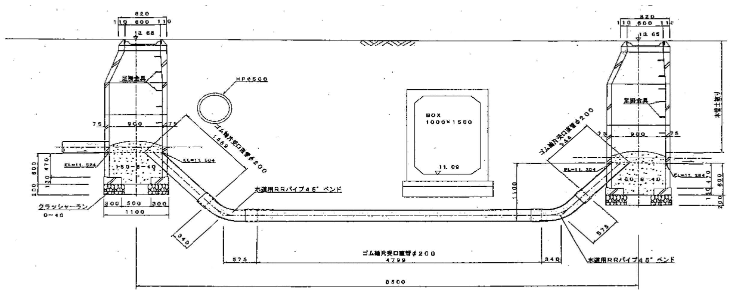

Figure-4 Structure drawing of inverted siphon

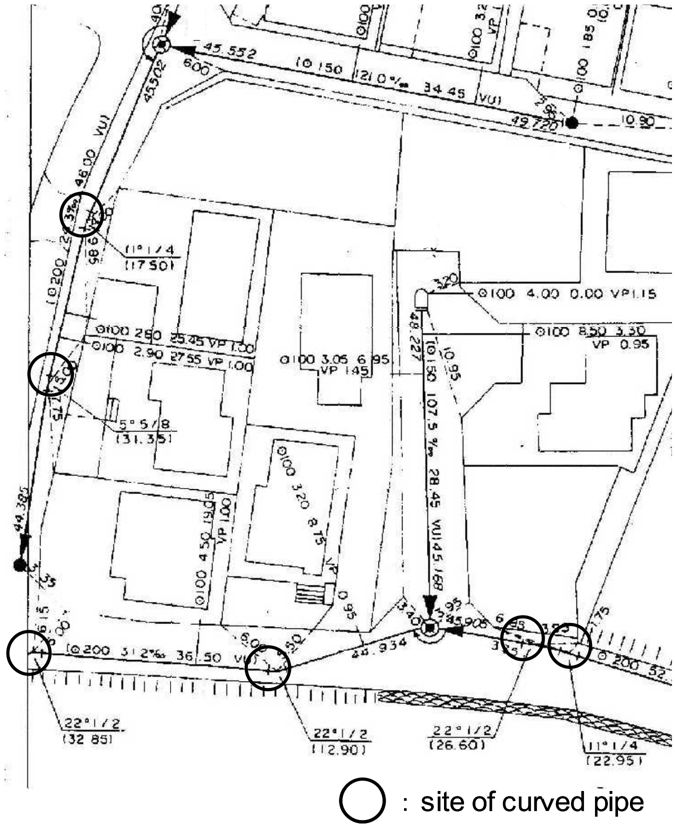

Figure-5 Use of curved pipe in K city


Figure-6 Curved Plastic Rib-pipe

"Extension of Sewerage System to Everyone who Needs it" project

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Background of the project

1. Existence of 24 million people who are waiting for sewerage system
2. Tight budgetary conditions of both national & local governments
3. Increasing needs to renewal & rehabilitation of facilities

Purpose of the Project

- To extend sewerage system quickly to everyone who needs it
- Reducing both cost and time of construction
- By new and ambitious ideas for planning, design and construction

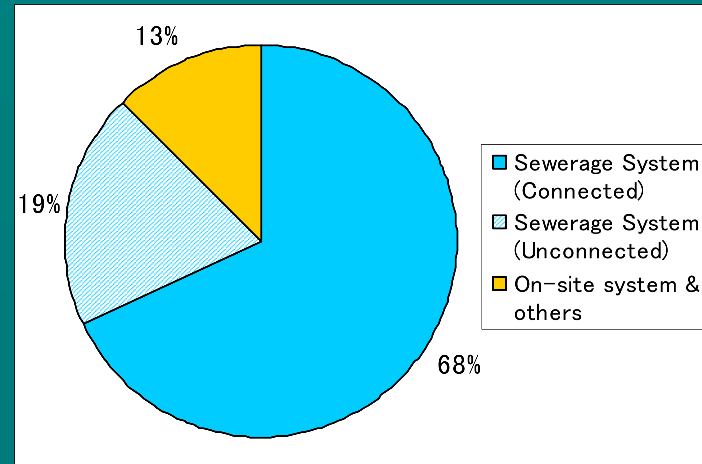
Overview

1. State of Wastewater Management
2. Efforts toward cost reduction up to now
3. Construction cost of Sewerage System
4. Promotion of the project

