Chapter III
Explanation of Main Technical Methods

1.5 Water quality

1.5.1 Selection of environmental impact assessment items and survey, forecast and evaluation methods

1) Ascertaining project characteristics

Table III.1.5-1 shows examples of the project characteristics to be identified with regard to water quality.

Table III.1.5-1 Examples of the project characteristics to be identified regarding water quality

Impact factor	Examples of the characteristics to be identified
Implementation of construction	• Specifics, method, and duration of construction • Location, extent, and volume of construction • Plans for temporary structures such as temporary diversion channels, as well as borrowing pits, reception sites for construction-generated soil, and others
Existence and use of facilities	• Specifics, location, and scale of facilities • Plans and policies regarding the in-service period and operation of facilities • Amounts and types of water withdrawn by the facilities and of water discharged or drained, as well as the locations (including heights) of water withdrawals and discharges/drainages

2) Ascertaining local characteristics

(1) Area

(a) Defining the Survey Area for an Inland Body of Water

First and foremost, the project proponent will define the survey area in an inland body of water in relation to the wider basin. “The geographical extent where the state of the environment will change at least to a certain extent” with regard to a river corresponds to the river reaches downstream from the project area. Nevertheless, the project proponent will define the survey area in the wider context of the entire basin that includes the project area, in light of the close relationship between the water quality and such factors as the area of the basin and the population and land use therein (Figure III.1.5-1(A)).

The project proponent will also define the lower reaches section in consideration of the vulnerable points and areas such as the confluence of the main river and its key tributary as well as the water intake points (Figure III.1.5-1(B)). If the environmental impact is likely to reach the estuary, the project proponent should consider the coastal waters into which the river flows (Figure III.1.5-1(C)).

In spite of these approaches to defining the survey area, the project proponent should get the overall picture of the entire river as each river has its own characteristics.

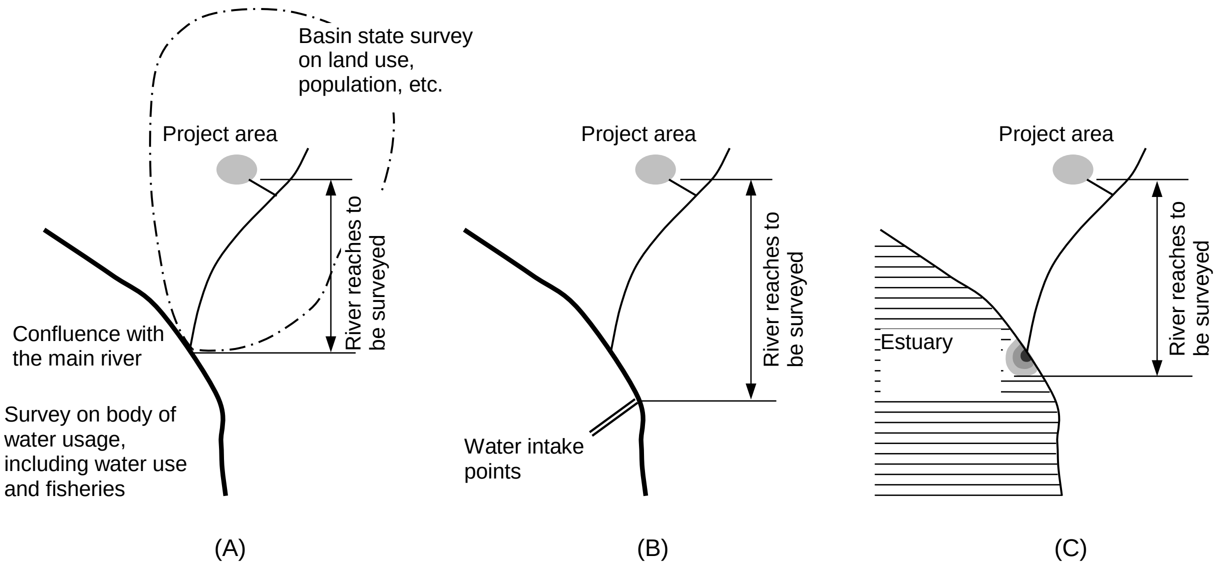


Figure III.1.5-1 Examples of defining the extent of the survey area with regard to a river

(b) Defining the Survey Area for Coastal Waters and Lakes

Strictly speaking, "the geographical extent where the state of the environment will change at least to a certain extent" cannot be defined for coastal waters or a lake until forecasts are made regarding that body of water. In the phase of selecting survey items and methods of survey, forecast, and evaluation for environmental impact assessment (EIA), the project proponent will define as the survey area a physically delineated area—the typical example of which may be a bay or coastal waters enclosed by such features as capes and promontories—or the basin of the river flowing into these waters (or, in the case of a lake, the basin of the river flowing into or out of that lake). In the process, past similar cases are used for reference.

(Points to note)

In selecting survey items and methods of survey, forecast, and evaluation for Environmental Impact Assessment while seeing the water environment from the perspective of the hydrologic cycle, it is important to understand how the project area is classified in the context of the hydrologic cycle within the basin. In the context of the hydrologic cycle, an area may be classified into two types: (i) the recharge area, which is characterized by water transfer from surface water to groundwater; and (ii) the discharge area, which is characterized by water transfer from groundwater to surface water. Or an area may be classified into three types: type (i), type (ii), and (iii) the transmission area. In Environmental Impact Assessment for the water environment, attention should be paid to the fact that environmental impacts that should be focused differ depending on this classification.

The level of the hydrologic cycle to be considered differs according to the project and the extent of its impact. Generally, the recharge area is a river's upper reaches, which are typically mountainous or hilly land while the discharge area is the lower reaches, which are typically flat land. However, within the same hilly area, for example, there are recharge and discharge areas in the local hydrologic cycle.

Table III.1.5-2 Area classification and examples of environmental impacts with regard to the hydrologic cycle

Area classification	Examples of environmental impacts
Recharge area	• Groundwater pollution • Less recharge due to changes in land cover • The impact of river water quality on ground water quality
(Transmission area)	• - Blocking of flow
Discharge area	• Changes in the groundwater flow system due to groundwater abstraction • The impact of groundwater quality on river water quality

(2) Identifying Local Natural and Social Conditions

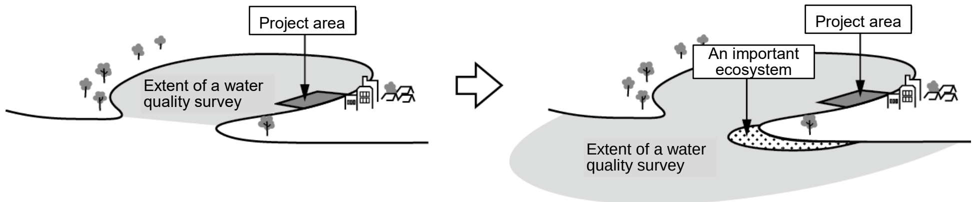
Tables III.1.5-3 and III.1.5-4 show examples of the characteristics to be identified with regard to the local natural and social conditions.

The information available on water quality is largely point-specific data in that it has been obtained at environmental reference points or the like. This is why a field survey is necessary to assess the situation between observation points along the inflowing river. A field survey makes it possible to obtain information that the available information does not provide, such as how inflow load for an urban river varies significantly depending on the time zone and what a river looks like during rainfall.

As for the observation points for which information is available, a field survey should preferably assess the local topography and features as well as the state of the contamination sources.

Table III.1.5-3 Examples of the characteristics to be identified with regard to natural conditions regarding water quality

Classification	Examples of the characteristics to be identified
State of the water environment	To assess the state of water quality, the project proponent will check the items such as those shown below. Before examining these discrete items, however, it is important to understand a number of local characteristics to get a general picture of the entire body of water in question. These may include: (i) topographic conditions of the body of water, including its scale, location, elevation, closedness, and bed slope; (ii) general land use within the basin; (iii) limnological turnover; and (iv) the tidal reach of the river. (a) State of water quality The water quality parameters for which environmental standards are set are constantly monitored at environmental reference points by prefectures as well as cities specified by Cabinet Order under the Water Pollution Prevention Act. In Class A river systems, these parameters are measured by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The project proponent will gather and organize these measurement data. Attention should be paid if discharge data at the time of flood are needed to assess

	water quality as water quality data are mostly those measured when the water level is within the normal range.[1] The project proponent will gather and organize the latest data as well as the data of past years to keep track of the changes over time. When predicting and assessing the water quality of a closed body of water, the project proponent should keep full track of the past state of water quality while considering the natural variability and accumulative property of that body of water. (b) State of the flow regime, etc. Streamflow, limnological turnover, and the state of tidal currents in coastal waters are part of the most fundamental information regarding water quality. Their characteristics need to be accurately identified in selecting Environmental Impact Assessment items and methods. Depending on the river, streamflow may have been already studied in a water quality survey described above. As for major rivers in Japan, MLIT conducts discharge observations. Attention should be paid to the fact that required discharge data may be data on high water discharge[2] or low water discharge depending on the purpose of the survey. As for coastal waters, the Hydrographic and Oceanographic Department of the Japan Coast Guard releases tidal current observations. (c) State of the material circulation The project proponent will locate and describe the spaces that play an important role in the material circulation, such as tidelands and seaweed beds, which have water purifying functions, as well as wetlands and lakes, which has the water detaining function.
Topography and geology	The project proponent will identify topographic and geologic features that may affect water quality.
Population or growth of flora and fauna, vegetation, and ecosystems	Water quality constitutes an important basis for ecosystems. If changes in water quality may affect the wider ecosystem in the phase of selecting Environmental Impact Assessment items and methods, that ecosystem as a whole needs to be considered in defining the extent and method of the survey. Studying ecosystems requires a perspective different from a perspective of an Environmental Impact Assessment that focuses solely on water quality. It should be remembered, for example, that dissolved oxygen in the bottom layer plays an important part. Studying water quality, on the other hand, requires assessing the state of the spaces that have water purifying functions, such as tidelands, seaweed beds, and reed beds. Therefore, in selecting the survey, forecast, and evaluation methods, the project proponent needs not only to cross-reference the survey results for the selected items but also to take their mutual impacts into full account.  **An example of expanding the extent of a water quality survey in light of ecosystem factors**

[1] "When the water level is within the normal range": River discharge may be classified in descending order as follows according to the daily discharge throughout the year:

- Plentiful discharge: the level below which the discharge does not fall for at least 95 days of the year
- Normal discharge: the level below which the discharge does not fall for at least 185 days of the year
- Low water discharge: the level below which the discharge does not fall for at least 275 days of the year
- Droughty discharge: the level below which the discharge does not fall for at least 355 days of the year

[2] High water discharge: The standard discharge on which a flood control plan is based, for example, the maximum flood discharge in a 100-year flood discharge, is referred to as "basic high water discharge." The flood discharge after being controlled by flood control structures such as dams and retarding basins are referred to as "design high water discharge."

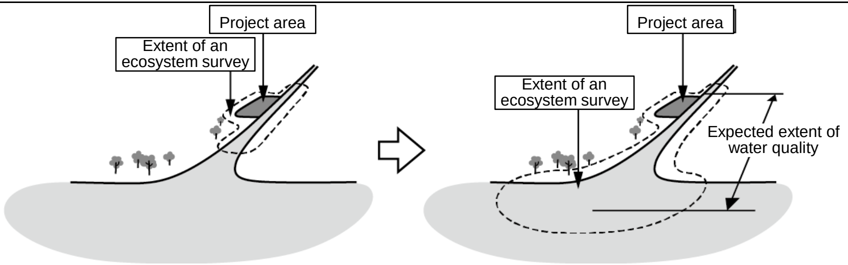
	 **An example of expanding the extent of an ecosystem survey in light of water quality factors**
Landscapes and spaces for enjoying contact with nature	Changes in water quality may affect landscapes as well as spaces for enjoying contact with nature. This can happen in, for example, an area where the water quality may be affected if it has a waterside landscape resource or a space for enjoying contact with nature, such as a space for waterfront observation or sea bathing that takes advantage of a body of water. In such cases, the project proponent should consider the interrelationship between the water quality and the landscapes or the space for enjoying contact with nature in defining the extent and method of the survey.

Table III.1.5-4 Examples of the characteristics to be identified with regard to the social conditions regarding water quality

Classification	Examples of the characteristics to be identified
Population and industry	(a) Population Check the population of the survey area and its distribution. (b) Industry The project proponent will identify the industries in the survey area that provide the sources of water contamination, etc. (e.g., mining and manufacturing, agricultural and livestock, fisheries including aquaculture and processing), including their general facts and figures and the location of their major facilities. The proponent will also locate the major facilities of any industry that is deemed vulnerable to changes in water quality. e.g., fisheries, recreational fishing grounds, aquaculture farms
Land use	(a) Land use Assess land use mainly with land use maps. The water environment is significantly affected by land cover of the basin of the body of water in question. The project proponent will work to assess not only land use by using land use maps but also land cover by using the available information such as vegetation maps and aerial photographs and conducting a field survey. This is because the discharge of sediment, sludge, and effluent associated with large site preparation work may be expected as a temporary contamination source. To predict long-term environmental impacts, the project proponent should understand the future directions of land use by analyzing the land use zoning of the survey area and the comprehensive plan of the local government chiefly with the help of relevant urban planning maps. If permanent alternations to the body of water are expected as in the case of a land reclamation project, the project proponent must get a firm grip on the future plan of such a project by, for example, studying the developments in relevant port and harbor plans. (b) Usage of rivers, lakes, and coastal waters The project proponent will study the usage of the body of water, including recreational uses, fishing rights, and water withdrawals. As such recreational uses may not be fully identified with the research of the available information alone, the project proponent should preferably conduct a field survey and/or an interview survey at the same time. (c) Man-made structures The project proponent will assess the state of man-made structures (dams, weirs, reclaimed land, etc.) that affect water quality or the flow regime based on

	topographic maps and field surveys. In particular, the location, structure, etc. of river structures in the riverine area should be fully studied.
Traffic	If the body of water in question is used for water traffic, the project proponent will get a general picture of that traffic. The proponent will also check the frequency and specifics of that traffic if it is a possible source of water contamination or used for recreational purposes as well.
Features/facilities deemed vulnerable	In addition to the spatial assessment of land use, the project proponent will take stock of the distribution of facilities considered vulnerable to changes in water quality.
Overview of sewerage development	The proponent will take assess the state of sewerage development, including as such aspects as the sewerage service area, the sewer connection rate, the capacity of the sewage treatment plant and the position of the outflow thereof, and effluent quality. Future plans for sewerage development will also be sorted out. This applies to wastewater treatment facilities other than sewerage, such as johkasou (Japanese septic tanks), agricultural community effluent treatment facilities, and community sewage treatment facilities.
Zoning, regulations, etc. by law	

3) Selecting environmental impact assessment items

(1) Arranging impact factors

Impact factors for water quality may include the implementation of construction work of different kinds that generates contaminants and the use of various facilities for drainage that includes contaminants. In identifying these factors, the project proponent should take into account the sources of water contamination shown in Table III.1.5-5, as well as other factors shown in Table III.1.5-6, including topographic alterations and the installment of structures that change the flow of water.

Table III.1.5-5 Major sources of water pollution

Type	Major Sources of Water Pollution
Municipal wastewater	Domestic wastewater; and wastewater from bars and restaurants, hotels, roadside restaurants, schools, research institutions, markets and distribution centers, vehicle and aircraft maintenance facilities, zoos, and aquariums
Industrial effluent	Effluent from common effluent treatment plants for various manufacturing sectors and industrial parks
Mining effluent	Effluent from mines, ore dressing, and refining; gravel digging; soil extraction
Agricultural effluent	Irrigation effluent, agrochemical residues, effluent from pastures and barns, effluent from aquaculture farms and fry hatcheries
Other	Effluent from vessels, final waste disposal sites, garbage incineration plants, night-soil treatment plants, sewage treatment plants, johkasou (Japanese septic tanks), agricultural community effluent treatment facilities
Construction work	Land preparation and excavation, tunnel excavation, boring, dredging/reclamation

Table III.1.5-6 Impact factors and some of their impacts on water quality

Impact factors			Some of the impacts on water quality
During construction work	Establishment of construction yards and material storing sites		Changes in water quality due to turbidity generation during rainfall
	Operation of construction machinery (heavy equipment)		Changes in water quality due to turbidity generation associated with construction work
	Earthwork such as excavation	Land reclamation	Changes in water quality due to turbidity generation associated with the work
		Excavation, ground cutting, filling	Changes in water quality due to turbidity generation during rainfall
		Use of soil stabilizers	Changes in water quality due to the effluence of soil stabilizers
	Tree felling, root removal		Changes in water quality due to turbidity generation during rainfall
	Installation of structures	Concrete placing	Changes in water quality due to laitance generation
	Installation of temporary structures	Construction and widening of site roads	Changes in water quality due to turbidity generation during rainfall
		Work to install construction facilities	Changes in water quality due to turbidity generation during rainfall
	Dredging work		Changes in water quality due to turbidity generation associated with the work
Existence and use	Topographic alternation	Existence of reclaimed land	Changes in substrate as well as salination due to changes in the flow regime
	Existence of structures	Existence of in-water structures such as breakwaters	Changes in substrate s due to changes in the flow regime
		Existence of reservoirs and water surface areas	Changes in water quality due mainly to the load of benthic fluxes from sediments in a new body of water
		Existence of ground structures	An increase in the rainfall impervious area, a decrease in the water production capacity, fragmentation of surface water (river water) systems
	Operation of facilities	Use of dams, weirs, and sluices	Changes in water quality and quantity in the upper and lower reaches due to changes in the water balance
		Use of a diversion channel	Changes both in water quality in the area into which the diversion channel flows and in discharge and water quality in the original river channel due to changes in the water balance
		Water intake and discharge by a thermal power station	Changes in water temperature and flow due to thermal discharge
		Water intake and discharge by a hydraulic power station	Changes in the water balance in the river system
		Operating activities at factories and other places of business	Water quality change and groundwater contamination due to factory effluent, sewage
	Waste disposal	Landfilling (final disposal)	Water quality change and groundwater contamination due to the discharge of leachate
	Farmland development and recreational facilities (ski resorts, golf courses)	Spraying of agrochemicals	Water quality change and groundwater contamination due to their underground percolation and their effluence into bodies of water
	Use of livestock facilities	Use of livestock facilities	Water quality change and groundwater contamination due to the underground percolation of excreta and their effluence into bodies of water
	Use of a terminal sewage treatment plant	Discharge of treated effluent	Changes in flow regime and water quality downstream due to the discharge of treated effluent
	Use of mineral pits	Use of mineral pits	Water quality change and groundwater contamination due to pit wastewater

Note: The table shows typical items only.

(Points to note) Interrelationships between the Components of the Hydrologic Cycle and Their Impacts on Other Components

The components of the hydrologic cycle may include surface water (water on the surface of the planet), groundwater (water in the saturated ground), and soil water (water in the unsaturated soil zone). These components are closely related to one another.

For this reason, the work to assess the impacts of the implementation of the proposed project should consider not only the direct impacts on specific components; it should also pay attention to the possibility that components not directly related to the project may be affected indirectly or as if in a chain reaction and keep the relationship between these components in mind.

For example, the hydrologic cycle is not only related to the environmental factors of the water environment such as water quality and substrates; indeed it is a fundamental system that determines the state of a number of such elements, including flora and fauna, ecosystems, soil, ground, landscapes, and spaces for enjoying contact with nature. When predicting and assessing the impact on water quality, the project proponent should consider the impact on these other factors as well.

(2) Arranging environmental elements

Generally, the environmental elements regarding water quality include contaminants and hazardous substances for which regulatory standards, etc. are established by law or regulation as shown in Table III.1.5-7. Attention should be paid, however, to substances that have recently be recognized as being hazardous as well as to substances that are not subject to regulation by law but of much interest to local communities.

Table III.1.5-7 Major water contaminants

Classification		Water contaminants
	Related to human health	Cadmium, total cyanide, lead, hexavalent chromium, arsenic, total mercury, alkylmercury, PCB, dichloromethane, carbon tetrachloride, 1,2-dichloroethane, 1,1-Dichloroethene, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethylene, tetrachloroethylene, 1,3-dichloropropene, thiuram, simazine, thiobencarb, benzene, selenium, nitrate nitrogen and nitrite nitrogen, fluorine, boron, 1,4-dioxane
	Related to the living environment	Hydrogen ion concentration (pH), biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), dissolved oxygen (DO), coliform group bacteria, total nitrogen (T-N), total phosphorus (T-P), normal-hexane extracts, the bottom dissolved oxygen (bottom DO)
	Environmental standards for the conservation of aquatic life	Total zinc, nonyl phenol, n-alkylbenzenesulfonic acid and its salts
	Dioxins	Polychlorinated dibenzofuran, polychlorodibenzo-p-dioxin, co-planar polychlorinated biphenyls
Hazardous substances for which effluent standards are established		Cadmium and its compounds, cyanogen compounds, organic phosphorus compounds (parathion, methyl parathion, methyl demeton, and EPN only), lead and its compounds, hexavalent chromium compounds, arsenic and its compounds, mercury and alkylmercury and other mercury compounds, alkylmercury compounds, polychlorinated biphenyl, trichloroethylene, tetrachloroethylene, dichloromethane, carbon tetrachloride, 1,2-dichloroethane, 1,1-dichloroethene, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,3-dichloropropene, thiuram, simazine, thiobencarb, benzene, selenium and its compounds, boron and its compounds, fluorine and its compounds, ammonia, ammonium compounds, nitrite compounds and nitrates, 1,4-dioxane

(3) Selecting environmental impact assessment items

The project proponent will select the items to be studied in an environmental impact assessment (EIA) in relation to impact factors and environmental elements.

(Points to note) A variable may not be selected as an Environmental Impact Assessment item (i) if it is clear that the extent of the environmental impact is non-existent or negligible as far as that variable is concerned, or (ii) if it is clear that there will be no areas or other features/facilities subject to environmental impacts regarding that variable in or around the project area for a significant period of time. In this case, it is important to show the information that forms the grounds for this decision in "Project content" or "Regional overview" in the scoping document. The phase in "areas or other features/facilities subject to environmental impacts" in clause (ii) above refers primarily to areas involving the human living environment or areas where a natural environment exists that is affected by changes in water quality. Given the continuity of a body of water, clause (ii) is inconceivable in reality.

4) Selection of survey, forecast and evaluation methods

(1) Approaches to Method Selection

In the classification of the environmental elements regarding to the water environment, a number of elements including water quality, substrate, and groundwater are so closely related to one another; therefore, in selecting the methods, it is desirable to look at all the selected items related to the water environment as a whole—rather than considering the interrelationships between each selected item and the others—and, on that basis, identify the survey, forecast, and evaluation methods. The project proponent should keep in mind that discharge and the flow regime are part of the information essential for water quality forecast.

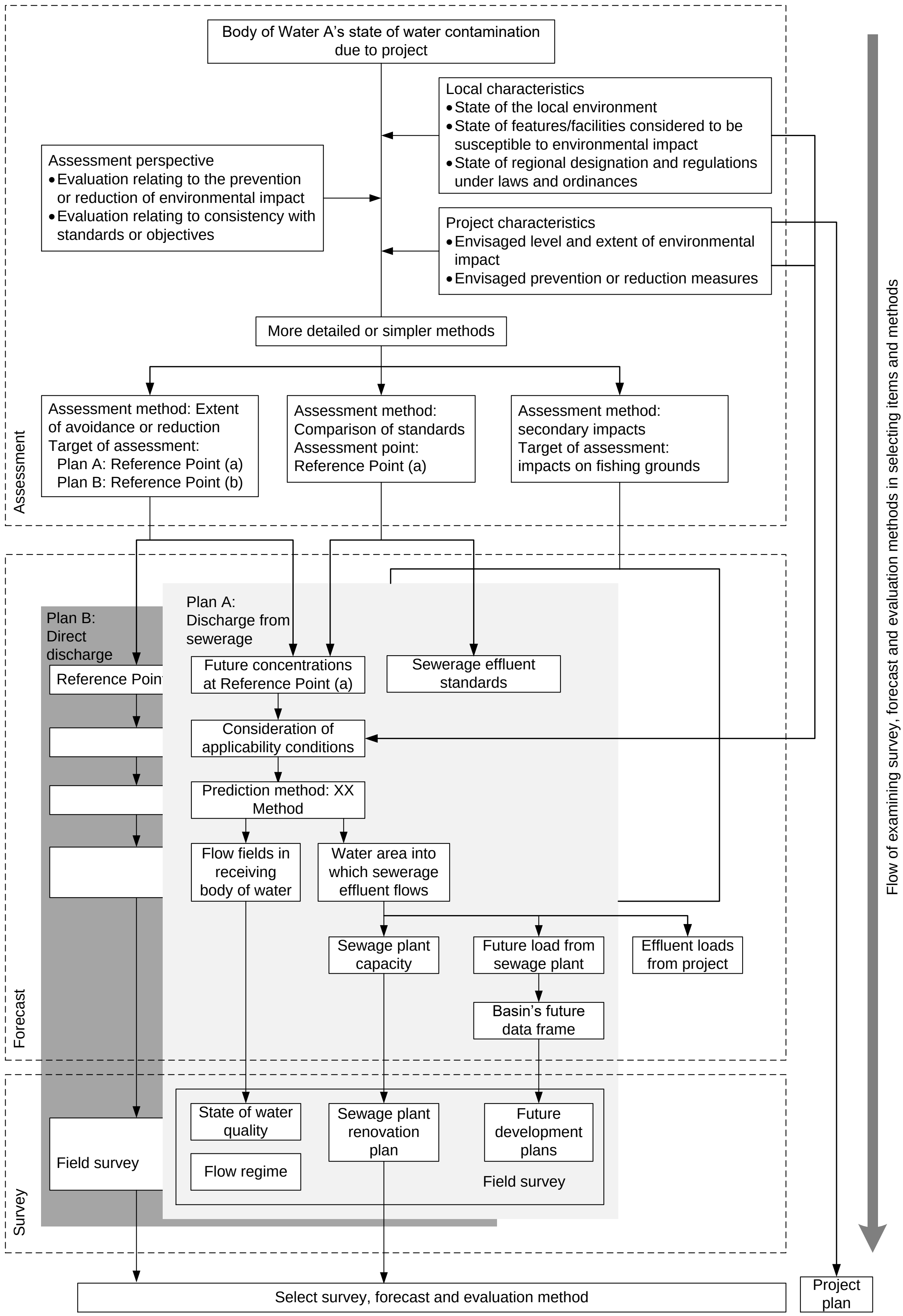


Figure III.1.5-2 An example of identifying the survey, forecast and assessment methods for water quality

Also, water quality is closely related to other environmental elements such as "ecosystems," "topography and geology," and "spaces for enjoying contact with nature." Moreover, the survey, forecast, and assessment of water quality often constitute a precondition for the survey, forecast, and assessment of other selected items. For these reasons, it may be necessary to integrate the processes of examining each of the selected items that are likely related to one another. For instance, water quality is a fundamental element of ecosystems while it is affected by the production functions and water purifying functions of ecosystems. In addition, the flow and quantity of water directly influence the temporal and spatial distribution of water quality while they are influenced by the topography of the body of water in question. Furthermore, water quality is one of the elements that characterize landscapes and spaces for enjoying contact with nature; in particular, it is an essential element in waterfront areas.

In this context, the project proponent should consider the characteristics of the species in question in selecting the area, location, and timing of the survey and forecast. These characteristics include, among other aspects or perspectives, their life history, habitats, and feeding grounds. Different aspects or perspectives mean that different points of survey and forecast will be selected. The survey locations in a river, for example, are generally set near the riverbank from the perspective of habitats, although they are set in the middle of the stream from the hydraulic perspective. If migratory fish such as salmon is of interest, the project proponent should consider the season when it goes upstream in selecting the timing of the survey. The proponent should also keep in mind that the variables to be surveyed, predicted, and assessed will depend on the aspect or perspective in question, which may be the perspective of hydraulics or ecosystems in the case of surveying, predicting and assessing water quality.

The proponent should also take large variability in the body of water into account in identifying the survey, forecast, and evaluation methods as necessary. Large variability, as represented by the impact of floods or typhoons, can definitely occur over the long-term in bodies of water, which usually undergo daily or seasonal variability. These events have tended to be disregarded as being singular; however, they do occur—only less frequently.

(Points to note) Environmental elements that may be linked to water quality

The following environmental elements may be associated with water quality:

- *Topography ⇔ flow and quantity of water ⇔ water quality ⇔ substrate*

  The project proponent should keep in mind that water quality is affected by a spike in loads as well as changes in the flow and quantity of water, which in turn is affected by topographic changes.

- *Ecosystems ⇔ water quality ⇔ substrate*

  Water quality is an essential element; it constitutes s basis for aquatic ecosystems. Surveying, predicting, and assessing this fundamental element is a precondition for surveying, predicting, and assessing ecosystems.

  Ecosystems serve a variety of functions through organisms, their habitats, and interrelationships among organisms. In surveying, predicting, and assessing water quality in closed bodies of water in particular, attention should be paid to ecosystem's water purifying functions in relation to the material circulation.

- *Landscapes and spaces for enjoying contact with nature ⇔ water quality ⇔ substrate*
  Water quality is one of the elements that characterize landscapes and spaces for enjoying contact with nature; it is a particularly important element in waterfront areas.

(Points to note) Cases where the variables to be surveyed, predicted, and assessed may differ depending on the aspect or perspective

For example, the variables to be surveyed, predicted, and assessed may differ in the cases as described below:

- For the flow regime of a river, the important variable may be water velocity at the thalweg from the perspective of water quality or hydraulics; however, it may be water velocity near to either bank from the perspective of ecosystems.
- For water quality in eutrophicated coastal waters, relevant variables may be annual mean values from the perspective of water quality; however, it may be season-specific values from the perspective of ecosystems, such as the decrease in DO in the bottom layer water in the summer

(2) More detailed or simpler survey and forecast methods

A number of approaches can be taken to elaborate the methods of surveying and predicting water quality. These approaches may include (i) conducting a detailed field study to identify the conditions necessary for forecasts and environmental mitigation measures; (ii) densely distributing survey locations and forecast locations; (iii) adopting a sophisticated forecast method; and (iv) elaborating input conditions for the forecast model. Approaches to simplifying survey and forecast methods may include (i) setting conditions necessary for forecasts based on the available information; and (ii) adopting a method designed to assess the extent of the impact by calculating pollution loads or a method designed to predict the impact by comparing with past similar cases.

Criteria for adopting elaborated or simplified methods of survey and forecast may include the following:

(Examples when examining more detailed survey and forecast methods)

1. Where the extent of the environmental impact could be significant
2. Where there is an area or feature/facility vulnerable to environmental impacts
   - A body of water that tends to retain contaminants due to a high degree of closedness
   - A facility that requires special care, such as one for withdrawing water for tap water
   - A body of water that is productive and of fishery value as it includes fishing grounds, aquaculture farms, or seaweed beds
3. Where there is an area or feature/facility designated by law or regulation in the context of environmental conservation
   - A water or land area designed under the Water Pollution Prevention Act
   - A lake or area designated under the Act on Special Measures concerning Conservation of Lake Water Quality
   - A part of the Seto Inland Sea or the prefecture(s) concerned defined by the Act on Special Measures concerning Conservation of the Environment of the Seto Inland Sea

4. Where there is an area whose environment has already been, or could be, degraded significantly
   - An area where environmental standards for water contamination have not been met
   - An area where the applicable targets for water quality in the environmental master plans of the local governments have not been attained.
5. Where local or project characteristics render forecast rather difficult when a standard method is used
   - An area that has a complex flow regime due to its topographic or other characteristics
6. Where there is something on which the local government and the project proponent place special value for environmental conservation
   - There is something that the local government and the project proponent deem important especially for environmental conservation in light of local characteristics, project characteristics, the environmental conservation policy for the project, and the like.

(Examples when examining simpler survey and forecast methods)

1. Where it is clear that the extent of the environmental impact will be small
   - If the project proponent can explain, based on contaminant discharges, that the extent of the environmental impact will be small, he or she may make forecasts in terms of pollution loads rather than with, for example, diffusion calculations.
2. Where the extent of the environmental impact can be clearly assessed based on similar cases
   - The project proponent may use the findings of past surveys for similar projects to estimate and forecast the extent of the environmental impact.

1.5.2 Survey

1) Examination of survey items

As far as water quality is concerned, the project proponent will study environmental elements that constitute the hydrologic cycle. In a current status survey, therefore, the project proponent should gain a detailed understanding of the current conditions of Environmental Impact Assessment items for the water quality that may be affected by the implementation of the proposed project, based on the findings of the survey designed to identify local characteristics and the specifics of the project. The proponent should also conduct additional survey if the findings of the survey designed to identify local characteristics are insufficient with regard to (i) water quality items that are closely related to one another apart from the Environmental Impact Assessment items to be assessed for water quality, and (ii) information needed for setting parameters to be used for forecast and assessment as well as for studying reproducibility.

Generally speaking, the project proponent will select survey items for water quality from the parameters for which environmental standards are established. Attention should be paid, however, to (i) substances that are newly recognized as hazardous substances, and (ii) substances that are not subject to regulation by law but are of much interest to local communities. A water quality survey should preferably monitor basic data that indicates water properties such as temperature, the degree of clearness, transparency, turbidity, and salinity. The measurement of these parameters is relatively easy. The flow and quantity of water are essential items to be surveyed in Environmental Impact Assessment regarding the water environment since they constitute the most basic data for predicting water quality.

(Points to note) Examples of survey items that should be focused in the variability mechanism of water quality

Eutrophication and bottom-layer hypoxia are often some of the problems facing inland waters along the Pacific coast, among other coastal waters. In predicting water quality in such waters, the project proponent should create a forecast model that takes into consideration the material circulation involving organic substances and nutrient salts, including internal production.

(Examples of the items to be measured in a water quality survey

- Inflowing fresh water from rivers, etc.; organic substances, nitrogen, and phosphorus in seawater
- Amounts of internal production, organic substances decomposed and deposited, nutrient salts dissolved from the bottom sediment in coastal waters
- Bottom dissolved oxygen (the bottom layer DO), sulfides, etc. associated with hypoxia in coastal waters

(Reference) Bottom dissolved oxygen (bottom layer do) and the degree of clearness in coastal waters

The bottom dissolved oxygen (bottom layer DO) has recently been added to the group of environmental standards concerning the living environment. It has been defined as an indicator of the direct impact on the habitation and reproduction of fish, selfish, and other aquatic creatures as well as on the growth of seaweeds and other aquatic plants. The idea is to conserve or regenerate spaces where aquatic organisms that use the bottom layer can maintain their populations. The degree of clearness in coastal waters has newly been established as an indicator of the direct impact on the growth of aquatic plants. The idea is to conserve and regenerate spaces for the growth of aquatic plants such as seaweeds and submerged plants with a view to conserving a sound water environment and excellent spaces for aquatic recreation. This indicator is designed so that the public can institutively understand it.

2) Concept of survey method

(1) Water quality

The temporal and spatial variability of water quality is caused by physical, chemical, and biological actions of the body of water. Predicting water quality requires schematically describing the mechanism of this variability. In conducting a survey, it is important to identify the physical actions (such as flow and turbulence) and chemical and biological actions that determine the mechanism of the body of water in question.

Describing such a mechanism is important not only for creating a forecast model but also for studying the reproducibility of forecasts and the findings of a follow-up survey. Table III.1.5-8 shows important items and approaches in the survey and forecast processes for each major type of bodies of water.

Table III.1.5-8 (1) Examples of important items and approaches in the survey and forecast processes for water quality

<table>
<tr><th colspan="2">Type of body of water</th><th colspan="2">Examples of important items and approaches</th></tr>
<tr><td rowspan="2">River</td><td>All reaches except the tidal reach</td><td>Upstream water quality</td><td>In all reaches except the tidal reach, where the generally fast current promotes mixing, the water quality there depends much on the water quality of influent, affluent, and effluent. The flow in these reaches is determined essentially by cross-sectional shape, gradient, and discharge of the river. Varied flow calculation is typically used for streaming calculation.
Water quality forecast methods include the method of solving the stoichiometric equation based on the estimated current, as well as the method that considers the amount purified that corresponds to and the travel time of the water mass.</td></tr>
<tr><td>Tidal reach</td><td>Tides
Estuarine eutrophication
Brackish water</td><td>The tidal reach is characterized by the influence of salinity from the sea and the reciprocating flow—or at least changes in the water velocity—due to the tides. To what extent salinity goes upstream in the river depends on a number of factors, including the gradient of the river, the discharge from upstream, and the amplitude of the estuarine tides. The larger the discharge is, the shorter the ascending distance is. Paradoxically, the ascending distance is longer at the time of neap tide, when the tidal force is weak and the vertical mixing of fresh water and seawater is likely slow, rather than at the time of spring tide, when the tidal force is strong and the vertical mixing is likely fast.
Generally, in an estuary with a long tidal reach, the upper current goes toward the estuary while the lower current goes upstream to carry brackish water with it.
When a weir makes the tidal reach short, for example, the weakened upstream current, coupled with the resultant difference in density between the upper and lower layers that hinders the mixing, may result in hypoxia immediately downstream from the weir. Also, the weakened current upstream from the weir may result in eutrophication as this section of the river becomes more like a lake.
The unsteady flow computation method is typically used for streaming calculation in the tidal reach, where the flow undergoes temporal changes due to the influence of the tides. Also, the analysis of the difference in current direction between the upper and lower layers of the river due to the instruction of brackish water requires a multilayer model that takes density distribution into account. Once the current is estimated, water quality will be predicted with the stoichiometric equation. If hypoxia or a freshwater red tide is a problem in an area of residence, the mechanism of water contamination due to eutrophication should be considered.</td></tr>
</table>

Table III.1.5-8 (2) Examples of important items and approaches in the survey and forecast processes for water quality

<table>
<tr><th>Type of body of water</th><th colspan="2">Examples of important items and approaches</th></tr>
<tr><td rowspan="2">Lakes</td><td>Residence time</td><td>The residence time of a lake is usually expressed by the ratio of the lake volume (m^3) to the annual mean flow into the lake (m^3/year). Eutrophication is deemed possible in lakes with a residence time of two weeks or more; most lakes in Japan meet this criterion.
The water quality of a lake can be analyzed by dividing lake contamination into (i) exogenous contamination, which is caused by influent loads; and (ii) endogenous contamination, which is caused by chemical and biological reactions within the lake. In a lake with a short residence time, the effect of exogenous contamination is stronger and the water quality of the lake depends on the properties of the influent. The longer the residence time is, the slower the lake's response to influent variability is and the greater role endogenous contamination plays in the workings of lacustrine ecosystems.
For this reason, residence time is a major criterion for considering the mechanism of water contamination by eutrophication in predicting the water quality of a lake.</td></tr>
<tr><td>Eutrophication</td><td>In general, a natural lake undergoes the process of trophic succession process over a long time on the order of several hundreds to thousands years, from an oligotrophic lake to a eutrophic lake and to a low moor. This process results from sedimentation that occurs as part of the hydrologic cycle within the natural basin. However, the current problem of eutrophication occurs in a relative short period of time compared to the geologic time scale as a result of large loads of nutrient salts generated by human activity. This problem poses various obstacles for water use.
For lakes in which eutrophication is observed to be progressing and those for which the implementation of the project may raise such a possibility, the project proponent should consider the mechanism of eutrophication-induced water contamination in predicting water quality.</td></tr>
</table>

Table III.1.5-8 (3) Examples of important items and approaches in the survey and forecast processes for water quality

Type of body of water		Examples of important items and approaches	
Coastal waters	Inland waters along the Pacific coast	Inflow load Eutrophication Bottom-layer hypoxia Tidal current	Bay areas are shallow in water depth and high in closedness. These areas are characterized by large inflow loads, progressing eutrophication, and bottom-layer hypoxia in the summer. The tidal current is fast at the mouth and in the channel. These coastal waters tend to experience worsening water quality in the summer. For water quality forecasts, it is desirable to use a model that can factor in the mechanism of eutrophication-induced water contamination. A multilayer model that corresponds to this model is desirable as a water current model.
	Semi-open coastal areas	Prevalence of ocean and tidal currents Internal tides	Coastal waters along the Pacific coast that are open to the ocean, as well as bays that are deep in water depth and wide at the mouth. The currents in the former are influenced by the Japan Current, the Kurile Current among other ocean currents. The average current in these waters should be calculated based largely on most frequent values in current observation. The latter is characterized by the fact that the water mass in the middle and lower layers has the properties of the middle and lower layers of water in the Pacific. Although the surface layer varies by season, the density stratification exists throughout the year in the surface water and the middle and lower layers of water. For this reason, it is known that a significant current (internal tides) exists based on the internal stratification. At present, the currents in and the water quality of these waters are predicted just as in the case of coastal waters open to the ocean. Nevertheless, it is necessary to establish a numerical analytic method that simulates internal tides with sufficient accuracy and precision.
	Coastal waters facing the Sea of Japan	Ocean current Reversal of the littoral current	The tidal amplitude is generally smaller in the waters along the coast facing the Sea of Japan than in waters along the Pacific coast; the associated reciprocating (tidal) flow is weaker as well. Offshore, the Tsushima Warm Current flows northward, often creating counter currents in the nearby coastal waters. It is often observed that such counter littoral currents flow alternately northward and southward or eastward and westward in a cycle of two to three days. Water quality forecasts may be made that correspond the currents in both direction in parallel with the coastline.
	Subtropical coastal waters	Prevalence of ocean and tidal currents	Tidal currents or ocean current elements prevail in some subtropical coastal waters. Based on the observed current data, a model needs to be created for each waters. The water quality in these waters is generally high. A stoichiometric model for COD is often used for water quality forecasts. It may be necessary, however, to consider the mechanism of eutrophication-induced water contamination for coastal waters with high levels of closedness and inflowing pollution loads.

Source: Compiled from Center for Environmental Information Science, ed. *Kankyo Asesumento no Gijutu [environmental assessment techniques]*, 1999, Chuohoki Publishing.

(2) Flow regime

The mechanism of variability, including flows and major factors that dictate it, vary significantly according the characteristics of a body of water. This should be kept in mind in establishing the frequency and points of the survey.

Attention should also be paid to the fact that coastal waters, relatively large lakes, weirs, estuaries, and other waters with a relatively large vertical space have a stratified structure made up of water with different density, affecting the flow of water and the distribution of substances in the water.

(Points to note)

- The mechanism of variability, including flows and major factors that dictate it:
  River: precipitation, influent, effluent, etc.
  Lake: inflow and outflow of river water, wind, influent, effluent, etc.
  Coastal waters: the ebb and flow, wind, ocean current, river water, etc.

Note that these factors differ depending on the topography. An estuary, for example, has both the characteristics of river and those of coastal waters or a lake.

- Stratified structure

The stratified structure, which is formed by differences in water density, should preferably be surveyed along with the measurement of water temperature and salinity for coastal waters and the measurement of water temperature and turbidity for a lake. Since water with the same density behave as a water mass, it is also important to measure water temperature and salinity as well as DO and turbidity for describing the behavior of anoxic water and turbid water, etc. in a body of water.

3) Concept of survey area and location

(1) Survey area

The project proponent will identify the survey area for water quality by estimating the balance of each contaminant, the extent of diffusion thereof, the range of change in the flow regime, among other variables. In the process, attention should be paid to different aspects, including (i) project characteristics such as the types and locations of contamination sources, (ii) the natural conditions such as topography and geology and the current state of the water environment, (iii) local characteristics in terms of social conditions including land use, and (iv) the characteristics of the water contaminants to be surveyed.

