14. Sewerage / Urban Drainage Sub-sector

Guideline:

(1) Sewerage (Adaptation Project)
(2) Sewerage (BAU Development with Adaptation Options)
(3) Urban Drainage (Adaptation Project)
(4) Urban Drainage (BAU Development with Adaptation Options)
Basic Concept (Sewerage)

<table>
<thead>
<tr>
<th>A. General Description</th>
<th>Increase in intensity and frequency of rainfall, and temperature rise due to climate change will negatively affect the hygienic environment of urban areas. In areas where sewerage system malfunctions or has insufficient capacity, human settlement is exposed to higher risks of inundation by floodwater, which contains both contaminated water and stormwater. Such inundation in urban areas will potentially cause outbreak of infectious diseases such as cholera, typhoid, and diarrhea. Furthermore, contaminated floodwater will worsen the environment in and around rivers and coastal areas. In areas where no sewerage system is available, such situation will be exacerbated with the anticipated impacts due to climate change. In the sewerage sub-sector, the development, extension and upgrading of sewerage systems themselves are considered as an adaptation project, while improving living conditions, the social environment, and hygiene, which would worsen due to climate change.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Vulnerability</td>
<td>1) Major Climate Change Impacts on the Sewerage Sub-sector</td>
</tr>
<tr>
<td></td>
<td>A) In Case of Existing Sewerage Treatment System</td>
</tr>
<tr>
<td></td>
<td>• Degradation of organic materials is likely to be prompted by bacteria and microscopic organisms due to temperature rise and changes in solar irradiation condition.</td>
</tr>
<tr>
<td></td>
<td>• In case of a combined sewerage system, the increased intensity of rainfall may cause flooding of contaminated water that will eventually flow into rivers and coastal areas without any treatment.</td>
</tr>
<tr>
<td></td>
<td>B) In Case of No Existing Sewerage Treatment System and Commonly Expected Impacts</td>
</tr>
<tr>
<td></td>
<td>• Retention and inundation by sewerage and contaminated water will considerably exacerbate the hygienic environment in urban areas.</td>
</tr>
<tr>
<td></td>
<td>• Climate change will amplify the conditions of a worsened hygienic environment, and potentially cause outbreak of water and vector borne diseases such as diarrhea, cholera, and typhoid therefore increasing the morbidity and mortality rates of such diseases.</td>
</tr>
<tr>
<td></td>
<td>2) Other Factors that Influence the Sewerage Sub-sector Associated with Climate Change Impacts</td>
</tr>
<tr>
<td></td>
<td>• Changes in lifestyle and industry structures together with the growth of the population and the economy will increase water demand and thereby demand for sewerage treatment.</td>
</tr>
<tr>
<td></td>
<td>• The recycling of greywater, which is yet to be popular in developing countries in general, can complement shortage in water resources and will require drastic changes to the sewerage treatment process.</td>
</tr>
<tr>
<td></td>
<td>3) Adaptive Capacity to Climate Change</td>
</tr>
<tr>
<td></td>
<td>• The adaptive capacity is higher in areas where water supply and sewerage systems are available.</td>
</tr>
<tr>
<td></td>
<td>• Slums or poverty-stricken areas possess lower adaptive capacity, regardless of existence of sewerage systems.</td>
</tr>
<tr>
<td></td>
<td>• Areas with urban drainage networks possess higher adaptive capacity.</td>
</tr>
<tr>
<td></td>
<td>• Areas with healthcare or medical facilities which can respond to infectious diseases possess higher adaptive capacity.</td>
</tr>
</tbody>
</table>
Areas where informative and preventive activities regarding infectious diseases are active possess higher adaptive capacity.

4) Spatial Distribution of Vulnerability
   a) Climate Change
   Sewerage systems are considered as consolidated system from end users (sewerage connectors) through sewerage pipes and treatment plants to drainage areas. Therefore, it is considered that there is no spatial difference for climate change impacts within the system.

   b) Sensitivity in the Sewerage Sub-sector
   Sensitivity is likely higher for densely populated areas within the target areas for sewerage development. Sensitivity may differ according to the existing coverage of the sewerage system as well as the existing level of effective functions.

   c) Adaptive Capacity
   Adaptive capacity may differ according to population distribution and socio-economic conditions (inclusion of slums) within the target areas.

<table>
<thead>
<tr>
<th>C. Adaptation Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Rehabilitation and Extension of the Sewerage System (also applicable in the case of new development)</td>
</tr>
<tr>
<td>■ Replacement and dredging of the sewerage pipes</td>
</tr>
<tr>
<td>■ Upgrading and improvement of the sewerage system</td>
</tr>
<tr>
<td>■ Strengthening O&amp;M system and capacity</td>
</tr>
<tr>
<td>■ Adapting and renewing design capacity (diameters of sewerage pipes, storage and osmosis plant and treatment method) accounting for the future climate change impacts</td>
</tr>
<tr>
<td>■ Strengthening of water quality management at drainage areas</td>
</tr>
<tr>
<td>■ Informative and Preventive Activities to Raise the Awareness of Beneficiaries</td>
</tr>
<tr>
<td>■ Disseminating information on contaminated water</td>
</tr>
<tr>
<td>■ Raising the awareness of beneficiaries regarding hygienic conditions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D. Maladaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Maladaptation in Adaptation Measures</td>
</tr>
<tr>
<td>■ Climate change may not be realized as projected, which will result in the excess or lack of facilities’ capacity.</td>
</tr>
</tbody>
</table>