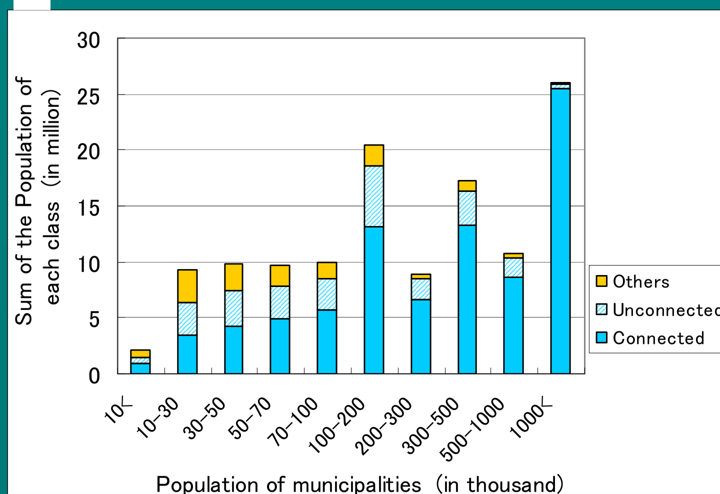
Definition of the terms

- Connected population
  : *Population covered by sewerage system*
- Unconnected population
  : *Population to be covered by sewerage system, but not now*

State of Wastewater Management in 2004



Distribution of unconnected population



Summary of the state of Unconnected population

- Ratio: 19% of the total population in Japan cannot use sewerage system.
- Distribution:
  89% of the unconnected population belongs to the municipalities of 10 to 500 thousand in population.

Efforts toward Cost Reduction up to now by the national government

- In 1997, Program toward cost reduction of public works.
  Documents to encourage cost reduction of sewerage system construction.
- In 2001 & 2005, Action programs toward cost reduction of sewerage system construction.

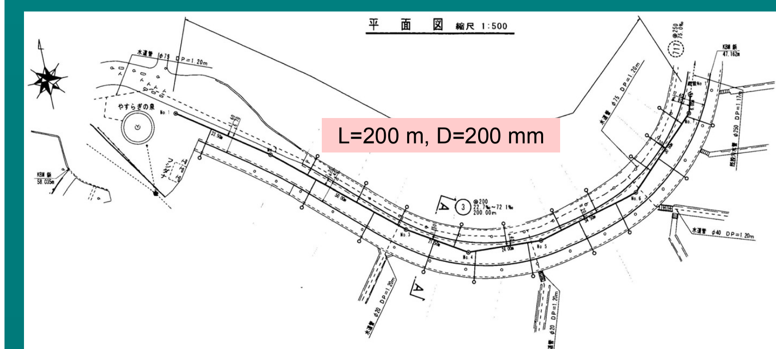
An Example of the results up to now

:Revision of the standard for pipe installation under public roads in 1999

- Small pipe (with a diameter of 300 mm or less) can be buried more shallowly than before.
- Minimum depth for small pipe
  Before → After
  100cm → 60cm under roadway
  50cm under sideway

Change of the cost in 10 years

Plan of sewer pipe installation in K city



Case study for cost comparison

Example：
- ・Installation of sewer pipe by open cut method
- ・Diameter 200 mm, Length 200 m
- ・Gradient of road 23～72 ‰

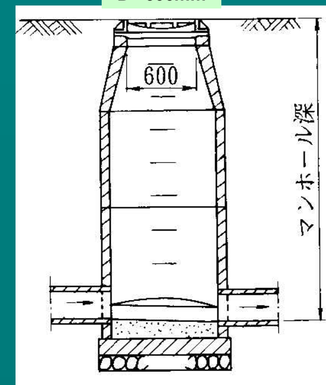
Method:
- ・Calculate the cost under the conditions adopted in 1996 and 2006 by K city, and proposed in 2006 by PWRI