(2) Survey locations

Although a body of water intrinsically has continuity, a number of points are generally established to survey the area. These survey locations are often distributed in a mesh-like pattern while taking into account the confluence, water quality reference points, water quality change points and other factors for rivers, or for coastal waters or lakes, the topography of bays, capes, promontories, and other features. For a field study, the project proponent will set survey locations while considering the aspects described in Table III.1.5-9. If the project proponent wishes to use the available information, he or she should do so after confirming that it meets the conditions described in Table III.1.5-9. For lakes or coastal waters, survey locations will be distributed also in a vertical direction as necessary.

Table III.1.5-9 Approaches to setting survey locations for water quality

Type of survey location	Approaches to setting survey locations
Points that represent the area	The proponent will choose survey locations where the discharge and flow regime are stable and the impact of other specific contamination sources is low for points that will represent the water quality of the body of water in question. To keep track of the past record, it is advisable to select environmental reference points. For a lake and coastal waters, survey locations are often distributed in a mesh-like pattern to survey the spatial distribution regarding water quality.
Points where the impact will possibly be particularly high	As points where the impact of the project will possibly be particularly high, the project proponent will select survey locations, for example, contaminant discharge points or points immediately downstream from the project site.
Points where there is an object that requires special consideration for environmental conservation	For points where there is a feature/facility that requires special consideration for environment conservation, the project proponent will select points of importance mainly in the context of using the body of water, such as water intake points for tap water and fishing grounds.
Points where the environment has already deteriorated significantly	The project proponent will select points where the state of water quality is thought to have already deteriorated due to the influence of other contamination sources.
Points where contamination is building up	With regard to the points where contamination is thought to be building up due to other contamination sources nearby, the project proponent will assess the pre-project state to distinguish the impact of the proposed project and other impacts.

4) Concept of survey period and time

For the timing of the survey, the project proponent should keep seasonal variability in mind and see to it that the amplitude of variability can also be estimated. The forecast method should be adjusted. Where necessary, the project proponent should consider making continuous measurement, possibly with a self-recording sensor at representative points. As a rule, the project proponent should decide the period and timing of the survey so as to avoid the direct impact of rainfall. Yet a survey during rainfall may worth considering as the case may be.

1.5.3 Forecast

1) Basic approach to forecast

Water contamination occurs when the concentration of contaminants that have flowed into a body of water becomes higher than the national levels. This concentration is determined by three factors: (i) advection due to currents in body of water; (ii) mixing (diffusion) caused by water turbulence, and (iii) physical, chemical, and biological actions within the body of water.

These factors differ greatly depending on the coastal waters, lake, river, or any other body of water. Furthermore, even within the same body of water, the mixing of water may be sufficient with a fast current; it may be insufficient with a slow current and the resultant density stratification.

In this way, the mechanism of determining the water quality differs greatly depending on the body of water. It is impossible, however, to consider the whole range of such different mechanisms in predicting changes in water quality. It is more practical to consider major processes in such forecast. As the characteristics of the project, including its location, scale, and duration, as well the structures to be installed, the expected extent of the impact should be considered in making forecasts. It is therefore necessary to select a forecast method that can consider the dominant process and the project characteristics according to the features of the body of water.

Environmental impact assessment (EIA) may involve the predicting and assessment processes that focus on means values such as annual averages for comparison with the environmental standards, etc. This is a marked tendency for forecast and assessment for coastal waters, for which forecasts are more difficult. An approach that puts much value on mean values, on the other hand, makes forecasts difficult. This can be easily understood by knowing that an anoxic water mass formed in the bottom layer in the summer in coastal waters will have a significant impact on benthos. This is only one example of the phenomena for which environmental variability should be considered.

It is therefore desirable to keep track of how the water quality of the body of water for which forecasts will be made varies throughout the year. If such variability has a significant impact on the ecosystems, the impact of the project on that variability should preferably be assessed.

(Points to note) Basic approaches to selecting the forecast method

- Quantitative forecasts should be made as much as scientifically and technically feasible.
- The level of forecast uncertainty should be clearly assessed.
- Citing similar cases and scientific findings is important. When applying such data to the impact of the proposed project, the background to the data should be taken into full account as the data may reflect geographical gaps in environmental conditions.
- Quantitative forecast with, for example, a numerical model requires making sure that the quantity of state for water quality, etc. of the body of water in question and the mechanism of the material circulation, etc. can be fully reproduced in the process of developing such a model.
- When biological and ecological actions are considered as conditions for forecast, etc., organisms' physiological and ecological characteristics and ecosystem functions, etc. should be adequately considered as there are many uncertain elements. (When considering the water purifying functions of organisms in tidelands, for example, it is important to consider the physiology and ecology of benthos as well as their purifying capacity.)
- The impact that is considered small in the short term may turn out to be large in the long term because of its accumulative nature (for instance, sedimentation of organic substances and nutrient salts on the bottom of a closed body of water). Also, two different projects may result in the comparable levels of environmental change, but their levels of impact may be different due to changes in the background. Attention should therefore be paid to the temporal scale of environmental change in setting the duration and timing of the forecast.
- The following tables show some of the phenomena and functions according to the characteristics of the body of water and the project:

Table III.1.5-11 Some of the phenomena that should be considered according to the characteristics of the body of water and the project

Phenomena	Forecast concept	Remarks
Red tide and water bloom (algae bloom, etc.)	As of now, it is difficult to qualitatively predict an abnormal proliferation of phytoplankton at the local level.	Because these phenomena involve organisms and their variability is important, seasonal variability should preferably be considered in predicting them. (Indicator: chlorophyll a)
Bottom-layer hypoxia	A multilayer model that can factor in pycnocline can predict bottom-layer hypoxia by properly assessing the oxygen consumption rate of bottom sediment.	To reproduce a blue tide, a phenomena in which an anoxic water mass in the bottom layer wells up to the surface layer, it is important to properly set different kinds of conditions such as topographic conditions including submarine topography and wind conditions. (Indicator: DO)
Changes in substrate's properties/conditions	These changes can normally be predicted with the 3-D diffusion calculation of the suspended substances (SS) that considers the sedimentation and scouring fluxes based on field data.	How to give the feed rate of SS remains a research challenge. (Indicator: SS)
Riverbed armoring	Riverbed armoring is a phenomenon in which the riverbed is covered only with coarse pebbles after fine sediment supply is restrained with a dam, etc.	It hinders the movement of riverbed materials, which in turn may make the hyporheic zone anaerobic. This may further render inappropriate the habitats of benthic animals that live chiefly on loose stones.

Table III.1.5-12 Some of the functions that should be considered according to the characteristics of the body of water and the project

Function	Approach
Water exchange	Water exchange may be influenced by a structure in enclosed coastal waters or changes in flows into or out of a lake caused by a project. One approach to assess water exchange is to conduct a field study or numerical simulation on water balance. For such numerical simulation, it is important to set parameters that can achieve a satisfactory reproduction of changes in the body of water in question. However, creating models for all is difficult. This suggests the need to properly evaluate the characteristics of the body of water in assessing water exchange.
Water self-purification capacity	The water self-purification capacity or functions can be assessed with a water quality simulation model that can factor in the capacity of water purification by organisms. Such models include a lower trophic level ecosystem model and a tideland ecosystem model. Nevertheless, much trial and error will be needed to set proper parameters for such a model based on the available research material and field survey findings.

(Points to note) Assessing the range of variability

Assessment of the range of variability involves a number of processes as shown in Figure III.1.5-3. These include identifying the variability of interest and checking the availability of a model that can describe that variability.

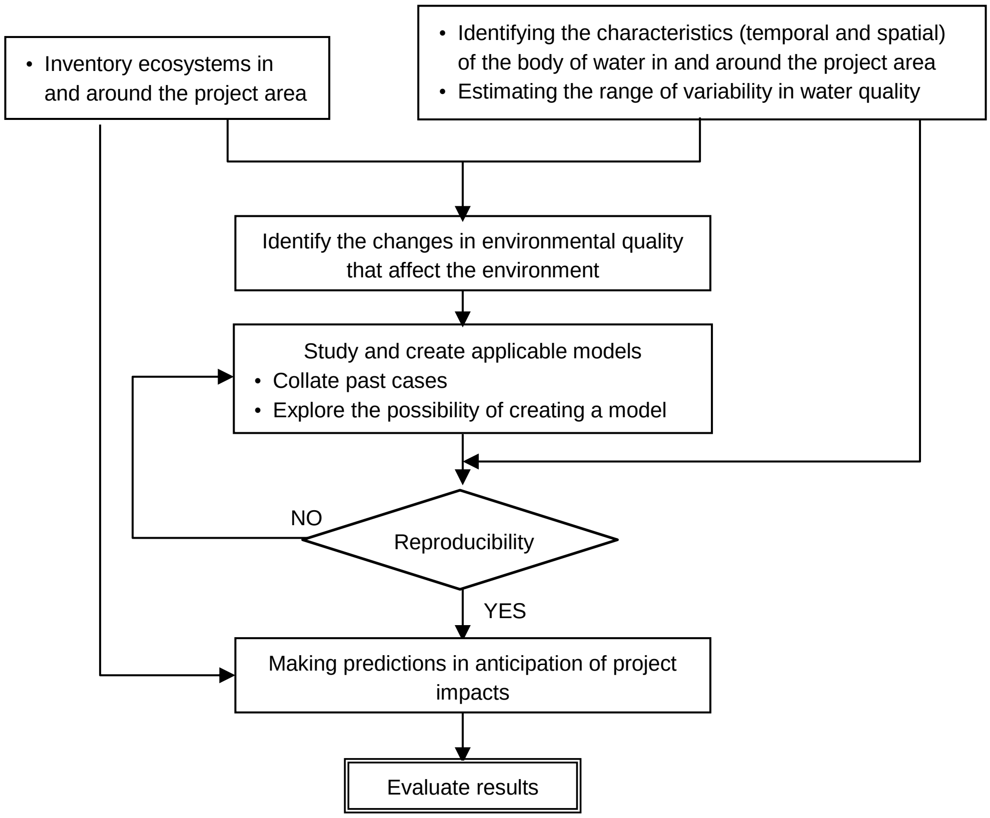


Figure III.1.5-3 Steps to assess the range of variability

2) Concept of forecast method

As noted earlier, what matters in predicting water quality is to select a forecast method what can factor in the dominant process in a body of water and the characteristics of the project according to the features of that body of water.

Tables III.1.5-13 through III.1.5-20 show some of the major forecast methods for each environmental element and characteristic of rivers, lakes, and coastal waters. Note that rough estimation of the extent of the impact by taking advantage of similar cases, statistical techniques, and analytic solutions is effective for an effective forecast process before making detailed forecasts. Such forecasts of the complex topographic conditions and water-depth conditions as well as changes in phenomena over time can be made with numerical simulations and hydraulic model tests.

• Rivers

Projects in inland areas include dam and land readjustment projects that involve land alteration covering a relatively large area, as well as road and railway projects that involve crossing river zones. In such projects, forecasts are made with regard to (i) rain-induced turbidity from bare soil associated with site preparation, (ii) turbidity associated with excavation in low-water channels and work to construct diversion water channels, and (iii) alkaline effluent associated with concrete placing works.

Table III.1.5-13 Some of the major forecast methods for river water quality (water contamination, turbidity)

Object of forecast	Type of river	Forecast method	Brief description
Water contamination/ turbidity	Non-tidal river	Streeter-Phelps equation and its modifications (self-purification model)	This equation has been developed to predict BOD concentrations primarily in non-tidal rivers, providing an analytic solution to a diffusion equation where the river flow is assumed to be a uniform flow.
		Dilution/mixing equation (complete mixing equation)	A technique to find concentrations with simple dilution calculation on the assumption that effluent into a body of water is completely mixed with that body of water.
		Forecast with numerical simulation	The two-dimensional one-layer stationary model is mainly used.
		Forecast based on past similar cases	For forecasts at the time of flood caused by rainfall, findings on SS and discharge in areas with similar soil are gathered to create an L-Q equation (L: SS load; Q: the quantity of flow). Separately, the discharge from the area of the proposed dam project is estimated based both on the peak discharge from that area or upstream and downstream therefrom and on the area ratio. This discharge in turn is substituted in the L-Q equation above to estimate the expected peak AA concentrations.
			A technique to qualitatively predict the impacts of the proposed project based on past similar cases that correspond to this particular project in terms of the content of the project or the scale of associated construction work, etc. in light of project characteristics and local characteristics. These cases should be fully analyzed to determine their applicability to the forecast.
	Tidal river	Ketchum's method (tidal prism method)	A technique of one-dimensional analysis for tidal rivers or narrow bays on the assumption that effluent and seawater are completely mixed together. The assumption is that effluent that has flowed into one zone of a bay at high tide is completely mixed with seawater and, at low tide, flows out of that particular zone and never reenters the zone.
		Preddy's method (mixing equation)	A technique that builds on Ketchum's method. It introduces the mixing coefficient derived from the values actually measured in a tidal river to predict water quality.
		Forecast with numerical simulation	The two-dimensional multilayer non-stationary model is mainly used.
		Forecast based on past similar cases	A technique to qualitatively predict the impacts of the proposed project based on past similar cases that correspond to this particular project in terms of the content of the project or the scale of associated construction work, etc. in light of project characteristics and local characteristics. These cases should be fully analyzed to determine their applicability to the forecast.

Source: Compiled from:

- Environmental Impact Assessment Division, Planning and Coordination Bureau, Environment Agency, *Kankyo Eikyo Hyoka Seido Sogo Kenkyukai Gijutsu Senmon Bukai Kanren Shiryoshu [compendium of relevant information for the technical task force of the general study group on the environmental impact assessment system]*, 1996.
- Ministry of the Environment, Doro Oyobi Tetsudo Kensetsu Jigyo Ni Okeru Kasen no Nigori to ni Kansuru Kankyo Eikyo Hyoka Gaidorain [environmental impact assessment guidelines on turbidity, etc. in rivers in road and railway construction projects], 2009.
- River Project Environmental Impact Assessment Committee, *Damu Jigyo ni okeru Kankyo Eikyo Hyoka no Kangaekata [concept of environmental impact assessment in dam projects]*, 2000, Water Resources Environment Technology Center.

• Lakes (including reservoirs)

Forecasts are made with regard to the environmental impacts of the existence and use of dam reservoirs, reservoirs for hydroelectric power stations. These impacts concern water turbidity and changes in water temperature; they also include the impact of eutrophication on the river downstream from the area of the proposed project.

Table III.1.5-14 (1) shows some of the numerical analysis simulation models—major forecast methods for the material balance with regard to water turbidity, water temperature, and eutrophication in lakes including reservoirs.

(Points to note) Use of methods for general forecast

Stratification is one of the physical phenomena most related to changes in water temperature and turbidity in dam reservoirs. In reservoirs where stratification occurs, there is a large gap in water temperature between the upper and lower layers, which may result in lower water temperatures or prolonged water turbidity downstream, depending on the position of the intake point used for discharge. *Indicators for determining the cold water phenomenon*, which assesses the possibility of stratification, include the annual turnover rate, the internal field rate, and the July turnover rate. Based on these criteria, the project proponent should preferably assess the possibility of stratification and select an appropriate forecast model accordingly.

Whether a body of water is eutrophic or not can be examined with the Vollenweider model. If this model suggests the possibility of eutrophication, numerical simulation regarding the material balance in relation to eutrophication can be conducted to make the forecast process efficient.

Source: River Project Environmental Impact Assessment Committee, *Damu Jigyo ni okeru Kankyo Eikyo Hyoka no Kangaekata [concept of environmental impact assessment in dam projects]*, 2000, Water Resources Environment Technology Center.

Table III.1.5-14 (1) Some of the numerical analysis simulation models for lakes (including reservoirs)

Type of model	Box model	Vertical one-dimensional model	Horizontal two-dimensional model
Features	• Dividing the body of water into several boxes in the longitudinal direction and calculating changes in water quality associated with flows into and out of each box. • Hydraulic variables are for the balance only. • The water quality is the average value for each box.	• Dividing the body of water into layers and calculating the vertical distribution of hydraulic and water quality variables. • Hydraulic and water quality variables are average values for the layer.	• Dividing the body of water into a horizontal mesh and calculating the distribution of hydraulic and water quality variables • Although hydraulic and water quality variables are measured for each cell, it is assumed that the vertical distribution is uniform.
Conditions for lakes to which the model is applicable	• It can be assumed that the water quality distribution is uniform within each box. • Temporal changes in currents can be ignored to some extent.	• In addition to the conditions for lakes to which a box model is applicable: • It can be assumed that the horizontal distribution of currents and water quality values in a lake of a relatively small size is uniform. • The lake is simple in shape.	• In addition to the conditions for lakes to which a box model is applicable: • Lakes whose vertical distribution of water quality can be assumed to be uniform (e.g., large and shallow fresh water lakes) • Lakes that have a relatively complex shape, such as those with inlets • Reservoirs for which in-reservoir measures should be considered
Objects of calculation	• Average values within the water quality boxes • Heat exchange on the water surface • Material balance (inflows/outflows + sedimentation) • In the case of two or more boxes, advection/diffusion in the longitudinal direction can be considered. • Loads from substrates can be considered	In addition to the objects of calculation for a box model: • Vertical distribution of hydraulic and water quality variables	In addition to the objects of calculation for a box model: • Horizontal distribution of hydraulic and water quality variables
Benefits	• A short calculation time • Capable of long-term water quality forecasts	• A short calculation time • Capable of long-term forecasts of hydraulic and water quality variables	• Faster than 3-D calculations • Capable of medium-term (more than one year up to several decades) forecasts of hydraulic and water quality variables
Drawbacks	• Unsuitable to lakes with stratification as all-layer mixing is assumed. • Incapable of describing the distribution of water quality in one box • Difficult to consider the impact of flow changes	• Unable to keep track of horizontal changes in water quality • Difficult to describe local phenomena	• Unsuitable to lakes with stratification as vertical changes in water quality cannot be described.
Phenomena; measures taken	• Eutrophication (algae bloom) • Forecast of the effects of dredging	• Eutrophication (algae bloom) • Forecast of the effects of aerating circulation facilities	• Eutrophication (algae bloom) • Forecast of the effects of dredging • Impact assessment of water conveyance projects

Source: Kosho Gijutsu Kenkyukai [study group on limnological technology], *Kosho ni okeru Suiri Suishitsu Kanri no Gijutsu [hydraulic and water quality management techniques for lakes]*, 2007.

Table III.1.5-(2) Some of the numerical analysis simulation models for lakes (including reservoirs)

Type of model	Vertical two-dimensional model	3-D Model
Features	• Dividing the body of water into longitudinal and vertical meshes and calculating the longitudinal and vertical distribution of hydraulic and water quality variables • Although hydraulic and water quality variables are measured for each cell, it is assumed that the lateral distribution is uniform.	• Dividing the body of water into longitudinal, lateral, and vertical meshes and calculating the three-dimensional distribution of hydraulic and water quality variables • The three-dimensional distribution of hydraulic and water quality variables can be obtained.
Conditions for lakes to which the model is applicable	In addition to the conditions for lakes to which a vertical one-dimensional model is applicable: • Lakes whose shape is long and narrow like a river and whose lateral distribution of water quality can be assumed to be uniform (e.g., dam lakes) • Lakes whose shape is relatively complex, such as those whose tributary further branches out (applicable to some extent)	In addition to the conditions for lakes to which a vertical two-dimensional model is applicable: • Lakes with the horizontal and vertical distribution of water quality (e.g., those with density currents and those whose depth is large) • Lakes whose plane shape is complex
Objects of calculation	• Longitudinal and vertical distribution of hydraulic and water quality variables	In addition to the object of calculation in the left: • Three-dimensional distribution of hydraulic and water quality variables
Benefits	• Faster than 3-D calculations • Capable of medium-term (more than one year up to several decades) forecasts of hydraulic and water quality variables	• Capable of three-dimensional description of the phenomena • Capable of describing the local hydraulic and water quality features • Capable of factoring in density currents, wind-induced currents, etc. • Capable of considering arrangement plans for more sophisticated facilities for in-lake measures
Drawbacks	• Capable of designing measures to control stratification • Incapable of describing lateral changes in water quality • Incapable of describing currents that causes horizontal distribution such as drift currents	• Huge calculation time because of three-dimensional mesh division • Unsuitable for mediumto long-term calculations
Phenomena; measures taken	• Eutrophication (algae bloom) • Density currents due to brackish water	• Eutrophication (algae bloom) • Blue tide • Density currents due to brackish water • Forecast of the effects of dredging • Control of density stratification

Source: Kosho Gijutsu Kenkyukai [study group on limnological technology], *Kosho ni okeru Suiri Suishitsu Kanri no Gijutsu [hydraulic and water quality management techniques for lakes]*, 2007.

• Coastal waters

In coastal waters, forecasts are made with regard to the impacts on water quality either by a public waters reclamation project alone or by such a project in conjunction with a project to construct an airport, final waste disposal site, power station, etc. Specifically, water contamination is measured by chemical oxygen demand (COD) and, as necessary, other variables such as total nitrogen (T-N) and total phosphorus (T-P), while water turbidity is measured by suspended solids (SS).

Table III.1.5-15 briefly describes major methods of predicting impacts of water contamination and turbidity in coastal waters. Tables III.1.5-16 provide a brief description of major numerical simulation forecasts by type of coastal waters. Examples of such forecasts are given in Tables III.1.5-16 through III.1.5-20.

Table III.1.5-15 Some of the major forecast methods for water quality (water contamination and turbidity) in coastal waters

Object of forecast	Forecast method	Brief description
Water contamination associated with land reclamation	Forecast with numerical simulation	This method makes calculations with a combination of a water current model that solves non-linear simultaneous differential equations such as the equations of motion and the equations of continuity and water quality model that solves the material circulation among water quality parameters. Recent advances in computers have placed the method in the mainstream of water quality forecasts in environmental impact assessment. (Benefits) • Capable of calculation for a given topographic condition or a water quality condition • Capable of factoring in complex boundary conditions that change over time • Capable of describing water quality mechanisms involving eutrophication among other complex phenomena as long as quantitative formula that describe natural phenomena can be established (Points to note) • Produces inaccurate results if the theoretical formula on which calculation is based fails to fully reflect natural phenomena
	Forecast based on past similar cases	A method to qualitatively predict the impacts of the implementation of the proposed project of land reclamation, etc. based on past similar cases that correspond to this particular project in scale and in light of the conditions of surrounding bodies of water (characteristics of these bodies of water such as the location, etc. of inflowing rivers, those of changes in water contamination, etc.) as well as project characteristics and local characteristics. These cases should be fully analyzed to determine their applicability to the forecast.
Water turbidity associated with land reclamation, etc.	Forecast with numerical simulation	This method generally begins with predicting currents first, and, based on the results of this forecast, predict the extent of diffusion and concentration of water turbidity. (Benefits) • Capable of calculation for a given topographic condition or a water quality condition • Capable of factoring in complex boundary conditions that change over time (Points to note) • Produces inaccurate results if the theoretical formula on which calculation is based fails to fully reflect natural phenomena.
	Forecast with analytic solutions	A method to obtain analytic solutions by simplifying a diffusion equation under several conditions and solving that particular equation. This can be made by, for example, the following techniques: <point source, two-dimensional, temporary> • Joseph-Sendner's diffusion equation Applicable on the assumption that turbulence is assumed uniform on the horizontal plane <point source, two-dimensional, continuous > • Okubo-Pritchard diffusion equation Applicable on the assumption of a constant average current in a steady state • Iwai' solution Applicable on the assumption of a constant average current in a steady state • Joseph-Sendner's diffusion equation Applicable to spillage and effluent of fresh water
	Forecast based on past similar cases	A method to qualitatively predict the impacts of the implementation of the proposed project of land reclamation, etc. based on past similar cases that correspond to this particular project in scale and in light of the conditions of surrounding bodies of water (characteristics of these bodies of water such as the location, etc. of inflowing rivers, those of changes in water contamination, etc.) as well as project characteristics and local characteristics. These cases should be fully analyzed to determine their applicability to the forecast.

Source: Compiled from:
- Waterfront Vitalization and Environment Research Foundation, *Kowan Bun'ya no Kankyo Eikyo Hyoka Gaidobukku [an environmental impact assessment guidebook in the ports and harbors sector]*, 2013.
- Ports and Harbors Bureau, Ministry of Land, Infrastructure, Transport and Tourism, *Kowan Koji ni okeru Nigori Eikyo Yosoku no Tebiki [a guide on the forecast of impacts of turbidity caused by port and harbor construction works]*, 2004.

Table III.1.5-16 Brief description of numerical simulation forecasts by type of coastal waters

Object of forecast	Type of coastal waters	Examples of qualitative forecast	
Current	Zones of an open coastal waters that are not subject to the impact of river inflow	Since there are not external forces like river inflow, a simple two-dimensional one-layer model that factors in tidal currents is often adopted.	Table III.1.5-(i)
	Zones of an open coastal waters that are subject to the impact of river inflow	A multi-layered model is often adopted that factors in tidal currents in the coastal waters in question as well as density currents due to freshwater inflow.	Table III.1.5-(ii)
	Inland bays and enclosed coastal waters	A multi-layered model is often adopted that factors in tidal currents in the coastal waters in question as well as density circulating currents (estuarine water circulation) caused by seawater inflow at the bay mouth and freshwater inflow at the bay head, and wind-induced drift currents.	Table III.1.5-(iii)
	Coral reefs and shallow waters	A multi-layered model is often adopted that factors in wave-induced currents (nearshore currents), land emergence and submergence in shallow waters due to the ebb and flow, and wind-induced drift currents.	Table III.1.5-(iv)
Water contamination Forecasts are made of the advection, diffusion, etc. of water contamination based on the results of the calculation of the currents.	Coastal waters where the advection and diffusion of conservative substances contribute to water quality (open coastal waters)	In the case of open coastal waters, for which neither internal production nor the impact of the substrate need to be considered, a forecast model is often adopted that uses the result of flow regime calculation, handles such conservative substances as inflowing COD, and builds on advection and diffusion calculations.	Table III.1.5-(i)
	Coastal waters where eutrophication due to inflow loads and internal production by organisms contribute to water quality (inland bays and enclosed coastal waters)	A forecast model is often adopted that factors in two kinds of phenomena. The first is the advection and diffusion of contaminants flowing from the land area. This kind of phenomena are calculated based on the results of flow regime calculation gained from a forecast model that factors in phenomena caused by density circulating currents (estuarine water circulation) due to seawater inflow at the bay mouth and freshwater inflow at the bay head. The second kinds of phenomena are those caused by internal production and dissolution from the substrate in the bay. These phenomena need to be considered because primary production is active in inland bays and enclosed coastal waters.	Table III.1.5-(ii)
Water turbidity Forecasts are made of the advection, diffusion, etc. of water contamination based on the results of the calculation of the currents.	Open coastal waters (into which no river flows)	Since there are not external forces like river inflow, a SS diffusion model is often adopted that is based on a simple horizontal two-dimensional diffusion simulation that factors in tidal currents.	Table III.1.5-(i)
	Open coastal waters (into which a river flows)	A forecast model based on an advection and diffusion equation that also covers the SS sedimentation process is often used. This model builds on the results of flow regime calculation gained from a forecast model that also factors in density currents fresh water inflow.	Table III.1.5-(ii)
	Inland bays and enclosed coastal waters	A forecast model based on an advection and diffusion equation that also covers the SS sedimentation process is often used. This model builds on the results of flow regime calculation gained from a forecast model that factors in phenomena caused by density circulating currents (estuarine water circulation) due to seawater inflow at the bay mouth and freshwater inflow at the bay head.	Table III.1.5-(iii)

Note: This table organizes some, not all, of the forecast methods for currents and water contamination by type of coastal waters where reclamation or other projects are proposed, based on the existing environmental impact statements.

Source: Waterfront Vitalization and Environment Research Foundation, *Kowan Bun'ya no Kankyo Eikyo Hyoka Gaidobukku [an environmental impact assessment guidebook in the ports and harbors sector]*, 2013.

Table III.1.5-17 Examples of numerical simulation forecast for coastal waters (currents)

Classification		(i) Open coastal waters (into which no river flows)	(ii) Open coastal waters (into which a river flows)
Purpose of forecast		A steady-state analysis model is used for forecast with regard to coastal waters that face the open sea and where the nearshore current is not found to be periodic (coastal waters where tidal currents do not prevail).	A numerical model that also involves vertical flow calculation is used for predication with regard to coastal waters subject to the impact of both tide-induced periodic currents facing the open sea and the freshwater flow from rivers. Such a model factors in density currents due to the inflow of river water as well as tidal currents in the coastal waters in question.
Details of the forecast method (model)	Item	Permanent currents	Tidal currents and density currents
	Computational mesh	Cell width: 50-400 m (Minimum cell width: 50-100 m)	Cell width: 50-600 m (Minimum cell width: 50-100 m)
	Model	Plane two-dimensional simulation (steady-state analysis model)	A multi-layered model that factors in tidal currents, density currents, and drift currents due in large part to oceanographic conditions

Classification		(iii) Inland bays and enclosed coastal waters	(iv) coral reefs and shallow waters	
Purpose of forecast		Forecasts are made with a numerical model that factors in the existence of bay-wide density circulating currents and ring currents (e.g., density circulating currents caused by seawater from the bay mouth and fresh water inflow at the bay head) in closed coastal waters.	The purpose is to predict the impact of changes in river inflow on surrounding coastal waters.	For coastal waters with a complex topography such as coral reef areas and shallow bodies of water that face the open sea, forecasts are made with a numerical model that factors in (i) changes in the currents in coastal waters in question (tidal current), (ii) changes in waves, and (iii) land emergence and submergence in shallow waters due to the ebb and flow.
Detailed of the forecast method (model)	Item	Tidal current, density currents	Tidal current	Waves (nearshore currents), tidal current
	Computational mesh	Cell width: 100 m to 1km (Minimum cell width: 100–200 m)	15 m	Cell width: 16.7–450 m (Minimum cell width: 16.7m)
	Model	A multi-layered model that factors in bay-wide three types of currents—tidal currents, density currents, drift currents—and density currents due to fresh water inflow	A two-dimensional one-layer non-stationary model (layer division: one-layer)	For changes in waves, a wave deformation model based on the energy balance equation method (that factors in wave refraction, wave shoaling, breakers, and structure-induced reflected waves); for changes in tidal currents, a multi-layered model (that can factor in the characteristics of the currents in surrounding coastal waters as well as tidal currents, drift currents, nearshore currents, land emergence and submergence in shallow waters due to the ebb and flow)

Note: This table organizes some, not all, of the forecast methods for currents by type of coastal waters where reclamation or other projects are proposed, based on the existing environmental impact statements.

Source: Waterfront Vitalization and Environment Research Foundation, *Kowan Bun'ya no Kankyo Eikyo Hyoka Gaidobukku [an environmental impact assessment guidebook in the ports and harbors sector]*, 2013.

Table III.1.5-18 Examples of numerical simulation forecast for coastal waters (water contamination)

Classification		(i) Coastal waters where the advection and diffusion of conservative substances contribute to water quality (open coastal waters)	(ii) Coastal waters where eutrophication due to inflow loads and internal production by organisms contribute to water quality (Inland bays and enclosed coastal waters)
Purpose of forecast		Changes in water quality caused by the advection and diffusion of COD and other conservative substances flowed from rivers, etc. are predicted based on changes in the flow regime caused by the existence of reclaimed land.	In inland bays and closed coastal waters, eutrophication due to inflow loads from the land area as well as internal production by plankton contributes to water quality. Accordingly, changes in COD, T-N, T-P, and DO are predicted. The advection and diffusion of COD, T-N, and T-P due to river inflow, etc., as well as the rise and fall of plankton are considered in the process.
Details of the forecast method (model)	Item	COD, T-N, T-P, pH, salinity, etc.	COD, T-N, T-P, DO, Cl-
	Computational mesh	Cell width: 16.7–450 m (Minimum cell width: 16.7-50 m)	Cell width: 100 m–1 km (Minimum cell width: 100–200 m)
	Model	Forecasts are made with the advection and diffusion equation for conservative substances based on the results of flow regime calculation (gained from a multi-layered model). Also predicted are pH associated with the implementation of construction and salinity, etc. during rainfall according to the project characteristics and the local characteristics.	Forecast are made with a lower trophic level ecosystem model that factors in (i) the advection and diffusion contaminants that have flowed from the land area; and (ii) the production, respiration, excretion, and death of plankton; (ii) the decomposition and sedimentation of non-living organic substances as well as the dissolution thereof from the bottom sediment and their oxygen consumption.

Note: This table organizes some, not all, of the forecast methods for water contamination by type of coastal waters where reclamation or other projects are proposed, based on the existing environmental impact statements.

Source: Waterfront Vitalization and Environment Research Foundation, *Kowan Bun'ya no Kankyo Eikyo Hyoka Gaidobukku [an environmental impact assessment guidebook in the ports and harbors sector]*, 2013.

Table III.1.5-19 Examples of numerical simulation forecast for coastal waters (water turbidity)

Classification		(i) Open coastal waters (into which no river flows)	(ii) Open coastal waters (into which a river flows)		(iii) Inland bays and enclosed coastal waters
Purpose of forecast		The diffusion of turbidity (SS) resulting from dredging works in coastal waters is predicted based on the results of flow regime predictions.	The diffusion of turbidity (SS) resulting from revetment construction work, land reclamation work, etc. in coastal waters is predicted based on the results of flow regime predictions. Sedimentation is also considered in the process.		The diffusion of turbidity (SS) resulting from revetment construction work, land reclamation work, etc. in coastal waters is predicted based on the results of flow regime predictions. Sedimentation is also considered in the process.
Details of the forecast method (model)	Item	SS	SS	SS	SS
	Computational mesh	Cell width: 20–400 m (Minimum cell width: 20–50 m)	15 m	Cell width: 16.7–450 m (Minimum cell width: 16.7–50 m)	Cell width: 100–900 m (Minimum cell width: 100-200 m)
	Model	Forecast with horizontal two-dimensional diffusion simulation	Two-dimensional one-layer non-stationary model (layer division: one-layer)	Forecasts are made with the advection diffusion equation that also involves the sedimentation process of diffuse matter. (A multi-layered model is used for diffusion calculations.)	Forecasts are made with the advection diffusion equation that also involves the sedimentation process of diffuse matter. (A multi-layered model is used for diffusion calculations.)

Note: This table organizes some, not all, of the forecast methods for water turbidity by type of coastal waters where reclamation or other projects are proposed, based on the existing environmental impact statements.

Source: Waterfront Vitalization and Environment Research Foundation, *Kowan Bun'ya no Kankyo Eikyo Hyoka Gaidobukku [an environmental impact assessment guidebook in the ports and harbors sector]*, 2013.

As for power station projects, forecasts are made with regard to water turbidity and contamination, and, as necessary, thermal discharge and changes in water temperature associated with plant operations. Table III.1.5-20 provides a brief description of some of the major forecast methods for changes in water temperature.

Table III.1.5-20 Some of the major forecast method for water quality (water temperature) in coastal waters

Object of forecast	Type of discharge	Forecast method and a brief description thereof
Changes in water temperature due to thermal discharge associated with the operation of power stations	Surface-layer discharge	Numerical simulation is mainly used. A simplified forecast model that involves (simplified) sea current calculation, discharge current calculation, and temperature calculation may be used depending on the topography, oceanographic and meteorological conditions, and discharge conditions.
	Submerged discharge	Hydraulic model tests are said to be effective for this purpose. In the case of a large extent of diffusion, numerical simulation is used at the same time. A submerged diffusion forecast model that is based on a 3-D model applicable to the forecast of thermal discharge diffusion, which is more three-dimensional may be used for a large submerged discharge or a combination of surface layer discharge and submerged discharge. A simplified forecast model that makes a simplified forecast of the extent of diffusion of thermal discharge based on the existing empirical formulae is also available for the parameters of outlets, including their shape and discharge.

Source: Compiled from:

- Marine Ecology Research Institute and JAPAN NUS Co., Ltd., *Heisei 22 Nendo Kokunaigai ni okeru Hatsudensho To kara no Onhaisui ni yoru Kankyo Eikyo ni Kakaru Chosa Gyomu Hokokusho [research report on the environmental impact of thermal discharge from power stations, etc. in Japan and abroad for fiscal 2010]*, 2011.
- Ministry of Economy, Trade and Industry, *Kaitei: Hatsudensho ni Kakaru Kankyo Eikyo Hyoka no Tebiki [a guide on environmental impact assessment for power stations (revised)]*, 2015.

(1) Concept of forecast conditions

(a) Identifying standard unit values

Standard unit values to be used for forecast do differ depending on a range of factors such as technical factors and lifestyles as well as local characteristics. It is therefore necessary to identity the latest information or the availability and content of information suitable for the area in question.

(b) Setting flow/current parameters

Flow/current zones in a body of water are determined by such parameters as discharge, tides, and tidal current; they constantly change according to the cycle of these parameters and the natural conditions surrounding them. The flow/current parameters to be focused in the forecast process significantly influence forecast results. Accordingly, they should be identified according to the features/facilities of assessment (e.g., mean concentrations, short-term, high concentrations, etc.).

(2) Forecast uncertainty

Future forecasts are generally based on future environmental conditions after confirming the validity of the created model following the assessment of its reproducibility of the current state. The more complex the model becomes, the more involved parameters are. This allows for a combination of parameters that is more effective for reproducing the current state. Such a combination, however, may not be relevant in the environment in the future, meaning that future changes in the environment may not be predicted accurately enough.

When predicting future environmental changes with a complex model, as in the case of forecast for eutrophicated coastal waters, model validity assessment at one point in the baseline year may not be sufficient. This is because a number of coefficients involved in the model may mean that there is more than one combination of parameters that is capable of reproducing the water quality of the baseline year.

In particular, if loads and other variables may change significantly with a long project duration and a long period of time between the baseline point and the predication point, it may be necessary to increase the forecast accuracy by assessing reproducibility at the baseline year and an earlier point in time (two-point correction).

(Points to note) Reproduction calculation

(1) Approach

The more complex the forecast model is, the more likely it is possible to make a combination of parameters that can improve baseline reproducibility. Such a combination will not necessarily lead to accurate forecast of future changes in the environment.

To predict water quality in an inland bay, for example, the reproduction model requires the following among other calculation parameters:

Water flow/current model: fresh water inflow, sea level variation on the open boundary, water temperature and salinity on the open boundary, eddy viscosity coefficients, eddy diffusion coefficients, climate (wind, sunshine), etc.

Water quality model: inflow loads, open boundary concentrations, rate constants (e.g., production rate, decomposition rate, sedimentation rate, dissolution rate)

As shown in Figure III.1.5-4, calculation for reproducibility essentially uses the actual measured values for the baseline reproduction year as far as fresh water inflow, loads, and boundary conditions among these forecast parameters are concerned. Other parameters are set by trial and error in light of their reproducibility. The process of predicting future environmental changes involves adding topographical changes associated with the project, modifying fresh water inflow, inflow loads, etc., and using baseline values for other parameters.

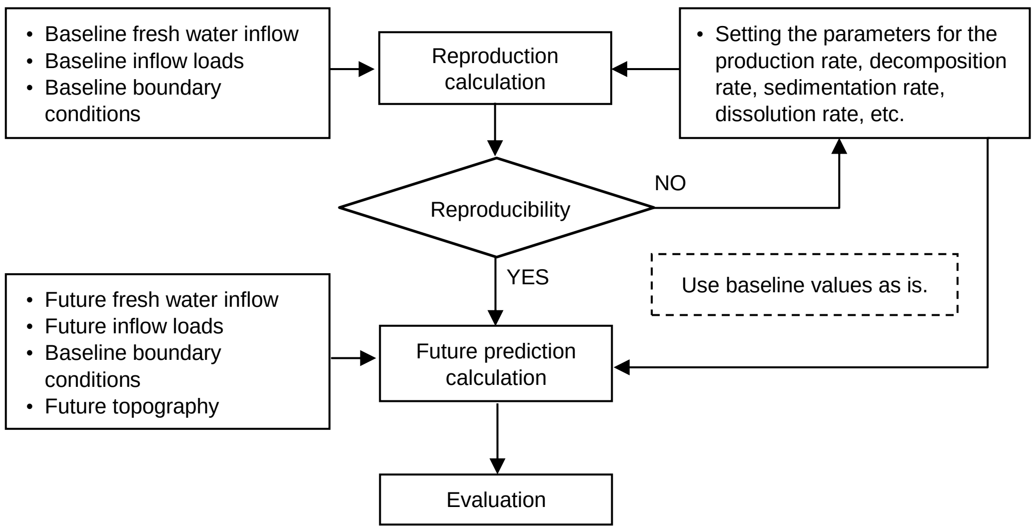


Figure III.1.5-4 Forecast flow for water quality

Nevertheless, the velocity constants such as the production rate and the decomposition rate are the functions of the characteristics of the ecosystems (the dominant species of phytoplankton in particular) and water temperature in the body of water in question. There is no guarantee that the present relationships will continue. One effective way to address this problem is what is called the “two-point correction” approach, which assesses the reproducibility of past observed values with a combination of the parameters that have achieved baseline reproduction.

(2) Points to note

Because reproducibility assessment is made at two difference time slices as noted earlier, the two-point correction approach needs to set a range of parameters that correspond to both time slices. Forecast parameters for the standard forecast model are divided into those used as coefficients in the model’s governing equation and those in input conditions in it. The latter include inflow loads and boundary conditions.

The two-point correction process is shown in Figure III.1.5-5. This process is two-fold: (i) reproducibility assessment with the parameters for the most recent year (Reproduction Year 1); and (ii) reproducibility assessment with those for a year somewhat earlier (Reproduction Year 2). In the second part, the correction process assesses the relevance of the parameters for Reproduction Year 1 to those for Reproduction Year 2. If they are found to be irrelevant, the process identifies the factors surrounding this irrelevance and set more relevant parameters for the future. These procedures should come before future forecasts.