■ Maladaptation Common to “Business as Usual” Project
- Established sewerage systems may not be fully utilized if many households can not connect to the system due to financial reasons.
### Guideline: Sewerage (Adaptation Project)

#### A. General

**Necessity of Adaptation**
Increase in intensity and frequency of rainfall, and temperature rise due to climate change will cause inundation and exacerbated hygienic conditions in urban areas. If areas possess ineffective or insufficient sewerage and urban drainage systems, it will potentially cause outbreaks of infectious diseases such as cholera, typhoid, and diarrhea.

**Adaptation Measures**
The development of sewerage systems (sewage treatment plant, installation of sewerage network and pump stations, etc.) will improve the hygiene and living conditions of the environment in the target areas.

**Outcome of Adaptation Measures**
Risks of which will worsen the hygiene and living conditions of the environment due to climate change will be reduced, and the morbidity rate of infectious diseases will improve.

#### B. Vulnerability Assessment

<table>
<thead>
<tr>
<th>Step 1</th>
<th>1) Assess Past and Present Climate Trends and Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collect from meteorological weather stations and regulatory agencies the available past meteorological records on maximum hourly rainfall, rainfall intensity and patterns, annual and monthly average temperatures, and cycles of extreme events.</td>
</tr>
<tr>
<td></td>
<td>Clarify past inundation conditions of commercial and residential areas during heavy rainfall if any, through meetings with local residents and relevant organizations concerned.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 1</th>
<th>2) Assess Future Exposure to Climate Hazards and Perturbations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) Study Future Weather Conditions</td>
</tr>
<tr>
<td></td>
<td>Together with counterpart agencies, the review climate change policy of the country, and confirm the climate change scenarios, analysis models, and the target year for the implementation of adaptation measures suitable in the country.</td>
</tr>
<tr>
<td></td>
<td>Estimate precipitation aspects such as intensity, frequency, and volume as well as temperature changes for the target year based on the analysis results on climate change.</td>
</tr>
</tbody>
</table>

|        | b) Study Other Factors related to Socio-economic Changes |
|        | Study change factors for hygienic conditions such as population growth and industrial development through review of the regional and urban development plans, land use regulations, etc. |

<table>
<thead>
<tr>
<th>Step 1</th>
<th>3) Assess Future Sensitivity to Climate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a) Study Past Damage</td>
</tr>
<tr>
<td></td>
<td>Data and information on infectious diseases that are highly associated with exacerbated hygienic conditions in the target areas should be collected and examined for the past 5-10 years based on morbidity and mortality rates. Such information could be available from statistical documents, local healthcare centers, and regional administration offices.</td>
</tr>
<tr>
<td></td>
<td>Reconnaissance surveys and meetings with the stakeholders will be required in order to clarify the existing conditions of sewerage water discharged into the surrounding bodies of water as well as to clarify the source of odor, and distributions and deposit of sewerage pollution materials. It is also necessary to survey flood conditions due to the overflowing of stormwater and sewerage draining.</td>
</tr>
<tr>
<td></td>
<td>Water quality surveys will be required in the surrounding body of water where stormwater and sewerage are discharged, which may cover the past 5-10 years data in order to clarify</td>
</tr>
</tbody>
</table>
the medium-term changes in water quality.

b) Study Present Condition of Facilities and Measures
Clarify the present conditions and functional validity of the existing sewerage system.

c) Assess Future Sensitivity to Climate Change
Assess the future sensitivity to climate change of the sewerage sub-sector based on the relationship between past discharge conditions of sewerage water, health impacts, existing conditions of facilities, and expected future climate conditions with consideration on future socioeconomic change factors.

Step 2
4) Determine and Project Adaptive Capacity to Climate Change
a) Identification of Adaptive Capacity
In case of absence of existing sewerage networks or system, adaptive capacity against sewerage water, sewerage pollution materials, and odor is significantly low. Thus, adaptive capacity should be assessed by the following indicators:
- Preventive activities against infectious diseases by residents in the target areas
- Knowledge level of residents regarding sewerage water or contaminated water
- Geographical distribution of existing medical institutions, healthcare centers, which can treat infectious diseases

In case that existing sewerage network or system is available and functioning as designed, adaptive capacity is considered relatively high. However, if the existing facilities are in a condition that requires rehabilitation or extension, the same indicators listed above will be applicable.

b) Clarify Exacerbating Factors for Climate Change Impacts
Since the indicators mentioned above in a), are indirectly related to the sewerage development project, it is considered that changes in values of these indicators are correlated with a degree of vulnerability. Yet, these indicators will be replaced with changes in number of infectious disease patients after the project.