Design parameters for cost comparison

	Case-1	Case-2	Case-3
Year	1996	2006	2006
Minimum depth of pipe	1.2 m	1.2 m	***0.7 m***
Type of pipe	VU	*Rib-pipe*	*Rib-pipe*
Filling material			
under pipe	Sand	Sand	Sand
over pipe up to 30 cm	Sand	*Improved soil*	*Improved soil*
Width of trench	110 cm	110 cm	***85 cm***
Width of road base repair	170 cm	*110 cm*	***85 cm***
Retaining wall	Installed	Installed	***Not installed***
Type of manhole	Type-1	Type-1	Type-1, ***Small, & Curved pipe***
Depth of inlet to sewer	80 cm	80 cm	***60 cm***

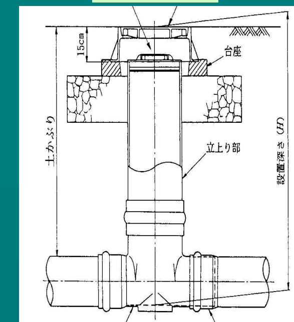
Type of Manhole

D= 600mm



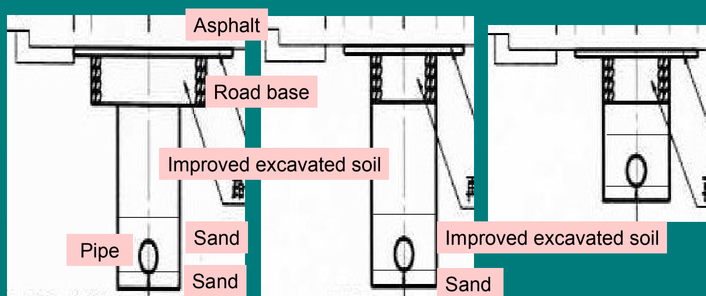
Type-1 (ordinary type)

D= 300mm



Small type in plastic

Revision of road repair and filling material



In 1996 In 2006 In 2006 + proposal

Results of cost comparison

	Case-1	Case-2	Case-3
Total cost (million yen)	32.6	19.5	12.7
Cost per unit length (yen/m)	163,000	97,400	63,400
(EUR/m)	*(1,087)*	*(649)*	*(422)*
Relative value	100	59.8	38.9

Construction cost of whole sewerage system

(Cost = investment /new customers)

1. Average cost in Japan (1998 to 2002)
   : 980,000 yen/customer
   (6,500EUR/customer)

2. Cost in the municipalities that are almost completing construction

Selection of municipalities

Conditions for selection

A: Ratio of connected population to total population is 80% or more

B: Construction works started after 1990

C: Both sewers and treatment plants are owned by one municipality

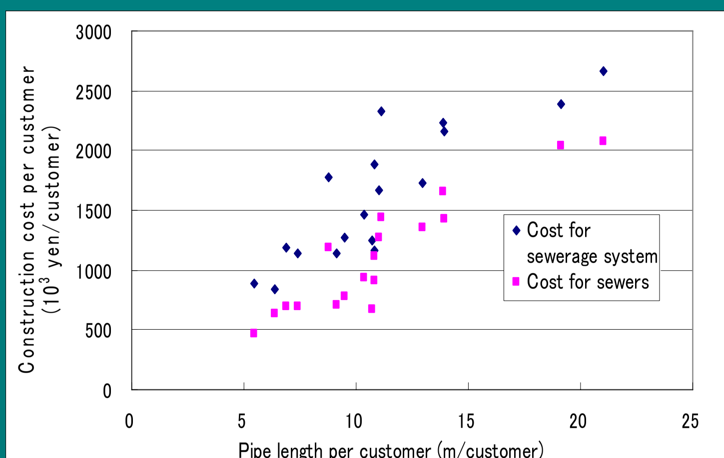
D: No investment to rain water control

Characteristics of selected 18 municipalities

: Located in non-urbanized area

: Population of 1,881 to 17,806 in 2003

Sewer pipe length and construction cost



Target of construction cost

One idea is
to balance construction cost with customers' charge.

Trial calculation was done
using the data of the municipalities practicing good sewerage management.