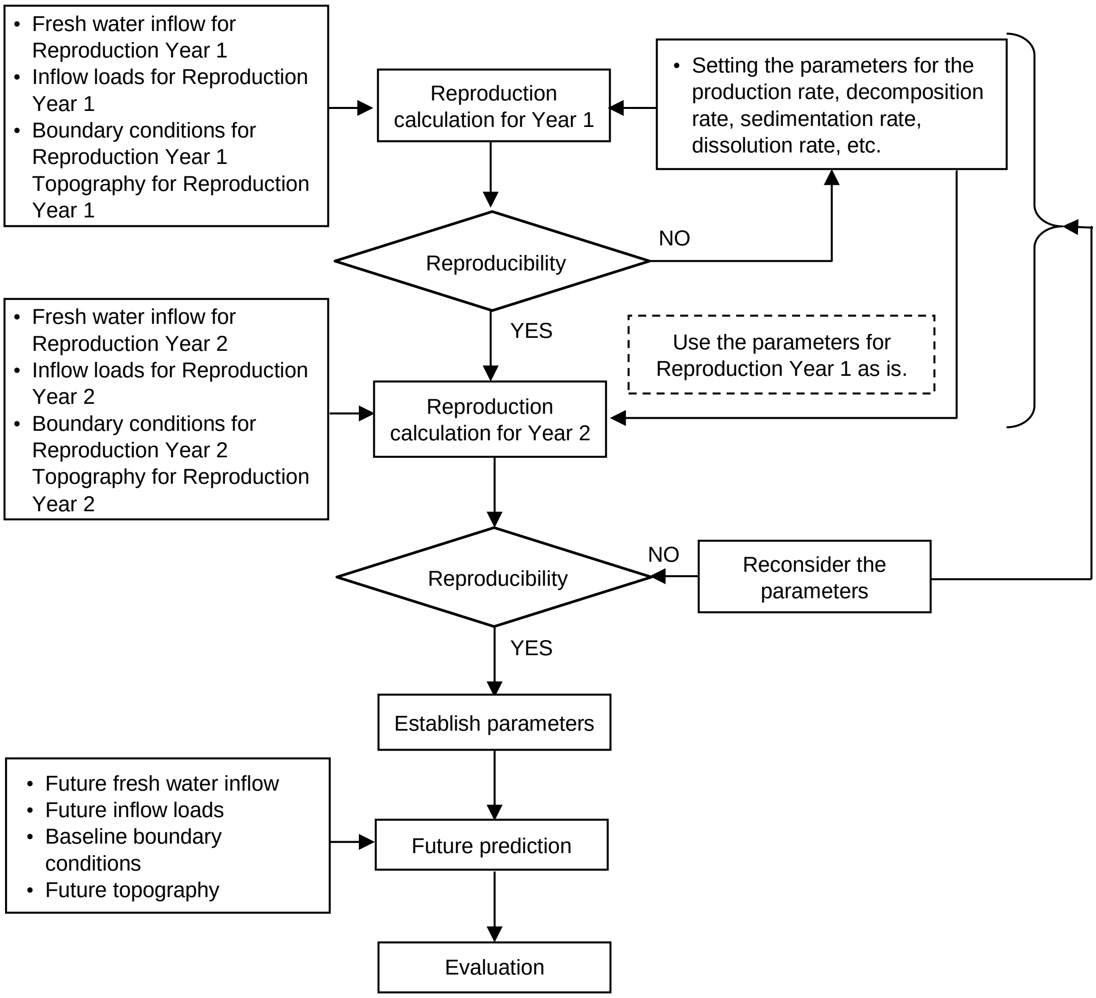


Figure III.1.5-5 Example of the two-point correction process

(Points to note) Sensitivity analysis[3]

(1) Basic Approach

In general, forecast results of based on a simulation model depend significantly on the parameters and input conditions. Parameter values are gained from a field study or laboratory experiment. It is not always possible, however, to set values most appropriate for the characteristics of the area in question. In fact, parameter values are often set in reference to existing literature. It is also unavoidable that the process of setting forecast parameters such as inflow loads contains uncertainties. Improving forecast accuracy requires identifying beforehand which parameter or input condition contributes significantly to the forecast results from the model and paying particular attention to those with significant contribution in setting forecast parameters.

(2) Points to note

Sensitivity analysis for a model is inefficient when it covers all the parameters if they are large in number. A more efficient approach is to roughly estimate the order of the term to which each of the parameters is relevant and then remove the parameters whose contribution is found to be clearly small.

The process of conducting sensitivity analysis with a lower trophic level ecosystem model can be explained as follows. The process if five-fold: (i) setting up a basic case for calculation; (ii) singling out one parameter for sensitivity analysis; (iii) setting up a case where that the value of that parameter is multiplied; (iv) expressing the calculation result at a given point in that case in a value relative to that in the basic case, as shown in Figure III.1.5-6; and (v) using such a figure to identify which parameter is more sensitive to others. As clearly shown in this figure, unless an efficient case is set up, there will be a great number of cases that should be calculated.

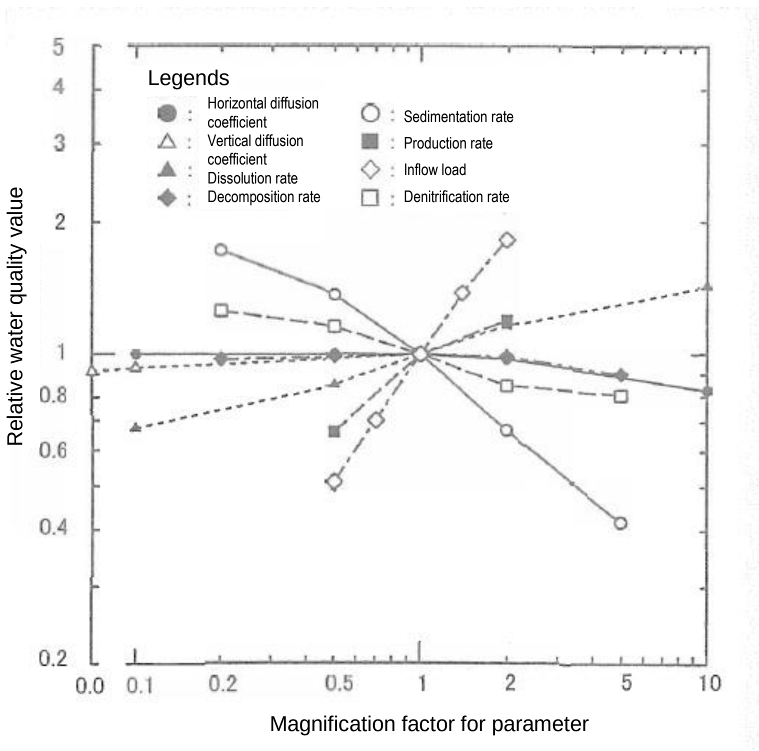


Figure III.1.5-6 Example of sensitivity analysis

[3] Sensitivity analysis: A technique to assess the degree to which a parameter influences the forecast model by changing each parameter and confirming to what extent such a change alters the results from the model.

3) Concept of forecast area and location

As in the case of “Concept of survey area and location,” the project proponent will identify the forecast area by estimating the balance of each contaminant, the extent of diffusion thereof, the range of changes in the flow regime, among other variables. In the process, attention should be paid to difference types of factors, including (i) project characteristics such as the types and locations of contamination sources, (ii) the natural conditions such as topography and geology and the current state of the water environment, (iii) local characteristics in terms of social conditions including land use, and (iv) the characteristics of the water contaminants for which forecast is made.

(Points to note) Basic approach to identifying the forecast area

<Rivers>

The forecast area will extend to the boundary downstream where the impact of the effluent, etc. from the proposed project is deemed negligible after being diluted by river water.

<Relatively small lakes>

The forecast area will be the entire lake or, depending on the extent of the impact, delineated downstream as in the case of river described above.

<Coastal waters and relatively large lakes>

In numerical simulation, the following considerations should be given so that the way the boundary conditions are set will not significantly influence the forecast results.

- The extent will be delineated in such a way that the project impact will not reach the boundary.
- The open boundary will be set outside the strait area or any other narrow terrain.
- The open boundary will be the geographical extent where sea level variation and water velocity variation that are needed for current calculation, as well as water quality measurement data need for water quality calculation, are measured in an adequate spatial and temporal frequency or otherwise known.

4) Concept of forecast time

The typical forecast time will be the point in time when the generation of contaminants such as turbidity due to the construction work is the largest. However, if the construction work is so extensive in area and leaves additional places vulnerable to its impact, forecasts may have to be made more than once in light of the location and timing of such work.

The forecast time for the impact of the existence of project-related structures or facilities shall be when the site preparation for them is completed; however, it shall be when outer revetment is completed before the completion of the main part of a land reclamation project.

The forecast time for the impact of the use of project-related facilities will be when such facilities are completed and their effluent into public waters, if any, reaches a steady state. However, forecasts may have to be made in an intermediate timing if much time is needed for such effluent to reaches a steady state after project-related facilities start operations or if the effluent discharge changes significantly during the period of forecast.

In the case of qualitative forecast with numerical simulation, it is a common practice to make calculations regrading reproducibility for model calibration. The year of baseline reproduction will generally be made to coincide with the time when the current status survey is conducted. In line with this, necessary parameters (the quantity, load, etc. of the influent) will be set.

It is not always possible, however, to set the parameters identical to those that were set at the time of the current status survey. In fact, such parameters as the quantity and load of the influent are sometimes set based on various statistical data. In such cases, it is necessary to fully study the similarities and developments in natural and social conditions between the baseline reproduction year and the year when the parameters are set.

For a body of water where the annual variation in water quality is small, it is sufficient to predict annual mean water quality values. For a body of water where such variation is large, however, the characteristics of that variation should be taken into account in determining the timing of forecast.

(Points to note) Basic approach to identifying the forecast area

When predicting the impact of turbidity generation due to construction work, if there is a place vulnerable to the impact of turbidity, it is necessary to identify the year and season when the impact on this particular place will be the greatest as the timing of forecast.

<Examples>

- For places with a seaweed bed: vulnerability to the impact of turbidity may vary by season.

This is because such vulnerability varies depending on the growth stage of seaweeds and algae. This points to the need to select the season of forecast in line with the lifecycle of seaweeds and algae living in such a seaweed bed.

- For places with a swimming beach: The summer should be selected as the timing of forecast since the impact of turbidity is the greatest in the season when swimming beaches are used.

(Points to note) Determining the timing of forecast in consideration of the characteristics of annual variation in water quality

It is necessary to select either of the two options for the timing of water quality forecast. One option is to make such forecast throughout the year. The other option is to make such forecast in the season when the water quality values are most representative of those in the whole body of water. The second option reflects the fact that water quality varies significantly by season in such bodies of water as those with progressive eutrophication due mainly to seasonal changes in internal production. Additionally, if it is deemed necessary to predict phenomena that often occur in the summer such as anoxic water mass and blue tides, water quality forecast should be made in or around the summer as well.

For rivers, arrangements should be made to accommodate the variation in water quality, which is significantly influenced by changes in discharge. Such arrangements include making forecasts by flood year, drought year, or season.

1.5.4 Environmental mitigation measures

1) Procedures for examining environmental mitigation measures

As far as water quality is concerned, it has been customary to devise a policy of environmental mitigation measures so that it will be aligned with the criteria and targets of environmental standards, etc. regarding water contamination or turbidity.

There are many environmental elements, however, that may be affected by changes in water quality; the water environment is also a component of the natural environment, which involves ecosystems and spaces for enjoying contact with nature, as well as of the ground environment. Therefore, it is also important to design environmental mitigation measures for the water environment as a whole. This process involves taking into account a number of factors, including (i) the state of water use in the body of water in question, (ii) the usage of the body of water itself, (iii) the current state of the ecosystems, (iv) the usage of spaces for enjoying contact with nature, and (v) the results of the assessment of the impacts on other environmental elements that may be related to water quality.

(Points to note) Importance of environmental preservation consideration at early stages

As shown in many case studies, large projects such as those for infrastructure development may have no small impact on the surrounding environment. For example, associated topographic alternation (changes in the flow regime in coastal waters and the expansion of the rainfall impervious area in the land area) and the existence of associated structures may disturb the natural water balance and deteriorate water quality.

It is therefore necessary to get the most out of the lessons learned so far and incorporate measures that give consideration to environmental preservation at the possible earliest stage.

(Points to note) Some of the major criteria for devising a policy of environmental mitigation measures

The following list shows some of the major criteria for devising a policy of measures for conserving the water environment:

- What has been done before the stage of scoping document
- Project characteristics (e.g., location/arrangement, scale/shape/structure, impact factors)
- Local characteristics (e.g., hydraulic conditions of rivers, lakes, and coastal waters; the state of water quality and the substrate; the state of water use; the usage of the body of water; the state of ecosystems; the state of landscapes and spaces for enjoying contact with nature)
- Environmental standards on water contamination, as well as the current environmental performance with regard to the environmental master plans and environmental consideration guidance, if any, of the local government
- Input received in the processes of scoping document and draft environmental impact statement
- Results of environmental impact forecasts.

2) Specific environmental mitigation measures

Table III.1.5-21 shows some of the environmental mitigation measures for water quality. These measures can be combined with compensatory mitigation measures. The process of devising measures to compensate for the value of the water environment should involve considering that the water environment is in a complex system in which water circulates throughout the environment while being subject to natural or anthropogenic impacts and interrelated to ecosystems. Accordingly, the process should pay due attention to its effects and the impacts of compensatory mitigation measures on hydrologic cycle systems.

Table III.1.5-21 Examples of environmental mitigation measures for water quality

Stages of project planning	Impact factors		Examples of environmental mitigation measures (Except compensatory mitigation measures)
Location, arrangement, scale, structures/facilities, equipment, etc.	Topographic alternation	Existence of reclaimed land	Identifying project location and scale in consideration of changes in the flow regime and water quality
	Existence of structures	Existence of in-water structures such as breakwaters	Identifying project location and scale in consideration of changes in the flow regime and water quality
Operation management, and administration of facilities	Operation of factories and other places of business	Operation of thermal power stations	Identifying cooling and other systems to help curb the quantities of water intake and discharge
		Operating activities at factories and other places of business	Establishing a sewage treatment plant and discharging the effluent into sewerage
	Waste disposal	Waste landfilling	Establishing a leachate treatment facility
			Monitoring leakage and adopting a construction method for leakage prevention
	Use of rivers water		Curbing the consumption of and reusing river water
Site preparation work, construction work, etc.	Establishing a construction yard and material storing site		Constructing a stormwater reservoir for flood control
	Operation of construction machinery (heavy equipment), etc.		Establishing a turbid water treatment plant and installing turbidity diffusion prevention equipment such as contamination prevention film
	Earthwork such as excavation	Land reclamation	Adopting a construction method that minimizes turbidity; establishing a turbid water treatment plant; installing turbidity diffusion prevention equipment such as contamination prevention film
		Excavation, ground cutting, filling, etc.	Constructing a stormwater reservoir for flood control; controlling groundwater level recession (cutoff method)
		Use of soil stabilizers	Selecting eco-friendly soil stabilizers; adopting a construction method that prevents the effluence of soil stabilizers
	Felling, grubbing, etc.		Constructing a stormwater reservoir for flood control
	Installation of temporary structures	Construction and widening of construction roads	Constructing a turbid water treatment plant and a stormwater reservoir for flood control
		Work to install construction equipment	Constructing a turbid water treatment plant and a stormwater reservoir for flood control
	Dredging work		Adopting a construction method that minimizes turbidity; installing turbidity diffusion prevention equipment such as contamination prevention film

Note: This table shows only typical measures for environmental conservation for water quality.

(Points to note) Technical difficulty with compensatory mitigation measures

The water environment serves a number of environmental preservation functions in hydrologic cycle processes. They include *securing water quantities needed to support the vital activity of humans and the workings of nature, the transportation of heat and matter, water purification by soil and running water, and the maintenance of various ecosystems*. If the very best environmental mitigation measures designed to prevent or reduce the impact of the project are to impair these functions of the water environment, then such impaired functions shall be compensated.

Nevertheless, the water environment is in a complex system in which water circulates throughout the environment. In the process, water is subject to natural or anthropogenic impacts, including evaporation, percolation, retention, and flow; it also interacts with ecosystems and spaces for enjoying contact with nature, among other things. The functions of the water environment in the circulating system that exists in such a complex and delicate balance are technically difficult to compensate for. Such difficulty should be kept in mind.

The Environmental Impact Assessment process assumes that the project proponent tries to prevent and reduce the environmental impacts of the project to the extent feasible. The proponent shall do so primarily by taking two kinds of measures: pollution source control in the project area and measures centering on promoting seawater exchange.

Table III.1.5-22 provides a brief description of major environmental improvement technologies for water quality.

Table III.1.5-22 (1) Brief description of major environmental improvement technologies for water quality

Classification	Title of environmental improvement technology	Effects of environmental improvement technologies	Points to note in application
(i) Technologies effective mainly in improving the substrate environment	• Bottom sediment dredging	• Removing the bottom sediment that is unfavorable as a habitat of fish and shellfish will improve a large area of the substrate and reduce the dissolution of nutrient salts into the water.	• Space should be secured for disposing of the dredged sediment. • Attention should be paid to how long the effects will last in the face of the impacts of the loads. • Efforts should be made to prevent the generation and diffusion of turbidity during the construction work.
	• Sand covering	• Covering the bottom sediment that is unfavorable as a habitat of fish and shellfish with good-quality sand or other materials will improve the substrate and reduce the dissolution of nutrient salts into the water.	• Whether the water depth needed for using the water surface should be checked. • Attention should be paid to how long the effects will last in the face of the impacts of the loads. • Efforts should be made to prevent the generation and diffusion of turbidity during the construction work.
	• Sea-bottom cultivation	• Stirring up the sedimentation layer of the substrate that is unfavorable as a habitat of fish and shellfish will provide oxygen, thereby promoting the decomposition of organic substances and improving the substrate.	• Consideration should be given to the life history, etc. of local species in identifying the timing and location of implementation. • Attention should be paid to how long the effects will last in the face of the impacts of the loads. • Efforts should be made to prevent the generation and diffusion of turbidity during the construction work.

(ii) Technologies effective mainly in promoting seawater exchange and conserving water quality	• Water-route making	• Constructing a water route by excavating the flat ground in shallow waters (shallow bays and tideland areas) will increase the water velocity, thereby promoting seawater exchange and reducing sludge accumulation along the coast. This in turn will help to render the substrate more habitable for organisms.	• Space should be secured for disposing of the dredged sediment. • This technology is effective in places with a small depth of water. • (In places with a large depth of water, it is difficult to generate a gap in water velocity in relation to the surrounding area.) • Regular excavation is needed for maintenance. • Efforts should be made to prevent the generation and diffusion of turbidity during the construction work.
	• Slit-type breakwaters • Perforated breakwater • Breakwater with a submerged mound	• Promoting seawater exchange with these breakwaters will help to conserve water quality.	• A measure that takes advantage of designed to waves, tides, etc. • Calmness should come before seawater exchange. • The impact on the surrounding environment should be assessed.
	• Permeable breakwater	• Permeable breakwaters will increase the degree of closedness of the body of water, thereby helping to prevent the seawater exchange process from slowing down. They will also serve to provide a seaweed bed and a habitat for fish and shellfish.	• Case studies in a number of bays and harbors across the country have proved that permeable breakwaters are effective in inviting fish and shellfish in droves.

Source: Compiled from Center for Environmental Information Science, ed. *Kankyo Asesumento no Gijutu [environmental assessment techniques]*, 1999, Chuohoki Publishing.

Table III.1.5-(2) Brief Description of major environmental improvement technologies for water quality

Classification	Title of environmental improvement technology	Effects of environmental improvement technologies	Points to note in application
(iii) Technologies effective mainly in maintaining and enhancing the habitats of organisms	• Creation of shoals and tidelands	• Creating a shoal tideland chiefly with sand laying and earth covering will help to form seaweed beds as well as spawning grounds and habitats of fish and shellfish.	• Conservation measures are required for local organisms.
	• Submerged breakwaters, and attachment sites for periphyton for the propagation of resources	• Installing these structures will serve to propagate resources.	• Such installment should seek to minimize the loss of exiting shore reefs and seaweed beds. • Habitats should be designed to accommodate local vegetation. • The construction work should be timed to accommodate the life of the species concerned.
	• Seaweed bed creation	• Seaweed bed creation will help to enhance the water purifying functions of algae as well as the functions of the seaweed as the habitat of fish and their fry.	• Waves and currents, the substrate, the conditions of light, water temperature, and other factors should be analyzed to determine the feasibility of creating a seaweed bed and, if found feasible, decide on the type of seaweed bed.
	• Artificial reef • Leg-type detached breakwater • Man-made headland	• The effect of preventing the erosion of sand and gravel beaches as well as the sedimentation effect will help to maintain and enhance the water purifying functions of the foreshore and the habitats of local organisms. • Numeral openings in the structure will provide a habitat for benthos and fish. • The formation of a calm area or an excess current area behind the structure will provide a habitat for benthos and larvae and juvenile fish among other organisms. • The structure will also provide attachment sites for seaweeds and periphyton.	• The propriety of the emergence in the sand and gravel environment of organisms that originally live in rock reef areas should be fully considered beforehand.
	• Earth covering of revetments and dikes	• Covering a revetment or dike with earth will make it possible to plant or transplant coast vegetation and maintain and increase the scale of the foreshore.	• Local native species should be planted. • Covering should be done with locally-available sand as much as possible to prevent the invasion of non-native species.
	• Eco-friendly revetment	• Eco-friendly revetments, represented by gentle-slope riprap revetments, will provide a habitat for organisms with their structure and the materials used for them. It will also serve as a water purifying filter and a space that allows citizen to enjoy close contact with water.	• The sloping part is essentially structured to be applicable anywhere. It should be noted, however, that this part has its limitations when it comes to the use of the water surface.

Source: Compiled from Center for Environmental Information Science, ed. *Kankyo Asesumento no Gijutu [environmental assessment techniques]*, 1999, Chuohoki Publishing.

1.5.5 Evaluation

The evaluation process concerns the prevention e or reduction of environmental impacts. When the national government or the local government has standards or targets in its environmental preservation strategy for the selected items, the process also involves evaluating their alignment with these standards or objectives.

1) Evaluation relating to prevention or reduction

Evaluation on prevention or reduction is aimed at identifying and evaluating the efforts by the project proponent to prevent or reduce environmental impacts. Evaluation approaches include comparing several options for environmental mitigation measures, assessing whether feasible and better technologies are adopted, and evaluating whether efforts are made to avoid environmental degradation from the current state.

2) Evaluation relating to consistency with standards or objectives

Table III.1.5-24 shows examples of standards or objectives for water quality set by the national or local governments.

Table III.1.5-24 Examples of standards or objectives for water quality

National government	Environmental Quality Standards for Water Pollution under the Basic Environment Act Environmental quality standards for water pollution under the Act on Special Measures against Dioxins Regulatory standards under the Water Pollution Prevention Act
Local governments	Standards, etc. in pollution control ordinances, ordinances on the conservation of the living environment, etc. Standards and targets in environmental master plans or environmental management plans

Evaluation of the alignment with the standards or objectives means evaluation of whether the implementation of the proposed project will be in line with the environmental preservation strategies of the national and local governments concerned. Accordingly, the project proponent should understand how the standards or targets he or she refers to fit in the environmental preservation strategies and then clarify which standards or targets to use for evaluation and why.

In comparing these standards or objectives with the forecast results, the project proponent should show the portion of the concentrations attributable to the proposed project and that attributable to other factors separately and clarify the extent of the impact of the project per se. On that base, it is important to make an evaluation in terms of not only whether or not the forecast results meet the standards or targets but also whether the extent of the impact of the proposed project could interference with environmental preservation in light of the standards and targets.

The points where measurements are made in light of environmental standards are referred to as assessment points. It should be kept in mind that assessment points are selected as representative points to assess the performance with regard to the environmental standards for bodies of water.

(Points to note) Environmental standards and regulatory standards

Environmental standards are designed to be administrative targets that should preferably be maintained to preserve the environment. They are different in concept from regulatory standards under the Water Pollution Prevention Act. Effluent standards and total pollutant load regulating standards under the Water Pollution Prevention Act represent the standards primarily designed to regulate effluent concentrations and quantities from factories and other places of business with facilities that generate water contaminants. These standards must be observed regardless of whether they are subject to environmental impact assessment or not. Environmental standards, by contract, are designed to be achieved and maintained with a wide range of administrative policy measures.

When referring to the environmental standards in conducting an environmental impact assessment, the project proponent should make an appropriate assessment on the understanding that he or she is required to prevent or reduce the impact of the project to the extent feasible, not only in terms of whether forecast results conform to environmental standards, but also with a view to maintaining the natural elements of the environment in good conditions.

(Points to note) In cases where environmental mitigation measures will be taken by an entity other than the project proponent

In cases where environmental mitigation measures will be taken by an entity other than the project proponent, the project proponent should make it clear that the materialization of such measures is already in sight, as in the case where a sewage treatment plant is expected to involve an advanced treatment design.

If the project proponent is the same, it is possible to implement environmental mitigation measures outside the proposed project and take their effects into account, as in the case where the port authority implements a land reclamation project and gives care to the environmental preserve functions of a nearby breakwater and other facilities, including their permeability.

1.5.6 Follow-up survey

Environmental Impact Assessment entails some uncertainty in its findings as it comes before project implementation. A follow-up survey is designed to offset such forecast uncertainty. It may be conducted if the uncertainty is significant or if the project proponent takes environmental mitigation measures whose effects are not well-established. The need to conduct a follow-up survey shall be assessed in light of the seriousness of the environmental impact. Depending on the results of such a survey, it may be necessary to modify the environmental mitigation measures or implement additional ones.

Clearly, a follow-up survey focuses on the project impacts on the discharge of water contaminants, the state of water intake and pumping, and topographic changes, among other aspects. It should also study the state of water contaminant sources and water intake and pumping around the project area, as well as the social conditions at large, in order to check whether the forecast parameters for Environmental Impact Assessment are aligned with these aspects.

Likewise, it is desirable to make effective use of the available information from surveys conducted by entities other than the project proponent such as the national and local governments (including discharge and water quality measurement data, groundwater level observation data, ground subsidence observation data, and the results of survey on complaints).

The locations for a follow-up survey for water quality will center around the locations deemed most vulnerable to the impact of the project as well as the points where forecast and assessment have been made in Environmental Impact Assessment. Other locations will essentially include locations where the project impact is deemed negligible in light of the forecast results in Environmental Impact Assessment. These locations are needed to obtain background values.

If a follow-up survey focuses on a river or any other water environment that is variable due to the effects of precipitation or effluent, it is necessary to keep track of the past variations for some period of time. As for the environmental impacts that take a long period of time to manifest themselves, that particular period should also be considered.

(Points to note) Important considerations in selecting the items subject to a follow-up survey

For the purpose of project impact assessment, a follow-up survey may be inadequate if it focuses only on the items selected for Environmental Impact Assessment. It is therefore necessary to get a grip on the related environmental elements, the state of the surrounding environment, and the progress in project implementation.

● An example of selecting related items subject to a follow-up survey

A follow-up survey on water turbidity caused by construction work in a lake or coastal waters may study the following items:

- Precipitation: The impacts of rainfall-induced turbidity (e.g., the inflow of rainfall-induced turbidity from a river, sediment stir-up caused by increased discharge in a river) will be determined.
- Flow regime (flow direction and water velocity): turbidity sources will be located.
- Chlorophyll a, pH, DO, etc.: The impact of phytoplankton, etc. in red tides, etc. will be determined.
- Existence of a ship sailing nearby during the survey: The impact of sediment stir-up by a large ship will be determined.

● Some of the findings of a project progress survey:

- Location and volume at the time of survey of the construction work that caused turbidity

● Some of the findings of a survey of the surrounding environment

A follow-up survey on water contamination with DO, BOD, COD, T-N, T-P, etc. may study the following items:

- Inflow loads from adjacent rivers, places of business, etc. around the project area (The loads due to the other factors than the project will be quantified for comparison with forecast parameters.)
- Progress in sewerage development (The loads due to the other factors than the project will be quantified for comparison with forecast parameters.).

(Points to note) Importance of environmental monitoring of water quality

Even measures based on rather established technologies such as water treatment plants and turbidity diffusion prevention equipment have varying degrees of effectiveness depending on how these technologies are managed and operated. It is therefore desirable to conduct regular environmental monitoring to see if they are serving their required purposes to move the project forward.

1.6 Substrates

1.6.1 Selection of environmental impact assessment items and survey, forecast and evaluation methods

1) Ascertaining project characteristics

Table III.1.6-1 shows examples of the project characteristics to be identified with regard to substrates.

Table III.1.6-1 Examples of the project characteristics to be identified regarding substrates

Impact factors	Examples of the characteristics to be identified
Implementation of construction	• Specifics, method, and duration of construction • Location and extent of construction • Plans for temporary structures such as temporary diversion channels, as well as borrowing pits, reception sites for construction-generated soil, and others
Existence and use of facilities	• Specifics, location, and scale of facilities (structures such as weirs and bridge piers) • Plans and policies regarding the in-service period and operation of facilities (structures such as weirs and bridge piers) • Hydrological changes associated with the use of facilities (structures such as weirs and bridge piers)

2) Ascertaining local characteristics

(1) Area

(a) Defining the survey area for an inland body of water

In defining the survey area for substrates in an inland body of water, the project proponent will clarify the positional relationship between the project area and the public waters in light of hydrological conditions. “The geographical extent where the state of the environment will change at least to a certain extent” with regard to river substrates represents the river reaches downstream from around the project area if the project involves constructing such structures as bridge piers. If the project involves constructing a weir, this particular geographical extent refers to a varying part of the water surface area upstream the weir and of the river reaches downstream depending on changes in the flow regime caused by the construction of the weir and the resultant growth of the water surface area. Nevertheless, the project proponent will define the survey area in the wider context of the entire basin that includes the project area, in light of the close relationship between the substrates and such factors as the area of the basin and the population and land use therein

In spite of these guidelines on defining the survey area, the project proponent should get the overall picture of the entire river as each river has its own characteristics.

(b) Defining the survey area for coastal waters and lakes

Strictly speaking, it is impossible to define “the geographical extent where the state of the environment will change at least to a certain extent” for substrates in coastal waters and lakes without making a forecast. In the phase of selecting the items to be studied and the survey, forecast, and evaluation methods to be used in Environmental Impact Assessment, the project proponent will select a physically delineated area—the typical example of which may be a bay or coastal waters enclosed by such features as capes and promontories—or the basin of the river flowing into these waters (or, in the case of a lake, the basin of the river flowing into or out of that lake) as the survey area. In the process, reference will be made to past cases.

Table III.1.6-2 Area classification and examples of environmental impacts with regard to substrates

Area classification	Examples of environmental impacts
Rivers, coastal waters	• Stir-up of contaminated substrates by construction work
Rivers - coastal waters	• Deterioration of substrates due to the blocking of flow

(2) Identifying local natural and social conditions

Tables III.1.6-3 and III.1.6-4 show examples of the characteristics to be identified with regard to the local natural and social conditions.

The information available on substrates is largely point-specific data in that it has been obtained at environmental reference points or the like. This is why a field survey is necessary to assess the situation between observation points along the inflowing river.

As for the observation points for which information is available, a field survey should preferably assess the local topography and features as well as the state of the contamination sources.

Table III.1.6-3 Examples of the characteristics to be identified with regard to substrate-related natural conditions

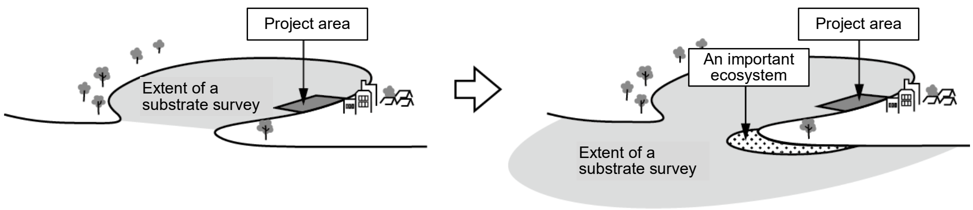
Classification	Examples of the characteristics to be identified
State of the water environment	To assess the state of water quality, the project proponent checks the items such as those shown below. Before examining these discrete items, however, it is important to assess a number of local characteristics to get a general picture of the entire body of water in question. These may include: (i) topographic conditions of the body of water, including its scale, location, elevation, closedness, and bed slope; (ii) general land use within the basin; (iii) limnological turnover; and (iv) the tidal reach of the river. (a) State of substrates No survey has been systematically conducted on the state of substrates at the national level. At the prefectural level, however, such survey has been conducted on some the highly-contaminated lakes. (b) State of the flow regime, etc. Streamflow, limnological turnover, and the state of waves and tidal currents in coastal waters are part of the most fundamental information regarding substrates. Their characteristics need to be accurately assessed in selecting Environmental Impact Assessment items and methods. Streamflow may have been already studied in a water quality survey. As for major rivers in Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) conducts discharge observations. Attention should be paid to the fact that required discharge data may be data on high water discharge or low water discharge depending on the purpose of the survey. As for coastal waters, the Hydrographic and Oceanographic Department of the Japan Coast Guard releases tidal current observations. (c) State of the material circulation The project proponent will locate the spaces that play an important role in the material circulation, such as tidelands and seaweed beds, which have water purifying functions, as well as wetlands and lakes, which has the water detaining function.
Topography and geology	The project proponent will identify topographic and geologic features that may affect substrates.
Population or growth of flora and fauna, vegetation, and ecosystems	Substrates constitute an important basis for ecosystems. If changes in substrates may affect the wider ecosystem in the phase of selecting study items and the survey, forecast, and evaluation methods for Environmental Impact Assessment, that ecosystem as a whole needs to be considered in defining the extent and method of the survey. Studying ecosystems requires a perspective different from a perspective of an Environmental Impact Assessment that focuses solely on substrates; for example, dissolved oxygen in the bottom layer plays an important part.  **An example of expanding the extent of a substrate survey from ecosystem factors only**
Landscapes and spaces for citizens to enjoy contact with nature	Changes in substrates may be a contributing factor. This can happen in, for example, an area where substrates may be affected if it has a waterside landscape resource or a space for enjoying contact with nature, such as a space for waterfront observation or sea bathing that takes advantage of a body of water. In such cases, the project proponent should consider the interrelationship between the substrates and the landscapes or the space for enjoying contact with nature in defining the extent and method of the survey.

Table III.1.6-4 Examples of the characteristics to be identified with regard to the social conditions regarding substrates

Classification	Examples of the characteristics to be identified
Population and industry	(a) Population Check the population of the survey area and its distribution. (b) Industry The project proponent will identify the industries in the survey area that provide the sources of substrate contamination, etc., including their general facts and figures and the location of their major facilities. The proponent will also locate the major facilities of any industry that is deemed vulnerable to changes in substrates. e.g., fisheries, recreational fishing grounds, aquaculture farms
Land use	(a) Land use Assess land use mainly with land use maps. The water environment is significantly affected by land cover of the basin of the body of water in question. The project proponent will work to assess not only land use by using land use maps but also land cover by using the available information such as vegetation maps and aerial photographs and conducting a field survey. This is because the discharge of sediment, sludge, and effluent associated with large site preparation work may be expected as a temporary contamination source. To predict long-term environmental impacts, the project proponent should understand the future directions of land use by analyzing the land use zoning of the survey area and the comprehensive plan of the local government chiefly with the help of relevant urban planning maps. If permanent alternations to the body of water are expected as in the case of a land reclamation project, the project proponent must get a firm grip on the future plan of such a project by, for example, studying the developments in relevant port and harbor plans. (b) Usage of rivers, lakes, and coastal waters The project proponent will study the usage of the body of water, including recreational uses, fishing rights, and water withdrawals. As such recreational uses may not be fully identified with the research of the available information alone, the project proponent should preferably conduct a field survey and/or an interview survey at the same time. (c) Man-made structures The project proponent will assess the state of man-made structures (bridge piers, weirs, reclaimed land, etc.) that affect substrates or the flow regime based on topographic maps and field surveys. In particular, the location, structure, etc. of river structures in the riverine area should be fully studied.
Features/facilities deemed vulnerable	In addition to the spatial assessment of land use, the project proponent will take stock of the distribution of facilities considered vulnerable to changes in substrates.
Zoning, regulations, etc. by law	The project proponent will identify environmental standards, regulatory standards, target values, and relevant zoning, etc. under applicable laws and regulations. • Act on Special Measures against Dioxins • Provisional standards for substrate removal • Criteria for bottom sediment • Pollution control ordinances, ordinances on the conservation of the living environment, etc. of local governments • Environmental master plans, etc. of local governments

3) Selecting environmental impact assessment items

(1) Arranging impact factors

Impact factors for substrates may include the implementation of dredging or excavation to remove contaminated substrates, the use of weirs, and the resultant growth of water surface areas.

(2) Arranging environmental elements

Generally, the environmental elements regarding substrate contamination include substances for which regulatory standards, etc. are established in laws and regulations as shown in Table III.1.6-5. Attention should be paid, however, to substances that have recently be recognized as being hazardous as well as to substances that are not subject to regulation by law but of much interest to local communities.

Substrates provides as an essential habitat for benthos. When considering biodiversity, the project proponent will identify the environmental elements for assessment by using the available information for reference.

Table III.1.6-5 Major substrate contaminants

Classification of substances	Major substrate contaminants
Contaminants subject to environmental standards	Dioxins (polychlorinated dibenzofuran, polychlorodibenzo-p-dioxin, co-planar polychlorinated biphenyls)
Contaminants subject to the provisional standards for substrate removal	Mercury, PCB
Contaminants subject to the criteria for bottom sediment	Alkylmercury compounds, mercury or its compounds, cadmium or its compounds, lead or its compounds, organophosphorus compound, hexavalent chromium compounds, arsenic or its compounds, cyanogen compounds, polychlorinated biphenyl, copper or its compounds, zinc or its compounds, fluorides, trichloroethylene, tetrachloroethylene, beryllium or its compounds, chromium or its compounds, nickel or its compounds, vanadium or its compounds, organochlorine compounds set forth in item 24 of Appended Table 3-3 of the Enforcement Order of the Waste Management and Public Cleansing Act, dichloromethane, carbon tetrachloride, 1,2-dichloroethane, 1,1-dichloroethene, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,3-dichloropropene, thiuram, simazine, thiobencarb, benzene, selenium or its compounds, 1,4-dioxane

(3) Selecting environmental impact assessment items

The project proponent will select the items to be studied in an environmental impact assessment (EIA) in relation to impact factors and environmental elements.

(Points to note) Importance of environmental monitoring of water quality

A variable may not be selected as an Environmental Impact Assessment item (i) if it is clear that the extent of the environmental impact is non-existent or negligible as far as that variable is concerned, or (ii) if it is clear that there will be no areas or other features/facilities subject to environmental impacts regarding that variable in or around the project area for a significant period of time. In that case, the information that serves as the grounds on which the above decision is made needs to be expressed in the section entitled "Specifics of the Proposed Project" or "Overview of the Area."

The phase in "areas or other features/facilities subject to environmental impacts" in clause (ii) above refers primarily to areas involving the human living environment or areas where a natural environment exists that is affected by changes in substrates. Given the continuity of a body of water, clause (ii) is inconceivable in reality.

4) Selection of survey, forecast and evaluation methods

(1) Approaches to method selection

Substrates serve as a medium of accumulation and dissolution of substances, etc. related to water contamination; they constitute an essential element of the water environment. At the same time, substrates provide a habitat for benthos and other organisms. It is desirable to look at all the selected items concerned and, on that basis, identify the survey, forecast, and evaluation methods, rather than considering the interrelationships between the selected items.

The survey, forecast, and evaluation methods vary significantly depending on whether, for example, Environmental Impact Assessment focuses on the impact of the stir-up of contaminated substrates by dredging or excavation or on changes in substrates associated with changes in the flow regime. It is therefore necessary to clarify what the Environmental Impact Assessment will address and how before selecting the survey and forecast methods.

(2) More detailed or simpler survey and forecast methods

A number of approaches can be taken to elaborate the methods of surveying and predicting substrates. These approaches may include (i) conducting a detailed field study to identify the conditions necessary for forecasts and environmental mitigation measures; and (ii) densely distributing survey locations and forecast locations. Approaches to simplifying survey and forecast methods may include (i) setting conditions necessary for forecast based on the available information; and (ii) adopting a method designed to predict the impact by comparing with past similar cases.

Criteria for adopting elaborated or simplified methods of survey and forecast may include the following:

(Examples when examining more detailed survey and forecast methods)

1. Where the extent of the environmental impact could be significant
2. Where there is an area or feature/facility vulnerable to environmental impacts
   - A body of water that tends to retain contaminants, for example, due to a high degree of closedness
   - A facility or area that requires special consideration regarding the protection of human health or the conservation of the living environment, for example, an intake point for drinking water
   - A body of water that is productive and of fishery value as it includes fishing grounds, aquaculture farms, seaweed beds, etc.

3. Where there is an area or feature/facility designated by a law or regulation in the context of environmental conservation
4. Where there is an area whose environment has already been, or could be, degraded significantly
5. Where local or project characteristics make forecast rather difficult when a standard method is used
   - An area that has a complex flow regime due to its topographic or other characteristics
6. Where there is something on which the local government and the project proponent place special value for environmental conservation
   - There is something that the local government and the project proponent deem important especially for environmental conservation in light of local characteristics, project characteristics, the environmental conservation policy for the project, and the like.

(Examples when examining simpler survey and forecast methods)
1. Where it is clear that the extent of the environmental impact will be small
   - If the project proponent can explain, based the project design, that the extent of the environmental impact will be small, he or she may make forecasts by quantifying the impact factors that provide such explanations.
2. Where the extent of the environmental impact can be clearly assessed based on similar cases
   - The project proponent may use the findings of past surveys for similar projects to estimate and forecast the extent of the impact.

1.6.2 Survey

1) Examination of survey items

Generally speaking, the project proponent will select survey items for substrates from the parameters that serve as indicators of organic contamination such as chemical oxygen demand (COD), sulfides and ignition loss as well as from the parameters concerning heavy metals and other hazardous substances. A substrate survey should monitor these parameters as they are generally intertwined with basic data that indicates the physical properties of substrates such as water content and granulometry.

The properties of substrates are important for the habitats of benthos and other organisms that live on the bottom sediment. Their activity in turn affects substrates. For these reasons, a substrate survey should preferably focus on these organisms and their activity as well. Tidelands areas are home to varied ecosystems centering on benthos. Through their food chain, these ecosystems help to purify the water and substrates. They provide information important for understanding a material circulation system centering on the bottom sediment.

Furthermore, the project proponent should also study the history of contamination as necessary. This is because heavy metals or other hazardous substances that were discharged in the past may have accumulated in substrates even though their sources no longer exist in the basin.

2) Concept of survey method

As in the case of water quality, the temporal and spatial variability of substrates is also caused by physical, chemical, and biological actions of the body of water. The temporal scale is larger for the variability of substrates, however. This is because they stand largely on the balance between the sedimentation of substances in the water and their dissolution into the water; the surplus in the balance accumulates on the bottom sediment. The temporal scale for substrates is largely limited to the surface layer (the habitat range for benthos and microorganisms) as far as the vertical dimension is concerned. Soil particles, which constitute the bottom sediment, range in specific gravity from clay minerals to organism-derived particles. These particles accumulate selectively depending on the flow characteristics of the body of water and show distinctive patterns of horizontal distribution.

As in the case of water quality, a substrate survey should be designed to accommodate the temporal and spatial scale of the body of water in question. Yet, it needs longer-term data because substrates entail a longer-term variability as discussed above. Such a longer-term variability is checked by extracting bottom sediment core samples with a core sampler. Spatial data collection should be focused on the surface layer of the bottom sediment in the vertical direction and a large area in the horizontal direction.

A substrate survey should be subject to a separate applicable manual if any. Such a manual may be available for dioxins, for example.

3) Concept of survey area and location

(1) Survey area

The project proponent will identify the survey area by estimating the balance of contaminants, the extent of diffusion thereof, the range of change in the flow regime, among other variables. In the process, attention should be paid to different aspects depending on the impact factor. These aspects may include (i) the natural conditions such as topography and geology and the current state of the water environment, (ii) local characteristics in terms of social conditions including land use, and (iii) the characteristics of the water contaminants to be surveyed.

(2) Survey locations

If coastal waters or a lake is surveyed, sampling points will be distributed on a uniform mesh (typically 200–300 m). Additional locations may be needed in places where the distribution of accumulated sludge is variable, such as the estuary.

If a river or waterway is surveyed, sampling points will be distributed in a uniform mesh (typically 50 m) for a wide channel or placed downstream where sludge tends to accumulate in an interval of several dozens of meters (typically 50 m). Additional locations may be needed depending on the conditions of the body of water.

4) Period and timing of the survey

A substrate survey should preferably be timed to coincide with a water quality survey if such a survey is conducted in the body of water in question. The period of a substrate survey should preferably include the summer, when substrates and water quality are most interrelated. In this particular season, nitrogen and phosphorus dissolve into the water, resulting from phytoplankton growth (an increase in organic substances due to internal production) and associated bottom-layer hypoxia.

1.6.3 Forecast

1) Basic approach to forecast

Substrates are affected largely when water contamination will likely be noticeable due to changes in the flow regime with a weir or any other structure or when there is a contaminated substrate in the body of water.