Step 3
5) Assess Vulnerability
Assess vulnerability to climate change in the target area by overlapping the factors assessed in Steps 1 and 2 as follows:

<table>
<thead>
<tr>
<th>Items</th>
<th>Low</th>
<th>← Vulnerability →</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future sensitivity to climate change</td>
<td>Small</td>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>Condition of preventive activities against infectious diseases</td>
<td>Good</td>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>by residents in the target areas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geographical distribution of existing medical institutions, healthcare centers,</td>
<td>Sufficient</td>
<td></td>
<td>Insufficient</td>
</tr>
<tr>
<td>Present conditions and functional validity of existing sewerage system</td>
<td>Good</td>
<td></td>
<td>Poor</td>
</tr>
</tbody>
</table>
C. Project Evaluation of Adaptation Measures

<table>
<thead>
<tr>
<th>Items</th>
<th>Outcome</th>
<th>Method</th>
<th>Relative Operation and Effect Indicators</th>
</tr>
</thead>
</table>
| Future sensitivity to climate change | Regional hygienic conditions will be improved and climate change impacts on health will be reduced. | Quantitative | • BOD of Outlet Treated Water  
• River Polluted Condition |
| Condition of preventive activities against infectious diseases by residents in the target areas | Preventive knowledge against infectious diseases will be disseminated and the number of the patients will be reduced. | Qualitative | - |
| Geographical distribution of existing medical institutions and healthcare centers | Medical institutions / healthcare centers will be evenly located in and around the target areas. | Qualitative | - |
| Present conditions and functional validity of the existing sewerage system | Present conditions and functional validity of the existing sewerage system will be improved | Qualitative | - |

[Alternative Items for Assessment in Monitoring and Review]

<table>
<thead>
<tr>
<th>Type of Measures</th>
<th>Alternative Indicators</th>
<th>Method</th>
<th>Relative Operation and Effect Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural measures</td>
<td>Improvement of the target return period of extended and/or newly developed facilities</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td>Others</td>
<td>Changes in the number of the patients of infectious diseases</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Changes in number of beneficiaries</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Changes in beneficiaries’ awareness on hygiene</td>
<td>Qualitative</td>
<td>-</td>
</tr>
</tbody>
</table>

D. Necessary Consideration for Planning of Adaptation Measures

1) Monitoring and Review
In this sub-sector, the sewerage development project itself will contribute to the improvement of hygienic conditions which are potentially exacerbated by climate change (reduced vulnerability = strengthened adaptive capacity). Therefore, it is difficult to distinguish the effects of an ordinary project with that of an adaptation project for sewerage development. Thus, while requiring periodical monitoring of climate conditions, project monitoring will also be required based on the assessment items set in “C. Project Evaluation of Adaptation Measures” mentioned above.

2) Flexibility to Climate Change
Principally, the project components for adaptation measures are the same as for ordinary sewerage development. However, specific attentions will be required for the discharge capacity of sewerage pipes and storage facilities considering the increased stormwater inflow due to changes in rainfall patterns.

3) Consideration to Maladaptation
Check maladaptation caused by the project and plan the corresponding countermeasures.
### B. Vulnerability Assessment

<table>
<thead>
<tr>
<th>Required Data</th>
<th>Data</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1) Assess Past and Present Climate Trends and Risks</strong></td>
<td>Past and present meteorological data</td>
<td>Collect observed data such as meteorological data, from meteorological stations and other relevant agencies.</td>
</tr>
<tr>
<td><strong>2) Assess Future Exposure to Climate Hazards and Perturbations</strong></td>
<td>Future climate</td>
<td>Estimate future climate conditions using the data from the analysis models and climate change scenarios adopted in the country, based on the observed meteorological and hydrological data in the target area.</td>
</tr>
<tr>
<td></td>
<td>Socio-economic incidence</td>
<td>Collect information about development plans in and around the target areas and country from relevant organizations and other agencies.</td>
</tr>
<tr>
<td><strong>3) Assess Future Sensitivity to Climate Change</strong></td>
<td>Number of the patients of infectious diseases</td>
<td>Referring to national or regional statistics, collect data and information on the number of patients from relevant agencies or organizations (Ministry / Department of Health, healthcare centers and clinics), in order to assess infectious diseases due to poor hygienic conditions.</td>
</tr>
<tr>
<td></td>
<td>Present conditions of sewerage water discharge and flood</td>
<td>It is necessary to conduct reconnaissance survey for existing sewerage and drainage networks, while clarifying conditions of sewerage flow, areas of inundation, and distribution of sewerage polluted materials by review of literatures and cadastral maps if available.</td>
</tr>
<tr>
<td></td>
<td>Present conditions of water quality in surrounding water bodies</td>
<td>Collect water quality data in the surrounding bodies of water where stormwater and sewerage are discharged. Clarify the availability of past data at relevant organizations such as water resources management, and collect as much data as possible. Consider subcontracting the survey on water quality in and around the target areas.</td>
</tr>
<tr>
<td><strong>4) Determine and Project Adaptive Capacity to Climate Change</strong></td>
<td>Condition of preventive activities against infectious diseases by residents in the target areas</td>
<td>Clarify present activities on preventive measures against infectious diseases from the Ministry/Department of Health, healthcare centers, and other relevant agencies, while clarify the programs of the government and NGOs that are associated with information dissemination on sewerage and contaminated water to the residents of the target areas.</td>
</tr>
<tr>
<td></td>
<td>Geographical distribution of existing medical institutions and healthcare centers</td>
<td>Clarify present geographical distribution of health related facilities, which can treat infectious diseases in order to assess the present capacity of treatment.</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>Information related to adaptation</td>
<td>Review and study the adaptation policy by reviewing past studies and other information about adaptability to climate change in and around the target areas, if available.</td>
</tr>
</tbody>
</table>
Guideline: Sewerage (BAU Development with Adaptation Options)