Conditions of Calculation

Items	Conditions
Customers' charge	200 yen/m^3-wastewater
Maintenance cost	80 yen/m^3-wastewater
Volume of wastewater	0.25m^3/d/customer
Coverage by charge	Maintenance cost + half of Capital cost
Ratio of bond/investment	50, 60, 70%
Interest rate	2, 3, 4%

Calculated cost

(thousand yen/customer)

Interest rate	Ratio of bond/investment 50%	60%	70%
2 %	858	715	613
3 %	766	638	547
4 %	688	573	491

■Promotion of the project

- Proposal from municipalities & private companies
- Selection of the ideas and
  the municipalities which will do them
- Evaluation of the ideas:
  Cost and Applicability to other municipalities
- Construction of sewerage system
  using revised methods

List of ideas presented by PWRI

Shallow installation

- Use of ***inverted siphon***
- Raise of ***upper limit of velocity*** in sewer
- Reduction of ***gradient of house connection***

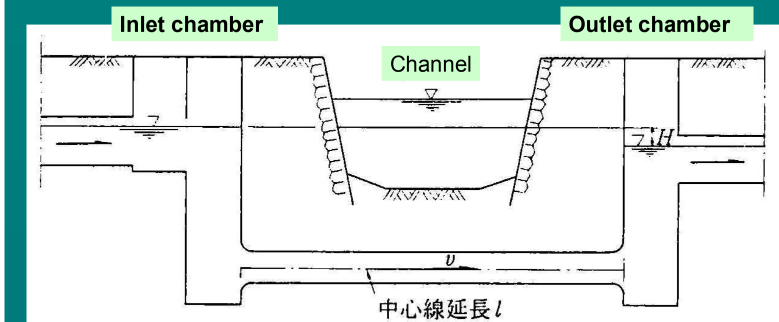
Reduction of manholes

- Use of ***curved pipe***
- Use of ***small manhole***
- Raise of ***maximum distance*** between manholes

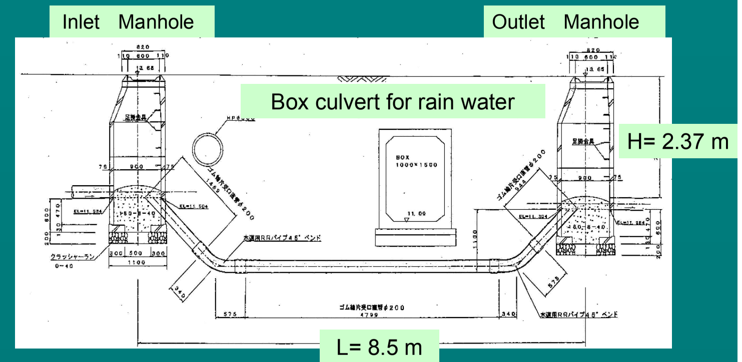
Others

- Reduction of ***diameter of inlet to sewer***
- Reduction of ***HRT of Bioreactor***

Conventional type of Inverted siphon in Japan



Improved type of inverted siphon



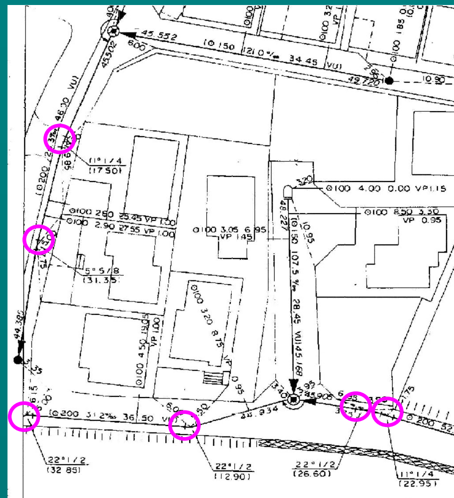
Exit pipe from inlet manhole of inverted siphon

8 months of operation, 3 houses discharged

Exit pipe from inlet manhole

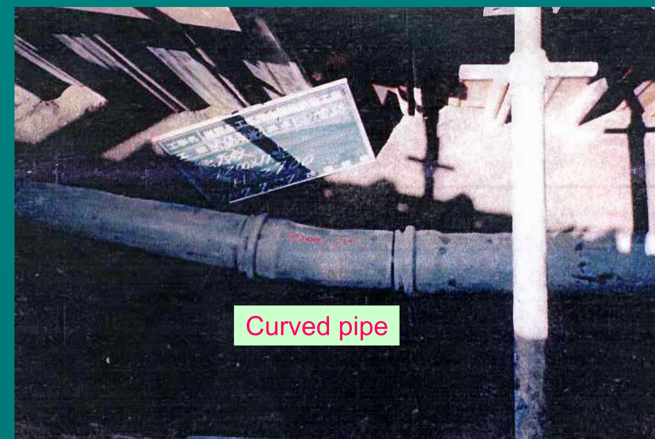
1 year of operation, 5 houses discharged