The forecast of substrate degradation associated with a flow regime change should be made together with the forecast of water quality. Depending on the situation, it may need to factor in the impact on benthos and other organisms. The forecast of the stir-up of a substrate contaminated by construction work may focus on whether hazardous substances included in that substrate will likely diffuse or not. An appropriate forecast method should be selected according to the object of assessment.

2) Concept of forecast method

It is generally understood that substrate contamination increases when contaminants in the water are deposited as water contamination increases. Also, the local sedimentation of contaminants may be likely when an area of stagnation appears in the flow due to the construction of a structure or reclaimed land in the body of water. In addition, contaminants may diffuse due to the stir-up of the substrate that was contaminated when a structure, etc. was constructed.

For these reasons, the project proponent will predict changes in substrates in view of (i) mitigation measures during the construction work for the proposed project and measures for effluent from facilities, and (ii) forecast results on changes in water quality and the variation in the flow in light of these measures. Specifically, the project proponent will predict the extent of change from the present conditions of substrates based on the extent of change in water quality and the flow. The proponent may as well calculate the amount of change in substrates based either on the amount of sedimentation in the material circulation in the water or on the balance between that amount and the amount of dissolution. In this case, consideration should also be given to the above-mentioned difference in time scale between water quality and substrate as well as to changes in substrates in the bottom sediment.

3) Concept of forecast area and location

The project proponent will identify the forecast area for substrates in light of the possible extent of the impact estimated from the project description as well as project characteristics and local characteristics. The identification process will take into account a number of factors, including the local topography and geology, the current state of the water environment, the balance of each contaminant estimated from the project description, the extent of diffusion, and the possible extent of area subject to changes in the flow regime.

4) Concept of forecast time

The typical forecast time will be the point in time when the extent of alteration of substrates due to the construction work is the largest. However, if the construction work is so extensive in area and leaves additional places vulnerable to its impact, forecasts may have to be made more than once in light of the location and timing of such work.

The forecast time for the impact of the existence of project-related facilities or structures shall be when their construction is completed; however, it shall be when outer revetment is completed before the completion of the main part of a land reclamation project.

1.6.4 Environmental mitigation measures

1) Procedure of designing mitigation measures

As far as substrates is concerned, it has been customary to devise a policy of environmental mitigation measures so that it will be aligned with the criteria and targets of environmental standards, etc. regarding substrates.

There are many environmental elements, however, that may be affected by changes in substrates; the water environment, including substrates, is also a component of the natural environment, which involves ecosystems and spaces for enjoying contact with nature, as well as of the ground environment. Therefore, it is also important to design environmental mitigation measures for the water environment as a whole. This process involves taking into account a number of factors, including (i) the state of water use in the body of water in question, (ii) the usage of the body of water itself, (iii) the state of the ecosystems and spaces for enjoying contact with nature, and (iv) the impacts on other environmental elements that may be related to substrates.

2) Specific environmental mitigation measures

Environmental mitigation measures for substrates include bottom sediment dredging and sand covering, major technologies designed to improve the substrate environment. The Environmental Impact Assessment process assumes that the project proponent tries to prevent and reduce the environmental impacts of the project to the extent feasible. The proponent shall do so primarily by taking measures designed to improve the substrate environment in the project area.

Table III.1.6-6 Some of the environmental improvement technologies that can serve as environmental mitigation measures for substrates

Classification	Title of environmental improvement technology	Effects of environmental improvement technologies	Points to note in application
Effective technologies	• Bottom sediment dredging	• Removing the bottom sediment that is unfavorable as a habitat of fish and shellfish will improve a large area of the substrate and reduce the dissolution of nutrient salts into the water.	• Space should be secured for disposing of the dredged sediment. • Attention should be paid to how long the effects will last in the face of the impacts of the loads. • Efforts should be made to prevent the generation and diffusion of turbidity during the construction work.
	• Sand covering	• Covering the bottom sediment that is unfavorable as a habitat of fish and shellfish with good-quality sand or other materials will improve the substrate and reduce the dissolution of nutrient salts into the water.	• Whether the water depth needed for using the water surface should be checked. • Attention should be paid to how long the effects will last in the face of the impacts of the loads. • Efforts should be made to prevent the generation and diffusion of turbidity during the construction work.
	• Sea-bottom cultivation	• Stirring up the sedimentation layer of the substrate that is unfavorable as a habitat of fish and shellfish will provide oxygen, thereby promoting the decomposition of organic substances and improving the substrate.	• Consideration should be given to the life history, etc. of local species in identifying the timing and location of implementation. • Attention should be paid to how long the effects will last in the face of the impacts of the loads. • Efforts should be made to prevent the generation and diffusion of turbidity during the construction work.

Source: Compiled from Center for Environmental Information Science, ed. *Kankyo Asesumento no Gijutu [environmental assessment techniques]*, 1999, Chuohoki Publishing.

1.6.5 Evaluation

The evaluation process concerns the prevention or reduction of environmental impacts. When the national government or the local government has standards or targets in its environmental prevention strategy for the selected items, the process also involves evaluating their alignment with these standards or objectives.

1) Evaluation relating to prevention or reduction

Evaluation on prevention or reduction is aimed at identifying and evaluating the efforts by the project proponent to prevent or reduce environmental impacts. Evaluation approaches include comparing several options for environmental mitigation measures, assessing whether feasible and better technologies are adopted, and evaluating whether efforts are made to avoid environmental degradation from the current state.

2) Evaluation relating to consistency with standards or objectives

Table III.1.6-7 shows examples of standards or objectives for substrates set by the national or local governments.

Table III.1.6-7 Examples of standards or objectives for substrates

National government	Monitoring standards in the Guidelines on the Treatment and Disposal of Substrates Provisional standards for substrate removal Environmental quality standards for water pollution (including substrate contamination) under the Act on Special Measures against Dioxins Criteria for bottom sediment
Local governments	Standards, etc. in pollution control ordinances, ordinances on the conservation of the living environment, etc. Standards and objectives in environmental master plans or environmental management plans

Evaluation of the alignment with the standards or objectives means evaluation of whether the implementation of the proposed project will be in line with the environmental preservation strategies of the national and local governments concerned. Accordingly, the project proponent should understand how the standards or targets he or she refers to fit in the environmental preservation strategies and then clarify which standards or targets to use for evaluation and why.

In comparing these standards or objectives with the forecast results, it is important to make an evaluation in terms of not only whether or not the forecast results meet the standards or objectives but also whether the extent of the impact of the proposed project could interference with environmental conservation in light of the standards and objectives.

1.6.6 Follow-up survey

Environmental Impact Assessment entails some uncertainty in its findings as it comes before project implementation. A follow-up survey is designed to offset such forecast uncertainty. It may be conducted if the uncertainty is significant or if the project proponent takes environmental mitigation measures whose effects are not well-established. The need to conduct a follow-up survey shall be assessed in light of the seriousness of the environmental impact. Depending on the results of such a survey, it may be necessary to modify the environmental mitigation measures or implement additional ones.

Clearly, a follow-up survey focuses on the project impacts on the extent of alteration of substrates and topographic changes, among other aspects. It should also study the state of water contaminant sources around the project area, as well as the social conditions at large, in order to check whether the forecast parameters for Environmental Impact Assessment are aligned with these aspects.

Likewise, it is desirable to make effective use of the available information from surveys conducted by entities other than the project proponent such as the national and local governments.

The points for a follow-up survey for substrates will center around the points deemed most vulnerable to the impact of the project as well as the points where forecast and assessment have been made in Environmental Impact Assessment.

1.7 Groundwater

1.7.1 Selection of environmental impact assessment items and survey, forecast and evaluation methods

1) Ascertaining project characteristics

Table III.1.7-1 shows examples of the project characteristics to be identified with regard to groundwater.

Table III.1.7-1 Examples of the project characteristics to be identified regarding groundwater

Impact factors	Examples of the characteristics to be identified
Implementation of construction	• Specifics and duration of construction • Location and extent of construction • Extent, method, depth of excavation • Type, extent, and depth of earth retaining work • Location and scale of borrowing pits and reception sites for construction-generated soil • Location, extent, and duration of auxiliary processes such as drainage work, pneumatic engineering, freezing work, and chemical grouting
Existence and use of facilities	• Specifics, location, and scale of facilities • In-service period of facilities • Location and depth of underground structure • Specifics, location, and scale of water pumping facilities • Specifics, location, and scale of drainage facilities • Specifics, location, and scale of groundwater recharging facilities • Changes in ground cover

2) Ascertaining local characteristics

(1) Area

The survey area of environmental impact assessment (EIA) is defined as "an area that includes the geographical extent where the state of the environment will change at least to a certain extent with the implementation of the proposed project or the extent where the environment is subject to direct alteration and its surrounding area, etc." in the Basic Matters under the Environmental Impact Assessment Act. To capture the groundwater flow at a regional level, it is primarily necessary to focus on the groundwater basin and identify the recharge area and the discharge area in the hydrologic cycle. In doing so, it should be kept in mind that the inland basin may not geographically correspond to the groundwater basin. Further, the groundwater flow is classified by geographical extent into the regional system, local system, and the intermediate system in between.

Defining the survey area for identifying local characteristics with regard to groundwater requires fully studying the project characteristics, the natural and social environments surrounding the proposed project and accurately deciding which groundwater flow system is subject to the project impact. Table III.1.7-2 shows the recommended scale and accuracy of the base map used in a groundwater survey.

Table III.1.7-3 shows the standard horizontal extent of a groundwater survey for excavation projects. Table III.1.7-4 shows the standard extent of a groundwater environmental survey for an excavation project that focuses on unconfined groundwater in the shallow layer (up to approx. 10 m deep underground) on a plain. Attention should be paid to the varying extent of the survey area by type of soil or stratigraphy.

Table III.1.7-2 Scale and accuracy of the base map that correspond to the size of the groundwater survey area

Classification of flow system	Size of survey area	Base map's scale, accuracy, and availability
Regional ↑	National or regional	1:200,000 regional maps (GIS)
	Prefectural or basin level	1:50,000 - 1:25,000 topographic maps (GIS)
(Intermediate)	Municipal or tributary/distributary level	1/25,000 topographic maps (GSI) - 1/10,000 forest base maps (Forest base maps are available for forest areas only.)
	Cities and their surroundings	1/10,000 topographic maps (GSI) (available for urban areas only)
↓ Local	Specific small areas	1/2,500 - 1/5,000 scheme drawings of various kinds Produced by local governments, etc.

Source: Compiled from Japan Institute of Country-ology and Engineering (JICE), *Chikasui Chosa oyobi Kansoku Shishin (An) [guidelines on groundwater survey and observation (draft)]*, 1993.

Table III.1.7-3 Standard extent of a groundwater survey associated with underground excavation

Soil	Extent of a survey*
Sand and pebble ground	1,000–1,500 m
Sand ground	500–1,000 m
Cohesive soil ground	100–500 m

* The extent of a survey denotes the distance from the periphery of the excavation site.

Source: Compiled from Japan Institute of Country-ology and Engineering (JICE), *Chikasui Chosa oyobi Kansoku Shishin (An) [guidelines on groundwater survey and observation (draft)]*, 1993.

Table III.1.7-4 Standard extent of a survey of unconfined groundwater associated with underground excavation in the shallow layer in Tokyo prefecture

Survey area* / Stratigraphy	Area of detailed survey**	Areas of rough survey***
Stratigraphy equivalent to the Kanto loam formation	100–150 m or less	200–300 m or less
Stratigraphy equivalent to the sand gravel layer	150–300 m or less	300–500 m or less

* The extent of a survey means the distance from the periphery of the excavation site.
** Detailed survey involves the measurement of water levels in all the existing wells, plus water examination as necessary.
*** Rough survey involves the measurement of water levels in open wells, plus water examination as necessary.

Source: Bureau of Construction, Tokyo Metropolitan Government, (2012) *Koji ni Tomonau Kankyo Chosa Hyojun Shiyosho oyobi Kankyo Chosa Yoryo [standard specifications of environmental surveys and environmental survey guidelines associated with construction work]*, Tokyoto Kosaikai, 2012.

(2) Identifying local natural and social conditions

Tables III.1.7-5 and III.1.7-6 show examples of the characteristics to be identified with regard to the local natural and social conditions.

Of the survey locations for groundwater level and quality for which data is gathered from existing materials, those where a significant decrease or increase in water level is currently observed and those where the groundwater quality exceeds the standards should be studied in a field survey to get a grip on the adjacent groundwater use facilities and the state of the contamination sources in and around the project area.

(Points to note) Field survey for identifying local characteristics

A field survey is important for two reasons. First, it helps to confirm and correct the local data gained by collating existing materials and fill the information gap. Second, it helps to get the overall picture of the environmental quality and local characteristics of the area in question. Through a field survey, well-experienced engineers should find clues to identifying the survey items and methods of survey, forecast, and evaluation for Environmental Impact Assessment.

As far as groundwater is concerned, it is often difficult to get a general picture of the local characteristics only by researching existing materials compared with other environmental elements. It may therefore be necessary to consider conducting hydrogeological survey or more detailed field study.

Table III.1.7-5 (1) Examples of the characteristics to be identified with regard to natural conditions regarding groundwater

Classification	Examples of the characteristics to be identified
State of the atmospheric environment	(a) Precipitation It is necessary to gather and organize existing materials on precipitation, an important element in analyzing a hydrologic cycle system. (b) Evapotranspiration Direct measurement data of evapotranspiration is quite limited. The typical approach to estimating evapotranspiration is usually estimated from meteorological data using the Thornthwaite method or the Penman method. These methods are designed to estimate potential evapotranspiration (theoretical evapotranspiration that would be lost on a lawn that is provided with sufficient water). Because the actual evapotranspiration is less than potential evapotranspiration, caution is needed in such estimation. The following meteorological data is required for the Thornthwaite and Penman methods: • Thornthwaite method: monthly mean air temperature • Penman method: air temperature, air humidity, the percentage of sunshine, wind velocity, water vapor pressure
State of the water environment	(a) State of groundwater • Properties of groundwater Groundwater is classified by the state of stratigraphic gaps into pore water,* fissure water,** and cavern water.*** It is also divided into unconfined groundwater****(a.k.a. “free groundwater”) and confined groundwater**** according to the presence or absence of pressure. Any groundwater survey should decide which type the groundwater of interest is classified into. The project proponent will confirm the properties of groundwater in the area in question from one or more of the sources that include boring surveys that were conducted by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and local governments; actual measurements at existing wells; and inquiries to well administrators or drillers.

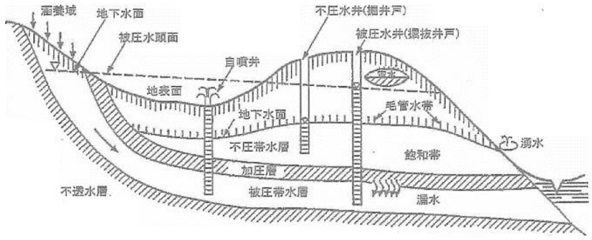
* Pore water: Groundwater in pores between grains that makes up the stratigraphy

** Fissure water: Groundwater in joints and cracks of rock or in pores in the fracture zone

*** Cavern water: Groundwater in cavities in limestone, lava, etc.

****Confined and unconfined groundwater: *Confined groundwater* exists below the confining bed made up of aquicludes and impermeable layers and has a pressure higher than the atmospheric pressure. For instance, a well drilled in a location where the hydraulic head (the height of the water column at a given point in place supported by the hydrostatic pressure) is higher than the ground surface is what is called “artesian well.” *Unconfined groundwater*, on the other hand, does not have a confining bed above it and below the ground surface; its pressure is essentially in equilibrium with the atmospheric pressure. It should be remembered, however, that these two types of groundwater are not always two discrete categories, making the distinction between them unclear sometimes. Confined groundwater in the figure below, for example, becomes unconfined groundwater at its recharge area (near the far left in the figure), where its pressure is in equilibrium with the atmospheric pressure. Its boundary with confined groundwater varies according to changes in groundwater recharge.

In the context of environmental impact assessment (EIA) for groundwater, it should be remembered that what is originally confined groundwater changes to unconfined groundwater (“unconfining of confined groundwater”), which in turn can affect groundwater use. This may happen, for example, when a site preparation project in a recharge area may reduce groundwater recharge.



Schematic diagram of confined and unconfined groundwater

Source: Soki, Yamamoto, *Chikasuigaku Yogo Jiten* [glossary of geohydrology], 1986, Kokon Shoin.

Table III.1.7-5 (2) Examples of the characteristics to be identified with regard to natural conditions regarding groundwater

Classification	Examples of the characteristics to be identified
State of the water environment	• Groundwater level and flow Across the country, groundwater levels are monitored by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the Ministry of Agriculture, Forestry and Fisheries, the Ministry of Economy, Trade and Industry (METI), and local governments. Such monitoring data, however are rarely organized into time series data and published regularly. Although the Tokyo Metropolitan Government monitors groundwater levels as well as ground subsidence and regularly publish such data in annual reports, the monitoring points and layers are limited in number. Japan is known for its substantial use of groundwater; for example, well water is still used for domestic purposes in suburban and rural areas. Data on groundwater levels and their distribution can be gathered by looking at the actual usage of groundwater in the country. Organizing data thus gathered, including the past and latest past by type of aquifer* makes it possible to know the current state of the groundwater recharge and flow and their changes over time. • Groundwater basin In light of such groundwater data as mentioned above and the local topography and geology, the project proponent will roughly define the extent of the groundwater basin and decide whether the project area is located in a groundwater recharge or discharge area in that basin within the hydrologic cycle system. • Groundwater quality Since fiscal 1989, groundwater quality has been monitored by the national and local governments under the Water Pollution Prevention Act. Such monitoring data are regularly published as “results of the nationwide water quality survey of public water areas.” Because the monitored well vary from year to year, these results do not indicate changes at a given point in place over time; they lend themselves to keep track of groundwater quality at the regional level. Other existing materials include MILT, gen. ed. Chikasui Suishitsu Nenpyo [chronological tables on groundwater quality]. It should be used carefully as its monitoring parameters and presentation method are not necessarily unified. In addition, academic journals include numeral reports on groundwater quality. However, only a few of these reports are based on stationary monitoring; most of them are based on one-time survey or a series of up to five surveys. Yet they can be useful as data that complements the results of above-mentioned surveys. (b) Springs Some of the conditions of springs (properties, quantities, and water quality) may be monitored by local governments’ sections responsible for environmental preservation and river administration and published as annual reports. Fact-finding inquires to local governments, nature preservation groups, and local communities can be a useful source of information as some springs have traditionally been a source of domestic or agricultural water for local communities. They may be also the source of local place names or minor rivers. The project proponent should preferably conduct a field survey based on the information obtained to better assess the current state of affairs; some springs have shrunk or dried up due to recent urbanization. (c) Rivers To assess rivers, the project proponent will locate them on a topographic map and gather and organize information on their discharge, basins, and underflow water as well as water withdrawals from them that are monitored by MLIT or the local governments concerned.
State of soil and ground	(a) Soil As soil plays an important role in the unsaturated zone in terms of groundwater assessment, the project proponent should preferably take stock of its characteristics and distribution. Survey results on biodiversity parameters and aerial photos will be used to assess vegetation on the ground surface. (b) Infiltration capacity As there is no extensive or comprehensive data on infiltration capacity available, the project proponent will assess infiltration capacity and its distribution based on the type of soil and its infiltration characteristics of each type.

* Aquifer: A porous stratum in which water and other fluids flow easily.

Table III.1.7-5 (3) Examples of the characteristics to be identified with regard to natural conditions regarding groundwater

Classification	Examples of the characteristics to be identified
Topography and geology	Existing materials on topography include regional and topographic maps, land classification maps, and land condition maps on a scale of 1:200,000 to 1:2,500 available from the Geospatial Information Authority of Japan (GSI) and other institutions. The project proponent should gather information according to the topography and geology of the survey area as well as the description and scale of the project and associated construction work. Aerial photos provide a powerful source of information for areas on which there is little available information in such forms as landform classification map or hydrogeological map; they make it possible to read local vegetation, land use, subtle relief, and lineaments.* Another useful source of information is MLIT's LP data (laser profiler data or 3-D topographic data based on aerial laser surveying).
Population or growth of flora and fauna, vegetation, and ecosystems	The impact on groundwater may in turn affect local flora, fauna, or ecosystems if the area with such impact includes a habitat of a precious animal or plant, or a marsh, spring or any other important element of the natural environment. In this case, the project proponent should remember that the impact on flora or fauna includes both withering due to a lower groundwater level and inundation due to a higher groundwater level. If such secondary impact on flora, fauna, or ecosystems is deemed possible, changes in groundwater (in terms of water level and quality) should be taken into account as a condition for forecasting such impact.
Landscapes and activities for enjoying contact with nature	The impact on groundwater may affect landscapes as well as activities for enjoying contact with nature. This can happen if the area prone to the impact of groundwater includes any landscape resource or major space for enjoying contact with nature such as a groundwater-fed spring, river or marsh. In such cases, the project proponent should consider the interrelationship between groundwater and the landscapes or the activities for enjoying contact with nature in defining the extent and method of the survey.

* Lineaments: Topographic linear features such as ridges and valleys.

Table III.1.7-6 Examples of the characteristics to be identified with regard to the social conditions regarding groundwater

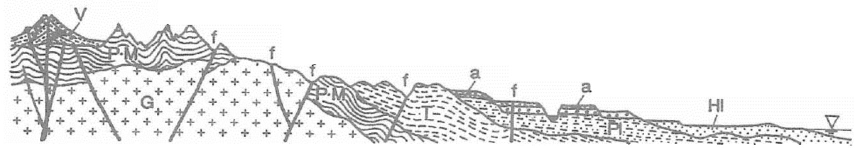
Classification	Examples of the characteristics to be identified
Population and industry	(a) Population Check the population of the survey area and its distribution. (b) Industry The project proponent will assess the state of the industries in the survey area that could affect groundwater level and quality, including their general facts and figures and the location of their major facilities. The proponent will also locate the major facilities of any industry that is deemed vulnerable to changes in groundwater level and quality.
Land use	(a) Land use The project proponent will assess land use mainly with land use maps. As necessary, the proponent will also use vegetation maps, aerial photographs, and other existing materials and even conduct a field survey. (b) Land use zoning Describe the land use zoning of the survey area chiefly with the help of relevant urban planning maps. Forecasting long-term environmental impacts requires forecasting the future directions of land use by reviewing the comprehensive plan of the local government concerned. (c) Ground cover Local ground cover is assessed by describing land use patterns (classification by urban function, types of agricultural land, types of forests, and waterbody and water use facilities) based on various information published by the Geospatial Information Authority of Japan (GSI), prefectural governments, MLIT, and the Cabinet Office, including land use maps, land use status maps, land classification maps, aerial photos, water use maps, and urban planning maps. A field survey may be necessary as well. (d) Underground structures Assess huge underground structures that affect groundwater behavior such as tunnels, subways, (group of) buildings with huge basements, and dams. Specifically, identify the location of such structures, if any, with topographic maps, urban planning map, and other existing materials. As necessary, confirm their structure, scale and other properties by inquiring the administrators of such structures.
Groundwater usage	Obtain the statistics on the quantities of groundwater by type of use, including tap water, agricultural water, and industrial water. Locate the major points in place for the use of the existing wells (for domestic, industrial, and agricultural uses), thermal wells, and springs. Identify the location of, and the consumption at, related facilities. The sources of information that is available for public perusal or purchase on the distribution of existing wells and other groundwater use facilities, facility scale, water withdrawal capacity, the depth of use (the aquifer for abstraction), and the track record of water pumping include Chikasui Yosuiryo Jittai Chosa [groundwater pumpage survey] (the Ministry of the Environment), Zenkoku Chikasui (Fukaido) Shiryo Daicho [national groundwater (deep well) register] (MLIT), the Census of Manufacturers (METI), the Statistics on Water Supply and Zenkoku Suido Shisetsu Chosho [national record on water supply facilities] (the Ministry of Health, Labour and Welfare), as well as reports under prefectural government ordinances. Records of household wells are maintained by some local governments or public health centers in a well register; however, it is not accessible to the public as it concerns private properties. To find out the location and structural scale of thermal wells, make inquiry of the nearest public health center or the prefectural government's section responsible for natural environmental preservation. Information on facilities that use groundwater or a spring for the source of tap water can be obtained from the register of groundwater abstractions for tap water, which is maintained by the water supply management bureau of each prefectural government. This register provides information on water supply coverage and the types of source water (groundwater and surface water).
Objects deemed vulnerable	In addition to the spatial assessment of land use, the project proponent will take stock of the distribution and arrangement of facilities, etc. considered vulnerable to changes in groundwater level or quality.

(Points to note) Local characteristics regarding groundwater

Of particular importance are local characteristics such as *topography and geology*, which determine the groundwater storage and flow, and *precipitation and evapotranspiration*, which recharge groundwater.

For example, *topography and geology* is an essential determining factor of the "vessel" of groundwater and surface water. Groundwater storage and flow vary by type of land, such as alluvial lowland, diluvial upland, hilly land, or mountainous land (see Figure III.1.7-1 and Table III.1.7-7). The determining factors of groundwater storage and flow include the pitch and permeability of the strata, bedrock cracks, and the geological structure. *Precipitation and evapotranspiration* are the starting point for assessing groundwater flow; they also influence seasonal variability, one of the important features of the hydrologic cycle. They provide an essential piece of information for examining what are known as "wet season" and "dry season."

As described above, *topography and geology* and *precipitation and evapotranspiration* should be fully considered as they are essential pieces of information in all the processes of Environmental Impact Assessment for groundwater, that is, survey, forecast, and evaluation.

Five major topographic types on a middle scale						
	Schematic cross section of topography and geology (in the case of Japan)					
	Name	Volcano	Mountainous land (in a narrow sense)	Hilly land	Terrace land (low-lying plateau)	Lowland
Morphological characteristics		A symmetrical elevation or round hollow with the crater (crest) at its center. The original shape was smoother than mountainous land.	A large rugged terrain with a relative height of 300 m or more between the main ridges and valley floors. Mostly steeply sloped with an angle of 30 degree or more with little flat land.	An area lower than the adjacent mountainous land with its main ridges being of similar elevation. The relative height between the main ridges and valley floors is less than 300 m.	A flat elevated land a step higher than lowland, surrounded with scarps or bordering on a scarp on one side. The flat land will not be submerged in a 100-year flood or storm surge.	A low flat land along a river or shoreline that will be submerged in a 100-year flood or storm surge without a man-made levee or dike. Sand dunes and coral reefs are classified as lowland.
Geomorphic species makeup		Various types of volcanic body, volcanic original surface, lava flow field, pyroclastic flow field, hilly land formed with a volcanic detritus flow, piedmont alluvial fan, crater, caldera, etc.	Ridges, valleys, topography of previous cycle (summit flat surface, low-relief surface), landslide/landslip landform, taluses, alluvial cones, fault topography, etc. The valley floors are narrow, with the fragmented formation of valley lowland.	Almost the same as mountainous land. It is characterized, however, by the continuous formation of terrace land or valley lowland on the valley floors. Gently sloping land, rather than steeply sloping land, dominates.	It is often characterized by a series of terraces (treads and scarps). Treads are separated by large and small hollows.	Alluvial fans, meander plains, deltas, tidelands, riverbeds, natural levees, low hinterland, beach ridges, sand dunes, inter-levee lowland, former lagoons, wave-eroded terraces, former watercourses, dammed-up tributary floors, etc.
Main geomorphic agents and processes		Emplacement, explosion, etc. of volcanic ejecta due to volcanic activity. Denudation processes in general.	It is uplifted by diastrophism and denuded by landslides, landslip, rivers, and glaciers.	The same as mountainous land.	Formed by lowland emergence due to ground uplift or sea level fall.	Land made flat by sedimentation and erosion involving rivers, sea, and wind. Also formed by coral growth or peat sedimentation.
Main landform materials (rock just under the ground surface)		Quaternary lava, pyroclastic rocks	Hard rock (pre-Quaternary rocks as well as volcanic/plutonic rock, hypabyssal rock, and metamorphic rock) dominates.	Soft rock (Neogene and Quaternary sedimentary rocks) dominates.	Unconsolidated terrace deposits, pyroclastic fall	Unconsolidated deposits (Holocene), coral rag
Landform materials problematic in terms of topological disasters and earth work		Unconsolidated pyroclastic material, solfataric clay. For the rest, the same as mountainous land.	Fracture zone, weathered rock, talus accumulation, serpentinite, shale.	The same as mountainous land.	Thick terrace deposits; for terrace scarps, the same as mountainous land.	Soft ground (thick clay/peat layers), medium sand layer of high water content
Age of formation of basic morphology		The Quaternary Active volcanos are mostly after around 10,000 years ago.	From the end of the Tertiary to the Pleistocene in the Quaternary (up to several million years ago)	From the end of the Tertiary to the Pleistocene in the Quaternary (after several million years ago)	From the Pleistocene to the Holocene in the Quaternary (after several hundred thousand years ago)	The Holocene in the Quaternary (after around 10,000 years ago)
Likely natural disasters		Eruptions and ash falls for active volcanos. For old volcanos, the same as mountainous land.	Landslides, landslip (rockslides), debris flows, flash floods, avalanches	The same as mountainous land. Cave-ins and subsidence in mining areas.	Relatively rare on treads. For scarps, the same as mountainous land.	Floods, inundation inside levee, storm surges, tsunamis, sand drift, and ground subsidence, as well as sand liquefaction in times of earthquakes
State of groundwater		The same as mountainous land except for abundant and good-quality springs in the piedmont and harmful water near the crater and fumaroles.	Fissure water and cayern water only; groundwater is deep down and scarce. High-pressure groundwater inside mountainous land.	The same as mountainous land. Yet, confined groundwater exists but is small in quantity.	The same as hilly land, except for perched groundwater in a few cases.	Largely free groundwater; confined groundwater in a few cases. Shallow and abundant except in alluvial fans and slight elevations. Brackish water along the shore.
Main agricultural land uses		The same as mountainous land.	Natural forests, plantation forests, grassland, waste land (bare rock land)	Plantation forests, grassland, orchards, tea gardens, mulberry fields, ordinary upland field	The same as hilly land except for irrigated rice paddy fields on treads	The same as hilly land for slight elevations. Rice paddy fields, fish farms, etc. in flat land.

V: volcanic ejecta; P-M: Paleozoic-Mesozoic; G: plutonic rocks; T: Tertiary; Pl: Pleistocene (diluvium); Hl: Holocene (alluvium); f: fault; a: volcanic ash layer

Source: Takasuke, Suzuki, *Introduction to Map Reading for Civil Engineers volume 1: Geomorphological Basis for Map Reading [in Japanese]*, 1997, Kokon Shoin.

Figure III.1.7-1 Five major topographic types and their features

Table III.1.7-7 Hydrogeological characteristics by topographic type and points to note for groundwater storage and flow

Topographic classification	Hydrogeological characteristics	Points to note for groundwater storage and flow
Volcano	• Often characterized by irregular, heterogeneous, and alternating strata of relatively hard pyroclastic rocks and soft or unconsolidated pyroclastic flow deposits. • Generally permeable. Surface water is scarce. Groundwater levels are often low. • Springs of abundant confined groundwater are often found on the piedmont fringe, etc.	• If the mountain body is permeable, the boundary of the hydrologic cycle system does not match the topographic divide. • Groundwater may flow along the former topography that has been buried under pyroclastic flow deposits. • Attention should be spring catchments on the piedmont fringe.
Mountainous land	• Largely made up of relatively hard bedrock. Groundwater generally flows along fracture zones and cracks. • Other elements of the hydrologic cycle include colluvium in the surface layer, shallow groundwater and soil water in the superficial weathered zone.	• Groundwater flow is determined by the geological structure, especially faults and the distribution of cracks; therefore, the boundary of the hydrologic cycle system does not necessarily match the topographic divide. • In volcanic rock areas and limestone areas in particular, structure factors determine groundwater flow. • The relationship between shallow groundwater or surface water and deep groundwater significantly varies depending on the geological structure and the positional relationship of the overburden.
Hilly land	• Largely made up of unconsolidated sedimentation layers of the period from the Neogene to the Quaternary. Groundwater flow is determined by stratigraphic permeability and distribution. • Groundwater is largely recharged by ground surface percolation or surface water. Residual soil layers serve as an important aquifer.	• On its fringe, groundwater continues into the neighboring mountainous land, low-lying plateau, and lowland. • Volcanic hilly land is often characterized by the motley accumulation of relatively hard volcanic rocks and unconsolidated volcanic ash, making groundwater storage and flow complex.
Low-lying plateau	• Largely made up of unconsolidated sedimentation layers of the period from the Quaternary to Neogene. Surrounding by scarps, it is shaped more like a block. • Groundwater is largely recharged by precipitation on the plateau surface; it is independent from the surroundings. • Groundwater flow in the plateau is determined by the stratigraphic distribution and permeability. • The groundwater table is generally low; however, groundwater may flow out as a spring on the scarp line on the plateau fringe.	• Groundwater recharge from mountainous land and hilly land should also be considered toward its boundary with these types of land. • Groundwater flow is influenced not only by ground surface topography and aquifer distribution but also by the surface shape of the aquiclude basement. • Groundwater may continue into the lowland zone depending on the distribution depth of the aquiclude basement. • Due to the discontinuous aquiclude distribution, perched groundwater may occur locally, showing a behavior different from that of the groundwater below.
(Alluvial fans)	• Largely made up of deposits from mountainous rivers, with significant lateral transition. • In the head and center of the fan, groundwater levels are low and the river flows underground. At the fan end, on the other hand, groundwater levels are high and confined groundwater may spring.	• Groundwater is intertwined with mountainous rivers. • In particular, it flows along the former river bed as underflow water in the head and center of the fan.
Lowland	• The groundwater is largely unconfined or confined groundwater that flows mainly in the alluvium (partly in the diluvium). • The groundwater is largely recharged by ground surface percolation and the underflow and percolation of surface water. • Along rivers, stratigraphic properties vary by microtopographic classification such as natural levees and former river beds, which constitutes a determining factor of groundwater flow. • Often developed as a built-up area. The hydrologic cycle system may have been altered by the existing use of groundwater use or changes in land use patterns over time.	• Due to an unclear topographic divide, the classification of the hydrologic cycle system remains unclear as well. • Along rivers, attention should be given to groundwater flow along the former river bed. • In addition to primary impacts such as changes in groundwater level, special attention should be given to secondary impacts such as ground subsidence and ground surface change. • Attention should also be paid to changes that have already occurred in the hydrologic cycle system as well as to its relationship with the project impact. • Along the coast, brackish water intrusion may occur resulting from changes in the balance between the inflow and the outflow in the hydrologic cycle system.

(Points to note) Regional variation in precipitation and evapotranspiration

Precipitation and evapotranspiration vary from region to region; they depend on the climatic characteristics of different regions in Japan, including the Pacific coast, the Japan Sea coast, inland areas, Northeast Japan, and Southwest Japan.

Precipitation observation data is open to the public and available from the Japan Meteorological Agency, MLIT, prefectural governments, and other entities. Attention should be given to topographic effects and altitude characteristics as well as to how to handle snow accumulation in snowy regions. Observation data on evapotranspiration, on the other hand, is quite scarce. It is thus necessary to estimate potential evapotranspiration (theoretical evapotranspiration that would be lost on a lawn that is provided with sufficient water) by applying the Thornthwaite method or the Penman method. It should be noted, however, that the actual evapotranspiration is less than potential evapotranspiration. Attention should also be given to different characteristics of different estimation methods.

Figure III.1.7-2 shows examples of differences between evapotranspiration and effective precipitation by region. High precipitation is observed in Akita and Toyama, which have much snow in the winter as well as in Fukuoka, which has much rain in the summer. Because there is little regional variation in potential evapotranspiration that is estimated from monthly mean air temperature using the Thornthwaite method, effective precipitation that is thought to percolate underground without evapotranspiration is high in areas with much precipitation including snowfall.

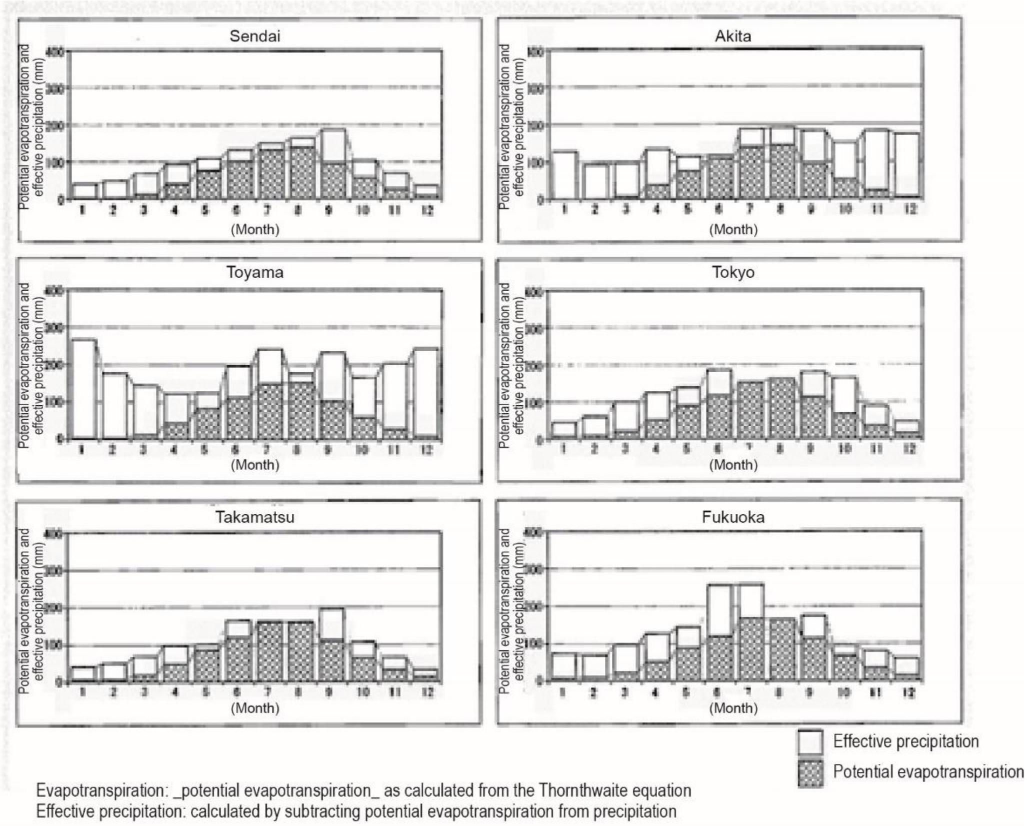


Figure III.1.7-2 Examples of differences between evapotranspiration and effective precipitation by region

3) Selecting environmental impact assessment items

(1) Arranging impact factors

Table III.1.7-8 shows some of the project's potential impact factors for groundwater.

Table III.1.7-9 shows typical types of construction work that can affect groundwater behavior.

It should be kept always in mind that the impact manifests itself in various ways depending on where these impact factors occur in the hydrologic cycle system.

Table III.1.7-8 Impact Factors and Some of Their Impacts on Groundwater

Impact factors			Some of the impacts on groundwater
During construction work	Earthwork such as excavation	Use of soil stabilizers	Water quality change and groundwater contamination due to the effluence of soil stabilizers
		Discharge of groundwater	Groundwater subsidence
	Installation of temporary structures	Work to install construction equipment	Groundwater flow interruption
Existence and use	Topographic alternation	Existence of reclaimed land	Groundwater flow interruption, salination
	Existence of structures	Existence of tunnels, depressed structures, levees, dikes, breakwaters, bridges (bridge piers), etc.	Groundwater flow interruption due to seepage control
		Existence of dam bodies	Groundwater elevation in the region upstream from a dam body and groundwater subsidence in the region downstream, changes in the hydrologic cycle due to changes in discharge, changes in groundwater temperature
		Existence of ground structures	An increase in the rainfall impervious area, a decrease in the water production capacity
	Operation of facilities	Use of diversion channels	Changes in groundwater quality
		Water intake and discharge by a hydraulic power station	Changes in the water balance in the river system
		The intake of geothermal fluids and the reinjection of thermal water at geothermal power plant	Adjacent groundwater subsidence and changes in groundwater flow due to the withdrawal of thermal water vapor; groundwater flow change due to water reinjection; impacts on hot springs
		Operating activities at factories and other places of business	Groundwater subsidence due to water pumping; water quality change and groundwater contamination due to the effluence of sewage, etc.
	Waste disposal	Landfilling (final disposal)	Water quality change and groundwater contamination due to the discharge of leachate
	Farmland development and recreational facilities (ski resorts, golf courses)	Spraying of agrochemicals	Water quality change and groundwater contamination due to their underground percolation and their effluence into bodies of water
	Use of livestock facilities	Use of livestock facilities	Water quality change and groundwater contamination due to the underground percolation of excreta and their effluence into bodies of water
	Existence and use of borrow sites and mineral pits	Existence and use of such sites and pits (topographic alternation)	A decrease in the water production capacity; groundwater flow change; water quality change and groundwater contamination due to waste liquids and pit wastewater

Notes:
1. This table shows only typical measures for environmental preservation for water quality.
2. Pit wastewater: Water that contains heavy metals dissolved from mine ore and flows out to the ground surface. A decrease in the groundwater table below the ore body associated with mine development exposes ore containing heavy metals to air, thus oxidizing it and making it dissolvable. Then water that has infiltrated from the ground surface dissolves such heavy metals. This dissolution process is also made possible by rainwater seeping into ore dumps.

Table III.1.7-9 Typical types of construction work that can affect groundwater behavior

Classification	Type of work
Earthwork	Excavation (cut-off trench) work, filling (back filling) work, groundwater level lowering work
Piling/pulling work	Impacting/vibration work, cast-in-place piling work
Tunneling work Bridge substructure work	Pneumatic caisson work, pneumatic shield work
Earth retaining work	Water-shielding earth retaining work, diaphragm wall work
Temporary work	Dewatering work, water-shielding earth retaining work, diaphragm wall work, coffering, intermediate piles, posts
Soil stabilization work	Surcharge work, drainage work, chemical grouting, compacting work, groundwater level lowering work
Anchor work	Ground anchor
Subsurface exploration	Geological surveying (boring)

Source: Compiled from Center for Environmental Information Science, ed. *Kankyo Asesumento no Gijutu* [environmental assessment techniques], 1999, Chuohoki Publishing.

(2) Arranging environmental elements

Environmental elements regarding groundwater include groundwater level (including the quantity of water) and groundwater quality (including groundwater temperature). To identify such elements that can be affected by the project, the project proponent will first identify the project’s impacts, if any, on the functions and resources of groundwater.

Table III.1.7-10 shows major groundwater contaminants. Apart from these contaminations, attention should also be paid to substances that have recently be recognized as being hazardous as well as to substances that are not subject to regulation by law but of much interest to local communities. Although most projects do not assume the discharge of hazardous substances into groundwater, the project proponent should study the possibility that the project will result in the contamination of groundwater with hazardous substances.

Table III.1.7-10 Major groundwater contaminants

Statutory standards	Groundwater contaminants, etc.
Water quality indicators	Turbidity, chromaticity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), hydrogen ion concentration (pH)
Environmental Quality Standards Regarding Groundwater Contamination	Cadmium, total cyanide, lead, hexavalent chromium, arsenic, total mercury, alkylmercury, PCB, dichloromethane, carbon tetrachloride, vinyl chloride monomer*, 1,2-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethylene, tetrachloroethylene, 1,3-dichloropropene, thiuram, simazine, thiobencarb, benzene, selenium, nitrate nitrogen and nitrite nitrogen, fluorine, boron, 1,4-dioxane
Environmental Quality Standards Regarding Groundwater Contamination by Dioxins	Polychlorinated dibenzofuran, polychlorodibenzo-p-dioxin, co-planar polychlorinated biphenyls
Salination	Chloride ion concentration
Construction processes, materials used	pH, potassium permanganate consumption

* Effective from April 1, 2017, "vinyl chloride monomer" shall be referred to as "chloroethylene" (a.k.a. vinyl chloride or vinyl chloride monomer).