A. General

■ Necessity of Adaptation Options
In order to improve the hygiene and living conditions in the environment of the target areas or city, the project for development, extension, and rehabilitation of sewerage and drainage systems will be implemented. Due to the anticipated climate change impacts, increased rainfall intensity is likely to cause inundation damages coupled with increased stormwater in drainage systems, and it is highly concerned that hygienic conditions will deteriorate.

■ Adaptation Options
Appropriate measures will be implemented within the project with consideration of the climate change impacts.

■ Outcome of Adaptation Options
In the event of climate change, the developed sewerage system will function properly.

B. Vulnerability Assessment (Risk and Change)

Review the national policies related to climate change, and discuss and confirm with counterpart organization regarding applied climate change scenarios and analysis models, and target year for the implementation of adaptation measures. Project amount and patterns of rainfall, and relative temperatures at the planned base year using the analysis results of climate change projection for the target year, and assess the possible flood and inundation by sewerage and stormwater. Based on past water quality data, clarify the changes to water quality in the surrounding bodies of water where sewerage and stormwater are discharged.

C. Planning Adaptation Options

Plan adaptation options that account for future climate change and prevent hygienic conditions from deteriorating. Possible options are as follows:
- Structural measures such as development / extension / rehabilitation / upgrading of sewerage facilities.
- Non-structural measures represented by strengthening O&M system and water quality management.
- Awareness raising activities for preventive measures against infectious diseases.
- Combined implementation of various options

D. Project Evaluation of Adaptation Options

[Items for Assessment in Project Formulation]

<table>
<thead>
<tr>
<th>Items</th>
<th>Outcome</th>
<th>Method</th>
<th>Relative Operation and Effect Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morbidity and mortality rates of infectious diseases</td>
<td>Morbidity and mortality rates of infectious diseases, which are associated with poor hygienic conditions, will be reduced.</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td>Present conditions of sewerage and rainwater discharge</td>
<td>Flow volume of sewerage polluted materials into drainage will be reduced by development of sewerage networks.</td>
<td>Qualitative</td>
<td>-</td>
</tr>
<tr>
<td>Water quality</td>
<td>Water quality in surrounding bodies of water where treated water is discharged, will be improved by sewerage treatment.</td>
<td>Quantitative</td>
<td>• BOD of Outlet Treated Water • River Polluted Condition</td>
</tr>
</tbody>
</table>

[Alternative Items for Assessment in Monitoring and Review]

<table>
<thead>
<tr>
<th>Type of Measures</th>
<th>Alternative Indicators</th>
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<th>Relative Operation and Effect Indicators</th>
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<tbody>
<tr>
<td>Structural measures</td>
<td>Improvement of the target return period of extended and/or newly developed facilities</td>
<td>Quantitative</td>
<td>-</td>
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<tr>
<td>Others</td>
<td>Changes in the number of the patients with infectious diseases</td>
<td>Quantitative</td>
<td>-</td>
</tr>
</tbody>
</table>
Changes in the number of beneficiaries | Quantitative | -  
Changes in beneficiaries’ awareness on hygiene | Qualitative | -

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E. Necessary Consideration for Planning of Adaptation Options

1) Monitoring and Review

In this sub-sector, the sewerage development project itself will contribute to the improvement of hygienic conditions which are potentially exacerbated by climate change (reduced vulnerability = strengthened adaptive capacity). Therefore, it is difficult to distinguish the effects of an ordinary project with that of an adaptation project for sewerage development. Thus, while requiring periodical monitoring of climate conditions, project monitoring will be required based on the assessment items set in “D. Project Evaluation of Adaptation Options” mentioned above.

2) Flexibility to Climate Change

Principally, the project components for adaptation options are the same as for ordinary sewerage development. However, specific attentions will be required for the discharge capacity of sewerage pipes and storage facilities considering the increased stormwater inflow due to climate change.

3) Consideration to Maladaptation

Check maladaptation caused by the project and plan the corresponding countermeasures.