Use of curved pipe in K city



○ : site of curved pipe

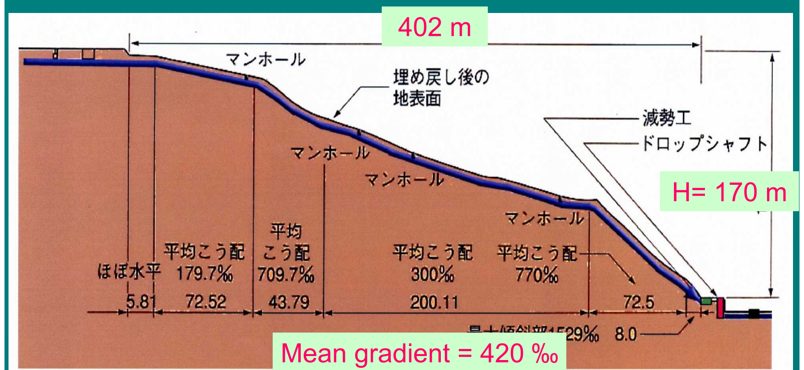
Curved pipe in construction site



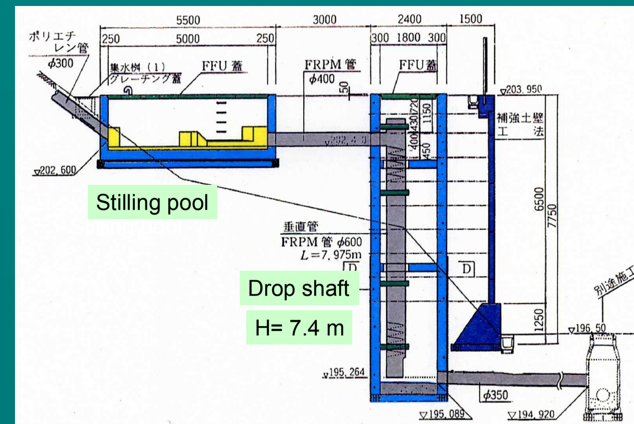
Curved Plastic Rib-pipe

Use of steep sewer to connect the area on the hill in Ohtsu city

Cross section view of steep sewer in Ohtsu city



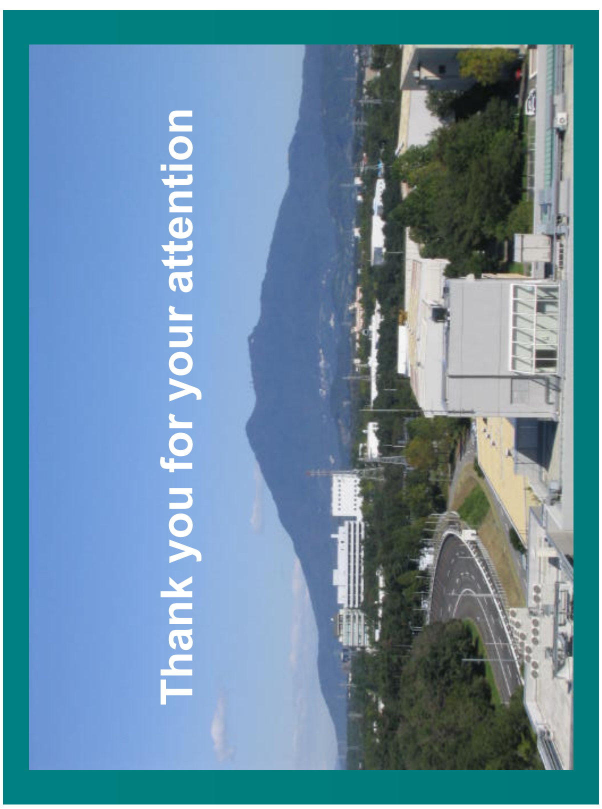
Energy absorbers utilized for steep sewer in Ohtsu city



Energy absorber for steep sewer (Stilling pond)

Prospects

The results of the project will help both the *extension* and the *reorganization* of sewerage system.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