(Points to note) Diversity of possible project impacts on the hydrologic cycle system

The project's impact factors for the hydrologic cycle system are diverse. They range from changes in groundwater level or quality resulting from the implementation of construction the use of facilities to groundwater flow interruption and follow pattern change resulting from the existence of facilities, and to changes in the balance between the recharge area and the discharge area associated with changes in ground cover patterns.

For this reason, the project proponent should consider the hydrologic cycle as a system, keep in mind what part of the hydrologic cycle system potential impact factors will act on, and then identify environmental elements that can cause such change.

The project proponent should also pay attention not only to the direct effects of the project's impact factors but also to other effects that may occur as if in a chain reaction.

Take, for example, the impacts of tunnel excavation on groundwater and those of a semi-underground road project on groundwater flow interruption. In these cases, environmental elements should be identified based on the concepts illustrated in Figures III.1.7-3 and III.1.7-4.

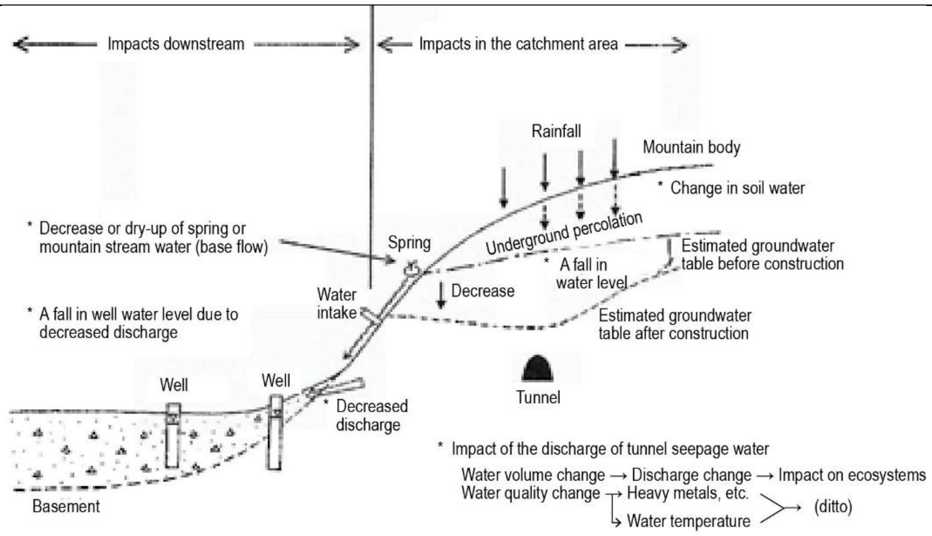


Figure III.1.7-3 Conceptual rendering of potential impacts of tunnel excavation on groundwater

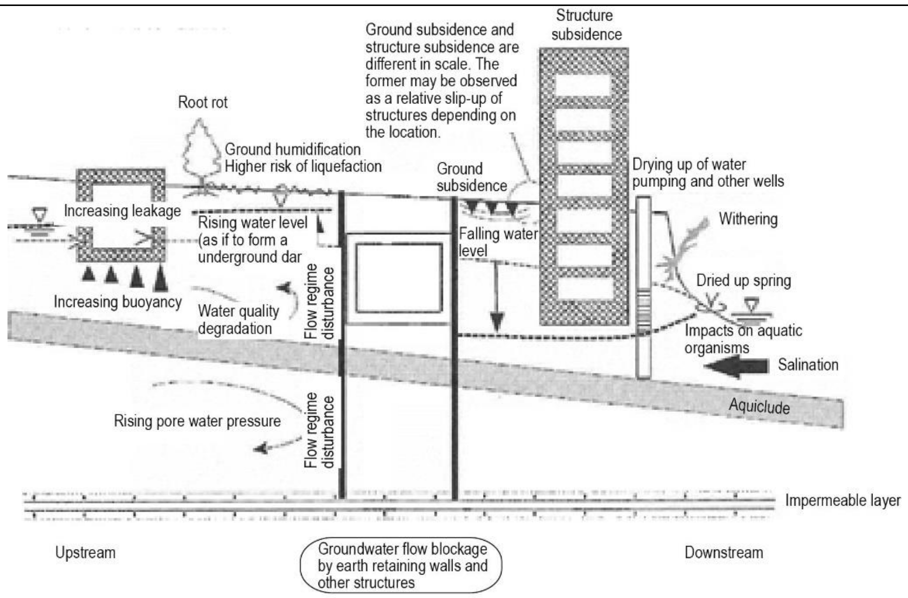


Figure III.1.7-4 Conceptual rendering of groundwater flow interruption due to a semi-underground road project and its environmental impacts

(3) Selecting environmental impact assessment items

The project proponent will select the items to be studied in an environmental impact assessment (EIA) in relation to impact factors and environmental elements.

(Points to note)

A variable may not be selected as an Environmental Impact Assessment item (i) if it is clear that the extent of the environmental impact is non-existent or negligible as far as that variable is concerned, or (ii) if it is clear that there will be no areas or other features/facilities subject to environmental impacts regarding that variable in or around the project area for a significant period of time. In this case, it is important to show the information that forms the grounds for this decision in “Project content” or “Regional overview” in the scoping document.

The phase “areas or other features/facilities subject to environmental impacts” in clause (ii) above refers primarily to areas involving the human living environment or areas where a natural environment exists that is affected by groundwater. Given the continuity of a body of water, clause (ii) is inconceivable in reality.

4) Selection of survey, forecast and evaluation methods

(1) Concept of examining methods

As far as groundwater is concerned, it is often difficult to augment quantitative assessment by researching existing materials in the scoping document process compared with other environmental elements. For this reason, the project proponent should consider conducting an adequate field survey in the process of identifying local characteristics. The project proponent should also give special attention to the possibility of (i) receiving feedback in the Environmental Impact Assessment implementation process; (ii) reconsidering the Environmental Impact Assessment items and survey, forecast, and evaluation methods; and (iii) revising the project purpose and the approach to Environmental Impact Assessment.

Groundwater, a component of the hydrologic cycle―a basic system that constitutes the natural environment―is intertwined with other environmental elements such as *topography and geology*, *ground*, and *ecosystems*. Moreover, the survey, forecast, and evaluation of groundwater often constitute a precondition for the survey, forecast, and evaluation of other selected items. For these reasons, it may be necessary to integrate the processes of examining each of the selected items that are likely related to one another. For instance, changes in the hydrologic cycle influence the state of the *ground* and thus constitute a determining factor for ground subsidence or ground stability. They also influence *flora*, *fauna*, and *ecosystems*; they can even change the way they look like. Furthermore, changes in the hydrologic cycle have implications for *landscapes* that include the very existence of springs, their value as historic and cultural assets, and *spaces for enjoying contact with nature* for citizens such as water parks.

(Points to note) How to understand the hydrologic cycle

The hydrologic cycle is a complex system. Three of its components, that is, *surface water*, *groundwater*, and *soil water* interrelate closely with one another and even interact with one another. It is therefore necessary to examine not only the impact on each component but also its implications for other components.

(Points to note) The hydrologic cycle and the conditions of the ground

The conditions of the ground, especially ground subsidence and ground stability, depend significantly on the state of groundwater in the ground of concern.

For example, a fall in groundwater level promotes consolidation settlement of the cohesive soil layer; it can even trigger ground subsidence. Changes in groundwater level on a slope disrupt the balance in pore water pressure; it can trigger landslides and other similar disasters. Furthermore, the movement of soil particles associated with groundwater flow can generate cavities in the ground, resulting in disasters such as the deformation of the ground surface.

(Points to note) The hydrologic cycle and flora, fauna, ecosystems

Each component of the hydrologic cycle not only influences flora and fauna; it is also an important component of the ecosystem.

For example, changes in soil water associated with changes in the hydrologic cycle influence the growth of plants, which in turn could change the ecosystem as a result. Also, the ecology of organisms whose lives depend directly on surface water such as aquatic organisms is likely prone to the direct impact of changes in surface water associated with changes in groundwater.

(Points to note) Variation and how to handle representative values

The components of the hydrologic cycle involve temporal variations such as seasonal ones. The forecast and evaluation processes should identify the characteristics of these variations and, after carefully considering the points in time for which forecasts are made, select appropriate representative values.

The forecast and evaluation processes should therefore take the range of these variations into account, rather than using average values all the time.

These processes should consider the conditions that maximize the impact on the event of interest. It should be remembered that these conditions differ depending on the event of interest. For instance, the forecast and evaluation of the impact on structures focus on the state when the groundwater level is high. By contrast, the forecast and evaluation of the impact on water use focuses on the state when groundwater level is low.

Variations in a non-stationary state should also be considered when dealing with short-term impacts as in the case of forecasting and evaluating the impacts of construction work.

(Points to note) Ground conditions and local environment characteristics

As ground conditions show varied characteristics depending on the local environment, groundwater, a component of that environment, has varied characteristics.

For this reason, the processes of surveying, forecasting, and evaluating groundwater should always consider the characteristics of the local environment, which influences ground conditions; they should also take good stock of these characteristics by actively adopting such means as field surveying.

(Points to note) Accuracy required for forecast and associated uncertainty

The project proponent should adopt a forecast method that accommodates the required level of forecast accuracy, which depends on “what to forecast.” The required quality and quantity of data vary depending on the forecast method adopted.

For this reason, the survey and forecast processes should follow the following steps: (i) identifying the final targets of evaluation, (ii) selecting the forecast method to adopt, and (iii) designing survey plans to obtain back data required for that method.

It should also be remembered that forecast results entail uncertainty. The project proponent should try to improve the accuracy of the forecast method and consider reviewing these results with a monitoring survey during construction work and in the operational phase.

(2) More detailed or simpler survey and forecast methods

A number of approaches can be taken to elaborate the methods of surveying and forecasting groundwater. These approaches may include (i) conducting a detailed field study to identify the conditions necessary for forecasts and environmental mitigation measures; (ii) densely distributing survey locations and forecast locations; (iii) adopting a sophisticated forecast method; and (iv) elaborating input conditions for the forecast model. Approaches to simplifying survey and forecast methods may include (i) setting conditions necessary for forecasts based on existing materials; and (ii) adopting a method designed to forecast the impact by comparing with past similar cases.

Criteria for adopting elaborated or simplified methods of survey and forecast may include the following:

(Examples when examining more detailed survey and forecast methods)

1. Where the extent of the environmental impact could be significant
2. Where there is an area or feature/facility vulnerable to environmental impacts
   - An area where groundwater is used for domestic, industrial, agricultural, or service water
   - An area where the hydrologic cycle is likely be affected significantly
   - An area with a lake or wetland that should be conserved in the context of conserving the natural environment or landscapes
   - An area in which chloride ion concentrations are expected and that has farmland, a water source, etc. that are affected by such changes
   - An area where historically or culturally important springs, wells, etc. are distributed

3. Where there is an area or feature/facility designated by a law or regulation in the context of environmental preservation
   - An area designated under the Industrial Water Act
   - An area designated under the Act on the Regulation of Pumping-up of Groundwater for Use in Buildings
   - An area designated under the pollution control ordinance, etc. of the local government concerned
4. Where there is an area whose environment has already been, or could be, degraded significantly
   - An area where environmental standards for groundwater have not been met
5. Where local or project characteristics make forecast rather difficult when a standard method is used
   - An area with a hydrogeological structure due to topographical or geological characteristics
   - Forecast of substances whose behaviors in groundwater, such as adsorption, dissolution, and diffusion are unclear
6. Where there is something on which the local government and the project proponent place special value for environmental preservation
   - There is something that the local government and the project proponent deem important especially for environmental preservation in light of local characteristics, project characteristics, the environmental preservation policy for the project, and the like.

(Examples when examining simpler survey and forecast methods)

1. Where it is clear that the extent of the environmental impact will be small
   - If the project proponent can explain, based the project design, that the extent of the environmental impact will be small, he or she may make forecasts by quantifying the impact factors that provide such explanations.
2. Where the extent of the environmental impact can be clearly assessed based on similar cases
   - The project proponent may use the findings of past surveys and evaluations for similar projects to estimate and forecast the extent of the impact.

1.7.2 Survey

1) Examination of survey items

Survey items for groundwater include groundwater level (flow direction, hydraulic gradient, etc.), discharge, and quality. Groundwater quality should be assessed in two different contexts: (i) changes in water quality due to the project; and (ii) the hydrologic cycle system, especially flow systems.

As a component of the hydrologic cycle system, surface water must be studied for forecasting and evaluating changes in the hydrologic cycle system resulting from the project. The survey items for surface water include discharge and water quality.

(Points to note) Considerations in selecting survey items

The components of the hydrologic cycle such as surface water, groundwater, and soil water are not independent from one another; they are intertwined. Environmental Impact Assessment for groundwater should keep this in mind in selecting survey items. In this context, particular attention should be paid if the project area or its vicinity has one or more of the areas listed below:

- An area where groundwater is used to supply water for domestic, agricultural, or other purposes
- An area with a lake or wetland that should be conserved in the context of conserving the natural environment or landscapes
- An area where historically or culturally important springs, wells, etc. are distributed
- An area where the pumping-up of groundwater is subject to regulation under the Industrial Water Act, the Act on the Regulation of Pumping-up of Groundwater for Use in Buildings, any applicable pollution control ordinances, etc. of local governments
- An area that is already affected by changes in groundwater level.

(Points to note) Water quality survey for assessing the groundwater flow system

As the dissolved constituents of groundwater and surface water are closely related to the storage, origin, and flow system of groundwater, the analysis of the characteristics of these constituents provide a clue to these groundwater properties.

Such analysis generally focuses on the major dissolved constituents of groundwater and surface water (Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, HCO_3^-, Cl^-, NO^{3-}). The features of the quantities of these dissolved constituents thus analyzed are often used to estimate the flow system. Analysis may also be conducted on tritium, the isotopes of ^2H, ^{18}O, and ^{15}N, and water temperature.

2) Concept of survey area and location

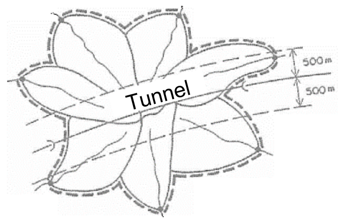
(1) Survey area

The project proponent will identify the survey area for groundwater in light of the characteristics of the proposed project and local characteristics. To this end, the proponent will identify the project's impact factors and the environmental elements that could be affected to define the possible extent of the impact. Rather than mechanically delineating the extent in terms of a fixed straight-line distance, the project proponent should define it appropriately to better reflect the basin of surface water and groundwater. When considering such a basin, it should be remembered that topographical and geological conditions determine the groundwater flow and the runoff characteristics of surface water and groundwater and that these runoff characteristics vary depending on the stream order.

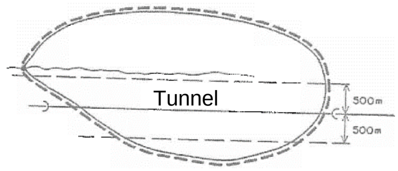
The components of the hydrologic cycle are closely related to other environmental elements such as *ecosystems*. It is thus important to factor in such relationships in defining the survey area.

The extent where the impact of the project is likely negligible should be considered as a control area especially in a follow-up survey. It should preferably be included in the survey area as necessary.

Tables III.1.7-3 and Table III.1.7-4 illustrate the extent of a survey associated with underground excavation. In one case, the extent of a survey associated with the excavation of a mountain tunnel was defined as “any basin that overlaps an area bounded by two imaginary lines each of which runs in parallel with the road at a distance of 500 meters from either side of it” (see Figure III.1.7-5).



If the tunnel will pass a mountain body made up of several basins, the survey should cover all these basins.



If the tunnel will pass at one end of a single large basin, the survey should cover the entire basin rather than that part of the basin only.

Figure III.1.7-5 Example of defining the extent of a survey for the excavation of a mountain tunnel

Source: Sano, Nobuo, “Jizen Chosa no Keikaku to Chosa Gijutu [preliminary survey planning and survey techniques,” *Heisei 7 Nendo Shinpojiumu (Tonneru to Chikasui) Yokoshu* [compilation of abstracts of papers presented to FY1995 symposium on tunnels and groundwater [organized by the Japan Society of Engineering Geology].

(2) Survey locations

For surface water, the project proponent will set up one or more survey locations in each basin. The proponent should consider subdividing such basins as appropriate in light of such factors as topographical and geological conditions, the state of groundwater, the distance from the area vulnerable to the impacts of the projects such as topographic changes.

Survey locations for groundwater level are generally limited to spring points where groundwater appears on the ground surface as well as exiting wells and observation wells. However, the project proponent should adequately examine their distribution and density and consider digging observation wells by mechanical boring or other means as the case may be. Topographical and geological conditions and the state of groundwater should also be taken into account when setting up survey locations for groundwater quality as in the case of surface water.

(Points to note) Distribution and density of groundwater survey locations

For as survey locations for groundwater, the project proponent should select the points in place where the properties, flow directions, and dynamics of the groundwater can be appropriately identified for forecast and evaluation in light of the local topographical and geological conditions. Such points should represent each groundwater flow system. It is often the case with groundwater that there are two or aquifers in the

direction of depth as well, and each of which constitutes its own groundwater flow system. Attention should therefore be paid to the depth of the aquifer(s) that could be affected by the project.

For a field study on groundwater, survey locations are established according to the approaches described in Table III.1.7-11. If existing materials are to be used, they should meet the conditions described in Table III.1.7-11.

Table III.1.7-11 Approaches to setting survey locations for groundwater

Type of survey location	Approaches to setting survey locations
Points that represent the area	Survey locations and their number are determined in such a way that the properties, flow directions, and dynamics of groundwater in the survey area can be identified appropriately in light of the local topography and geology. If the survey area has two or more different topographies, survey locations should be set for each topography. Toward the boundaries of the topographies, survey locations may need to be set more densely. The survey should also cover areas that are affected by groundwater and those where rivers, lakes, spring, wells, or woodland that may be affected are distributed.
Points where the impact will possibly be particularly high	The points where the impact of the project will possibly be particularly high (e.g., points where groundwater subsidence is significant due to increased water pumping in the summer as well as in the winter (for snow melting water)) will be roughly established in light of the project characteristics and past similar cases. It is necessary to confirm that the impact of any other construction work on these points will be small.
Points where there is an feature/facility that requires special consideration for environmental preservation	Forecast locations may include points with features/facilities that should be particularly conserved, such as historically or culturally important springs and wells, tap water sources, and lakes and wetlands that should be conserved in the context of conserving the natural environment and landscapes. In such cases, the local topography and geology to be conserved should be considered. If these points may not be described as “representative points for the area,” such representative points should take precedence.
Points where the environment has already deteriorated significantly	The situation before project implementation should be assessed for areas where environmental standards for groundwater have not been met and those that are facing problems arising from changes in groundwater levels. The idea is to distinguish such impacts from the impacts of the proposed project.

3) Concept of survey period and time

For the timing of the survey, the project proponent should keep seasonal variability in mind and see to it that the amplitude of variability can also be estimated. The forecast method should be adjusted. Where necessary, the project proponent should consider making continuous measurement, possibly with a self-recording monitor at representative points.

The groundwater quality survey should be timed so that the direct impact of rainfall will be avoided.

(Points to note) Determining the survey frequency

The components of the hydrologic cycle system (surface water, groundwater, soil water) may entail seasonal variations as each component is intertwined with precipitation.

The range of such variations should be taken into account in the forecast and evaluation processes. It is therefore important for the survey process to determine the frequency and timing of survey so that this range for the elements of interest can be estimated appropriately.

The survey timing is generally determined based on the wet and dry seasons, which are estimated from the annual precipitation pattern. As far as groundwater is concerned, the survey should preferably avoid the time of stormwater immediately after rainfall. It should also be remembered that necessary data varies depending on the project type and focus.

For example, more detailed data will be necessary if numerical analysis is conducted in the forecast process. It is thus worth considering making continuous measurement with a self-recording monitor at representative points.

1.7.3 Forecast

1) Basic approach to forecast

The process of forecasting the impact on groundwater involves examining how the project's impact factors act on the *system* of the hydrologic cycle and then analyzing different impacts on different environmental elements.

The period of time it takes for a change to occur in the hydrologic cycle system varies significantly depending on a number of factors, including the scale of the proposed project, the scale of the hydrologic cycle system of concern, and the target period for forecast. These temporal and spatial scales should also be taken into account when determining the target time and period of forecast. In addition to these temporal and spatial scales, there are some other factors that should also be considered in selecting the forecast method. They include the characteristics of different forecast methods, especially the accuracy of forecast results gained from these methods.

Yet other factors should be considered as appropriate in the process of environmental impact forecast. Because the criteria and objectives of environmental standards, etc. are not in place for many components of the hydrologic cycle, past similar cases may need to be used for reference. The impact on water use may serve as an indicator for evaluation purposes.

(Points to note) Variations in background values the target period for forecast

The components of the hydrologic cycle including groundwater entail seasonal and interannual variations due to natural factors such as the effects of precipitation or human factors.

For this reason, the impact forecast process should involve factoring in the range of these variations for background values and its relations to the target time of forecast (seasonal, interannual, etc.).

(Points to note) Impact forecast methods and their forecast accuracy

In selecting the forecast method, attention should be paid to the characteristics of different methods as shown below:

- Different forecast methods involve different uncertainties of the forecast results gained.
- When reviewing past similar cases in the vicinity of the project area, it is necessary to identify the similarities and differences between the characteristics of the project area and those in such past similar cases.
- In the case of quantitative forecast based on numerical analysis, in particular, it should be remembered that forecast results will significantly differ depending on the accuracy of initial settings. Such relationship should be clarified.

2) Concept of forecast method

Forecast methods for groundwater are listed below. Particular attention should be paid to the fact that different methods involve different scopes, assumptions, and forecast accuracy.

- Forecast based on past similar cases
- Forecast based on an empirical formula
- Simplified calculation based on a hydraulic formula
- Runoff analysis based on a tank model
- Water balance analysis
- Groundwater analysis, flow analysis based on hydrologic cycle analysis, etc.
- Mass transfer analysis using advection-dispersion analysis techniques, etc.
- Model experiment

Of the forecast methods for groundwater, typical methods involving flow or mass transfer analysis are presented in Table III.1.7-12.

Table III.1.7-12 Typical forecast methods involving flow or mass transfer analysis for groundwater

Forecast method		Brief description
Groundwater Analysis	One-dimensional model	This model is applied to one-direction flow only. It is often used for consolidation settlement forecasts for confining beds associated with hydraulic head decreases in the aquifer.
	Horizontal two-dimensional model	This model is applied to the conditions that can be approximately represented by a horizontal flow in the absence of a horizontal flow. It is suitable for analyzing a relatively wide horizontal extent of groundwater flow.
	Cross-sectional, two-dimensional model	This model is applied on two assumptions: that there is no inflow or outflow in the cross-sectional vertical direction and that the plane flow direction is the same in a multilayer structure. It is suitable for clarifying hydraulic head changes in the aquifers in multilayer structure. This cross-sectional, two-dimensional model is typically used for identifying groundwater problems associated with underground excavation as well as work to address since as this often involves a multilayer structure. It lends itself to addressing local groundwater and linear structures such as waterways, rivers dikes, and roads.
	Quasi three-dimensional model (i) This model provides a technique to addressing a multilayer structure while considering semi-impervious confining beds.	It is used to analyze groundwater flow in a ground structure made up of two or more aquifers and semi-impervious confining beds. The model assumes that groundwater flows in a horizontal direction only in the aquifers and that the horizontal flow can be ignored in the confining beds. It is suitable for considering ground subsidence and groundwater development.
	Quasi three-dimensional model (ii) This model provides a technique to handle a multilayer structure while considering hydraulic constants for the ground as a function of groundwater level.	It is used to analyze groundwater flow in an aquifer made up of several permeable layers based on the Dupuit-Forchheimer assumption that the vertical flow is negligible. It calculates the hydraulic constants (the coefficient of transmissibility and the coefficient of storage) in several permeable layers as a function of groundwater level for analysis. This is a model that allows the hydraulic constants to vary as a function of groundwater level. This is because the coefficient of transmissibility and the coefficient of storage change according to the state of the aquifer if a fall in the groundwater level is so large as to change a confined aquifer to an unconfined aquifer or the groundwater level falls to the basement. It is superior to horizontal two-dimensional analysis in that it factors in the hydraulic constants for a multilayer structure. This model is suitable for analyzing a wide horizontal extent of groundwater flow if the groundwater level changes significantly.
	Quasi three-dimensional model (iii) Vertical slice method	This method is designed to make analysis by dividing the three-dimensional domain into cross-sectional, two-dimensional slices and analyzing each slice independently with the saturated-unsaturated cross-sectional, two-dimensional analysis method. It involves a serious of repetitions of two processes: (i) calculating the flow between slices using two-dimensional elements in accordance with Darcy's law, and (ii) reflecting the calculated flow in the cross-sectional, two-dimensional analysis. These features make this model particularly suitable for handling groundwater flow where bedrock fissures dominate and where there is a fracture zone. The model is useful for considering three-dimensional spring problems associated with tunnel excavation.
	Three-dimensional model	This model is applied to any three-dimensional domain. Creating a reproducible three-dimensional model requires sufficient ground information. This model is worth considering when such information is available.
Hydrologic cycle analysis	Hydrologic cycle model	This model provides a technique to make a coupled analysis of groundwater and surface water. It is suitable for assessing hydrologic cycle systems. It is often impractical for an individual project to study the hydrologic cycle in the area as a whole because gathering ground information for creating a model may be too much a burden for the project proponent. It should be remembered that this model is designed to study impacts in a wide area.
Advection-dispersion analysis		This model provides a technique to analyze mass transfer in groundwater; it can identify the behaviors of the contaminants. It is used with a groundwater analysis model.

Source: Compiled from Japan Institute of Country-ology and Engineering (JICE) Corporation., *Chikasui Chosa oyobi Kansoku Shishin (An)* [guidelines on groundwater survey and observation (draft)], 1993, Sankaido Publishing.

3) Concept of forecast area and location

Groundwater-related forecasts require assessing the state of surface water and groundwater in a series of hydrologic cycle systems. Attention should be paid to not only the topographic divide but also groundwater catchments in defining the forecast area.

It is also necessary to consider how large the flow system of concern is and how the area of impact fits in the wider hydrologic cycle system.

(Points to note) Topographic Divide and the Boundary of a Hydrologic Cycle System

Depending on the topographical and geological conditions, the boundary of a hydrologic cycle system may not correspond to the topographic divide.

For this reason, defining the forecast area requires paying adequate attention to the topography and geology characteristics of the area in question. It may be even necessary to estimate groundwater catchments through water balance calculation or other means.

(Points to note) Defining the Forecast Area in Light of the Area of Impact in the Hydrologic Cycle System

As mentioned in the preceding paragraphs on how to define the extent of a survey designed to identifying local characteristics, it should be remembered that the impact of the proposed project may have a wide range of implications for the hydrologic cycle system.

For example, if a project in the recharge area results in changes in the groundwater flow, such an impact may cause other effects such as reduced groundwater levels in that particular discharge area. The forecast area should therefore be defined so as to embrace both.

4) Concept of forecast time

The impact on the hydrologic cycle system is not always instantaneous. The time lag between the implementation of the project and the manifestation of project impacts such as changes in groundwater level varies greatly depending on the characteristics of the proposed project and the scale of the hydrologic cycle system of interest. Impact factors similar to those during the construction phase may continue to be in place even during the operational phase. Because the components of the hydrologic cycle system entail seasonal variations due to such factors as precipitation, the range and timing of such variations should be considered when setting background values for forecast.

In addition, since groundwater levels change according to meteorological conditions (notably precipitation), attention should also paid to the dry season when, with little precipitation, groundwater levels are the lowest during the year.

(Points to note) Defining the Forecast Area in Light of the Area of Impact in the Hydrologic Cycle System

• Time lag until the hydrologic cycle system is affected

In the case of forecasting the impact on the topographic hydrologic cycle system associated with ground surface alternation, for example, reduced recharge of adjacent groundwater may give rise to such effects as groundwater level change. These effects may not be instantaneous; they are more likely to manifest themselves with a certain time lag.

A longer time lag is expected until the impact of reduced groundwater recharge reaches the groundwater flow system downstream.

• Continuity of impact factors

A project to construct a linear underground structure, for example, may entail groundwater flow interruption during the construction phase due to groundwater management work. During the operational phase, this particular impact continues as groundwater flow interruption resulting from the existence of underground structure. It is difficult to distinguish between the two.

In such cases, the project proponent should regard the impact factors from the construction phase to the operational phase as a series of such factors and make forecasts and evaluations accordingly.

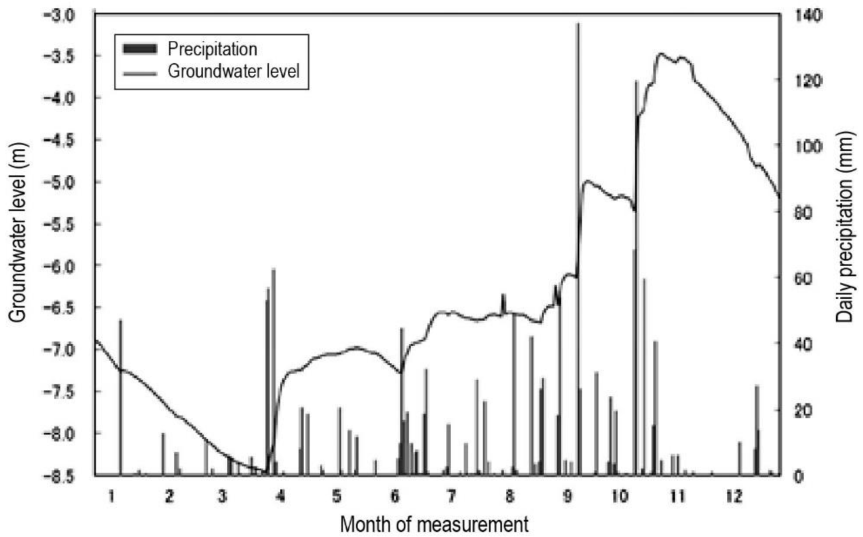
• Variations in groundwater

Groundwater and other components of a hydrologic cycle system entail different kinds of variations. It is therefore necessary to fully understand the features of these variations, including their ranges, at each of the survey, forecast, and evaluation phases.

Groundwater levels may entail daily variability, seasonal variability, and interannual variability. It should be remembered, however, that these kinds of variability show various distinctive features depending on the type of groundwater, the characteristics of the proposed project area (e.g., rainfall, ground cover patterns, geological conditions), and adjacent water use.

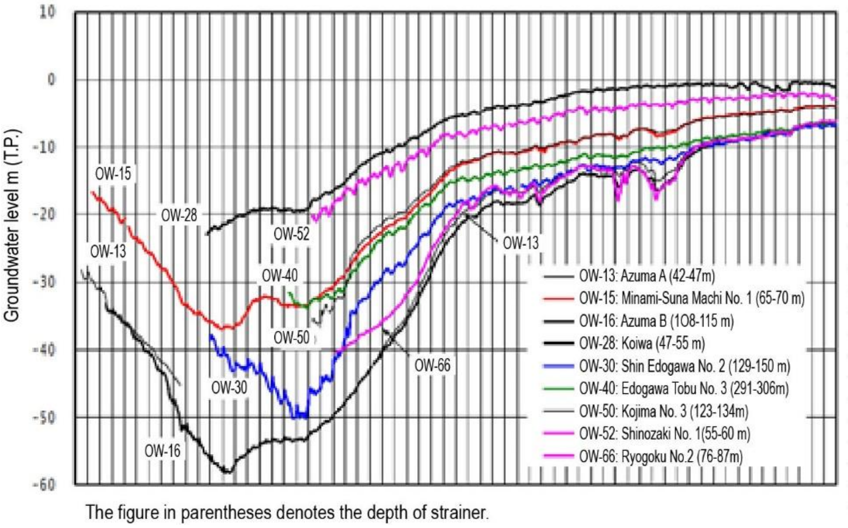
Take unconfined groundwater, for example. This kind of groundwater often shows a wide range of seasonal variations in term of volume and pattern depending on the location but may not display a wide interannual variability, as shown in Figure III.1.7-6.

By contrast, confined groundwater often shows a pattern of variations that is closely related to adjacent groundwater use (water pumping) as illustrated in Figure III.1.7-7. It should also be remembered that confined groundwater may show interannual variations on the order of one to two decade or more resulting from groundwater pumping regulations designed to control ground subsidence.



Source: Civil Engineering Support and Training Center, Tokyo Metropolitan Government, Annual Report C.E.S.T.C., TMG [in Japanese], 2014.

Figure III.1.7-6 Example of variations in unconfined groundwater levels (Higashikurume city, Tokyo)



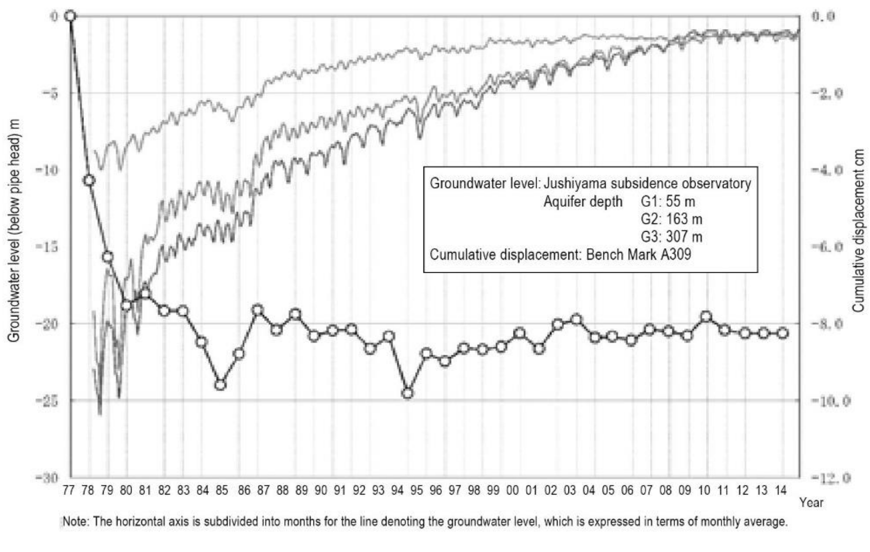
Source: Civil Engineering Support and Training Center, Tokyo Metropolitan Government, *Heisei 26 Nen Jiban Chinka Chosa Hokokusho [ground subsidence survey report 2014]*, 2015

Figure III.1.7-7 Example of interannual variations in confined groundwater levels (Tokyo)

• Groundwater variations in ground subsidence areas

In the past, ground subsidence due to excessive groundwater pumping often occurred in many of the Quaternary system* distribution areas. Due to water pumping regulations, however, subsistence has subsided or is on the path of recovery. Such areas may show interannual variations in groundwater levels on the order of one or two decades or more.

Figure III.1.7-8 shows interannual variations in groundwater levels and cumulative ground displacement in the Owari region, Aichi Prefecture. After groundwater pumping was regulated by Aichi Prefecture's pollution control ordinance in 1974, ground subsidence slowed along with groundwater elevation over the long term. More recently, subsidence has been subsiding in a cycle of infinitesimal elevation and subsidence.



Source: Aichi Prefectural Government, *Heisei 26 Nen Jiban Chinka Chosa Kekka [results of ground subsidence survey 2014]*, 2015.

* Note: The Quaternary system refers to the stratigraphy deposited during the Quaternary (the period from about 2.6 million years ago to the present). Generally, it is a soft, unconsolidated stratigraphy because it was formed rather recently.

Figure III.1.7-8. Variations in groundwater levels and cumulative ground displacement (Aichi prefecture)

(a) During construction work

The project proponent will check any change in work volume and location based on the overall construction work plan and, on that basis, make forecasts when the impact factors such as excavation and water pumping peak.

It should be remembered, however, that the time lag until the impact emerges varies depending on the type of construction work and that the impact factors of different operations at different times may be combined.

Attention should also be paid to the possibility that the extent of the impact will vary depending on the timing of construction work, the time when the impact emerges, and seasonal variations.

(b) During the operational phase

During the operational phase, the target time of forecast should be defined while keeping in mind that there will be a certain time lag until the impact on groundwater is in a steady state and that the impact on groundwater during construction work may continue into the operational phase.

If the hydrologic cycle system could be affected by impact factors other than the proposed project, this possibility, too, should preferably be considered in defining the target time of forecast.

(Points to note) Target time of forecast if construction work has long-term impacts

The impact on groundwater associated with tunnel excavation, for example, will likely reach equilibrium after several to 12 months following excavation work and then become an impact associated with the existence and use of the tunnels.

In this way, there is a time lag between the implementation of construction work and the time when its impact emerges. This should be taken into account when defining the target time of forecast.

1.7.4 Environmental mitigation measures

1) Procedures for examining environmental mitigation measures

(1) Examining environmental mitigation measures policy

The criteria for devising a policy of environmental mitigation measures for groundwater include, among others, water contamination control, the appropriate groundwater extraction volume, the permissible ranges of variations in groundwater level and discharge (flow) (e.g., the permissible level that factors in the range of variations (variability rate) during the period when the groundwater flow and level are stable). The process of devising a policy of environmental mitigation measures should pay attention to the fact that although such variations are caused by both natural and human factors, it is often difficult to distinguish between the two types of factors and assess to what extent each type contributes.

The policy devising process should also see to it that mitigation measures are aligned with any groundwater-related target of the environmental master plans of the local government concerned.

2) Specific environmental mitigation measures

Basic approaches to addressing groundwater flow interruptions may include (i) applying the groundwater flow preservation process without changing the shape of the structure or the basic construction method, and (ii) changing the shape of the main structure or the basic construction method altogether. In the case of tunneling work, for example, alternatives to the open-cut method include the caisson method and the shield tunneling method. These methods do not involve earth retaining walls. In the open-cut method, however, the embedment of such walls may block the aquifer. In this way, the groundwater flow preservation process is not the only solution. Changing the basic construction or process, taking compensatory mitigation measures, and compensating for losses are among the alternative solutions. It is important to compare all these options from a comprehensive perspective and identify optimal environmental mitigation measures.

Criteria for identifying such measures include: (i) the relationships between the aquifer(s) and the structure, (ii) the types of groundwater flow preservation construction methods, (iii) the timing of applying the groundwater flow preservation process. All these criteria, as well as the site situation and the feasibility, should be taken into consideration.

Also, the project impacts on groundwater quality are largely classified into (i) changes in water quality associated with changes in groundwater flow, and (ii) groundwater contamination by hazardous substances. Accordingly, environmental mitigation measures aim to prevent or reduce such changes or address groundwater contamination.

The environmental impact of groundwater contamination varies significantly depending on the properties of contaminants, local geology, and the depth and the scale of the aquifer where contamination occurs. Environmental mitigation measures should therefore be designed accordingly. The process of identifying appropriate environmental mitigation measures should preferably involve (i) surveying the types, concentrations, and distribution of contaminants; (ii) based the findings of such survey, carefully evaluating the urgency and cost-effectiveness of possible solutions; (iii) carefully conducting a prior cleanup test and a survey of the adjacent environment, and (iv) studying more effective techniques to address the impact. Such techniques vary by type of VOCs and heavy metals, indicating the need to identify measures that embrace technologies that better address these contaminants.

Table III.1.7-13 shows some of the environmental mitigation measures address problems associated with groundwater flow. Examples of groundwater flow mitigation measures ever conducted are presented in Tables III.1.7-14 and III.1.7-15 provides some of the environmental mitigation measures for groundwater quality.

(Points to note) Effectiveness of environmental mitigation measures for groundwater

Objective evaluation of the effectiveness of environmental mitigation measures presuppose that environmental elements or events involving them can be measured and observed quantitatively.

The impacts on groundwater in a hydrologic cycle system may vary greatly in terms of their type (the level, flow, discharge, quality, etc. of groundwater) and scale, depending on different factors of anthropogenic environmental stress associated with the project (e.g., the scale of construction, where and how the facility exists, the groundwater extractions, contaminant discharges). It is thus necessary to enhance the objectivity of effectiveness evaluation while reviewing past similar cases and introducing latest research findings as early as the project planning phase.

It should be remembered, however, that there may be a time lag until the impact is felt; in a hydrologic cycle system, groundwater changes (quantitatively or qualitatively) more slowly than surface water does. Also, particular attention should be paid to the temporal and special differences between unconfined groundwater and confined groundwater. The temporal difference is in flow time. Generally, confined groundwater flows more slowly than unconfined groundwater. The spatial difference is that in general, confined groundwater is distributed widely while unconfined groundwater is distributed in a limited area.

Table III.1.7-13 (1) Environmental mitigation measures for groundwater flow

Collection and recharge facilities	Collection and recharge facilities constitute the most important component of the groundwater flow preservation process. Where and how to collect groundwater upstream from the blockage of the aquifer due to the structure and how to restore (recharge) groundwater downstream will greatly influence the performance of the process.

Classification	Brief description	Features
Removal of earth retaining walls	This measure involves removing the blockers after the completion of the structure to restore the flow function of groundwater. This may be done by pulling out the steel sheet piles or dismantling the earth retaining walls.	• It is easy in terms of implementation. No maintenance work is generally unnecessary as the natural conditions are restored. • Applicability conditions include (i) that the structure itself does not block the aquifer, (ii) that the earth retaining walls can be pulled out or otherwise removed, and (iii) that the work will not interrupt the groundwater flow.
Collection and recharge piping	This measure involves drilling the earth retaining wall from inside and horizontally or obliquely into the aquifer behind and inserting collection and recharge pipes into the holes thus drilled. Such pipes may be replaced by a filter material.	• The applicability of this method during construction work makes it possible to address any event of groundwater flow interruption during such work by installing collection and recharge pipes and connecting them with temporary water conduction pipes. Experimental installation of a few collection and recharge pipes makes it possible to evaluate their effectiveness, which provides input for identifying measures to be taken. • The applicability during the construction phase allows for additional measures based on the effectiveness evaluation in light of groundwater conditions. • A small contact area with the aquifer compared with other collection and recharge facilities may point to the need to increase the number (density) of pipes depending on the groundwater and ground conditions. • Near to the site boundary, there may not be enough room for collection and recharge pipes of a sufficient length.
Earth retaining walls with collection and recharge functions	This method involves mounting a material with collection and recharge functions onto part of the earth retaining wall. Such a material may take a linear or plane shape. An increasing range of processes based on this technique have been developed or proposed in recent year amid growing need for groundwater flow preservation.	• A large collection and recharge area can be secured. • No site conditions will stand in the way because collection and recharge equipment is built in an earth retaining wall.
Collection and recharge well	This method involves digging wells outside the earth retaining wall to collect and recharge groundwater.	• A long track record proves the reliability of this process. • Such wells are dug on an experimental basis or as a preliminary measure. If they prove effective, their performance can be reflected in the construction design process. • No limit to the timing of installation means that this method provides an effective solution during the construction phase. Additional well can be dug as necessary. • How to secure the site for such well can be a problem.

Source: Japanese Geotechnical Society, *Chikasui Ryudo Hozen no Tameno Kankyo Eikyo Hyoka to Taisaku: Chosa, Sekkei, Seko kara Kanri made [environmental impact assessment and measures for groundwater flow preservation: from survey, design, and construction to management]*, 2004, Maruzen.