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F. Required Data

<table>
<thead>
<tr>
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<th>Remarks</th>
</tr>
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<tbody>
<tr>
<td><strong>B. Vulnerability Assessment</strong></td>
<td></td>
</tr>
<tr>
<td>Future climate</td>
<td>Estimate future climate conditions using data from the analysis models and climate change scenarios adopted in the country, based on the observed meteorological and hydrological data in the target area.</td>
</tr>
<tr>
<td>Number of the patients with infectious diseases</td>
<td>Referring to national or regional statistics, collect data and information on number of the patients from relevant agencies or organizations (Ministry / Department of Health, healthcare centers and clinics), assessing infectious diseases due to poor hygienic conditions.</td>
</tr>
<tr>
<td>Present conditions of sewerage water discharge and flood</td>
<td>It is necessary to conduct reconnaissance survey for existing sewerage and drainage networks, while clarifying conditions of sewerage flow, areas of inundation, and distribution of sewerage polluted materials by review of literatures and cadastral maps if available.</td>
</tr>
<tr>
<td>Present conditions of water quality in the surrounding water bodies</td>
<td>Collect water quality data in the surrounding bodies of water where stormwater and sewerage are discharged. Clarify the availability of past data at relevant organizations such as water resources management, and collect as much data as possible. Consider an option to subcontract the survey on water quality in and around the target areas.</td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>Information related to adaptation</td>
<td>Review and study the adaptation policy as well as the past studies and other information about adaptation to climate change in and around the target area, if available.</td>
</tr>
</tbody>
</table>
References and Key Different Features

1) Wise Adaptation to Climate Change
According to this document, recycling sewerage water is effective in mitigating drought impacts. In developing countries, the development level of sewerage networks and systems is generally low, therefore the improvement of hygienic conditions tends to be more prioritized rather than recycling in the context of sewerage development. Thus, this guideline emphasizes more on the aspect of hygienic condition.

2) Handbook for Climate Change Adaptation in Water Sector
This handbook warns that temperature rise and decrease of river discharge due to reduced rainfall will result to the deterioration of water quality and water resource exploitation. Also, sewerage development will be important to prevent water contamination and runoff of surface water, and to maintain capacity of natural depuration through flora and wetland conservation. In this regard, water quality management of the surrounding bodies of water proposed in this guideline is in line with the contents of the handbook.

3) Three Unexpected Impacts by Global Warming – Contamination of Portable Water by Sewerage
The numerical model projected an impact of increased rainfall due to climate change on sewerage networks in Wisconsin, United States. The results indicated that untreated water will potentially flood into the lakes in case of large-scale hurricane attacks. This implies that source of drinking water will be contaminated by pathogenic bacteria and viruses, which will urge to take necessary measures such as improving flow capacity of sewerage pipes for the possible increase of rainfall intensity.

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Basic Concept (Urban Drainage)

| A. General Concept | Increase in intensity and frequency of rainfall, and temperature rise due to climate change will negatively affect the hygienic environment of urban areas. In areas where drainage systems or networks malfunction or have insufficient capacity, human settlement is exposed to higher risks of inundation by floodwater, which contains both contaminated water and stormwater. Such inundation in urban areas will potentially cause outbreak of infectious diseases such as cholera, typhoid, and diarrhea. Furthermore, contaminated flood will likely include toxic chemicals and deteriorate the water environment in and around rivers and coastal areas. In areas without urban drainage systems, networks and stations, such situation will exacerbate due to the anticipated impacts of climate change. In the urban drainage sub-sector, the development, extension and upgrading of drainage systems themselves are considered as an adaptation project, while improving the living conditions, social environment, and hygiene, which would worsen due to climate change. |
| B. Vulnerability | 1) Major Climate Change Impacts on the Urban Drainage Sub-sector  
A) In Case of Existing Drainage System  
・ Depending on the flow capacity of the existing drainage network, the increased hourly rainfall due to heavy rains will cause flooding and result in inundation in some locations of urban areas.  
・ In case of a combined sewerage system, the increased amount and intensity of rainfall will cause contaminated floods, which will be discharged without treatment into the surrounding bodies of water, such as rivers, lake, and coastal areas.  
B) In Case of No Existing Urban Drainage System and Commonly Expected Impacts  
・ Retention and inundation by contaminated water and materials will considerably exacerbate the hygiene of the environment in urban areas.  
・ Climate change will amplify the conditions of a worsened hygienic environment, and potentially cause outbreak of water and vector borne diseases such as diarrhea, cholera, and typhoid, thus, increasing the morbidity and mortality rates of such diseases.  
2) Other Factors that Influence the Urban Drainage Sub-sector Associated with Climate Change Impacts  
・ Changes in lifestyle and industry structures together with the growth of the population and the economy will increase solid wastes, which will be dispersed in urban areas, and then potentially reduce the capacity of the drainage system due to congestion or clogging.  
3) Adaptive Capacity to Climate Change  
・ The adaptive capacity is higher in areas where sewerage systems are available.  
・ Slum or poverty-stricken areas possess lower adaptive capacity, regardless of existence of drainage systems.  
・ Areas with healthcare or medical facilities that can respond to infectious diseases possess higher adaptive capacity.  
・ Areas where informative and preventive activities regarding infectious diseases are active possess higher adaptive capacity. |
4) Spatial Distribution of Vulnerability  
  a) Climate Change  
Urban drainage systems are considered as consolidated systems including drainage channels, networks, and pump stations within drainage basins. Therefore, it is considered that there is no spatial difference for climate change impacts within the system.

b) Sensitivity in the Urban Drainage Sub-sector  
Sensitivity is likely higher for densely populated areas within the target areas for drainage development. Sensitivity may differ according to the existing coverage of the drainage system and landscape as well as the existing level of effective functions.

c) Adaptive Capacity  
Adaptive capacity may differ according to population distribution and socio-economic conditions (inclusion of slums and others) within the target areas.

### C. Adaptation Measures

- Rehabilitation and Extension of the Urban Drainage System (also applicable to the case of new development)
  - Replacement and dredging of drainage pipes and channels
  - Upgrading and improvement of drainage systems and drainage pump stations
  - Development of flood control basins and regulating ponds
  - Strengthening the O&M system and capacity
  - Adapting and renewing design capacity (flow capacity of drainage channels, capacity of regulating pond or flood control basins, and capacity of pumps) accounting for the future climate change impacts
  - Strengthening water quality management at drainage areas

- Informative Activities to Raise Awareness of the Beneficiaries
  - Disseminating information on contaminated drainage water
  - Raising the awareness of beneficiaries regarding hygienic conditions

### D. Maladaptation

- Maladaptation in Adaptation Measures
  - Climate change may not be realized as projected, which will result in the excess or lack of facilities’ capacity.

- Maladaptation Common to “Business as Usual” Project
  - Drastic population growth and insufficient O&M activities may cause early clogging of drainage channels and result to the malfunctioning of the drainage network.
### A. General

#### Necessity of Adaptation
Increase in intensity and frequency of rainfall, and temperature rise due to climate change will cause inundation and exacerbated hygienic conditions in urban areas. If areas possess drainage systems that are malfunctioning or have insufficient capacity, it will potentially cause outbreaks of infectious diseases such as cholera, typhoid, and diarrhea. Stormwater contaminated with solid waste and chemical materials will flow into the surrounding bodies of water, therefore seriously affecting water quality.

#### Adaptation Measures
The development of urban drainage systems (open and closed drainage channels, pump stations, etc.) will improve drainage capacity and hygienic conditions, reduce the risk of floods, and enhance socio-economic activities in the target areas.

#### Outcome of Adaptation Measures
Risks of flooding and inundation due to malfunctioning drainage systems will be reduced, and socio-economic activities and the morbidity rate of infectious diseases will be improved.

### B. Vulnerability Assessment

#### Step 1
1) Assess Past and Present Climate Trends and Risks
Collect the available past meteorological records referring to maximum hourly rainfall, rainfall intensity / pattern, annual and monthly average temperatures, and cycles of extreme events, from meteorological weather stations and regulatory agencies. Clarify past inundation conditions of commercial and residential areas during heavy rainfall if any, through meetings with local residents and relevant organizations concerned.

2) Assess Future Exposure to Climate Hazards and Perturbations
   a) Study Future Weather Conditions
   Together with counterpart agencies, review the climate change policy of the country, and confirm the climate change scenarios, analysis models, and the target year for the implementation of adaptation measures suitable in the country. Estimate precipitation aspects such as intensity, frequency, and volume as well as temperature changes for the target year based on the analysis results on climate change.

   b) Study Other Factors related to Socio-economic Changes
   Study change factors for hygienic conditions such as population growth and industrial development through review of the regional and urban development plans, land use regulations, etc.

3) Assess Future Sensitivity to Climate Change
   a) Study Past Damage
   Data and information on the infectious diseases cases that are highly associated with exacerbated hygienic conditions in the target areas should be collected and examined for the past 5-10 years based on morbidity and mortality rates. Such information could be available from statistical documents, local healthcare centers, and regional administration offices. Reconnaissance surveys and meetings with the stakeholders will be required in order to clarify the present conditions of flood and inundation in residential and commercial areas during past heavy rainfall, and assess the flood-prone areas in the target areas.
   In case there are existing drainage network, it is necessary to clarify the functional...
conditions through reconnaissance and hearing survey at agencies or organizations concerned.
Water quality surveys will be required in the surrounding bodies of water where stormwater and sewerage are discharged, which may cover the past 5-10 years data in order to clarify the medium-term changes in water quality.

b) Study Present Condition of Facilities and Measures
Clarify the present conditions of the drainage system if available in terms of its coverage areas and functional validity.

c) Assess Future Sensitivity to Climate Change
Assess the future sensitivity of the urban drainage sub-sector to climate change based on the relationship between the past discharge conditions of drainage water, health impacts, existing conditions of facilities, and expected future climate condition, with consideration on future socio-economic change factors.

Step 2
4) Determine and Project Adaptive Capacity to Climate Change
a) Identification of Adaptive Capacity
In case of absence of existing drainage networks or systems, the adaptive capacity against flood is significantly low. Thus, the adaptive capacity should be assessed by the following indicators:
- Preventive activities against infectious diseases by residents in the target areas
- Geographical distribution of existing medical institutions and healthcare centers, which can treat infectious diseases

In case that existing drainage networks or systems are available and functioning as designed, the adaptive capacity is considered relatively high. In addition to the above indicators, in this case, it will be necessary to clarify the design and effective capacities of discharge, and conditions of O&M through inventory survey.

b) Clarify Exacerbating Factors for Climate Change Impacts
Since the indicators mentioned above in the previous item a), are indirectly related to the drainage development project, it is considered that changes in values of these indicators are correlated with a degree of vulnerability. Yet, these indicators will be replaced with changes in the number of patients with infectious disease after the project. Furthermore, in case there are existing drainage networks, vulnerability to climate change is also accorded by the level of sewerage system development.