Table III.1.7-13 (2) Environmental mitigation measures for groundwater flow

Water conduction facilities	A water conduction facility serves as an aquifer, conducting groundwater collected in a water collection facility to a recharge facility. As a general rule, water conduction should preferably done by gravity flow, the kind of flow due to a difference in water level between the upstream and the downstream. However, a pump or any other power-driven means may be used if gravity flow alone fails to generate enough water conduction capacity.

Classification	Brief description	Features
Water conduction through the lower part of the building frame	This method uses the aquifer in the lower part of the building frame of the structure as a water conducting layer. This is suitable if there is an aquifer in the lower part of the structure and if the earth retaining wall in this part can be removed. The original aquifer may be used as it is for a water conducting layer. Alternatively, the aquifer may be replaced by a filter material that is as permeable or more permeable.	• The use of original aquifer costs less and can secure a large cross-section for water conduction. • The use of a filter material entails additional processes: excavation work and replacement work.
Water conduction piping (inverted siphon water conduction)	This method conducts groundwater collected upstream to the downstream side using a pipe. It is also known as "inverted siphon water conduction" because making the pipe's inside full to take advantage of the principle of siphon for efficient water conduction.	• It is relatively easy in terms of design and construction. • Installing a water conduction pipe on the side of the inner wall of the structure and mounting a current meter make it easy to minor the performance.
Water conduction through the upper part of the building frame	This method uses the upper part of the building frame of the structure as a water conducting layer. As the main body construction work involves excavating the upper part of the building frame, a filter material that is as permeable as the original aquifer or more permeable is used for the back filling material.	• It is ease to construct and relatively inexpensive for cut and cover tunnels because a water conducting layer is formed by replacing the back filling material.

Source: Japanese Geotechnical Society, *Chikasui Ryudo Hozen no Tameno Kankyo Eikyo Hyoka to Taisaku: Chosa, Sekkei, Seko kara Kanri made [environmental impact assessment and measures for groundwater flow preservation: from survey, design, and construction to management]*, 2004, Maruzen.

Table III.1.7-14 (1) Examples of groundwater flow preservation work

- Groundwater Flow Preservation in Cut and Cover Tunneling Work along Metropolitan Expressway Saitama Omiya Route

Brief description of work	Collection and recharge	Water conduction	Water conduction work	Groundwater variation forecasts and the effectiveness of measures
This preservation process was applied to a 450 m-road tunnel along Metropolitan Expressway Saitama Omiya Route, which runs east and west from Shin-Omiya Bypass and a JR line along Prefectural Highway Yono-Omiya. It was constructed with earth retaining walls (soil cement pillar line wall, etc.) using the cut and cover tunneling method. The excavation depth is 30 meters. This tunnel cuts across an alluvial lowland flanked by low-lying plateaus. In this site, below the alluvium (with a thickness of 5 m) lie the first and second aquifers. Groundwater generally runs from the north to the south. The flow preservation process was applied to minimize the dam-up and dam-down of groundwater by earth retaining walls.	Removal of earth retaining walls	Water conducting layer in the upper part of the building frame	Because the aquifers are relatively shallow and the groundwater level is rather high in this site, the method to construct a water conducting layer in the upper part of the building frame was adopted as the post-work groundwater flow preservation process. This method involves backfilling the upper part of the building frame with single-sized crushed stone (with a combination of No. 5, 6, 7 stones with a weight ratio of 3:3:4) for water conduction and crushing earth retaining walls and replacing them with single-sized crushed stone for groundwater collection and recharge so that the preservation section is secured. A water collection part was constructed outside of the earth retaining walls because in their surroundings, it was feared that the coefficient of permeability would decrease due to the cement content and muddy water during the work. The water conduction section was identified in consideration of groundwater levels, the longitudinal location of the tunnel's upper slab, and street boundaries.	Along the section to which the groundwater flow preservation process was applied, water level observation wells were dug in the water collection side, north of the retaining wall (groundwater upstream) and in the recharge side, south of the retaining wall (groundwater downstream). The purpose was to evaluate the effectiveness of the preservation method. The observed gap in water level was approximately 0.3 m between the collection well north of the retaining wall and the recharge well in the south. This figure almost matches the groundwater subsidence amount in the first and second aquifers that were calculated based on three-dimensional seepage analysis on the assumption that the preservation method is applied (approximately 0.3 m south of the earth retaining wall compared with the initial state). A record of groundwater level variations during the observation period indicates that observation wells north and south of the retaining wall show similar patterns. All these finding suggest that each facility works effectively in the section to which the preservation method was applied.

- Groundwater Mitigation Measures in the Grounding Work for the JR Senseki Line

Brief description of work	Collection and recharge	Water conduction	Water conduction work	Groundwater variation forecasts and the effectiveness of measures
This work is designed to underground the JR Senseki Line at a level crossing with a road in the Sendai Station east district. A set of boxes for the tunnel are installed underground with the open-cut method that involves excavation with a total length of approximately 3,200 m. In some parts of this section, a retaining wall was to be installed with the soil cement pillar line wall method with a high seepage control performance. It was feared that such a wall would retain groundwater, resulting in a dam-up phenomenon upstream and groundwater depletion downstream. To address this concern, a water conducting layer was constructed after a set of boxes was installed.	Removal of earth retaining walls	Water conducting layer in the upper part of the building frame and siphon-type water conduction piping	Two different methods are used to install earth retaining walls in light of the conditions of the excavation ground. One is the soldier piles and lagging method, which was applied where underwater discharge is small. The other is the soil cement pillar line wall method, which was applied where underwater discharge is large. In the section(s) where the latter was applied, the groundwater flow preservation process was applied. Specifically, in places where a water conducting layer with an adequate thickness can be secured, the earth retaining wall (soil cement pillar line wall) was removed by way of cutting or drilling, the surroundings of the boxes were backfilled with permeable materials, and a water conducting layer was constructed. In places where a water conducting layer cannot be secured in the layer above the upper slab of the building frame, siphon-type water conduction equipment was installed.	Quasi three-dimensional FEM analysis suggested that as long as the proportion of the water conduction section is at least 10%, the effectiveness remains the same. Accordingly, this proportion was set at 10%. No groundwater variations attributable to the work were observed. Monitoring is still underway.

Source: Japanese Geotechnical Society, *Chikasui Ryudo Hozen no Tameno Kankyo Eikyo Hyoka to Taisaku: Chosa, Sekkei, Seko kara Kanri made [environmental impact assessment and measures for groundwater flow preservation: from survey, design, and construction to management]*, 2004, Maruzen.

Table III.1.7-14 (2) Examples of groundwater flow preservation work

■ Measures to Preserve Miyamizu Water Vein in Underground Part Construction as Part of the Elevation Work for the Hanshin Main Line

Brief description of work	Collection and recharge	Water conduction	Water conduction work	Groundwater variation forecasts and the effectiveness of measures
In constructing footing beams of railway viaducts in a series of grade separation works, groundwater observations arrangements were made for possible impacts on groundwater and water conduction pipes were put in place.	Removal of earth retaining walls	Water conduction piping in footing beams in the permeable backfilling layer	Because the temporary track method for railway elevation involves construction work in a small space, footing beams are usually constructed with all steel sheet piles closed. In consideration of possible impacts on groundwater, the coffering section due to steel sheet piles was minimized. Also, underground walls were built in an every other manner in a divided construction process to prevent dam-up phenomena. Furthermore, in permeable sections, penetration sleeves for water conduction were installed in footing beams. PVC pipes with a diameter of 50 mm were used for water conduction piping because his size does not affect reinforcement. They were arranged in an interval of 2 m in the east-west direction. In coffering with steel sheet piles, cobblestone was evenly laid with a thickness of 30 cm. After footing beams were put in place, single-sized crushed stone was laid at the prescribed depth as back filling, and the remaining void was backfilled with decomposed granite.	The ongoing monitoring of groundwater level and quality precedes the start of the construction work. Groundwater flow data from observation wells upstream and downstream indicates no changes in the hydraulic gradient before and after the construction work. No permanent water level subsidence is expected.

■ Groundwater Mitigation Measures in the Subway-related Construction Work at Kobe-Sannomiya Station

Brief description of work	Collection and recharge	Water conduction	Water conduction work	Groundwater variation forecasts and the effectiveness of measures
This is a subway-related construction work using the open-cut method with an excavation depth of 22-30 m. After underground diaphragm earth retaining walls were built in this construction work, it was unclear when the groundwater level would began to change. Accordingly, water level observation holes were used to monitor groundwater levels. It was decided to take mitigation measures when it becomes apparent that a dam-up phenomenon has occurred.	Collection and recharge piping in drilled into earth retaining walls	Water conduction piping in the bottom slab the building frame	The construction of a seepage control earth retaining wall with H steel piles and precast concrete panels resulted in a water level rise of approximately 2 m upstream of the wall and a water level fall of approximately 0.3 m downstream. This gave rise to leakages in the basements of adjacent buildings upstream and well drying downstream. As a temporary measures to address these problems, weep holes were drilled into the aquifer from the inside of the underground excavation site. Permanent measures included retaining seven sets of pipes for water collection and six sets of pipes for recharge even after the structure was completed, as well as mounting water conduction piping that connects with a cistern onto the inverted bottom slab of the building frame.	The weep holes drilled as a temporary measure proved effective as it resulted in a fall in the water level upstream that had risen sharply. The water conduction piping as a permanent measure stopped the fall in the water level downstream. As a result, the water levels both upstream and downstream remain at levels seen before the construction of the diaphragm retaining wall. It is worth adding that part of the groundwater flowing through the water conduction piping is used as grey water for lavatories at the station.

Source: Japanese Geotechnical Society, *Chikasui Ryudo Hozen no Tameno Kankyo Eikyo Hyoka to Taisaku: Chosa, Sekkei, Seko kara Kanri made [environmental impact assessment and measures for groundwater flow preservation: from survey, design, and construction to management]*, 2004, Maruzen.

Table III.1.7-14 (3) Examples of Groundwater Flow Preservation Work

■ Groundwater Mitigation Measures in the Construction Work for Fukuoka Municipal Subway Line No. 2

Brief description of work	Collection and recharge	Water conduction	Water conduction work	Groundwater variation forecasts and the effectiveness of measures
The groundwater in a park along this subway line is traditionally popular among the citizens as an exquisite water. Abundant in volume, the water is partly used for domestic water. The construction work involved excavating a 536-m underground tunnel under this park using the open-cut method. To restore the groundwater level after the completion of this work, the earth retaining wall above the upper slab of the building frame was removed. The void was backfilled with crushed stone to facilitate water conduction.	Removal of earth retaining walls	Water conducting layer in the upper part of the building frame	The earth retaining work involved inserting precast concrete panels in the retention section in the lower part and steel sheet piles in the removal section of the upper part to solidify the bentonite muddy water. The idea was to restore the groundwater with these panels and piles that are highly effective in cutting off water. For the groundwater flow preservation process, the solidified bentonite muddy water was drilled with and earth auger and the void was backfilled with sand. A water conducting layer was thus created by completely removing the earth retaining wall in the upper part of the building frame and using crushed stone for back filling in the aquifer.	Groundwater levels in the vicinity of the construction site are showing signs of recovery.

■ Groundwater Mitigation Measures for the Karasuma Line of Kyoto Municipal Subway

Brief description of work	Collection and recharge	Water conduction	Water conduction work	Groundwater variation forecasts and the effectiveness of measures
This is a subway extension work using the open-cut method. The total length of extension, including this work section and the adjacent work section, is approximately 1.0 km. The excavation is generally 10 m wide and 19.6 m at stations. It has a depth of 19.5 to 24.5 m. A soil cement pillar line wall was used as an impervious wall. The gaps in the soil cement pillar line wall were filled with coffering with the chemical feeding method. As this work involved the open-cut process that cut across a permeable sedimentation layer in an alluvial fan, the water conduction construction method was applied to prevent groundwater flow interruption.	Earth retaining walls with collection and recharge functions	Strut-suspended water conduction piping and water conduction piping in the lower part of the building frame	This work required a construction method highly effective in cutting off water for the earth retaining wall. Accordingly, the soil cement pillar line wall method was adopted. This groundwater flow preservation process involved installing a vertical catchwater on the impervious wall as early as in the construction phase and laying water conduction piping in the excavation to let the groundwater flow downstream. In places where collection and recharge wells were dug, a special core for the soil cement pillar line wall was built up. The core is connected to a jig and piping for cleaning. Mounted on its back is special equipment designed to remove solidified mud. Along an approximately 500-m line in this construction section, crushed stone is laid as a drain material at an interval of approximately 10 m on average with a depth of 6 m for water collection upstream and a depth of 12 m for recharge downstream. Water conduction piping with a diameter of 200 mm was installed.	Quasi three-dimensional FEM steady-state analysis suggested that the groundwater level would rise by a maximum of 3 m and fall by a maximum of 5 m. Although the level rose by 1 m during the construction work, it returned to normal after the work.

Source: Japanese Geotechnical Society, *Chikasui Ryudo Hozen no Tameno Kankyo Eikyo Hyoka to Taisaku: Chosa, Sekkei, Seko kara Kanri made [environmental impact assessment and measures for groundwater flow preservation: from survey, design, and construction to management]*, 2004, Maruzen.

Table III.1.7-15 Examples of environmental mitigation measures for groundwater quality

Classification	Type of measure	Features
VOCs	Soil vapor extraction	This soil cleaning technology involves extracting target contaminants in the unsaturated zone (between the ground surface and the groundwater table) with a vacuum pump, blower, etc.
	Groundwater water pumping	This cleaning technology involves aerating pumped groundwater to isolate target contaminants and using active carbon or other materials to absorb them. Target contaminants are treated with active carbon adsorption or ultraviolet degradation.
	Double vapor extraction	This technology extracts groundwater and soil vapor simultaneously. It involves decomposing or aerating target contaminants in the pumped groundwater and using active carbon or other materials to absorb target contaminants contained in the soil vapor. The technology is effective when contaminants exist near the groundwater table.
	Airsparging	This technology is designed to promote the cleaning of soil or groundwater by injecting air into the soil or groundwater so as to promote the vaporization of VOCs. It is suitable for the type of soil that lets the air pass easily.
	Iron powder method	This technology involves mixing soil or groundwater with iron powder to decompose VOCs. It adopts different processes for pollution source control and groundwater management. The process for groundwater management involves building a permeable wall containing iron powder in the ground to decompose VOCs that pass through it.
	High-pressure cleaning and pumped water aeration	This cleaning technology involves the in-situ process of watching away contaminants attached to soil particles with high-pressure water and air and aerating them. The injected high-pressure water and air must be recovered and treated appropriately.
	Bioremediation	Bioremediation refers to the technology designed to clean the soil and groundwater by taking advantage of the capacity of microorganisms to decompose hazardous substances. It is divided into two types of contaminant decomposing processes: (i) the process of activating indigenous microorganisms by feeding them with nutrients; and (ii) the process of injecting microorganisms that are effective in decomposing contaminants (bioaugmentation).
Heavy metals	Groundwater pumping	This is a technology whereby contaminated groundwater is pumped up and target contaminants contained in it are removed and collected. Pumped groundwater is generally cleaned by treatment equipment on the ground. It is cleaned with a combination of water treatment processes such as oxidation, reduction, neutralization, coagulation-sedimentation, filtration and adsorption for removal.
	Excavation and removal	The groundwater cleaning technology involves excavating contaminated soil, removing the contaminants contained in it, and preventing them from dissolving into groundwater. A boring or other survey is conducted to assess the extent and depth of contamination in order to define the extent of excavation.
	Immobilization	This technology involves mixing an immobilizing agent with the soil in situ or excavated soil to control the dissolution of contaminants. It provides a rather quick and inexpensive solution.
	Containment	This groundwater cleaning technology involves containing contaminated soil to prevent it from touching groundwater. In-situ immobilization requires a structure designed to prevent contaminants from leaking to the outside in light of ground permeability.
	Impervious containment or concrete pit containment	The technology involves containing excavated contaminated soil in a facility with a structure designed to prevent the leakage of contaminants.

Source: Water Environment Management Division, Environmental Management Bureau, Ministry of the Environment, *Chikasui o Kirei ni Suru Tameni* [making groundwater clean], 2004.

1.7.5 Evaluation

The evaluation process concerns the prevention or reduction of environmental impacts. When the national government or the local government has standards or objectives in its environmental preservation strategy for the selected items, the process also involves evaluating their alignment with these standards or objectives.

1) Evaluation relating to prevention or reduction

Evaluation on prevention or reduction is aimed at identifying and evaluating the efforts by the project proponent to prevent or reduce environmental impacts. Evaluation approaches include comparing several options for environmental mitigation measures, assessing whether feasible and better technologies are adopted, and evaluating whether efforts are made to prevent environmental degradation from the current state.

2) Evaluation relating to consistency with standards or objectives

Table III.1.7-16 shows examples of standards or objectives for groundwater set by the national or local governments.

Table III.1.7-16 Examples of standards or objectives for groundwater

National government	Environmental quality standards for groundwater pollution under the Basic Environment Act Groundwater percolation standards under the Water Pollution Prevention Act
Local governments	Regulations, etc. in guidance, ordinances, and guidelines on groundwater intake and contamination Objectives, etc. in environmental master plans, groundwater preservation management plans, and hydrologic cycle plans.

Evaluation of the alignment with the standards or objectives means evaluation of whether the implementation of the proposed project will be in line with the environmental preservation strategies of the national and local governments concerned. Accordingly, the project proponent should understand how the standards or objectives he or she refers to fit in the environmental preservation strategies and then clarify which standards or objectives to use for evaluation and why.

In comparing these standards or objectives with the forecast results, it is important to make an evaluation in terms of not only whether or not the forecast results meet the standards or objectives but also whether the extent of the impact of the proposed project could interference with environmental preservation in light of the standards and objectives.

1.7.6 Follow-up survey

Environmental Impact Assessment entails some uncertainty in its findings as it comes before project implementation. A follow-up survey is designed to offset such forecast uncertainty. It may be conducted if the uncertainty is significant or if the project proponent takes environmental mitigation measures whose effects are not well-established. The need to conduct a follow-up survey shall be assessed in light of the seriousness of the environmental impact. Depending on the results of such a survey, it may be necessary to modify the environmental mitigation measures or implement additional ones.

Clearly, a follow-up survey focuses on the project impacts on the state of groundwater intake and pumping, and topographic changes, among other aspects. It should also study the state of water intake and pumping in and around the project area, as well as the social conditions at large, in order to check whether the forecast parameters for Environmental Impact Assessment are aligned with these aspects.

It is desirable to make effective use of the available information from surveys conducted by entities other than the project proponent such as the national and local governments (including discharge and water quality measurement data, groundwater level observation data, ground subsidence observation data, and the results of survey on complaints).

Again, groundwater, each component of a hydrologic cycle system entails daily, seasonal, and interannual variations. These elements are affected by rainfall. The impact of construction or engineering work does not emerge immediately. For these reasons, the follow-up survey should factor in the local characteristics and the types of environmental impact.

(Points to note) Importance of regarding the hydrologic cycle

Environmental mitigation measures with regard to the hydrologic cycle involving groundwater entail not a few uncertainties surrounding their effectiveness and impacts. This is why a follow-up survey should be conducted to estimate such effectiveness and impacts. The findings of such follow-up surveys should, if published, provide valuable scientific insights for identifying environmental mitigation measures.

Some types of measures, such as recharging groundwater with a recharge well, are well established technically. Yet their effectiveness largely depends on how such facilities are managed and operated. Therefore, the project proponent should preferably conduct regular environmental monitoring to check whether such measures are producing expected outcomes while proceeding with the project.

(Points to note) Considerations in planning a follow-up survey

In planning a follow-up survey, the following considerations should be made:

- Any follow-up survey should be designed so that the impacts of the project and those of other factors can be distinguished as much as possible. This designing process should factor in changes in these impacts and the effects of environmental mitigation measures over time.
- If the follow-up survey finds it necessary to continue monitoring environmental changes, the points in place covered by follow-up survey and the method thereof should remain unchanged throughout the period of the follow-up survey.
- It is important to clarify the objectives of the follow-up survey and design the survey accordingly. (For example, a follow-up survey on the impacts of changes in groundwater quality on ecosystems should identify the survey locations, location, and timing (season) that are more vulnerable to such changes in the wider ecological context.)

- It is important to design the follow-up survey to be able to flexibly take additional measures if the environmental mitigation measures prove to be not effective enough or any other unexpected event happens during the survey.
- If a large-scale construction work lasts for a long time, interim forecast and evaluation results should be examined. If the project design or social conditions have changed significantly, it is important to be ready to make additional forecasts and, based on their results, reconsider the environmental mitigation measures.
- If the project proponent will not be the manager of the facilities after they are put into use, it is important to ensure that this particular manage will appropriately take over the responsibility to implement a follow-up survey and environmental mitigation measures.

(Points to note) Important considerations in selecting the items subject to a follow-up survey

For the purpose of project impact assessment, a follow-up survey may be inadequate if it focuses only on the items selected for Environmental Impact Assessment. It is therefore necessary to get a grip on other aspects, including the related environmental elements, the state of the surrounding environment, and the progress in project implementation.

These aspects include groundwater characteristics (groundwater storage, physical aspects of groundwater (e.g., groundwater level, flow direction), its quantitative aspects (e.g., recharge, discharge), and its qualitative aspects (e.g., pH, major dissolved constituents)). Yet other aspects to be examine may include the changes, if any, in adjacent land cover, and the performance of stormwater infiltration facilities installed in the project.

During a follow-up survey, it is also important to take stock of other construction works, if any, that may affect groundwater, as well as their location and scale, in and around the project area.

1.8 Topography and geology

1.8.1 Selection of environmental impact assessment items and survey, forecast and evaluation methods

1) Ascertaining project characteristics

Table III.1.8-1 shows examples of the project characteristics to be identified with regard to topography and geology.

Table III.1.8-1 Examples of the project characteristics to be identified regarding topography and geology

Impact factors	Examples of the characteristics to be identified
Implementation of construction	• Specifics, method, and duration of construction • Location and extent of construction • Extent and depth (height) of excavation, ground cutting, or filling work • Type, location, extent, and depth of piling work or earth retaining work • Type, location, and scale of temporary structures • Location and scale of borrowing pits and reception sites for construction-generated soil
Existence and use of facilities	• Specifics, location, and scale of facilities • In-service period of facilities • Location, extent, and depth of underground structures • Specifics, location, and scale of water pumping facilities • Location, structure, and scale of slopes (ground cutting and filling)

2) Ascertaining local characteristics

(1) Area

The extent where local characteristics are identified is defined in light of the local topographical and geological conditions as well as the project characteristics such as the type, location, scale, and construction method of the project.

(2) Identifying local natural and social conditions

Environmental impact assessment (EIA) for topography and geology should identify local topography and geology, important topographic and geological features, if any, and zoning and regulations by law.

Existing materials may be so outdated that they do not reflect the current state of affairs. It is thus necessary to conduct a field survey to verify that information.

Table III.1.8-2 Examples of the characteristics to be identified with regard to the national and social conditions regarding topography and geology

Classification	Examples of the characteristics to be identified
Topography and geology	Topography and geology See Chapter 3, 1.7. Groundwater.
Zoning, regulations, etc. by law	The project proponent will identify target values and relevant zoning, etc. under applicable laws and regulations. (Examples of applicable laws and regulations) • Nature Preservation Act • Convention Concerning the Protection of the World Cultural and Natural Heritage • Act on Protection of Cultural Properties • Other laws and regulations designed to conserve the environment • Local governments' ordinances, plans, etc. regarding important topographic and geological features

3) Selecting environmental impact assessment items

(1) Identifying impact factors and environmental elements

Impact factors for topography or geology include the disappearance or reduction of topography or geology associated with topographic alternation, as well as the impacts of changes in the conditions of the surrounding environment regarding topography or geology associated with the existence or use of structures, etc. (e.g., impact, degradation, and destabilization associated with changes in groundwater).

(2) Selecting environmental impact assessment items

The project proponent will select the items to be studied in an environmental impact assessment (EIA) in relation to impact factors and environmental elements.

(Points to note)

Environmental Impact Assessment for topography and geology focuses on the impact on important topographic and geological features (see Chapter 1, 1.3.1. Characteristics of Topography and Geology). Accordingly, depending on the positional relationship between the project area and important topographic and geological features, a variable may not be selected as an Environmental Impact Assessment item (i) if it is clear that the extent of the environmental impact is non-existent or negligible as far as that variable is concerned, or (ii) if it is clear that there will be no areas or other features/facilities subject to environmental impacts regarding that variable in or around the project area for a significant period of time.

In this case, it is important to show the information that forms the grounds for this decision in "Project content" or "Regional overview" in the scoping document.

4) Selection of survey, forecast and evaluation methods

(1) Concept of examining methods

Environmental Impact Assessment for important topographic and geological features should describe not only the impacts of direct alterations; it should also consider environmental impacts associated with changes in the conditions of the surrounding environment to identify the survey, forecast, and evaluation methods.

(2) More detailed or simpler survey and forecast methods

Criteria for adopting elaborated or simplified methods of survey and forecast may include the following:

(Examples when examining more detailed survey and forecast methods)

1. Where the extent of the environmental impact could be significant
2. Where there is an area or feature/facility vulnerable to environmental impacts
3. Where local or project characteristics make forecast rather difficult when a standard method is used
   - An area that has complex topographic and geological characteristics
   - An area that has particular topographic and geological features such as coral reefs, sand dunes, marshes, volcanos or volcano phenomena, palaeobios-containing stratigraphy, outcrops important in the history of the Earth
4. Where there is something on which the local government and the project proponent place special value for environmental preservation
   - There is something that the local government and the project proponent deem important especially for environmental preservation in light of local characteristics, project characteristics, the environmental preservation policy for the project, and the like.

(Examples when examining simpler survey and forecast methods)

1. Where it is clear that the extent of the environmental impact will be small
2. Where the extent of the environmental impact can be clearly assessed based on similar cases

1.8.2 Survey

1) Examination of survey items

The survey centers on research of existing materials and a field study. If these activities cannot gather required information at all or much of it, the project proponent may inquire of experts.

Table III.1.8-3 shows examples of survey on important topographic and geological features.

Table III.1.8-3 Examples of survey on important topographic and geological features

Example of survey	Type of information gained from survey
Survey on distribution and scale	The distribution and scale in the survey area is estimated.
Survey on features	Form, size, structure, basement (ground, geology), and condition are identified.
Survey on genesis	In formation on genesis in terms of historical geology, formation processes and mechanisms is gathered.
Survey on importance	The state of zoning under laws and regulations regarding environmental preservation as well as assessments in existing materials are sorted out. The regional and local importance of survey items are assessed based on the findings of the above-mentioned types of survey. The reasons why such items are deemed important in applicable laws and regulations are identified.

(Points to note) Survey on the importance of topographic and geological features

Topographic and geological features identified as being of importance in existing materials may include those identified so in the context of environmental preservation, or those whose reasons for such identification are irrelevant in the survey area. It is therefore important to carefully examine such reasons and local characteristics.

When identifying important topographic and geological features, adequate attention should also be paid to their value in a regional context in addition to a national context.

A case in point is topographic and geological features that are deep-rooted in local communities. These include (i) specific geographical features that are intertwined with the location of local communities or local sociocultural characteristics, (ii) local topographic features or natural phenomena that are traditional religious objects for the local community, and (iii) those that have created tangible and intangible value and now contribute to the local economy.

2) Concept of survey area and location

The survey area is identified as the geographical extent that is deemed large enough to assess the project impact in light of project characteristics and local characteristics. This extent includes the zone that could be affected by the project. The geographical extent of the impact of project implementation varies depending on a range of factors, including impact factors, topography, the geological structure, and the distribution of water systems. For this reason, the survey area should not be mechanically defined as the extent whose distance from the project area is constant; rather, it should be defined by topographic or geological unit or in light of other local characteristics. Finally, the survey area should preferably include a zone where information needed for forecasts is available from an adjacent type locality with regard to important topographic and geological features, even though this particular zone could not be affected by the project.

3) Concept of survey period and time

The project proponent can determine the period and timing of the survey at he or she seems fit because neither topography nor geology is subject to seasonal variations. It is a common practice, however, to avoid the periods when outcrops and other topographic features are difficult to identify, such as when vegetation is luxuriant and when it snows. If important topographic and geological features and natural phenomena vary by season, the period and timing of the survey should be defined in such a way that their characteristics can be appropriately assessed. In the case of fountains and springs, for example, their discharge and distribution are identified in the dry and wet seasons, separately.

1.8.3 Forecast

1) Concept of forecast method

The degree of disappearance or reduction of important topographic and geological features associated with topographic alternation is forecasted by superimposing the geographical extent of land alteration due to the project over the distributional extent of such features. The degree of impact associated with changes in the conditions of the surrounding environment is forecasted in light of a number of factors. They include the possible impact expected from local topographic and geological characteristics, as well as survey findings, past similar cases, and available scientific knowledge. In making the second type of forecast, it should be remembered that topographic features, especially sand dunes and marshes, are subject to changes in different aspects, including (i) meteorological conditions; (ii) elements of the water environment such as groundwater levels, tidal currents, and oceanic conditions; (iii) other basement environments; and (iv) the flora that covers the ground surface.

2) Concept of forecast area and location

Essentially, the forecast area should be the same as the survey area. Detailed forecasts are made in and around the points where important topographic and geological features are located. If ground stability needs to be forecasted, forecast locations in place may include points where a large slope is generated, those where housing and other facilities that need care, and those around major ecosystems and water systems.

3) Concept of forecast time

The target time of forecast should be a representative point in time during the construction phase of the project and a point sometime after the construction is completed. These points should be timed so that the impact of the projects and the effectiveness of environmental mitigation measures can be appropriately assessed in light of local topographic and geological characteristics and the project characteristics. Such a representative point in time may be when the site preparation work peaks or when the impact of the construction work is the largest.

If the construction work plan divides the whole process into two or more long subperiods and work sections, the target time of forecast should preferably established for each of these subperiods and work sections.

1.8.4 Environmental mitigation measures

1) Procedures for examining environmental mitigation measures

(1) Examining environmental mitigation measures policy

In devising a policy of environmental mitigation measures for important topographic and geological features, the degree of importance and characteristics of such features should be taken into account. Adequate attention should be paid to their value in a regional context in addition to a national context.

If a current status survey finds that a feature deemed important earlier has disappeared or its value has been lost and that it is not appropriate to take environmental mitigation measures for it, this finding should be described in a document that comes after draft environmental impact statement.

2) Specific environmental mitigation measures

In designing environmental mitigation measures, those designed to prevent or reduce the impact should take precedence.

Table III.1.8-4 shows examples of environmental mitigation measures for topography and geology.

Table III.1.8-4 Examples of environmental mitigation measures for topography and geology

Environmental impact	Examples of environmental mitigation measures	
Disappearance or reduction associated with topographic alternation	Steeper sloping	Adopting a retaining structure
		Adopting light filling, etc.
		Adopting anchor work, etc.
	Limiting the mortar and concrete parts	
	Record keeping	
Changes in groundwater	Adopting a recharge method	
	Adopting a water-tight structure	
	Adopting the water conduction method	
Accelerated degradation or destabilization	Adopting slope stabilization work	

Source: National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, and Public Works Research Institute, *Environment Impact Assessment Technique for Road Project (Edition of FY2012)* [in Japanese], Technical Note of NILIM No. 714, Technical Note of PWRI No. 4254, 2013.

1.8.5 Evaluation

The evaluation process concerns the prevention or reduction of environmental impacts. When the national government or the local government has standards or objectives in its environmental preservation strategy, the process also involves evaluating their alignment with these standards or objectives.

1) Evaluation relating to prevention or reduction

Evaluation on prevention or reduction is aimed at identifying and evaluating the efforts by the project proponent to prevent or reduce environmental impacts. Evaluation approaches include comparing several options for environmental mitigation measures, assessing whether feasible and better technologies are adopted, and evaluating whether efforts are made to prevent environmental degradation from the current state.

2) Evaluation relating to consistency with standards or objectives

Evaluation of the alignment with the standards or objectives means evaluation of whether the implementation of the proposed project will be in line with the environmental preservation strategies of the national and local governments concerned. Accordingly, the project proponent should understand how the standards or objectives he or she refers to fit in the environmental preservation strategies and then clarify which standards or objectives to use for evaluation and why.

In comparing these standards or objectives with the forecast results, it is important to make an evaluation in terms of not only whether or not the forecast results meet the standards or objectives but also whether the extent of the impact of the proposed project could interference with environmental preservation in light of the standards and objectives.

1.8.6 Follow-up survey

Environmental Impact Assessment entails some uncertainty in its findings as it comes before project implementation. A follow-up survey is designed to offset such forecast uncertainty. It may be conducted if the uncertainty is significant or if the project proponent takes environmental mitigation measures whose effects are not well-established. The need to conduct a follow-up survey shall be assessed in light of the seriousness of the environmental impact. Depending on the results of such a survey, it may be necessary to modify the environmental mitigation measures or implement additional ones.

A follow-up survey on important topographic and geological features may focus on changes in groundwater or the degradation of sand dunes or other fragile topography and geology. The period and timing of a follow-up survey should be appropriately identified in light of the characteristics of the survey targets.

1.9 Ground

1.9.1 Selection of environmental impact assessment items and survey, forecast and evaluation methods

1) Ascertaining project characteristics

Table III.1.9-1 shows examples of the project characteristics to be identified with regard to the ground.

Table III.1.9-1 Examples of the project characteristics to be identified regarding the ground

Impact factors	Examples of the characteristics to be identified
Implementation of construction	• Specifics, method, and duration of construction • Location and extent of construction • Extent and depth (height) of excavation, ground cutting, or filling work • Type, location, extent, and depth of piling work or earth retaining work • Type, location, and scale of temporary structures • Location and scale of borrowing pits and reception sites for construction-generated soil • Description and period of auxiliary processes such as drainage work, water cut-off, pneumatic engineering, freezing work, and chemical grouting
Existence and use of facilities	• Specifics, location, and scale of facilities • In-service period of facilities • Location, extent, and depth of underground structures • Specifics, location, and scale of water pumping facilities • Location, structure, and scale of slopes (ground cutting and filling) • • Location and scale of reception sites for construction-generated soil

2) Ascertaining local characteristics

(1) Area

The extent where local characteristics are identified is defined in light of the local topographical and geological conditions as well as the project characteristics such as the type, location, scale, and construction method of the project. Particular attention should be paid to the surrounding conditions as described below. In particular, the extent where local characteristics are identified downstream in the groundwater flow direction should be wide enough.

- Areas where ground subsidence zones or Quaternary systems that may entail subsidence or liquefaction are distributed
- Areas with high groundwater levels (e.g., filled land, rivers, coastal plains)
- Areas with possible ground deformation or disturbance (e.g., landslide areas, steep slopes, taluses, limestone land, remains of underground diggings)
- Areas where faults in close proximity are distributed
- Sediment discharge destinations, etc.

In defining the extent of a survey of ground subsidence associated with a fall in groundwater level, "Standard Extent of a Groundwater Survey Associated with Underground Excavation" can be used for reference (see Tables III.1.7-3 and III.1.7-4)

(2) Identifying local natural and social conditions

Tables III.1.9-2 and Table III.1.9-3 show examples of the characteristics to be identified with regard to local natural and social conditions.

Existing materials on the ground vary in map scale, content, perspective, and accuracy. For this reason, collecting and organizing existing materials alone do not lead to the adequate assessment of the state of the affairs; they should be interpreted by knowledgeable engineers. This is where a field survey comes into play, enhancing the accuracy of the information gained from existing materials and filling the information void on local characteristics.

Table III.1.9-2 Examples of the characteristics to be identified with regard to the natural conditions regarding the ground

Classification	Examples of the characteristics to be identified
State of the atmospheric environment	Precipitation See Chapter 3, 1.7. Groundwater.
State of the water environment	Groundwater See Chapter 3, 1.7. Groundwater.
State of the ground	(a) Land history Ground stability may be affected by site preparation works, floods, etc. in the past. The history of these events should be checked. (b) Ground subsidence
Topography and geology	(a) Topography and geology See Chapter 3, 1.7. Groundwater.

* *Aboido mappu*: A kind of hazard map that shows different types of designated hazard zones, including zones that suffered natural disasters in the past, those where such disasters are predicted, and slope failure hazard zones.

Table III.1.9-3 Examples of the characteristics to be identified with regard to the social conditions regarding the ground

Classification	Examples of the characteristics to be identified
Population and industry	(a) Population Check the population of the survey area and its distribution. (b) Industry Assess the state of the industries in the survey area that could affect groundwater pumping and other ground conditions, including their general facts and figures and the location of their major facilities.
Land use	(a) Land use Assess land use mainly with land use maps. If necessary, use vegetation maps, aerial photographs, and other existing materials and conduct a field survey as well. (b) Land use zoning Describe the land use zoning of the survey area chiefly with the help of relevant urban planning maps. It is also necessary to predict possible changes in land use zoning in the future by using such materials as the comprehensive plan of the local government concerned, including the land use guidance policy. (c) State of structures, etc. Describe the distribution and arrangement of roads, railways, buried pipelines, and other transportation facilities that are particularly vulnerable ground subsidence or deformation.
Groundwater usage	Obtain the statistics on the quantities of groundwater by type of use, including tap water, agricultural water, and industrial water. Locate the major points in place for the use of the existing wells. Identify the location of, and the consumption at, related facilities.
Objects deemed vulnerable	(a) Distribution and arrangement of facilities, etc. deemed vulnerable Describe the distribution and arrangement of facilities, etc. considered vulnerable to ground subsidence or deformation. (b) Distribution and arrangement of housing Describing the distribution and arrangement of housing should involve checking land use and land use zoning under the City Planning Act. It should also involve a field survey aimed at assessing the current state of affairs. It is also necessary to describe any possibility of future housing development by using such materials as the comprehensive plan of the local government concerned, including the land use guidance policy.

3) Selecting environmental impact assessment items

Environmental Impact Assessment for the ground has often focused on ground subsidence associated with project implementation. It is desirable, however, to focus also on changes in ground stability due to development activities (increased risks of ground deformation such as liquefaction and ground collapse as well as landslide, landslip, etc.) as Environmental Impact Assessment items.

Recent years have witnessed a growing number of projects that construct structures at great depths.[4] When a reductive stratum comes to contact with air (oxygen), the resulting chemical reactions may make ground water strongly acid, emit toxic gases, generate heat in the ground, or weaken the ground strength. All these possibilities should preferably be taken into account as well.

(1) Arranging impact factors

Possible impact factors for the ground should be identified in light of the characteristics of the project, including the act of altering the ground surface, the implementation of construction work that may trigger groundwater subsidence, the existence of facilities.

(2) Arranging environmental elements

Environmental elements regarding the ground include ground subsidence associated with project implementation and the impact of development activities on ground stability

Attention should also be paid to the state of active faults and the history of landslides and landslip in and around the project area.

(3) Selecting environmental impact assessment items

The project proponent will select the items to be studied in an environmental impact assessment (EIA) in relation to impact factors and environmental elements.

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[4] Great depth: The Act on Special Measures concerning Public Use of Deep Underground defines the term "underground at great depth" as underground at greater depth of (i) or (ii) in the following:
(i) Depth at which basements are not usually constructed (40 m or deeper underground)
(ii) Depth at which the foundation of buildings is not usually constructed (10 m or deeper from the surface of the bearing ground)

(Points to note)

A variable may not be selected as an Environmental Impact Assessment item (i) if it is clear that the extent of the environmental impact is non-existent or negligible as far as that variable is concerned, or (ii) if it is clear that there will be no areas or other features/facilities subject to environmental impacts regarding that variable in or around the project area for a significant period of time. In this case, it is important to show the information that forms the grounds for this decision in "Project content" or "Regional overview" in the scoping document.

The phase "areas or other features/facilities subject to environmental impacts" in clause (ii) above refers primarily to areas involving the human living environment or areas where a natural environment exists that is affected by changes in ground. However, clause (ii) is inconceivable in reality in light of the continuity of groundwater, which is closely associated with ground subsidence.

4) Selection of survey, forecast and evaluation methods

(1) Concept of examining methods

Environmental Impact Assessment for the ground should fully describe the local characteristics and the basin characteristics (land use, groundwater basins, groundwater use), as well as social factors such as the history and use of land and other projects.

Environmental impacts on the ground are closely related to the water environment. The prerequisites for forecasting the impacts on the ground often include the results of the survey and forecast concerning groundwater, as well as topography, stratigraphic compositions, and the sedimentation environment. In light of these factors, forecasts are made as to the degree, geographical extent, and timing of the project impact on the ground. Based on such forecast results, environmental mitigation measures are devised and implemented as necessary. It is also necessary to study techniques for comprehensively surveying, forecasting, and evaluating other environmental elements that may be relevant as well as the impacts on the ground.

(2) More detailed or simpler survey and forecast methods

A number of approaches can be taken to elaborate the methods of surveying and forecasting the ground. These approaches may include (i) conducting a detailed field study to identify the conditions necessary for forecasts and environmental mitigation measures; (ii) densely distributing survey locations and forecast locations; (iii) adopting a sophisticated forecast method; and (iv) elaborating input conditions for the forecast model. Approaches to simplifying survey and forecast methods may include (i) setting conditions necessary for forecasts based on existing materials; and (ii) adopting a method designed to forecast the impact by comparing with past similar cases. Criteria for adopting elaborated or simplified methods of survey and forecast may include the following:

(Examples when examining more detailed survey and forecast methods)

1. Where the extent of the environmental impact could be significant
2. Where there is an area or feature/facility vulnerable to environmental impacts
   - An area where the Quaternary ground that may entail subsidence or liquefaction is distributed

- An area with precision machinery and other industrial facilities (ground subsidence) or residences (landslide, landslip)

3. Where there is an area or feature/facility designated by a law or regulation in the context of environmental preservation
   - An area designated under the Industrial Water Act
   - An area designated under the Act on the Regulation of Pumping-up of Groundwater for Use in Buildings
   - A landslide-threatened area as provided by the Landslide Prevention Act
   - A steep slope area in danger of failure as provided by the Act on Prevention of Disasters Caused by Steep Slope Failure
   - An area designated under the pollution control ordinance, etc. of the local government concerned
4. Where there is an area whose environment has already been, or could be, degraded significantly
   - An area where ground subsidence is causing problems
   - An area where ground deformation is occurring or occurred in the past
5. Where local or project characteristics make forecast rather difficult when a standard method is used
   - An areas with complex topographic or geological features
   - An area with geological features such as coral reefs
6. Where there is something on which the local government and the project proponent place special value for environmental preservation
   - There is something that the local government and the project proponent deem important especially for environmental preservation in light of local characteristics, project characteristics, the environmental preservation policy for the project, and the like.

(Examples when examining simpler survey and forecast methods)

1. Where it is clear that the extent of the environmental impact will be small
   - If the project proponent can explain, based the project design, that the extent of the environmental impact will be small, he or she may make forecasts by quantifying the impact factors that provide such explanations.
2. Where the extent of the environmental impact can be clearly assessed based on similar cases
   - The findings of past surveys for similar projects may be used to estimate and forecast the extent of the environmental impact.

1.9.2 Survey

1) Examination of survey items

Survey items for the ground include topography, groundwater level, and the distribution and properties of aquifers and soft ground layers. Also to be described are the state of ground subsidence and deformation and the state of water pumping facilities in and around the project area.

2) Concept of survey method

To assess environmental impacts on the ground, it is important to describe the ground compositions (both in vertical and horizontal directions) based on geological/soil surveying. A boring survey is essential to confirm the stratigraphy, groundwater levels, and ground strength (N value[5]). It may also be necessary to identify or describe (i) hydraulic constants and water quality based on permeability and pumping testing; (ii) detailed strength characteristics based on samples with little disturbance; and (iii) consolidation characteristics of cohesive soil.