Step 3
5) Assess Vulnerability
Assess vulnerability to climate change in the target area by overlapping the factors assessed in Steps 1 and 2.
### Items for Assessment in Project Formulation

<table>
<thead>
<tr>
<th>Items</th>
<th>Outcome</th>
<th>Method</th>
<th>Relative Operation and Effect Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future sensitivity to climate change</td>
<td>Regional hygienic conditions will be improved and urban flood damage and climate change impacts on health will be reduced.</td>
<td>Quantitative</td>
<td>- Flooded Area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flooded Houses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Economic Value of Damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Affected population</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum Inundation Depth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Inundation Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BOD of Outlet Treated Water</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>River Polluted Condition</td>
</tr>
<tr>
<td>Condition of preventive activities against infectious diseases by residents in the target areas</td>
<td>Preventive knowledge against infectious diseases will be disseminated and the number of patients will be reduced.</td>
<td>Qualitative</td>
<td>-</td>
</tr>
<tr>
<td>Geographical distribution of existing medical institutions and healthcare centers</td>
<td>Medical institutions and healthcare centers, which can treat infectious diseases, will be evenly located in and around the target areas.</td>
<td>Qualitative</td>
<td>-</td>
</tr>
<tr>
<td>Present conditions and functional validity of existing drainage system</td>
<td>Present conditions and functional validity of existing drainage system will be improved</td>
<td>Qualitative</td>
<td>-</td>
</tr>
</tbody>
</table>

### Alternative Items for Assessment in Monitoring and Review

<table>
<thead>
<tr>
<th>Type of Measures</th>
<th>Alternative Indicators</th>
<th>Method</th>
<th>Relative Operation and Effect Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural measures</td>
<td>Improvement of the target return period of extended and/or newly developed facilities</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td>Others</td>
<td>Changes in number of the patients with infectious diseases</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Changes in the number of beneficiaries</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Changes in beneficiaries’ awareness on hygiene</td>
<td>Qualitative</td>
<td>-</td>
</tr>
</tbody>
</table>

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14. Sewerage / Urban Drainage
D. Necessary Consideration for Planning of Adaptation Measures

1) Monitoring and Review
In this sub-sector, urban drainage development project itself will contribute to the improvement of hygienic conditions which are potentially exacerbated by climate change (reduced vulnerability = strengthened adaptive capacity). Therefore, it is difficult to distinguish the effects of an ordinary project with that of an adaptation project for drainage development. Thus, while requiring periodical monitoring of climate conditions, project monitoring will also be required based on the assessment items set in “C. Project Evaluation of Adaptation Measures” mentioned above.

2) Flexibility to Climate Change
Principally, the project components for adaptation measures are the same as for ordinary drainage development. However, specific attentions will be required for the capacities of drainage channels, pump station, flood control basins and regulating ponds considering the increased stormwater inflow due to changes in rainfall patterns.

3) Consideration to Maladaptation
Check maladaptation caused by the project and plan the corresponding countermeasures.

E. Required Data

<table>
<thead>
<tr>
<th>Data</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Vulnerability Assessment</td>
<td></td>
</tr>
<tr>
<td>1) Assess Past and Present Climate Trends and Risks</td>
<td>Past and present meteorological data</td>
</tr>
<tr>
<td>2) Assess Future Exposure to Climate Hazards and Perturbations</td>
<td>Future climate</td>
</tr>
<tr>
<td>Socio-economic incidence</td>
<td>Collect information about development plans in and around the target areas and country from relevant organizations and other agencies.</td>
</tr>
<tr>
<td>3) Assess Future Sensitivity to Climate Change</td>
<td>Number of the patients with infectious diseases</td>
</tr>
<tr>
<td>Conditions of flood damages</td>
<td>It is necessary to conduct reconnaissance survey for existing drainage networks, while clarifying conditions of flood hazard areas by review of literature, meeting with residents or others and referring to cadastral maps, if available.</td>
</tr>
<tr>
<td>Present conditions of water quality in the surrounding water bodies</td>
<td>Collect water quality data in the surrounding bodies of water where stormwater and sewerage are discharged. Clarify the availability of past data at relevant organizations such as water resources management, and collect as much data as possible. Consider an option to subcontract the survey on water quality in and around the target areas.</td>
</tr>
<tr>
<td>4) Determine and Project Adaptive Capacity to Climate Change</td>
<td>Condition of preventive activities against infectious diseases by residents in the target areas</td>
</tr>
<tr>
<td>Geographical distribution of existing medical institutions and healthcare centers</td>
<td>Clarify present geographical distribution of health related facilities, which can treat infectious diseases in order to assess the present capacity of treatment.</td>
</tr>
<tr>
<td>Functional validity of the existing drainage system</td>
<td>In case there are existing drainage networks or systems, clarify the design and effective capacities of discharge, and the conditions of O&amp;M through reconnaissance and inventory surveys.</td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>Information related to adaptation</td>
<td>Review and study the adaptation policy by reviewing past studies and other information about adaptability to climate change in and around the target area, if available.</td>
</tr>
</tbody>
</table>
A. General

■ Necessity of Adaptation Options
In order to improve the hygiene and living conditions in the environment of the target areas or city, the project for development/extension/rehabilitation of urban drainage systems will be implemented. Due to the anticipated climate change impacts, increased rainfall intensity is likely to cause inundation damages coupled with increased stormwater drainage, and it is highly concerned that hygienic conditions will deteriorate.

■ Adaptation Options
Appropriate measures will be implemented within the project with consideration of the climate change impacts.

■ Outcome of Adaptation Options
In the event of climate change, the developed drainage system in urban areas will function properly.

B. Vulnerability Assessment (Risk and Change)

Review the national policies related to climate change, and discuss and confirm with counterpart organizations the applied climate change scenarios and analysis models, and target year for adaptation measures. Project the amount and patterns of rainfall, and relative temperatures at the planned base year using the analysis results of climate change projection for the target year, and assess possible flood and inundation by sewerage and stormwater. Based on past water quality data, clarify the changes to water quality in the surrounding bodies of water where sewerage and stormwater are discharged.

C. Planning Adaptation Options

Plan adaptation options that account for future climate change impacts and prevent hygienic conditions from deteriorating. Possible options are as follows:
- Structural measures such as development / extension / rehabilitation / upgrading of drainage facilities.
- Non-structural measures represented by strengthening O&M system and water quality management.
- Awareness raising activities for preventive measures against infectious diseases.
- Combined implementation of various options

D. Project Evaluation of Adaptation Options

<table>
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<th>Outcome</th>
<th>Method</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Morbidity and mortality rates of infectious diseases</td>
<td>Morbidity and mortality rates of infectious diseases, which are associated with poor hygienic conditions, will be reduced.</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td>Conditions of flood and inundation damages</td>
<td>Improved overall capacity of the drainage system will reduce the risk of flood damages.</td>
<td>Quantitative</td>
<td>Flooded Area, Flooded Houses, Economic Value of Damage, Affected population, Maximum Inundation Depth, Inundation Time</td>
</tr>
<tr>
<td>Water quality</td>
<td>Water quality in surrounding bodies of water where drainage water is discharged, will be improved by designated drainage networks.</td>
<td>Quantitative</td>
<td>BOD of Outlet Treated Water, River Polluted Condition</td>
</tr>
</tbody>
</table>

Guideline: Urban Drainage (BAU Development with Adaptation Options)
### Alternative Items for Assessment in Monitoring and Review

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<td>Others</td>
<td>Changes in the number of patients with infectious diseases</td>
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<td>-</td>
</tr>
<tr>
<td></td>
<td>Changes in the number of beneficiaries</td>
<td>Quantitative</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Changes in beneficiaries’ awareness on hygiene</td>
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### E. Necessary Consideration for Planning of Adaptation Options

1) Monitoring and Review

In this sub-sector, the urban drainage development project itself will contribute to the improvement of hygienic conditions which are potentially exacerbated by climate change (reduced vulnerability = strengthened adaptive capacity). Therefore, it is difficult to distinguish the effects of an ordinary project with that of an adaptation project for drainage development. Thus, while requiring periodical monitoring of climate conditions, project monitoring will be required based on the assessment items set in “D. Project Evaluation of Adaptation Options” mentioned above.

2) Flexibility to Climate Change

Principally, the project components for adaptation options are the same for ordinary drainage development. However, specific attentions will be required for flow capacity of drainage channels, and the capacities of flood control basins and regulating ponds, considering the increased stormwater inflow due to climate change.

3) Consideration to Maladaptation

Check maladaptation caused by the project, and plan the corresponding countermeasures.

### F. Required Data

#### B. Vulnerability Assessment

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<tr>
<th>Data</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td>Future climate conditions</td>
<td>Estimate future climate conditions using the data from the analysis models and climate change scenarios adopted in the country, based on the observed meteorological and hydrological data in the target area.</td>
</tr>
<tr>
<td>Number of the patients with infectious diseases</td>
<td>Referring to national or regional statistics, collect data and information on the number of the patients from relevant agencies or organizations (Ministry / Department of Health, healthcare centers and clinics) in order to assess infectious diseases due to poor hygienic conditions.</td>
</tr>
<tr>
<td>Conditions of flood damages</td>
<td>It is necessary to conduct reconnaissance survey for existing drainage networks, while clarifying conditions of flood hazard areas by review of literature, meeting with residents or others and referring to cadastral maps, if available.</td>
</tr>
<tr>
<td>Present conditions of water quality in the surrounding water bodies</td>
<td>Collect water quality data in the surrounding bodies of water where stormwater and sewerage are discharged. Clarify the availability of past data at relevant organizations such as water resources management, and collect as much data as possible. Consider an option to subcontract the survey on water quality in and around the target areas.</td>
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</tbody>
</table>
References and Key Different Features

1) Wise Adaptation to Climate Change¹

According to this document, the introduction of drainage management systems is effective to mitigate drought impacts. In developing countries, the development level of drainage networks or systems is generally low, therefore the improvement of hygienic conditions tend to be prioritized rather than drought mitigation in the context of drainage development. Thus, this guideline emphasizes more on the aspect of hygienic condition.