Although a survey on the state of ground subsidence and deformation is typically made by researching existing materials, it may be necessary to conduct field observation and leveling. Estimating the shrinkage of each underground layer may require the continuous measurement of groundwater levels and subsidence quantities at ground subsidence observation wells

3) Concept of survey area and location

(1) Survey area

The survey area is defined in light of a number of elements that affect the ground, including topographic distribution, the geological structure, the distribution of aquifers, and the soil engineering characteristics of the ground. The survey area may not be limited to the project area; it should preferably be defined in a wider context after reviewing various kinds of maps— including geotechnical engineering maps, hydrogeological maps, soil maps, and land use maps— to determine where the project area is topographically located and on what geological structure it stands. It is important to secure a wider extent of the survey downstream since the geographical extent of the impact of changes in groundwater level on the ground is wider downstream than upstream. To this end, the direction of the groundwater flow is estimated based on the topographic distribution and existing materials on the ground.

[5] N value: An indicator of ground strength. It denotes the number of drops it takes for a free-falling weight to be driven into a certain depth of the ground.

(2) Survey locations

A survey on the ground may be made on fixed points in place as in the case of a boring survey or long measuring lines as in the case of geophysical exploration or leveling. Survey locations or measuring lines may be defined according to the object of the survey. Survey locations and measuring lines for a field study are established defined according to the approaches described in Table III.1.9-4. If existing materials are to be used, they should meet the conditions described in Table III.1.9-4.

Table III.1.9-4 Approaches to setting survey locations for the ground

Type of survey location	Approaches to setting survey locations
Points that represent the area	Survey locations and measuring lines are determined in such a way that the state of the ground in the survey area can be assessed appropriately in light of the local topography and geology. If the survey area has two or more different topographies, survey locations and measuring lines should be set for each topography. Toward the boundaries of the topographies, such points and line may need to be set more densely.
Points where the impact will possibly be particularly high	The points where the impact of the project will possibly be particularly high (e.g., areas where the ground that may entail ground subsidence or changes in ground stability is distributed, steep slopes) will be roughly established in light of the project characteristics and past similar cases. It is necessary to confirm that the impact of any other construction work on these points will be small.
Points where there is an feature/facility that requires special consideration for environmental preservation	Points with a special feature/facility that should be conserved may need to be identified as part of the survey locations in light of the project characteristics and past similar cases.
Points where the environment has already deteriorated significantly	Areas where ground subsidence is already causing problems should be selected.

1.9.3 Forecast

1) Basic Approach to forecast

As far as the ground is concerned, there are no reference values or standards that serve as target of environmental preservation. Moreover, interactions with various functions of the ground and structural factors make things quite complex. For these reasons, evaluation may be made by reviewing past similar cases or identifying the impact of changes in the ground on groundwater use as an indicator. Forecasting environmental impacts therefore requires flexible arrangements that factor in these assessment aspects.

2) Concept of forecast method

The forecast method for ground should be selected from one of the following or the combination thereof that best fits the forecast purpose in light of such factors as the type and scale of the proposed project, local geology, and the state of groundwater.

- Forecast method based on actual measured values

- Forecast method based on theoretical formulae
- Forecast method based on numerical simulation
- Any other appropriate forecast method

Of the forecast methods for the ground, those that concern ground deformation associated with excavation are illustrated in Table III.1.9-5.

Table III.1.9-5 Examples of forecast methods that concern ground deformation associated with excavation

Forecast method	Brief description of forecast method
Methods based on actual measured values	• Water level displacement in the surrounding ground when the vibratory sand compaction pile (SCP) method or non-vibratory SCP method is being applied is generally evaluated based on actual measurement examples. • Peck[1)] presents a relational diagram on normalized quantity—calculated by dividing the subsidence quantity and the distance from earth retaining wall by excavation depth—for all kinds of ground. This diagram draws on many actual measurement examples, including those on settlement due to soil transfer and consolidation settlement. • Maruoka and Ikuta[2)] focuses on alluvial cohesive. With regard to soil whose N value is less than 10 (a deformation of 5 mm or more), they organize actual measured values where subsidence due to a deformed earth retaining wall, ground up-lift due to excavation, and the wraparound of the ground behind a earth retaining wall are major factors. • Abe and Kijima[3)] focuses on soft cohesive soil. Based on ten sets of measured data, they normalize the subsidence quantity by the excavation depth and make classification by the flexural rigidity of the wall into three types (diaphragm wall, column line pile, sheet pile).
Methods based on theoretical formulae	• Nozu and Takeuchi[4)] focuses only on the sand ground. Based on measured data, they present a relationship between the natural logarithm of the horizontal displacement of the surface of the surrounding ground associated with the application of the non-vibratory sand compaction pile method and the distance from the application site. • Matsuo and Kawamura[5)] focuses on soft or medium cohesive soil. Based on measured data, they identify three types of relationships: (i) the relationship between the maximum deflection of the earth retaining wall and the area of deflection, (ii) the relationship between the area of deflection and the area of subsidence, and (iii) the relationship between the maximum subsidence quantity and the area of subsidence. They then present the relationship between the maximum deflection quantity and the maximum subsidence quantity as a weak proportional relation. By analyzing circular slips, Matsuo and Kawamura also examines the maximum subsidence quantity, the extent of the subsidence impact, and the location of the maximum subsidence quantity. • Maruoka, Ikuta, et al.[6)7)] focus on soft cohesive soil. With the calculation that factors in the consolidation of the clay layer, they present the quantity of subsidence due to water pumping as well as the quantity of subsidence due to the deformation of the earth retaining wall. • Honda, Yamamoto, et al.[8)] presents the procedure of calculating the maximum subsidence quantity based on three assumptions at the time of pulling out the earth retaining wall: (i) that the void quantity and the subsidence quantity associated with the pulling-out are equal; (ii) that the impact will extend from the tip along the slip line, and (iii) that subsidence analysis presumes that the ground behind the wall is the largest triangle.
Methods based on numerical simulation	• All these methods described above have a few problems, one of which is the inability to factor in the strength of the surrounding ground as well as the presence or absence of a structure. Methods based on FEM analysis offer more accurate forecasts of the deformation amount of the surrounding ground or structures. • What matters for such analysis is the utilization of measured data, as suggested by Sugimoto and Sasaki,[9)] Mana & Clough,[10)] and Sugimoto.[11)]

References:

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2) Maruoka, Masao, and Yuko Ikuta (1986), “Surface Settlements Caused by Excavations in Alluvial Deposit” [in Japanese], *Proceedings of the 21st Japan National Conference on Geotechnical Engineering*, pp. 1369-1370.

3) Abe, Hiroshi, and Shiro Kijima (1977). "Nanjaku Nenseido Jiban no Daikibo Kussaku Koji ni okeru Shuhen Jiban no Chinka ni Tsuite" [subsidence in the neighboring ground during large-scale excavation work on weak viscous ground], *Proceedings of the 12th Japan National Conference on Geotechnical Engineering*, pp. 1161-1164.
4) Nozu, Mitsuo, and Hidekatsu Takeuchi (2001). "Doteki Shimekatame Sunakui Koho no Seko ni Tomonau Shuhen Jiban no Hen'i Yosoku" [displacement prediction of the surrounding ground associated with the application of the vibratory sand compaction pile method," *Proceedings of 46th Geotechnical Engineering Symposium, Japanese Geotechnical Society*, pp. 135-140.
5) Matsuo, Minoru, and Kunio Kawamura (1981). "Kussaku Genba Shuhen no Chinka Yosoku" [subsidence prediction for the ground surrounding excavation sites], *Proceedings of the 26th Japanese Geotechnical Society Symposium*, pp. 61-68.
6) Maruoka, Masao, Yuko Ikuta, Ishio Taguchi, and Yasushi Mende (1977). "Nekiri Yamadome Koji ni Tomonau Shuhen Jiban Chinkaryo no Suitei" [estimation of the subsidence quantity of the surrounding ground associated with excavation and earth retaining work], Proceedings of the 12th Japan National Conference on Geotechnical Engineering, pp. 1157-1160.
7) Ikuta, Yuko, Masao Maruoka, Shinichi Nagao, Takafumi Mitoma, and Tomiichi Abe (1978). "Jiban Joken ni Ojita Yamadome Keisoku Kanri Komoku to Keisoku Kanrihi [management items and expenses of earth retaining measurement according to ground conditions], *Yamadome no Shosokutei ni Kansuru Shinpojiumu Happyo Ronbunshu* [proceedings of the symposium on earth retaining measurements], Japanese Geotechnical Society, pp. 69-78.
8) Honda, Kenichi, Hiroshi Yamamoto, and Osamu Ae (1984). "Dodomeko Hikinuki ni Tomonau Jiban Chinka Yosoku Hoho ni Kansuru Ichi Kosatsu" [an examination of how to predict ground subsidence associated with the pulling out of earth retaining piles], *Collection of Summaries of the 39th Annual Academic Lecture Meeting of the Japan Society of Civil Engineers*, Ⅲ-199, pp. 397-398.
9) Sugimoto, Takao, and Shunpei Sasaki (1987). "Dodomeheki no Henkei to Chihyomen Chinkaryo no Kankei" [relationship between the deformation of an earth retaining wall and the subsidence quantity of the ground surface], *Proceedings of the 22nd Japan National Conference on Geotechnical Engineering*, pp. 1261-1262.
10) Mana, A.I. and Clough, G.W. (1981). Prediction of Movement for Braced Cuts in Clay, Jour. of the Geotechnical Engineering, Vol.107, No. GT6, pp. 759-777.
11) Sugimoto, Takao (1986). "Kaisaku Koji ni Tomonau Chihyomen Chinkaryo Yosoku ni Kansuru Kenkyu" [a study on predicting the subsidence quantity of the ground surface associated with cut and cover work], *Journal of Japan Society of Civil Engineers*, No. 373, pp. 113-120.

3) Concept of forecast area and location

The forecast area should cover the geographical extent where topographic changes, water pumping, etc. due to the proposed project could affect the ground. It should be wide enough to fully include such impacts; it may cover the areas around the project area (especially those downstream) depending on the scale and degree of the impacts and the characteristics of their objects.

4) Approaches to identifying the target time and period of forecast

The period of time it takes for a change to occur to the ground or in the hydrologic cycle system varies significantly depending on a number of factors, including the scale of the proposed project, the scale of the hydrologic cycle system of concern, and the target period for forecast. These temporal and spatial scales should also be taken into account when determining the target time and period of forecast.

The target time of forecast should be the point in time when the impact on the ground is the largest for each of the different phases and aspects that are defined according to the impact factors and characteristics of the proposed project. These phases or aspects include the construction and operational phases as well as the existence and use of land or structures. The target time of forecast may need to include points in time when the project changes the impact on the water environment and the habitats of organisms.

(Points to note) Determining the target time of forecast for the ground

The characteristics of the impact factors for the ground differ between the construction and operational phases. The target time of forecast should therefore be established for these two different phases. Specifically, it should be the points in time when the impact factors such as the depth of excavation, filling, and ground cutting and the water pumping rate are at the maximum in the construction phase work. The target time of forecast for the operational phase should be when project activities (water intake, discharge, etc.) reach to the normal state. Also, groundwater, which could trigger ground subsidence, liquefaction, and landslides, change accordingly to meteorological conditions (notably precipitation). This makes it necessary to consider the dry period when groundwater levels are the lowest during the year because of little precipitation in determining the target time of forecast.

Nevertheless, the impact on the hydrologic cycle system is not always instantaneous. The time lag between the implementation of the project and the manifestation of project impacts such as changes in groundwater level varies greatly depending on the characteristics of the proposed project and the scale of the hydrologic cycle system of interest. Impact factors similar to those during the construction phase may continue to be in place even during the operational phase. Because the components of the hydrologic cycle system entail seasonal variations due to such factors as precipitation, the range and timing of such variations should be considered when making forecasts in light of long-term observation data.

1.9.4 Environmental mitigation measures

1) Procedures for examining environmental mitigation measures

(1) Examining environmental mitigation measures policy

Devising a policy of environmental mitigation measures for the ground requires identifying their objectives. To this end, impact factors are extrapolated from the environmental elements that are predicted to be affected.

(Points to note) Importance of environmental consideration in the planning phase and the necessity to identify environmental mitigation measures in light of the past developments

Generally, as the project plan proceeds, there will be less room for amending the project plan. It is therefore desirable to identify the matters that need appropriate consideration for environmental preservation at the project planning phase, that is, the phase of identifying the location and scale of the project, the arrangement and structure of facilities. As far as the ground is concerned, the identification of these elements is the most important.

If the procedure of Primary Environmental Impact Consideration is done during the project planning phase, Environmental Impact Assessment in the project implementation phase should identify more specific environmental mitigation measures in light of what has been identified in that procedure with regard to the prevention or reduction of important environmental impacts. When the project moves onto the implementation phase, it is important to proceed with the results of the process of identifying environmental mitigation measures. For example, it may be necessary to reflect what has been identified with regard to such measures in the construction and operational planning in light of the degree of environmental impacts that have been identified in the procedures of draft environmental impact statement and environmental impact statement.

2) Specific environmental mitigation measures

Environmental mitigation measures for the ground should be designed to prevent, reduce, or compensate for the far-reaching impact of the act of altering land on the hydrologic cycle functions as well as the grave impact of ground subsidence and the loss of ground stability in the vicinity of the project area on the human living environment.

The possible impact on ground stability in the project area may be evaluated in the process of designing the project plan. It is extremely difficult to erase the impact on the ground whether it is far-reaching or limited to the project area and its immediate surroundings. Once the ground is degraded, it almost never returns to the original state. It can greatly affect the human living environment as well. Such impact should therefore be evaluated in detail before the project is implemented.

For this reason, it is important that the process of identifying the project specifics in different project phases is aligned with the process of identifying environmental mitigation measures in the Environmental Impact Assessment process. Table III.1.9-6 shows examples of environmental mitigation measures for different project phases.

Table III.1.9-6 Examples of environmental mitigation measures for different project phases

Project phase		Impact factors	Examples of environmental mitigation measures
Existence	Location, arrangement, scale, structure, facilities, equipment	Borrowing pits, quarries	Slope stabilization, planting
		Underground structure	Cutting off of water, soil stabilization
		Reclaimed land	Soil stabilization
		Reservoirs and water surface areas	Erosion control, slope stabilization
Use	Operation and maintenance of facilities	Large-scale water pumping at places of business	Alternative water sources, measurement management
		Impermeable land cover	Permeable land cover, stormwater infiltration pits
Work	Construction work	Ground cutting, filling, and other topographic alternations	Slope stabilization, planting
		Cut-and-cover, underground excavation	Cutting off of water during excavation work
		Large-scale filling	Auxiliary processes such as soil stabilization and discharge drain

(Points to note) Technical difficulty with compensatory mitigation measures

The ground environment is built on long-term relationships between humans and nature. Therefore, it is often quite difficult for the project proponent to create such environment with feasible and deliberate environmental mitigation measures alone. It is therefore necessary to fully consider a number of relevant factors, including (i) the uncertainty about the effectiveness of compensatory mitigation measures, (ii) the time it takes to achieve compensation (the time lag between the loss and compensation), and (iii) unclear criteria for effectiveness evaluation. While keeping such technical difficulties in mind, it is necessary to carefully discuss the environment to create, the time it takes to achieve the objectives, and management arrangements to make.

Identifying compensatory mitigation measures requires considering the current state of the environment where compensatory mitigation measures are taken and assess possible environmental impacts of such measures. In implementing compensatory mitigation measures, it should be remembered that their effectiveness vary significantly depending on what kind of environment to create and where such measures are taken.

1.9.5 Evaluation

The evaluation process concerns the prevention or reduction of environmental impacts. When the national government or the local government has standards or objectives in its environmental preservation strategy for the selected items, the process also involves evaluating their alignment with these standards or objectives.

1) Evaluation relating to prevention or reduction

Evaluation on prevention or reduction is aimed at identifying and evaluating the efforts by the project proponent to prevent or reduce environmental impacts. Evaluation approaches include comparing several options for environmental mitigation measures, assessing whether feasible and better technologies are adopted, examining the project proponent's efforts in light of various standards set by academic societies and established scientific evidence, and evaluating whether efforts are made to prevent environmental degradation from the current state.

2) Evaluation relating to consistency with standards or objectives

Evaluation of the alignment with the standards or objectives means evaluation of whether the implementation of the proposed project will be in line with the environmental preservation strategies of the national and local governments concerned. Accordingly, the project proponent should understand how the standards or objectives he or she refers to fit in the environmental preservation strategies and then clarify which standards or objectives to use for evaluation and why.

In comparing these standards or objectives with the forecast results, it is important to make an evaluation in terms of not only whether or not the forecast results meet the standards or objectives but also whether the extent of the impact of the proposed project could interference with environmental preservation in light of the standards and objectives.

1.9.6 Follow-up survey

Environmental Impact Assessment entails some uncertainty in its findings as it comes before project implementation. A follow-up survey is designed to offset such forecast uncertainty. It may be conducted if the uncertainty is significant or if the project proponent takes environmental mitigation measures whose effects are not well-established. The need to conduct a follow-up survey shall be assessed in light of the seriousness of the environmental impact. Depending on the results of such a survey, it may be necessary to modify the environmental mitigation measures or implement additional ones.

The points for a follow-up survey will center on the points deemed most vulnerable to the impact of the project as well as the points where forecast and evaluation have been made in Environmental Impact Assessment. To assess the extent of the project impact, it is also important to set some points where the project impact is considered non-existent or negligible for comparison purposes and grasp long-term observation data for the surrounding environment.

The forecasts from the Environmental Impact Assessment process are essentially used to establish such control points.

1.10 Soil[6]

1.10.1 Selection of environmental impact assessment items and survey, forecast and evaluation methods

1) Ascertaining project characteristics

Table III.1.10 shows examples of the characteristics to be identified with regard to soil contamination.

Table III.1.10-1 Examples of the project characteristics to be identified regarding soil contamination

Impact factors	Examples of the characteristics to be identified
Implementation of construction	• Specifics, method, and duration of construction • Location and extent of construction • Extent and depth (height) of excavation, ground cutting, or filling work • Type, location, extent, and depth of piling work or earth retaining work • Type, location, and scale of temporary structures • Location and scale of borrowing pits and reception sites for construction-generated soil • Description and period of auxiliary processes such as drainage work, water cut-off, pneumatic engineering, freezing work, and chemical grouting • The sources of carried-in earth and sand and the properties of materials
Existence and use of facilities	• Specifics, location, and scale of facilities • In-service period of facilities • Location, extent, and depth of underground structures • Specifics, location, and scale of water pumping facilities • Location, structure, and scale of slopes (ground cutting and filling) • Types, uses, quantities and location of substances to be used (unintentionally generated substances) • Location and scale of reception sites for construction-generated soil

2) Ascertaining local characteristics

(1) Area

The extent where local characteristics are identified is defined in light of the local topographical and geological conditions as well as the project characteristics such as the type, location, scale, and construction method of the project. Particular attention should be paid to the surrounding conditions as described below.

6 Soil: Only soil contamination is discussed here even though important soils in terms of academic value or scarcity can be subject to EIA. Such important soils are discussed in, for example, Japanese Society of Pedology, *Preservation of Endangered Soil: Red Data Book of Soils in Japan* [in Japanese], 2000. They are discussed in relation to *important topographic and geological features* (see 1.8 Topography and Geology).

- Present and past land use (especially the locations of waste disposal sites, waste dumping sites, refineries, chemical plants, drycleaners, etc.) and possible or actual contamination if any
- Sediment discharge destinations, etc.

In particular, the geographical extent downstream in the groundwater flow direction should be wide enough.

The geographical extent where local characteristics are identified is defined by referring to the standard maximum distances groundwater contamination can go as shown in Table III.1.10-2.

Table III.1.10-2 Standard maximum distances groundwater contamination can go

Designated hazardous substances	Standard value (m)
Class I designated hazardous substances (volatile organic compounds or VOCs)	Approx. 1,000
Hexavalent chromium	Approx. 500
Arsenic, fluorine, boron	Approx. 250
Cyanogen, cadmium, lead, mercury and selenium, and Class III designated hazardous substances (agrochemicals, etc.)	Approx. 80

Source: Soil Environment Division, Environmental Management Bureau, Ministry of the Environment, *Dojo Osen Taisakuho ni Motozuku Chosa oyobi Sochi ni Kansuru Gaidorain (Kaitei Dai 2 Han)* [guidelines on surveys and measures under the Soil Contamination Countermeasures Act, 2nd revised version]

(2) Identifying local natural and social conditions

Tables III.1.10-3 and III.1.10-4 show examples of the characteristics to be identified with regard to local natural and social conditions.

Existing materials on soil contamination may vary in map scale, content, and accuracy; some of them provide point-source data only. Therefore, collecting and organizing existing materials alone do not lead to the adequate assessment of the state of the affairs; they should be interpreted by knowledgeable engineers. This is where a field survey comes into play, enhancing the accuracy of the information gained from existing materials and filling the information void on local characteristics.

Table III.1.10-3 Examples of the characteristics to be identified with regard to the natural conditions regarding soil contamination

Classification	Examples of the characteristics to be identified
State of the atmospheric environment	Precipitation See Chapter 3, 1.7. Groundwater.
State of the water environment	Groundwater See Chapter 3, 1.7. Groundwater.
State of soils	(a) Land history It is important to understand the local land history in studying the present possibility of soil contamination. The elements of such history to be examined with regard to soil contamination include the past existence of factories and other places of business, etc., agricultural land use, the origins of materials for reclamation and filling. (b) Distribution and characteristics of soils (c) State of contamination by hazardous substances The Soil Contamination Countermeasures Act stipulates that pieces of land that are found to fail to meet prescribed standards by a soil contamination investigation be designated and published. Waste disposal sites or the remains of waste dumping sites were often not recorded before applicable regulations were put in place in 1977. For this reason, a survey on the state of contamination by hazardous substances should be centered on the inquiry of land owners and government officials in charge.
Topography and geology	Topography and geology See Chapter 3, 1.7. Groundwater.

Table III.1.10-4 Examples of the characteristics to be identified with regard to the social conditions regarding soil

Classification	Examples of the characteristics to be identified
Population and industry	(a) Population Check the population of the survey area and its distribution. (b) Industry Assess the state of the industries in the survey area that could provide a source of soil contamination, including their general facts and figures and the location of their major facilities.
Land use	(a) Land use Assess land use mainly with land use maps. If necessary, use vegetation maps, aerial photographs, and other existing materials and conduct a field survey as well. (b) Land use zoning Describe the land use zoning of the survey area chiefly with the help of relevant urban planning maps. It is also necessary to describe possible changes in land use zoning in the future using such materials as the comprehensive plan of the local government concerned, including the land use guidance policy.
Groundwater usage	Records of household wells are maintained by some local governments or public health centers in a well register; however, it is not accessible to the public as it concerns private properties. To find out the location and structural scale of thermal wells, make inquiry of the nearest public health center or the prefectural government's section responsible for natural environmental preservation.

	Information on facilities that use groundwater or a spring for the source of tap water can be obtained from the register of groundwater abstractions for tap water, which is maintained by the water supply management bureau of each prefectural government. This register provides information on water supply coverage and the types of source water (groundwater and surface water).
Objects deemed vulnerable	(a) Distribution and arrangement of facilities, etc. deemed vulnerable Describe the distribution and arrangement of facilities, etc. considered vulnerable to soil contamination. (b) Distribution and arrangement of housing Describing the distribution and arrangement of housing should involve checking land use and land use zoning under the City Planning Act. It should also involve a field survey aimed at assessing the current state of affairs. It is also necessary to describe any possibility of future housing development by using such materials as the comprehensive plan of the local government concerned, including the land use guidance policy.

3) Selecting environmental impact assessment items

(1) Arranging impact factors

Impact factors for soil contamination include demolition work, construction work, the use and disposal of contaminants and other substances, etc. These factors should be identified in light of the description of the proposed project.

(2) Arranging environmental elements

Environmental elements regarding soil contamination include hazardous substances for which standards are established under relevant laws and regulations as shown in Table III.1.10-5. Attention should be paid, however, to substances that affect the living environment (those that give off offensive odor, oil, etc.) and those of much interest to local communities even though they may not be subject to regulation by law.

Table III.1.10-5 Major soil contaminants

Classification		Major soil contaminants

* Effective from April 1, 2017.

(3) Selecting environmental impact assessment items

The project proponent will select the items to be studied in an environmental impact assessment (EIA) in relation to impact factors and environmental elements.

(Points to note)

A variable may not be selected as an Environmental Impact Assessment item (i) if it is clear that the extent of the environmental impact is non-existent or negligible as far as that variable is concerned, or (ii) if it is clear that there will be no areas or other features/facilities subject to environmental impacts regarding that variable in or around the project area for a significant period of time. In this case, it is important to show the information that forms the grounds for this decision in “Project content” or “Regional overview” in the scoping document.

The phase “areas or other features/facilities subject to environmental impacts” in clause (ii) above refers primarily to areas involving the human living environment or areas where a natural environment exists that is affected by changes in soil. Environmental Impact Assessment may not focus on soils if there are no zones that could cause soil contamination or soils of precious academic value in and around the project area.

4) Selection of survey, forecast and evaluation methods

(1) Concept

Environmental Impact Assessment for soil contamination may need to examine the transmission, dispersion, and exposure routes for forecasting and evaluating their impacts on the surrounding environment. Although it is important for Environmental Impact Assessment to focus primarily on the impact on human health, it may need to focus also on the impact on the living environment and even the habitats of local organisms depending on the adjacent environmental conditions. It is often difficult to assess the state of oil contamination by researching existing materials in the scoping document process. Depending on the findings of the field study, it may be necessary to reconsider the specific substances subject to Environmental Impact Assessment or the survey, forecast, and evaluation methods.

In light of the above, Environmental Impact Assessment for soil contamination needs to pay attention to the following:

- How to understand soil contamination in the target area
- Actual state of soil contamination
- Impacts on the surrounding environment before project implementation
- Environmental risks incurred by project implementation (construction work, soil contamination control work)
- New soil contamination due to project activities and its impact on the surrounding environment

(Points to note) How to understand soil contamination in the project area

Soil contamination generally refers to the existence in the soil of hazardous substances that are subject to environmental standards in excess of such standard values. It may be caused by human or natural factors or both.

For an Environmental Impact Assessment perspective, soils should be understand in light of a number of project characteristics, including adjacent land use, the local characteristics of water systems, and the possibility of construction-generated soil being transported to the outside.

- Actual state of the soil in the project area

Although the actual state of soil contamination is assessed primarily by referring to environmental standards, such assessment should be made in light of the characteristics of the project area. To reduce environmental impacts, it is especially important to locate contamination sources and understand the mechanisms of infiltration, advection, and diffusion of contaminants in the ground.

- Impacts on the surrounding environment before project implementation

Impacts of soil contamination on the surrounding environment before project implementation are assessed. This process involves a number of steps, including factoring in the state of the soil in the project area, identifying the objects of these impacts (e.g., an environments needed for healthy human life, the habits of local), examining their transmission route, and assessing their degree. The results of taking these steps need to be analyzed to decide whether some environmental mitigation measure is needed and, if so, what kind of measures is required.

- Environmental impacts caused by project implementation (construction, soil contamination control)

Assessment is made about the possibility that contaminants will be transmitted during project implementation, the possibility that new soil contamination will be generated, and the possibility that any environmental mitigation measure to address soil contamination will affect the environment.

<Cases where contaminants are transmitted to the surrounding environment >

1. When excavation or demolition work resulted in the transportation of contaminated soils or their dispersion into the air
2. When soil contamination control work emits polluted gases or discharge contaminated water
3. When contaminated soils are inappropriately transported out of the site.

<Cases where new soil contamination is generated>

1. When sols carried into the site for reclamation or filling are contaminated
2. When a facility containing hazardous substances in the project site is destroyed
3. When a chemical agent for chemical grouting or other purposes is mishandled

<Cases where environmental mitigation measures to address soil contamination give rise to a new environmental impact>

1. When soil replacement damages the intrinsic functions of the soil
2. When the construction of a seepage control structure disrupts aquifers or otherwise disturbs the groundwater environment
3. When changes in the physical properties of the soil or the quality of pore water due to soil amelioration affect local ecosystems

- Occurrence of new soil contamination due to project activities and its impacts on the surrounding environment

Assessment is made about the possibility of new soil contamination being generated in light of the project description.

<Cases where new soil contamination being generated>

1. When contaminated water leaks from a discharge route, pit, or tank
2. When a leachate infiltrates into the ground
3. When exhaust gas, soot or dust precipitates
4. When a pipe or tank breaks, a fire breaks, or an accident occurs during transportation

(2) More detailed or simpler survey and forecast methods

A number of approaches can be taken to elaborate the methods of surveying and forecasting soil contamination. These approaches may include (i) conducting a detailed field study to identify the conditions necessary for forecasts and environmental mitigation measures; and (ii) densely distributing survey locations and forecast locations. Approaches to simplifying survey and forecast methods may include (i) setting conditions necessary for forecasts based on existing materials; and (ii) adopting a method designed to forecast the impact by comparing with past similar cases.

Criteria for adopting elaborated or simplified methods of survey and forecast may include the following:

(Examples when examining more detailed survey and forecast methods)

1. Where the extent of the environmental impact could be significant
2. Where there is an area or feature/facility vulnerable to environmental impacts
   - An area with groundwater or a spring that serves as a source of service water is recharged
   - An area with agricultural land
   - An area with a soil that is important in terms of academic value or scarcity
3. Where there is an area or feature/facility designated by a law or regulation in the context of environmental preservation
4. Where there is an area whose environment has already been, or could be, degraded significantly
   - An area where environmental standards for soil contamination have not been met
5. Where local or project characteristics make forecast rather difficult when a standard method is used
   - An area that has complex topographic and geological characteristics
6. Where there is something on which the local government and the project proponent place special value for environmental preservation
   - There is something that the local government and the project proponent deem important especially for environmental preservation in light of local characteristics, project characteristics, the environmental preservation policy for the project, and the like.

(Examples when examining simpler survey and forecast methods)

1. Where it is clear that the extent of the environmental impact will be small
   - If the project proponent can explain, based the project design, that the extent of the environmental impact will be small, he or she may make forecasts by quantifying the impact factors that provide such explanations.
2. Where the extent of the environmental impact can be clearly assessed based on similar cases
   - The findings of past surveys for similar projects may be used to estimate and forecast the extent of the environmental impact.

1.10.2 Survey

1) Examination of survey items

Items to be surveyed with regard to soil contamination are identified by referring to the substances subject to regulation by law as shown in Table III.1.10-5, in light of the project characteristics and local characteristics.

2) Concept of survey method

A soil contamination survey is designed to elucidate the contamination mechanism and identify the transmission routes of contaminants based on the data gained from earlier surveys and as well as the project characteristics and local characteristics.

Assessing the actual state of soil contamination and identifying such routes with soil contamination surveying should accommodate the particular characteristics of the survey area, which include the availability of existing materials, the possibility of soil contamination, the characteristics local topography, geology, and groundwater, and expected impacts on the surrounding environment. However, there may be some cases where an adequate field study cannot be conducted in the survey phase.

Examples of land history surveys based on existing materials are presented in Table III.1.10-6. Table III.1.10-7 shows important matters to consider and points to note in conducting a soil contamination survey.

(Points to note) Selecting the survey method for soil contamination

The survey method for a field study can be identified by referring to a number of materials, including the Soil Contamination Countermeasures Act, the Act on Special Measures against Dioxins, *Kensetsu Koji de Sogusuru Jiban Osen Dojo Taisaku Manyuaru (Kaiteiban)* [manual on how to address ground contamination encountered in construction work (revised version)], and *Kensetsu Koji de Sogusuru Daiokishinrui Osen Dojo Taisaku Manyuaru (Zanteiban)* [manual on how to address dioxin contamination encountered in construction work (provisional version)].

These manuals are irrelevant to the possibility that naturally-occurring heavy metals in rock will harm human health since these harmful substances are different in nature from general soil contaminants. A useful source of information for selecting an appropriate survey method comes from *Kensetsu Koji ni Okeru Shizen Yurai Jukinzoku to Gan'yu Ganseki Dojo he no Taio Manyuaru (Zanteiban)* [manual on how to address rock and soils that contain naturally-occurring heavy metals in construction work (provisional version)].

If soils containing waste may affect the environment, *Kensetsu Koji de Sogusuru Haikibutsu Majirido Taio Manyuaru* [manual on how to address soils mixed with waste encountered in construction work] comes in handy.

Table III.1.10-6 Examples of land history survey

Materials for land history survey	How to use the materials
Copies of closed land registries Copies of building registries, etc.	Provide grounds for the type of land use such as forests and farmland and the name of the company that owned the premises in the past. However, the registered category of land may differ from the actual use of land. It is therefore necessary to gain relevant maps, aerial photographs, etc. to substantiate the actual land use.
Copies of commercial registers (certificates of corporate registered information) Materials from local governments, etc.	Provide information that identifies the business type of factories and other places.
Past maps issued by the Geospatial Information Authority of Japan (GSI) Past residential maps	Provide grounds for the presence or absence of factories as well as land use such as forests and farmland.
Past aerial photographs	Provide grounds for the presence or absence of factories as well as land use such as forests and farmland. Aerial photographs of circa. 1945 onward are available from the websites of GSI and MLIT.
Plot plans for factories and facilities, water discharge route maps, piping diagrams	Provide information that determines the presence or absence of any facility that handle hazardous substances. If effluent might be involved, its discharge route must be identified.
Various kinds of registration statements, applications for permission for factories	Hazardous substances that were handled in the past can be identified with a combination of the Water Pollution Prevention Act, the Sewerage Act, registration statements of establishment for facilities subject to pollution-related registration, and other documents prescribed by law concerning the use of hazardous substances.
Inquiries of interested parties and stakeholders	Such inquiries are made based on the materials described above.

Table III.1.10-7 Important matters to consider and points for soil contamination surveys

Important matters to consider	Points to note for survey
(i) Transmission characteristics of target contaminants	The existence form (solutions, power, mixture, etc.) of the target contaminant provide an important clue to its transmission characteristics. Also of importance are the characteristics of the target contaminant in terms of its dissolution into groundwater, changes in these characteristics associated with changes in the chemical environment (pH, oxidation-reduction potential, etc.), and its adsorption characteristics in relation to soil particles that comprise the soil in the project area.
(ii) Causes of soil contamination	It is necessary to examine the origin and route for the target contaminant (leakage from an underground pit, precipitation on the ground surface via the atmosphere, etc.) in order to determine whether it is infiltrated (transmitted) in the soil or how it has come to exist in the soil (filling, reclamation, etc.).
(iii) Transmission of contaminants	The geological and hydrogeological structure should be identified to evaluate the existence form and transmission characteristics of contaminants in the soil and the possibility that they will dissolve into groundwater, and the possibility that contaminated soil will move, fly, or flow onto the ground surface. Then the transmissivity of contaminants should be analyzed.

Source: Environmental Policy Bureau, Ministry of the Environment, *Technical Guidance on Environmental Impact Assessment: Air, Water, Soil, Waste and Greenhouse gases, etc.* [in Japanese], 2006, Japan Association of Environment Assessment.

3) Concept of survey area and location

(1) Survey Area

The project proponent will identify the geographical extent of the possible impact as the survey area for soil contamination in light of the characteristics of the proposed project and local characteristics. Rather than mechanically delineating the extent in terms of a fixed straight-line distance, the project proponent should define it appropriately as the extent where pollution could diffuse via groundwater or the atmosphere due to project implementation or the extent where local ecosystems could be affected. If contaminated soil is transported out of the project area for treatment, the destination for such soil should be included in the survey area.

(2) Survey locations

For a field study, the project proponent will set survey locations while considering the approaches described in Table III.1.10-8. If the project proponent wishes to use existing materials, he or she should do so after confirming that they meet the conditions described below:

Table III.1.10-8 Approaches to setting survey locations for soil contamination

Type of survey location	Approaches to setting survey locations
Points that represent the area	Setting survey locations for soil contamination requires complying with the Soil Contamination Countermeasures Act and considering the characteristics of the survey area. For example, if the survey area has two or more different topographies, survey locations and measuring lines should be set for each topography. Toward the boundaries of the topographies, survey locations and measuring lines may need to be set more densely.
Points where the impact will possibly be particularly high	The points where the impact of the project will possibly be particularly high will be roughly established in light of the project characteristics and past similar cases. It is necessary to confirm that the impact of any other construction work or contamination source on these points will be small.
Points where there is an feature/facility that requires special consideration for environmental preservation	Agricultural land, a water source area, or any other point with a special feature/facility that should be conserved may need to be identified as part of the survey locations in light of the project characteristics and past similar cases.
Points where the environment has already deteriorated significantly	Areas where soil contamination is already occurring should be selected.

1.10.3 Forecast

1) Basic Approach to forecast

Soil contaminants are largely divided into two types: heavy metals and volatile organic compounds (VOCs). These two types show different transmission characteristics in groundwater as described in Table III.1.10-2. It is therefore important for the forecast to take these characteristics into full account.

2) Concept of forecast method

The project proponent will identify a specific forecast method in light of its forecast accuracy. Potential methods include:

- Making qualitative forecasts based on past similar cases, etc.
- Analyzing mass transfer using the advection-dispersion analysis technique, etc.

3) Concept of forecast area and location

Soils are less transferable than groundwater when dispersion and discharge are not considered. For this reason, the forecast area usually matches the project area. If the impact on the hydrologic cycle system or the habitats of local organisms is forecasted, however, the forecast area should be aligned with the forecasts for the hydrologic cycle system or local ecosystems.

4) Concept of forecast time

The target time of forecast should be the point in time when the impact on the soil is the largest for each of the different phases and aspects that are defined according to the impact factors and characteristics of the proposed project. These phases or aspects include the construction and operational phases as well as the existence and use of land or structures.

1.10.4 Environmental mitigation measures

1) Procedures for examining environmental mitigation measures

(1) Examining environmental mitigation measures policy

Devising a policy of environmental mitigation measures for soil contamination requires identifying their targets. To this end, impact factors are extrapolated from the environmental elements that are forecasted to be affected.

Specifically, environmental mitigation measures may be designed to prevent, reduce, or compensate for the impact of soil contamination by hazardous substances on the human health, living environment and the habitats of local organisms.

2) Specific environmental mitigation measures

Table III.1.10-9 shows examples of environmental mitigation measures to address soil contamination.

Table III.1.10-9 Examples of environmental mitigation measures (for soil contamination)

Objectives of environmental mitigation measures	Specific environmental mitigation measures
Prevention of direct soil extraction (Class II designated hazardous substances (heavy metals, etc.))	• Paving • Making the site off-limits • Replacing soils (outside and inside the site) • Filling • Removing soil contamination (excavation, in-situ cleaning), etc.
Preventing groundwater extraction	• Measuring groundwater quality • In-situ containment • Impervious containment • Preventing the expansion of groundwater contamination (water pumping facilities, permeable groundwater cleaning walls) • Removing soil contamination (excavation, in-situ cleaning), etc. • Immobilization (in-situ immobilization, immobilization and backfilling), etc.

Source: National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, and Public Works Research Institute, *Environment Impact Assessment Technique for Road Project (Edition of FY2012)* [in Japanese], Technical Note of NILIM No. 714, Technical Note of PWRI No. 4254, 2013.

1.10.5 Assessment method

The evaluation process concerns the prevention or reduction of environmental impacts. When the national government or the local government has standards or objectives in its environmental preservation strategy for the selected items, the process also involves evaluating their alignment with these standards or objectives.

1) Evaluation relating to prevention or reduction

Evaluation on prevention or reduction is aimed at identifying and evaluating the efforts by the project proponent to prevent or reduce environmental impacts. Evaluation approaches include comparing several options for environmental mitigation measures, assessing whether feasible and better technologies are adopted, and evaluating whether efforts are made to prevent environmental degradation from the current state.

2) Evaluation relating to consistency with standards or objectives

Table III.1.10-10 shows examples of standards or objectives for soil set by the national or local governments.

Table III.1.10-10 Examples of standards or objectives for soil

National government	Environmental standards for soil contamination under the Basic Environment Act Environmental quality standards for groundwater pollution under the Basic Environment Act Designation standards under the Soil Contamination Countermeasures Act Environmental standards for soil contamination under the Act on Special Measures against Dioxins Designation requirements for areas for countermeasures against soil contamination under the Act to Prevent Soil Contamination on Agricultural Land
Local governments	Regulations, etc. in ordinances, guidelines, etc. on soil contamination prevention Objectives of the environmental master plans, etc.

Evaluation of the alignment with the standards or objectives means evaluation of whether the implementation of the proposed project will be in line with the environmental preservation strategies of the national and local governments concerned. Accordingly, the project proponent should understand how the standards or objectives he or she refers to fit in the environmental preservation strategies and then clarify which standards or objectives to use for evaluation and why.

In comparing these standards or objectives with the forecast results, it is important to make an evaluation in terms of not only whether or not the forecast results meet the standards or objectives but also whether the extent of the impact of the proposed project could interference with environmental preservation in light of the standards and objectives.

1.10.6 Follow-up survey

Environmental Impact Assessment entails some uncertainty in its findings as it comes before project implementation. A follow-up survey is designed to offset such forecast uncertainty. It may be conducted if the uncertainty is significant or if the project proponent takes environmental mitigation measures whose effects are not well-established. The need to conduct a follow-up survey shall be assessed in light of the seriousness of the environmental impact. Depending on the results of such a survey, it may be necessary to modify the environmental mitigation measures or implement additional ones.

A follow-up survey for soil contamination may be conducted if a field study is not possible in the Environmental Impact Assessment process. It may be designed to design environmental mitigation measures in more detail by conducting a field study during the construction phase or after the land or structures are put into use.

2. Environmental load

2.1 Waste[1]

2.1.1 Selection of environmental impact assessment items and survey, forecast and evaluation methods

1) Ascertaining project characteristics

Table III.2.1-1 shows an example of the contents of project characteristics relating to waste.

When the details of the project plan have yet to be decided, the contents are ascertained by reference to similar projects.

When seeking to reduce the overall volume of waste generated and the final disposal volume, there is a need to ascertain details not just of the project, but also of facilities connected with the recycling of the waste.

Table III.2.1-1 Examples of the Project Characteristics to Be Identified Regarding waste

Impact factors	Examples of the characteristics to be identified
Implementation of construction	• Specifics, method, and duration of construction • Land cutting, filling, and soil quality associated with the construction • Details and scale of existing buildings and structures to be removed • Types and volumes of construction byproducts associated with the construction, and waste treatment plans
Existence and use of facilities	• Types and volumes of waste associated with the operation of the facilities, and waste treatment plans

2) Ascertaining local characteristics

Waste forecast and evaluation is generally based on the volume of waste generated and the final disposal volume worked out from the project plan, so local characteristics in the vicinity of the project area have very little effect on the waste generated from the project.

There is, however, a need to ascertain these conditions when examining waste recycling or intermediate treatment of waste outside the scope of the project, when waste reduction plans or objectives have been set, or when there are insufficient final disposal sites or other issues characteristic of the area.

(1) Area

The details of local characteristics to be ascertained are primarily local waste-related plans, objectives and treatment conditions, so the scope of local characteristics to be ascertained is set with consideration given to local governments and authorities in the project area, or to the extent to which waste is treated or disposed of collectively.

[1] Waste: Includes general waste and industrial waste, construction byproducts such as waste soil generated during the building process, and byproducts generated after service commencement.

(2) Waste treatment or disposal conditions

There is a need to determine the distribution of waste treatment or disposal facilities and waste acceptance facilities in the vicinity of the project area.

3) Selecting environmental impact assessment items

(1) Arranging impact factors

Impact factors are arranged taking into consideration the connection between the state of waste generation shown in Table III.2.1-2 and the project.

Table III.2.1-2 State of waste generation

Impact factors		Types of waste
During construction work	Removal of existing structures	Waste asphalt, waste concrete, waste material, etc.
	Earthworks	Waste soil, roots, felled wood, etc.
	Foundation works	Waste soil, sludge, waste concrete, waste material, etc.
	Building works	Waste concrete, woodchips, material residue, etc.
After service commencement	Operation of facilities	Food waste, sewage or septic tank sludge, production residue, etc.
	Management and administration	Food waste, paper, sewage or septic tank sludge

(2) Arranging environmental elements

Waste-related environmental elements are arranged based on the types of waste shown in Table III.2.1-3

Table III.2.1-3 Main waste

Classification		Waste etc.
Waste	Industrial waste	Combustion residue, sludge, waste oil, waste acid, waste alkali, waste plastics, scrap paper, woodchips, waste textile, animal and plant residues, animal solid waste, waste rubber, scrap metal, glass waste, porcelain waste, slag, concrete debris, animal manure, animal carcasses, soot and dust, treated material for disposal of the above industrial waste.
	General waste	Waste other than industrial waste (household waste, human waste, other waste)
Other byproducts		Waste soil, useful items generated after service commencement (scrap metal etc.), and other valuable resources

(3) Selecting environmental impact assessment items

Environmental impact assessment items are selected from the connection between impact factors and environmental elements.

(Points to note)

A variable may not be selected as an Environmental Impact Assessment item (i) if it is clear that the extent of the environmental impact is non-existent or negligible as far as that variable is concerned, or (ii) if it is clear that there will be no areas or other features/facilities subject to environmental impacts regarding that variable in or around the project area for a significant period of time. In that case, the information that serves as the grounds on which the above decision is made needs to be described in the section entitled "Specifics of the Proposed Project" or "Overview of the Area in the scoping document."

Regarding (2), as waste has no direct impact on the area around the project area, there are no envisaged elements applicable to (2).

4) Selection of survey, forecast and evaluation methods

(1) Concept

In principle, in addition to ascertaining the volume of waste generated from the implementation of the project and examining environmental mitigation measures to reduce waste, environmental impact assessments relating to waste also involve ascertaining the final disposal volume of the generated waste, and evaluating whether the project proponent is preventing or reducing the volume of generated waste and the final disposal volume of waste to the extent practicable.

Survey, forecast and evaluation methods in waste-related environmental impact assessments vary according to the scope of the survey, forecast and evaluation, so in selecting survey, forecast and evaluation methods, the scope and idea behind setting the scope must be clearly indicated. The following expands on this.

(a) Concept of the scope of the forecast, survey and evaluation

To gain a proper understanding of the final disposal volume of waste, and evaluate from a waste prevention or reduction perspective, it is necessary to examine environmental mitigation measures for reducing the final disposal volume, which covers not just the volume of waste generated from the project, but also volume reduced by intermediate treatment facilities and the volume recycled by recycling facilities. To this end, setting the scope for ascertaining the waste (referred to as "system boundary" below; see the points to note in the next section) is critical.

When setting the system boundary outside of the scope of the project, the grounds for setting the system boundary and the details of the environmental mitigation measures outside of the project scope must be indicated as specifically as possible.

The project proponent will have a lower direct involvement in environmental mitigation measures outside of the project scope, so the uncertainty of the forecast and of the environmental mitigation measures is likely to increase. It is important to be able to confirm through a statement or other means that the project proponent can become involved in waste recycling or reduction or other environmental mitigation measures, and there is also a need to examine follow-up surveys to confirm the outcome of the environmental mitigation measures as required.

(Points to note) Evaluation of environmental load and setting the system boundary (Waste)

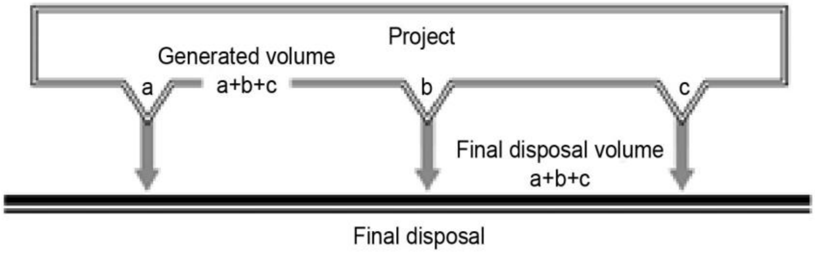
In waste evaluation, it is, first, important to reduce waste, then there is a need to forecast the volume of waste generated by the project, and evaluate from a prevention or reduction perspective.

Furthermore, from the viewpoint of establishing a sound material-cycle society, the waste generated by the project should be actively reused, then after examining recycling and thermal recycling, there is a need to forecast the final waste disposal volume, and evaluate from a prevention or reduction perspective.

To forecast the final disposal volume properly, the examination should include the reuse of waste at a project other than the project in question and waste volume reduction at a recycling facility or intermediate treatment facility, so setting an appropriate system boundary is critical.

The following is an example of expanding the system boundary to include reuse at another project, recycling at a recycling facility, and waste volume reduction at an intermediate treatment facility.

<When the system boundary is the within the project scope>



<When the system boundary expands to beyond the project scope>

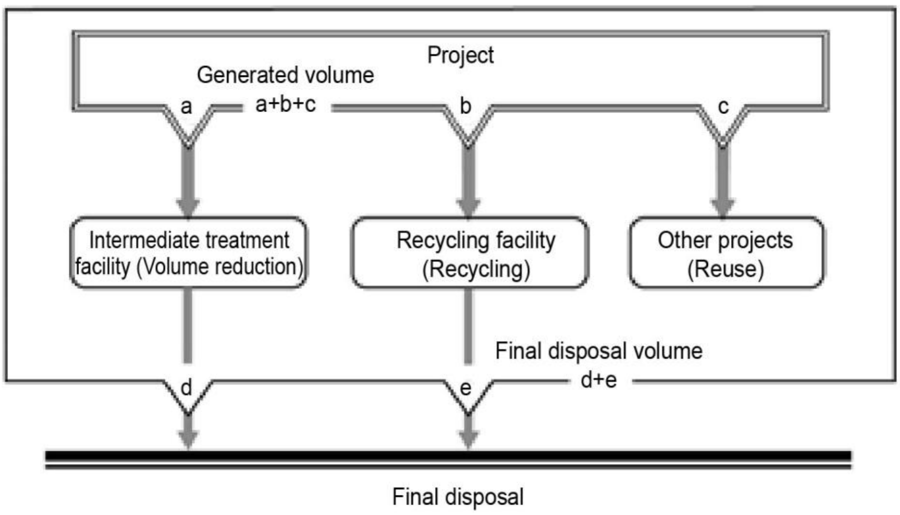


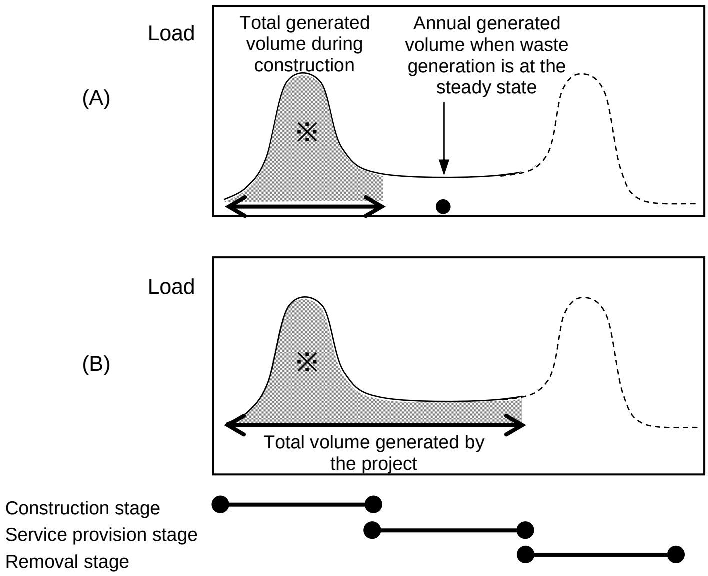
Figure III.2.1-1 Subject of waste forecast and evaluation and concept of system boundary

(b) Concept of survey, forecast and evaluation time and period

The following cases show the waste survey, forecast and evaluation time and period

(A): Time when waste generation reached a steady state during construction and the service provision stage

(B): Period from project commencement to the end of service provision



※When dismantling or removal is carried out concurrently with the project, this should be included in the examination.

Figure III.2.1-2　Concept of waste survey, forecast and evaluation time and period

With regard to waste-related survey, forecast and evaluation, to reduce the total generated volume and final disposal volume during the construction stage, and reduce the generated volume and final disposal volume per unit period during the service provision stage, at the bare minimum, the forecast and evaluation must cover the time when waste generation reaches a steady state during construction and the service provision stage.

When increasing the service life of facilities or material in an effort to reduce the generated waste volume and final disposal volume during the service provision stage, including that from maintenance and management, the survey, forecast and evaluation should be conducted over an extended period during the service provision stage.

Waste generation is forecast not only for the construction and service provision stages, but for the facilities and equipment removal stage as well, so consideration should be given to using material that is readily recycled to reduce the environmental load during this removal stage.

(2) More detailed or simpler survey and forecast methods

For more detailed waste-related survey and forecast methods, one example is that the examination could cover not just the generated waste volume and final disposal volume, but also storage, transportation, and treatment and disposal methods. For simpler survey and forecast methods, an example is that instead of forecasting the volume for each kind of waste, forecast just the total volume.

The following examples can be considered when examining more detailed or simpler survey and forecast methods.

(Examples when examining more detailed survey and forecast methods)

1. When there is a risk of significant environmental impact
   - When waste with properties that can cause damage to human health or the living environment, such as waste subject to special control, is generated, in addition to the generated waste volume and final disposal volume, the plan covering the storage, transportation, and treatment and disposal methods must also be clarified.
2. When there are areas where the environment has already seriously deteriorated or there is a high risk of serious deterioration
   - When the condition of waste disposal is overstrained, in addition to the generated waste volume and final disposal volume, a plan covering the treatment and disposal method, including a definite site for disposal, must be clarified as specifically as possible.

(Examples when examining simpler survey and forecast methods)

1. When it is clear that there is only minor environmental impact
   - When it is clear that only a small volume of waste will be generated, the forecast method may be simplified to forecast just the total volume instead of forecasting the volume for each kind of waste.
2. When the degree of environmental impact is clear from similar case examples
   - The forecast can be conducted by estimating the degree of impact from survey examples in similar projects.

2.1.2 Surveys

Surveys on topographical conditions and land use conditions provide the necessary information to ascertain the volume of concrete and asphalt concrete in existing structures and facilities and the distribution of trees that are to be felled, and also to ascertain disposal conditions for each type of waste at recycling facilities, intermediate treatment facilities, and final disposal sites. Where necessary, the surveys will also ascertain the systems in place at waste treatment facilities for accepting waste and their treatment capacity, and the scale and the framework of structures and facilities that are to be removed.

2.1.3 Forecasts

Forecasts cover the volume of waste generated, intermediate treatment volume, and final disposal volume for each of the waste types shown in Table III.2.1-3.

The methods of forecasting the volume of waste generated include estimation from the project plan, unit rate method, and statistical methods. Table III.2.1-4 gives an outline of each method.

Table III.2.1-4 Outline of forecast methods relating to volume of waste generated

Forecast method	Brief description
Estimation from project plan	In this method, the volume of excavated soil, felled trees, and concrete or asphalt concrete rubble from the removal of existing structures and facilities are estimated from land use and current topographical and geological conditions ascertained from local characteristics based on the location and scale of the project area, land development plans and construction methods detailed in the project plan. The waste generated after the operation of the facilities can also be estimated from the volume of waste generated at other facilities of a similar scale and framework.
Unit rate method	In this method, the volume of waste is calculated by multiplying the volume of activity by the waste generation unit rate on the assumption that the volume of waste generated is proportionate to the volume of activity, such as amount of production and population. Public data for each type of waste, such as those indicated below, can be used for unit rates, while it is also possible to use the unit rates for volume of products shipped estimated from operation results at existing manufacturing plants. In the case of general waste, local governments carry out surveys on the composition of waste, and the findings of such surveys can be used to estimate the volume of each type of waste generated. ● General waste from project activities • Survey examples by project category and waste type ● Industrial waste • *Kenchiku-kei Kongo Haikibutsu no Gentan-i Chosa Hokokusho [Report on the Survey into the Unit Rate of Construction Mixed Waste]* (Company), Japan Federation of Construction Contractors • *Kensetsu Haikibutsu no Hassei Yokusei ni Kansuru Kenkyu (2) [Research on Reducing Construction Waste]*, Annual Report of the Tokyo Metropolitan Research Institute for Environmental Protection 2002.
Statistical method	This is a method of modelling the volume of waste based on past waste volume trends. Future waste volume is estimated by applying the volume of waste to a trend line comprising time (fiscal year) and other indicators of waste generation as explanatory variables, and extending that trend line into the future.

2.1.4 Environmental mitigation measures

1) Examination of policies for environmental mitigation measures

Examples of aspects to focus on when examining policies for waste-related environmental mitigation measures include plans and objectives relating to waste reduction set by the national and local governments, the latest waste reduction technologies, and recycling and volume reduction technologies. It is essential to keep in mind that waste is generated by all kinds of project activities.

2) Content of environmental mitigation measures

Since waste is generated by all kinds of project activities, it is important to examine environmental mitigation measures for each of the project stages of construction, service provision, and removal, and for each project activity step including material input, construction/operation, and discharge. Table III.2.1-5 shows examples of environmental mitigation measures at each stage and step.

Table III.2.1-5 Examples of waste-related environmental mitigation measures for each stage

	Construction	Service provision	Removal
Material input	• Reuse byproducts • Use recycled resources • Use material that can be readily reused or recycled	• Reuse byproducts • Use recycled resources	• Reuse byproducts
Construction/ operation	• Sort and dismantle existing structures and facilities • Improve construction processes • Sort waste • Reduce waste volume by dehydration, crushing, incineration, etc.	• Improve manufacturing processes • Simple packaging • Sort waste • Reduce waste volume by dehydration, crushing, incineration, etc.	• Sort and dismantle existing structures and facilities • Improve construction processes • Sort waste • Reduce waste volume by dehydration, crushing, incineration, etc.
Discharge	• Transport byproducts to other projects • Transport byproducts to recycling facilities or intermediate treatment facilities	• Transport byproducts to other projects • Transport byproducts to recycling facilities or intermediate treatment facilities	• Transport byproducts to other projects • Transport byproducts to recycling facilities or intermediate treatment facilities

2.1.5 Evaluation

Evaluations not only cover the prevention or reduction of environmental impact, but when the national or local governments have set standards or objectives concerning the selected items in their environmental mitigation measures and policies, the evaluation also covers the consistency with these standards or objectives.

1) Evaluations relating to prevention or reduction

Evaluations relating to prevention or reduction evaluate and clarify the effort and consideration that the project proponent has given to preventing or reducing environmental impact. The methods used for these evaluations include a comparative examination of multiple drafts of environmental mitigation measures, and examination of whether the best practicable technologies have been adopted.

Evaluations focus on the volume of waste generated and final disposal volume, so the multiple drafts of environmental mitigation measures are envisaged to be connected with reducing the volume of waste or reducing the final disposal volume. The method used for the comparative examination of multiple drafts is to, first, ascertain the reduction volume resulting from the environmental mitigation measures through a comparison with the evaluation baseline [2] for each draft examined, then verify whether the maximum reduction is being achieved. In this case, the baseline is set as the generated volume or final disposal volume without consideration of the environmental mitigation measures for the project, or as the actual value derived from similar cases of an equivalent scale.

A: Baseline generated volume or final disposal volume

B: Generated volume or final disposal volume from the project when environmental mitigation measures have been adopted

C=A-B: Reduction resulting from the environmental mitigation measures (= focus of the evaluation)

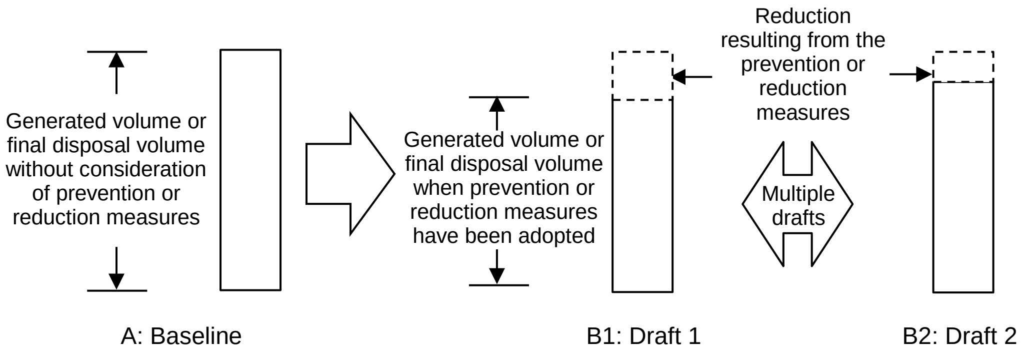


Figure III.2.1-3 Baseline concept

When making an evaluation based on the amount of reduction, the baseline is set as the generated volume or final disposal volume without consideration of the environmental mitigation measures for the project, then the evaluation must be made by the amount of reduction from the baseline.

There are cases where the final disposal volume of the waste generated from the project can be reduced by expanding the system boundary to activities at other projects or facilities. In such cases, after conducting the evaluation within the scope of the project, an evaluation can also be conducted over the expanded system boundary on the difference in the final disposal volume with and without environmental mitigation measures. In this case, the system boundary and the reason for setting that system boundary must be clearly stated.

[2] Baseline: The value that forms the standard when judging change or effect. It is used when ascertaining the degree of the outcome from the environmental mitigation measures, and when conducting a comparative examination of multiple drafts of environmental mitigation measures.

2) Evaluation relating to consistency with standards or objectives

Evaluations relating to consistency with standards or objectives evaluate whether environmental mitigation measures for the project are in line with environmental mitigation measures and policies formulated by the national or local governments. After ascertaining how the reference standards or objectives are positioned as environmental mitigation measures and policies, the idea behind using these standards or objectives for evaluation must be clearly indicated.

When comparing the standards or objectives with the forecast results, it is important to evaluate not just from the viewpoint of whether the forecast results meet the standards or objectives, but also from the viewpoint of, compared to the standards or objectives, whether the degree of impact from the project may hinder environmental preservation.

When estimating the outcome of environmental mitigation measures implemented by a person other than the project proponent, the fact that the content, outcome and implementation time of the environmental mitigation measures to be implemented by a person other than the project proponent are consistent with the project plan, and that the budget for these measures will be realized must be clearly indicated based on objective documents and other material.

2.1.6 Follow-up survey

Environmental impact assessments are conducted before the project is implemented, so the follow-up survey is viewed as compensating for uncertainty in that result, and when there is considerable uncertainty in the forecast or when adopting environmental mitigation measures for which there is incomplete knowledge regarding their outcome, the need for a follow-up survey must be examined according to the severity of the impact on the environment. There is also a need to examine additions to or revisions of the environmental mitigation measures as required based on the results of the follow-up survey.

In conducting the follow-up survey, naturally, the state of waste generation from the project is ascertained, but there is also a need to confirm whether such aspects as changes in social conditions are consistent with the forecast time.

The follow-up survey method should be one that enables a comparison of the follow-up survey results and the environmental impact assessment forecast results so as to confirm whether the actual volume of waste generated by the project and the final disposal volume are within the forecast range.

Through the wide distribution and use of environmental reports under the Act on the Promotion of Business Activities with Environmental Consideration by Specified Corporations, etc., by Facilitating Access to Environmental Information, and Other Measures (Environmental Consideration Promotion Act), a growing number of project proponents are implementing voluntary environmental management, and publicly releasing the outcomes of their efforts. In such cases, the publicly released outcomes of environmental management can also be used extensively in the follow-up survey to confirm that the volume of waste generated and the final disposal volume are within the forecast range. In addition, reports such as those on the state of implementing treatment plans under the high-volume waste discharging business system, and monitoring results implemented under laws and ordinances can also be used.

2.2 Greenhouse gases etc.[3]

2.2.1 Selection of environmental impact assessment items and survey, forecast and evaluation methods

1) Ascertaining project characteristics

Table III.2.2-1 gives an example of the content to be arranged as project characteristics relating to greenhouse gases.

When seeking to reduce greenhouse gas emissions by improving not just project efficiency, but overall efficiency covering all related project activities, the extent of those related project activities must be ascertained.

Table III.2.2-1 Example of the contents of project characteristics relating to greenhouse gases

Impact factors	Examples of the characteristics to be identified
Implementation of construction	• Specifics, method, and duration of construction • Type, number and operating period of construction machinery used in the construction works • Number, type (large, small), period, and traveling distance of vehicles used in the construction works
Existence and use of facilities	• Facility details, and energy use • Types and volume of gases emitted from the facilities • Trip generation rates from the facilities and vehicle types (large, small) • Traveling distance of trip generation and attraction

2) Ascertaining local characteristics

Greenhouse gas forecast and evaluation is generally based on the volume of emissions worked out from the project plan, so local characteristics in the vicinity of the project area have very little effect on the greenhouse gases emitted from the project.

There is, however, a need to ascertain these conditions when plans or objectives relating to greenhouse gas emissions have been set.

3) Selecting environmental impact assessment items

(1) Arranging impact factors

Impact factors are arranged taking into consideration the connection between the state of greenhouse gas emissions shown in Table III.2.2-2 and the project.

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[3] Greenhouse gases etc.: In addition to greenhouse gases, includes gases suitable for ascertaining the “volume of environmental load”, such as amount of tropical timber used, ozone depleting substance substances and harmful chemical substances, but environmental impact assessments for individual development projects generally focus on greenhouse gases, so here, this paper refers to greenhouse gases.

Table III.2.2-2 State of greenhouse gas emissions

Impact factors		Main activities
During construction	Operation of construction machinery	Fuel use and combustion, electricity use, etc.
	Running of vehicles used in construction works	Fuel use and combustion, etc.
After service commencement	Facilities operation	Fuel use and combustion, fuel leakage, use of electricity and heat, manufacturing industrial products, etc.
	Running of related vehicles	Fuel use and combustion, etc.
	Waste treatment	Waste incineration and disposal by landfill, etc.

(2) Arranging environmental elements

When arranging environmental elements relating to greenhouse gases, it is important to select substances with high global warming potential and significant environmental impact as environmental elements, even where the emissions envisaged from the project characteristics are low.

(Points to note) Global warming potential

Global warming potential expresses the level of the global warming effect per unit volume of each greenhouse gas as a ratio of the said effect caused by carbon dioxide. (see Chapter 1 Table 1.2-1)

(3) Selecting environmental impact assessment items

Environmental impact assessment items are selected from the connection between impact factors and environmental elements.

(Points to note)

When (1) it is clear that there is no environmental impact or extremely minor environmental impact concerning the said items, and when (2) it is clear that for a considerable period there will be no areas or other features/facilities subject to environmental impact concerning the said items in the project area or surrounding area, there may be no need to select those items as environmental impact assessment items. In this case, the information on which the above judgment is based must be indicated in the “Project details” or “Area overview” sections in the scoping document.

Regarding (2), as greenhouse gases have no direct impact on the area around the project area, there are no envisaged elements applicable to (2).

4) Selection of survey, forecast and evaluation methods

(1) Concept

To gain a proper understanding of the volume of greenhouse gas emissions, and evaluate from a prevention or reduction perspective, it is necessary to examine methods with a view not just to the volume of greenhouse gases emitted from the project, but also to the social impact or outcomes brought about by the project. To this end, setting the scope for ascertaining greenhouse gases (referred to as “system boundary”) is critical.

Survey, forecast and evaluation methods change depending on the setting of the system boundary, so when selecting survey, forecast and evaluation methods, the kind of system boundary that was set and the idea behind this must be clearly indicated. It should be kept in mind that the perspective of greenhouse gas evaluation can change significantly when the project scope is set as the system boundary, and when the system boundary is set over a broader area, especially in the service provision stage.

In this way, when selecting the method, the scope of the survey, forecast and evaluation must be fully examined.

The project proponent will have a lower direct involvement in environmental mitigation measures outside of the project scope, so the uncertainty of the forecast and of the environmental mitigation measures is likely to increase. Therefore, a follow-up survey to confirm the outcomes of the environmental mitigation measures must be examined as necessary.

(a) Concept of the scope of the forecast, survey and evaluation

Environmental impact assessments are premised on preventing or reducing the environmental impact caused by the implementation of the project as much as possible, so the system boundary is essentially the scope in which the project is implemented, and the evaluation focuses on how greenhouse gases emitted within that scope are prevented or reduced. Even in cases where prevention or reduction is difficult when the system boundary is set to the scope in which the project is implemented, expanding the system boundary has the potential to produce the outcome of preventing or reducing greenhouse gases over the community as a whole. It is also important to evaluate whether greenhouse gas emissions will be reduced after setting a broader system boundary, for example, setting the system boundary to a wide-area higher level development plan in a traffic infrastructure development project, or setting the system boundary to the overall electric power system in a power generation project.

However, when expanding the system boundary beyond the project implementation scope, it is important to clarify the feasibility of the plan for the overall system, and it should be kept in mind that there may be a need for a follow-up survey to confirm this outcome.

Since the system boundary varies according to the evaluation perspective, there is a need to clearly define these concepts in selecting environmental impact assessment items and the survey, forecast and evaluation methods, and indicate the kind of system boundary that has been set. When expanding the system boundary beyond the scope of the project in particular, the reasons for setting the system boundary must be clearly specified along with the overall system approach.

(b) Concept of survey, forecast and evaluation time and period

The following cases show the time and period for survey, forecast and evaluation of greenhouse gases.

(A): Time when greenhouse gas emissions reached a steady state during construction and service provision stage.

(B): Period from project commencement to end of service provision

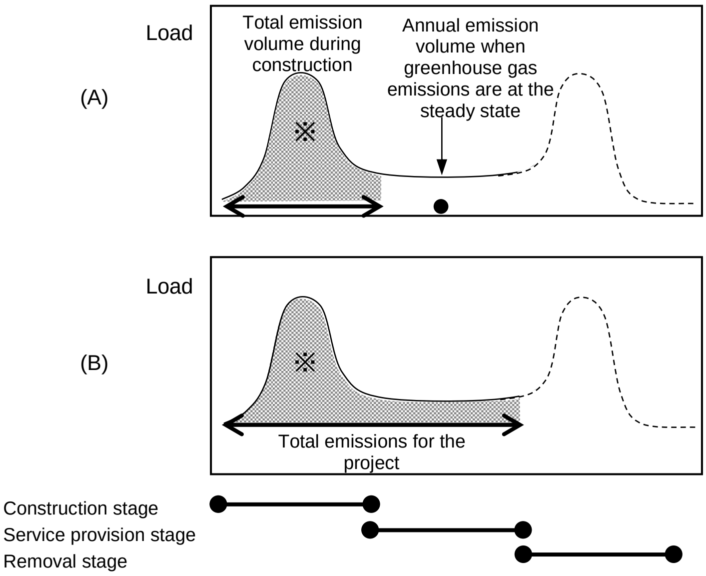


Figure III.2.2-1 Concept of greenhouse gas survey, forecast and evaluation time and period

Surveys, forecasts and evaluations relating to greenhouse gases should be conducted at the time when greenhouse gas emissions have reached the steady state during construction and in the service provision stage in an effort to reduce total emissions in each of those stages.

Total emissions for the overall project can also be included to evaluate the reduction in greenhouse gas emissions for the overall project due to such factors as an improvement in the service life of facilities.

(2) Examples when examining more detailed survey and forecast methods

Possible ways of making greenhouse gas survey or forecast methods more detailed can include dividing up the items subject to the forecast or evaluation. On the other hand, one of the ways of making survey or forecast methods simpler is to make use of similar case examples.

The following examples can be considered when examining more detailed or simpler survey or forecast methods.

(Examples when examining more detailed survey and forecast methods)

When there is a risk of significant environmental impact

- When the project scale is much greater than general projects and greenhouse gas emissions are assumed to be significant, the forecast can be conducted by dividing up the construction processes or project activities.

(Examples when examining simpler survey and forecast methods)

When the degree of impact is clear from similar case examples

- The forecast can be conducted by estimating the degree of impact from survey examples in similar projects.

2.2.2 Surveys

Surveys are, in principle, carried out to ascertain the energy efficiency, activity amount, and emission intensity of construction machinery, vehicles, and facilities and equipment.

2.2.3 Forecasts

Methods of forecasting greenhouse gas emissions include calculations using greenhouse gas emission factors, and calculations from fuel components. Both methods are outlined in Table III.2.2-3.

In forecasting greenhouse gas emissions in relation to the operation of construction machinery or construction vehicles, because there are cases where forecasts are also conducted on air quality and noise after the monthly number of vehicles or number of operating units of construction machinery during the construction period has been determined from the construction plan, consideration must also be given to the relationship with the conditions set in other selected items.

Table III.2.2-3 Examples of greenhouse gas forecast methods

Forecast method	Brief description
Calculation from emission factors	Calculations are made by multiplying activity amount by emission factors. The published data shown below can be used for emission factors for calculations. Activity classifications that establish the emission factors vary according to the purpose of use, so the published data to be used must be suitable based on the project characteristics. Emission factors are updated every year, so it is important to use the latest update at the time of the forecast. • Greenhouse gas emission calculation, report and publication system These published data are set as Japan's average values, so they cannot be used to ascertain the outcome of emission reduction measures through improvements to equipment or facilities relative to the same activity amount. In such cases, emission factors more in line with actual conditions can be set from similar case examples. Whichever emission factors are used, the reasons for setting those factors must be clearly indicated.
Calculation from fuel components	CO_2 emissions from fuel combustion can be calculated from the ratio of fuel use to fuel component, assuming that the carbon component of the fuel used is fully oxidized through complete combustion and emitted as CO_2.

(Reference) Life cycle assessment in infrastructure development

The relevant international standards (ISO14040 series) state that life cycle assessment (LCA) "studies the environmental aspects and potential impacts throughout a product's life from raw material acquisition through production, use and disposal". LCA is a suitable method for comprehensively studying inputs and outputs and emissions of CO2, waste, natural resources and the like through infrastructure development, and also the impacts from that.

The decision-making process for infrastructure development is done at each level of concept, design, construction, and material selection to promote fairer and more rational development. Applying infrastructure LCA at each level facilitates the implementation of infrastructure development with a lower environmental load.

The following shows the decision-making level and an outline of the calculation of environmental load.

- Concept level: This is the level at which the outline plan for the project is drawn up, such as a road outline plan, river development plan, or long-term ports and harbors concept. In the case of a road outline plan, the road functions (planned traffic volume, number of traffic lanes, etc.) and basic framework (surface, elevation, tunnels, etc.) are decided.
- Design level: This is the level at which the structural type and specifications of the infrastructure is examined, and structural cross-sections, general material, and quantities for each works type are decided.
- Construction level: This is the level at which construction methods and materials to be used are decided, and the infrastructure is built. For construction methods, decisions are made on the specific types of construction machinery to be used, while for material, decisions include where to purchase specific products.
- Material selection level: This is the level at which the environmental load associated with the production of individual material items is evaluated. The environmental load arising from production of the material can be evaluated for each manufacturing company or factory, and this enables the selection of material with a lower environmental load.

The environmental load at each level is calculated by the sum of the product of the unit rates and quantities shown below.

Decision-making level	Unit rate	Quantity
Concept level	Unit rate per structure	Scale of structure
Design level	Unit rate per works type	Workload for each works type
Construction level	Unit rate for material (general products, individual products)	Quantity of material (general products, individual products)
	Transport-related environmental load	Transport-related quantities
	Construction-related environmental load Environmental load relating to construction machinery Environmental load relating to scaffolding material	Construction machinery quantities Scaffolding material quantities
Material selection level	Raw material unit rate	Raw material quantities
	Environmental load relating to input energy	Amount of input energy
	Environmental load relating to estimated values covering amounts not yet counted.	–

Source: National Institute for Land and Infrastructure Management and Japan Society of Civil Engineers (2012), "Report on the Development of Life Cycle Assessment Methodology on Sustainability of Infrastructures – Practical Measures for Infrastructure LCA –".

2.2.4 Environmental mitigation measures

1) Examination of policies for environmental mitigation measures

When examining policies for environmental mitigation measures relating to greenhouse gases, it is important to ascertain plans and objectives relating to emission reduction stipulated by the national and local governments. In addition, examples of where focus should be placed after commencement of the service include selecting fuels with a small CO_2 emission intensity, improving energy efficiency by using highly efficient equipment when being supplied with energy, and selecting electric power with a small CO_2 emission intensity when being supplied with electric power. Moreover, during construction, focus should be on adopting energy-efficient construction methods.

2) Content of environmental mitigation measures

Similar to the case of waste etc., it is important to examine environmental mitigation measures for greenhouse gases for each of the project stages of construction and service provision, and for each project activity step including material input, construction/operation, and emission. Table III.2.2-4 shows examples of environmental mitigation measures at each stage and step.

Table III.2.2-4 Examples of environmental mitigation measures relating to greenhouse gases for each stage

	Construction	Service provision	Removal
Material input	• Use raw materials and other materials with low greenhouse gas emissions at the manufacturing stage	• Use low carbon fuels • Use non-fossil fuels • Use raw materials and other materials with low greenhouse gas emissions at the manufacturing stage	*
Construction/ operation	• Improve efficiency of construction machinery operation • Streamline and reduce the period of construction • Adopt fuel-efficient vehicles and machinery • Improve transport efficiency	• Improve the efficiency of power generating facilities • Reduce emissions by adopting advanced technologies • Save energy in manufacturing processes • Energy interchange among facilities • Utilize unused energy • District heating • Adopt fuel-efficient vehicles • Improve transport efficiency	*
Emission	*	*	*

Note 1: While specific environmental mitigation measures are not indicated in the table cells with an asterisk (*), apart from environmental mitigation measures relating to "use of raw materials, other materials and fuel with low greenhouse gas emissions in material input", and "improvement of efficiency in construction and operation", the environmental mitigation measures for waste etc. shown in Table III.2.1-5 can also apply to greenhouse gases.

Note 2: For environmental mitigation measures, refer to "Emission Control Guidelines"[4] drawn up and published by the national government under the Act on Promotion of Global Warming Countermeasures.

[4] Emission Control Guidelines: Guidelines drawn up and published by the national government under Article 25 of the Act on Promotion of Global Warming Countermeasures. These guidelines indicate measures for controlling greenhouse gas emissions (soft and hard measures) for each sector that the project proponent is obligated to strive to implement.

2.2.5 Evaluations

Evaluations consist of those relating to the prevention or reduction of environmental impact, and, when standards and objectives concerning selected items are set down in national or local government environmental mitigation measures and policies, those relating to consistency with these standards and objectives.

1) Evaluations relating to prevention or reduction

Evaluations relating to prevention or reduction clarify and evaluate the effort and consideration given by the project proponent to preventing or reducing environmental impact. Examples of the method for this include a comparative examination of multiple drafts of environmental mitigation measures for greenhouse gas emissions, and an examination of whether the best practicable technologies have been adopted.

(1) Evaluation by comparative examination of multiple drafts

Multiple drafts of environmental mitigation measures are envisaged to be those connected with the reduction of greenhouse gas emissions. Reduction by environmental mitigation measures is ascertained by comparison with the evaluation baseline for each multiple draft examined, and through this it will be verified whether the maximum reduction is being achieved. Comparison with the baseline is done with the following equation.

A: Baseline emission

B: Emission from the project when environmental mitigation measures have been adopted

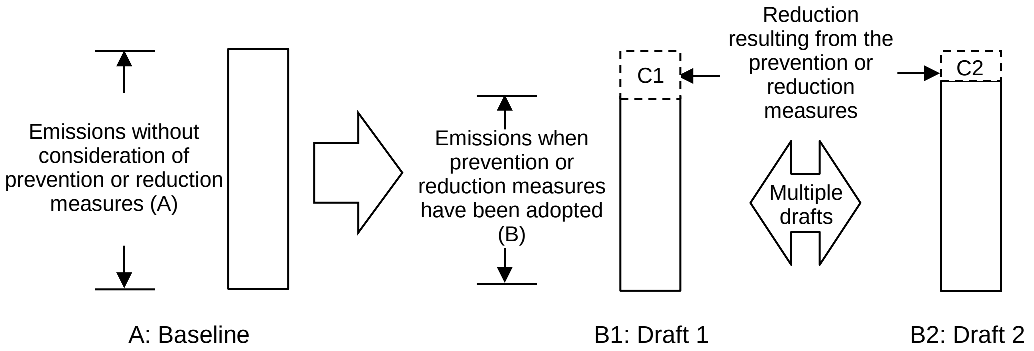
C=A–B: Reduction resulting from the environmental mitigation measures (= focus of evaluation)

When making an evaluation based on the reduction of greenhouse gas emissions, the baseline is set as the emissions from the project without consideration of environmental mitigation measures, then the evaluation must be made by the amount of reduction from the baseline.

Greenhouse gases are newly emitted with the implementation of the project, but there are cases where emissions can be reduced by expanding the system boundary to activities at other relevant projects or facilities. In such cases, after conducting the evaluation within the scope of the project, the baseline is set as the emissions for the expanded system boundary as a whole without the implementation of the project, and the evaluation can also be made on the difference between the baseline and the emissions with the implementation of the project. In this case, the system boundary and the reason for setting that system boundary must be clearly stated.

<When evaluating individual projects>

The baseline can be set as the emissions from the project without consideration of environmental mitigation measures, and also actual values obtained from similar projects of the same scale.



<When expanding the system boundary and evaluating the expanded system as a whole>

The baseline is set as the emissions for the system as a whole without the implementation of the project.

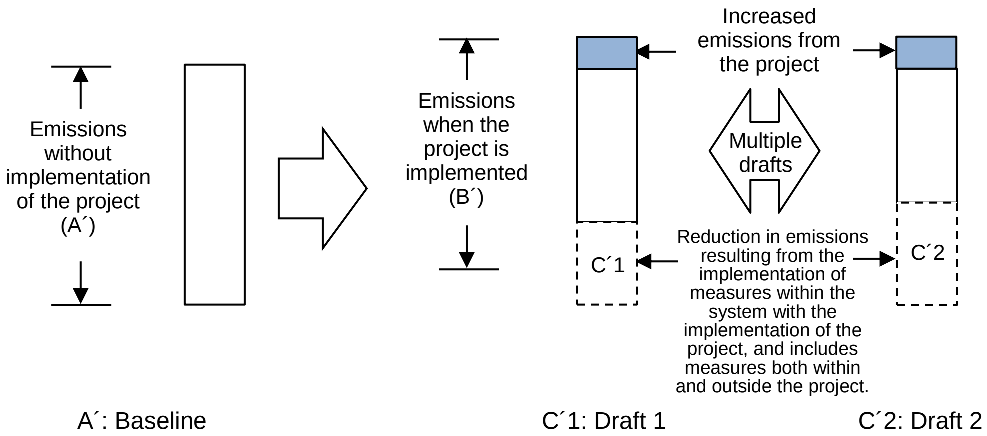


Figure III.2.2-2 Baseline concept

(2) Evaluation on the adoption of the best practicable technologies

With regard to the adoption of the best practicable technologies, here the evaluation is made on whether this is the maximum measure within the practicable scope in terms of the level of the technologies to be adopted and the practicability of those technologies.

- Technological level

This is to evaluate whether the technologies for the environmental mitigation measures have reached the optimum level by reference to the latest studies or similar case examples, exchange of technical information through industry groups, and discussions with interested parties.

- Practicability

This is to judge whether the environmental mitigation measures are practicable in the light of the project proponent’s scientific knowledge, implementation capability, and economic capacity, and evaluate how broadly the practicable scope of these measures is being expanded by the project proponent's efforts.

(Reference) BAT (Best Available Technology) regarding a thermal power plant

The "Summary of the Director-Level Conference on Thermal Power Generation Bidding of Tokyo Electric Power Company" (April 25, 2013) states that the "Commercialization and State of Development of the Latest Power Generation Technologies (BAT reference list)" for each of the (A)–(C) classifications below regarding BAT (Best Available Technology), which is one of the government's examination perspectives for CO2 when making an environmental assessment relating to thermal power plant s, will be compiled, published and reviewed annually.

(A) Latest power generation technologies that have already commenced operation as a commercial plant with no issues regarding economic feasibility and reliability.

(B) Power generation technologies whose construction as a commercial plant has commenced, and technologies whose adoption as a commercial plant has been decided and environmental impact assessment procedures have started.

(C) Power generation technologies other than those mentioned above at the development or validation phase.

When conducting an environmental assessment, the project proponent must, after examining the feasibility of adopting (B), endeavor to bring (B) up to at least the level of (A).

Source: Environmental Impact Assessment Network
http://www.env.go.jp/policy/assess/4-6tpg/index.html

2) Evaluation relating to consistency with standards or objectives

Evaluations relating to consistency with standards or objectives evaluate whether environmental mitigation measures for the project are in line with environmental mitigation measures and policies formulated by the national or local governments. After ascertaining how the reference standards or objectives are positioned as environmental mitigation measures and policies, the idea behind using these standards or objectives for evaluation must be clearly indicated.

The national government "Environmental Master Plan" and "Global Warming Countermeasures Plan", and local government action plans (district measures) drawn up by local governments set objectives for reducing greenhouse gas emissions. Industry groups, too, may raise greenhouse gas reduction objectives in plans and policies such as "The Commitment to a Low Carbon Society".

When comparing the standards or objectives with the forecast results, it is important to evaluate not just from the viewpoint of whether the forecast results meet the standards or objectives, but also from the viewpoint of, compared to the standards or objectives, whether the degree of impact from the project may hinder environmental preservation.

When estimating the outcome of environmental mitigation measures implemented by a person other than the project proponent, the fact that the content, outcome and implementation time of the environmental mitigation measures to be implemented by a person other than the project proponent are consistent with the project plan, and that the budget for these measures will be realized must be clearly indicated based on objective documents and other material.

2.2.6 Follow-up survey

Environmental impact assessments are conducted before the project is implemented, so the follow-up survey is viewed as compensating for uncertainty in that result, and when there is considerable uncertainty in the forecast or when adopting environmental mitigation measures for which there is incomplete knowledge regarding their outcome, the need for a follow-up survey must be examined according to the severity of the impact on the environment. There is also a need to examine additions to or revisions of the environmental mitigation measures as required based on the results of the follow-up survey.

In conducting the follow-up survey, naturally, the state of greenhouse gas emissions from the project is ascertained, but there is also a need to confirm whether such aspects as changes in social conditions are consistent with the forecast time.

The follow-up survey method should one that enables a comparison of the follow-up survey results and the environmental impact assessment forecast results so as to confirm whether the actual greenhouse gas emissions from the project are within the forecast range.

The system under which greenhouse gas emissions are calculated, reported and the information is publicly released, and the results of monitoring implemented under laws and ordinances can also be used in the follow-up survey. In addition, with the formulation of environmental reporting guidelines and the like, a growing number of project proponents are implementing voluntary environmental management, and publicly releasing the outcomes of their efforts. In such cases, the outcomes of environmental management can also be used extensively in the follow-up survey to confirm that the greenhouse gas emissions are within the forecast range. When using these results, it must be made clear whether there is any disparity in the system boundary concept between the environmental impact assessment stage and the environmental report.